Guidebook for operationalisation of the Planning Code

(Pursuant to Section 13.2.6 of the MEGC 2020)

In accordance with the

Maharashtra Electricity Regulatory Commission

(Electricity Grid Code) Regulations, 2020

MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.

Prepared by

STATE TRANSMISSION UTILITY

MAHARASHTRA STATE ELECTRICITY TRANSMISSION COMPANY LIMITED

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LIST OF ABBREVIATIONS

Abbreviation/Acronym	Expanded Form
AC	Alternating Current
AP	Average Pricing
ATC	Available Transfer Capacity
CEA	Central Electricity Authority
DC	Direct Current
DGR	Distributed Generation Resource
EHV	Extra High Voltage
EMTP	Electromagnetic Transient Phenomena
FACTS	Flexible Alternating Current Transmission System
FIDVR	Fault Induced Dynamic Voltage Recovery
GCC	Grid Coordination Committee
HVDC	High Voltage Direct Current
InSGS	Intra-State Generation System
InSTS	Intra-State Transmission System
ISTS	Inter-State Transmission System
InvIT	Infrastructure Investment Trust
kA	Kilo Ampere
kV	kilo Volt
kWh	kilo Watt Hour
LOLP	Loss of Load Probability
LTA	Long Term Access
MEGC	Maharashtra Electricity Grid Code, 2020
MERC	Maharashtra Electricity Regulatory Commission
MOD	Merit Order Dispatch
MSETCL	Maharashtra State Electricity Transmission Company Limited
MSLDC	Maharashtra State Load Despatch Centre
MP	Marginal Pricing
MTOA	Medium Term Open Access
MVA	Million Volt Ampere
MW	Mega Watt
NCD	Non-Convertible Debentures

NPV	Net Present Value
POC	Point of Connection
RE	Renewable Energy
ROE	Return on Equity
ROW	Right of Way
SCED	Security Constrained Economic Despatch
STU	Maharashtra State Transmission Utility
TCUI	Transmission Capacity Utilisation Index
VoLL	Value of Lost Load
VSC	Voltage Source Converter
VVI	Voltage Variation Index

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1. Preamble

1.1. In compliance with the various provisions of Maharashtra Electricity Regulatory Commission (Electricity Grid Code) Regulations, 2020 more specifically Regulations 13.2.6, the Guidebook for operationalisation of the Planning Code covering detailed modalities for implementation of the technical planning criteria and financial planning criteria, information requirements from Users/Requesters, suitable forms/formats and periodic reporting/publication of zone-wise transmission utilisation index and voltage variation index is to be formulated by State Transmission Utility (STU).

1.2. In line with Section 39 of the Electricity Act, the STU shall act as the nodal agency for Intra-STS planning in coordination with distribution licensees and Intra-State Generators system connected/to be connected in the STU grid. The STU shall be the single point contact for the purpose of InSTS planning and shall be responsible on behalf of all the Intra-State entities, for evacuation of power from State generating stations, meeting requirements of DISCOMS and drawing power.

1.3. Transmission planning criteria is mainly based on the two main criteria viz. technical criteria and financial criteria. The requirement of any new scheme, InSTS line, substation, latest technologies such a HVDC and FACTS, EHV substations more than 220kV level needs to be studied by STU or concerned transmission licensee both for technical and financial aspects.

1.4. STU shall carry out planning at a macro level so as to facilitate development of bulk transmission arrangement for transfer of power from surplus areas to deficit load centers.

1.5. Broad transmission system requirement for all the generation projects in a given area shall be worked out and the same shall be then phased in a manner to match commissioning time frames of different groups of generators materializing in similar time frame. The ultimate objective of the entire exercise is to optimize the investment required in the planning of the grid.

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2. Definitions

2.1. **Adequacy** – A measure of the ability of the power system to supply the aggregate electric power and energy requirements of the customers within components ratings and voltage limits, taking into account planned and unplanned outages of system components. Adequacy measures the capability of the power system to supply the load in all the steady states in which the power system may exist considering standards conditions.

2.2. **Available Transfer Capacity**: The transfer capability of the inter-control area transmission system available for scheduling commercial transactions (through long term access, medium term open access and short-term open access) in a specific direction, taking into account the network security. Mathematically ATC is the Total Transfer Capability less Transmission Reliability Margin.

2.3. **Connectivity** – In relation to a generating station, including a captive generating plant, a consumer or a Licensee, means the state of getting connected to the Intra-State Transmission System.

2.4. **Grid Code / MEGC** - The Code specified by the Commission under clause (h) of sub-section (1) of Section 86 of the Act.

2.5. **Loss of Load Probability (LOLP)** - In a given zone and during a given time period, the probability that resources would be insufficient to meet the demand needs.

2.6. **Long-term access** – The right to use the Intra-State Transmission System for a period exceeding seven years.

2.7. **Medium-term open access** – The right to use the Intra-State Transmission System for a period exceeding three months but not exceeding five years.

2.8. **Open Access** – The non-discriminatory provision for the use of transmission lines or distribution system or associated facilities with such lines or system by any licensees or consumer or a person engaged in generation in accordance with Regulations of the appropriate Commission.

2.9. **Reliability** - A measure of the ability of a system, generally given as numerical indices, to deliver power to all points of utilization within acceptable standards and in amounts desired. Power system Reliability (comprising generation and transmission & distribution facilities) can be described by two basic functional attributes i.e. Adequacy and Security.

2.10. **Security** – A measure of power system ability to withstand sudden disturbances such as electric short circuits or unanticipated losses of system components or load conditions together with operating constraints. Another aspect of Security is system integrity, which is the ability to maintain interconnected operation. Integrity relates to the preservation of interconnected system operation, or avoidance of uncontrolled separation, in the presence of specified severe disturbances.

2.11. **Transmission Licensee** - The Licensee granted Transmission Licence by the Commission under Section 14 of the Electricity Act 2003 to transmit electricity.

2.12. **Value of Lost Load (VoLL)**: It is a momentary indicator expressing the costs associated with an interruption of electricity supply.

2.13. **User or InSTS User**: A person such as InSGS including, CPP, Renewable Energy Generators or Distribution Licensee or Consumers connected to the InSTS;

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3. Technical Planning Criteria

Planning criteria shall be based on the Security philosophy on which the Intra-State Transmission System (InSTS) has been planned considering past experience of STU and Users, future plan of various State Government agencies, etc. The transmission planning philosophy shall be guided by "Manual on Transmission Planning Criteria, 2013" published by the Authority, National Electricity Plan including its amendments thereof, and other guidelines as specified by the Authority and amended from time to time.

4. Implementation aspects of Technical Planning Criteria

4.1. InSTS planning has to be done in compliance with Security criteria as per "Manual on Transmission Planning Criteria, 2013" published by the CEA and amendment thereof to be done by CEA.

4.2. InSTS is planned to ensure N-1 compliance in the system. Both N-1 and N-1-1 criteria shall be complied with in the power system to be augmented in future. In the InSTS plan prior to 2013, N-1-1 criteria was not considered and only N-1 compliance is taken care of. In the future planning, effort shall be made to augment the transmission system such that N-1-1 criteria is also complied with in the entire system.

4.3. "Manual on Transmission Planning Criteria, 2013" published by the CEA is enclosed with this guidebook as **Annexure-1**.

4.4. STU shall carry out appropriate system studies while developing the transmission system plan. The basic input data required for carrying out system studies is as follows:

a. Time frame of study

b. Location of generating plants and capacity (Point of injection)

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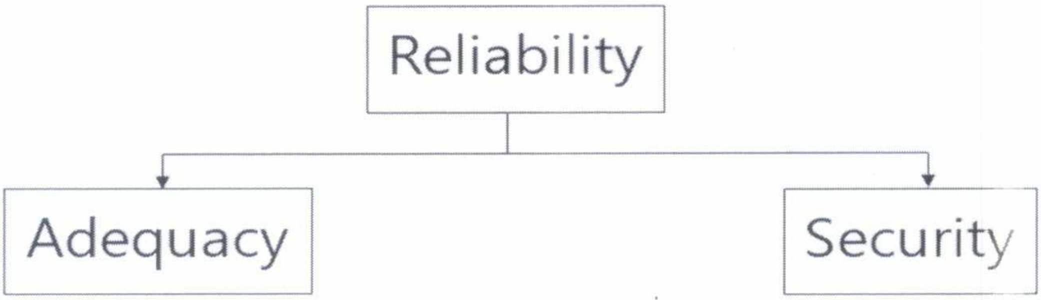
c. Points of power drawal (load centers) & quantum

d. Topology of transmission network at different voltage levels

e. Connectivity of various transmission elements & their capacity

f. Other aspects like transmission Right of Way (ROW), space availability at terminating points, etc.

4.5. Transmission system planning is done to ensure Reliability with attributes of Adequacy and Security.



a. Adequacy relates to the existence of sufficient facilities within the system to satisfy the consumer load demand at all times.

b. Security relates to the ability to withstand sudden disturbances

To determine of Adequacy and Security, the studies required to be carried out includes:

4.5.1. Load Flow Studies

4.5.2. Short Circuit Studies

4.5.3. Stability Studies

4.5.4. Electromagnetic Transient Phenomena Studies (EMTP / Transients)

Above study shall be conducted for different planning scenarios such as -

a. Maximum Load

b. Minimum load

c. Special Area Despatches

d. Seasonal Variations

- High Hydro Season
- Low Hydro Season

4.6. Criteria for load flow studies

4.6.1. Grid to be capable of withstanding N-1 contingency without load shedding or generation rescheduling and with load shedding or generation rescheduling in the following contingencies:

a. N-1 with depletion in parallel corridor

b. N-1-1 Contingencies

c. For major generating station evacuation, complex and double circuit line outage to be considered.

4.6.2. Voltages level at different buses within the limits as given in the table:

Nominal Voltage (in kV)	Maximum Voltage (in kV)	Minimum Voltage (in kV)
765	800	728
400	420	380
220	245	198
132	145	122

Reference - CEA- Grid Standard Regulation and CERC – Indian Electricity Grid Code

4.6.3. Angular separation between adjacent buses to be less than or equal to 30 degrees under N-1 and less than or equal to 40 degrees under N-1-1.

4.7. Criteria for Short Circuit Studies:

Short Circuit studies are carried out for different types of faults as indicated below –

a. Shunt and series faults

b. Single line to ground fault

c. Line to line fault

d. Three phase fault

e. Double line to ground fault

f. Open conductor

4.7.1. To determine maximum fault current that would be present during a system disturbance.

4.7.2. Assessment of fault capacity (fault current in kA, short circuit MVA) increase due to expansion of system. If capacity exceeds the protective device capacity, a dangerous situation occurs for both operating personnel and system equipment.

4.7.3. Determination of maximum & minimum short-circuit currents during symmetrical and unsymmetrical faults (balanced/unbalanced faults).

4.7.4. Determination of ratings of required circuit breakers.

4.7.5. Investigation of schemes of protective relaying.

4.7.6. Determination of voltage levels at strategic points during a fault.

4.7.7. Studies to minimize short circuit level by series reactors.

4.8. Criteria for Stability Studies:

Stability Studies have to be carried out to examine stability issues with respect to –

4.8.1. Angular stability (Large Signal Stability / Transient stability, Small signal stability)

a. Steady-state: Response of synchronous machine to a gradually change system condition (say load).

b. Dynamic: Response to small disturbances occur on the system, producing oscillations. System response may not become apparent for some 10 to 30 Sec.

c. Oscillations of successively smaller amplitudes, system dynamically stable, otherwise unstable source usually an interaction between control systems.

d. Transient: Response to large disturbances due to change in rotor speeds, power angles, power transfer, faults etc. System response usually evident within a few seconds.

4.8.2. Voltage Stability - Voltage collapse and Fault induced dynamic voltage recovery (FIDVR) phenomena due to induction motor and thermostat loads are examined using voltage stability studies from P-V & Q-V curves. (Power and Voltage curves and Reactive power and Voltage curves)

4.9. Criteria for Electromagnetic transient studies:

Electromagnetic transient studies shall be done for assessment of –

4.9.1. Lightning Overvoltages

4.9.2. Switching Overvoltages

4.9.3. Insulation Coordination

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4.9.4. Design of surge arrestor and PIR of breakers (pre insertion resistance) etc.

4.10. Transmission projects are planned for -

a. Evacuation of Power from Generation projects
b. Grid Strengthening
c. Evacuation network from ISTS substation in the state

4.11. The transmission planning is done considering applications from transmission system users applying for -

a. Connectivity
b. Long Term Access (LTA)
c. Medium Term Open Access (MTOA), However, no augmentation is done to grant MTOA

4.12. Generation linked transmission projects to be planned based on proposal of generation utility(s) for setting up of green field or generation expansion projects along with following details -

a. Location and capacity of the project
b. Expected commissioning schedule
c. Beneficiaries and their allocation of power

4.13. Grid Strengthening is to be planned mainly based upon the operational feedback given on quarterly basis by WRLDC and MSLDC and constraints in Grid operation including congestion, compliance of N-1 and N-1-1 criteria in real time operation and also based upon evacuation network from ISTS substation in the state to load centers.

4.14. Based on the User request for Connectivity, LTA and MTOA for InSTS, to supplement ISTS planning as agreed in the coordinated transmission planning process in compliance with standing power committees (Co-ordinated by CEA)

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and in accordance with National Electricity Plan, STU shall prepare two base cases in a year – 30th June and 31st December considering the applications received till that time.

4.15. Each of the planning base cases has to be studied to ensure that the additional proposed transmission element should not result in overall average utilization of the grid by less than 40% for off peak load.

During off peak conditions, system operators back down thermal generation to 55% of Machine capability rating (MCR) and hydro generation is withdrawn resulting in generation availability of around 50% with respect to peak generation. As such the transmission system gets lightly loaded and utilization can go as low as 50% or lower. Such possibilities cannot be avoided, as in most of the developed countries off peak load corresponds to 50% or less off peak load and accordingly transmission planning takes care of high voltage issues by planning of reactors, FACTS devices, etc.. The Reliability considerations and LOLP on annual basis requires that transmission system should be capable of catering to the peak load conditions. The complexity of planning increases due to location and size of RE generation and distributed generation resource (DGR) close to load centers and transmission system loading during off peak hours can go down to 40% of off-peak load. This can result in additional capex for voltage control and also underutilization. In case of underutilization possibilities below 40%, alternative options can be explored.

4.15.1. Various transmission planning options to be considered with different voltage levels, different technologies

a. AC - 220kV, 400kV, 765kV, 1200kV

b. AC with FACTS devices

c. DC - HVDC / VSC based HVDC,

d. Hybrid - Hybrid AC & DC,

e. Substations at different locations and different routes for transmission paths, etc.

To ensure Reliability requirements (Adequacy and Security) and to fulfill the objective of generation evacuation, grid strengthening, ISTS evacuation etc.

4.15.2. Various options considered to fulfill technical requirement of Adequacy, Security, reduction of losses, relieving overloads on other lines, improvement in stability margins etc., to be examined and the best option should be chosen based on the technical as well as financial criteria (Capital cost with capitalization of incremental loses brought to Net present value).

Example on economic analysis of various alternative options

Table 1 – Two Alternatives are given for erection of transmission line from Point A to point B with different technologies.

Sr. No.	Alternative	Estimated Cost (Rs. Cr.)
1	Alternative A	5390
2	Alternative B	4090

Table 2 – Rank evaluation based on considering incremental transmission

Sr. No.	Alternatives	Project Estimated Cost (in Rs. Cr)	Incremental Transmission loss (in MWh)	Equivalent lost cost (in Rs. Cr)	Cumulative cost (in Rs. Cr)	Rank
1	Alternative A	5390	0	0	5390	2
2	Alternative B	4090	300	400	4490	1

4.15.3. The new transmission elements added based on the above criteria are examined for off peak scenario. The power flow on new elements from load flow study corresponding to off peak condition is compared with corresponding power flow for peak load conditions. If line loading on any elements is less than 40% during off peak as compared to peak load conditions such elements are identified and alternative options explored such as -

a. Providing FACTS devices like series capacitors on parallel lines to increase power flow.

b. To provide phase shifting transformers for diversion of power flows.

c. To explore alternatives of different voltage levels,

d. To change route selection of lines and alternative location of substations.

4.16. In case a proposal is meant to support the National system, GCC should duly record such a proposal for sponsoring the same to become part of ISTS.

5. Financial Criteria

5.1. The transmission planning of InSTS is part of coordinated development of transmission system elements, particularly with reference to Inter-State/Inter-Regional Transmission System elements vis-à-vis Intra-State Transmission System elements. The coordinated transmission plan ensures that no duplication is done by ISTS licensees and InSTS licensees such coordination is done through regional standing committees coordinated by CEA.

5.2. As per financial planning criteria according clause 13.2.1 (a) of MEGC 2020 Optimum utilisation of the existing capacity and planned capacity addition of the transmission system element. The STU while processing the applications for LTA from Users, system studies have to be carried out to check if the LTA request is accommodated using the margins in existing transmission capacity before planning of augmentation of network. In case of need for planning of corridors and new substations for LTA customers, it has to be seen that the augmented network is not underutilised. To avoid under-utilisation of the augmented capacity, LTA requirements from different users can be combined to plan augmentation and accordingly the timelines have to be decided. In the interim, it can be explore to accommodate the LTA applicants can be accommodated by exploring the possibility of providing LILO of existing lines.

5.3. Prior to inclusion of any new transmission system element entailing capital outlay exceeding threshold limit of INR 100 Crore or such other threshold limit to be stipulated by the Commission from time to time, as part of transmission system plan, STU shall evaluate and present alternate options of meeting the User/Requester requirement (with or without transmission element, factoring optimal capacity expansion than sought for, or evaluate alternate technology options, consider deferment or prioritisation considerations etc.) and accordingly undertake scenario analysis of various cases and present it to

User/Requester in order to ensure economical and efficient development of transmission system element(s) to economise overall Return of Investment for transmission system as whole.

5.4. The recovery of cost from the transmission system is done based on various transmission pricing methodologies

a. Postage stamp method
b. Average pricing Method (AP Method based on power tracing)
c. Marginal pricing method (MP Method)
d. Load flow-based method like Megawatt-mile
e. Nodal Pricing method
f. POC / Hybrid methodology (AP and MP method as is being done at interstate level)

5.5. At present the tariff of the transmission system is recovered through postage stamp method in most of the states including Maharashtra where the users pay as per the peak demand of the users. In case of ISTS the transmission charges are recovered from users based on POC methodology (Hybrid methodology comprising AP and MP method). The POC methodology is based on distance sensitivity, direction sensitivity and quantum of usage. However, to make the equitable sharing and fairness of recovery of the cost from transmission system users, the POC methodology adopted has to be modified and to socialise the transmission charges burden through various components such as National Component (NC), Regional Component (RC), Transformer Component (TC), Balance Component of AC system Charges (AC-BC). Usage-based component (recovered through POC mechanism) comprise around 25% and around 75% of transmission charges have to be socialised in order to ensure equitability and fairness in recovery.

5.6. In InSTS, recovery of incremental cost due to augmentation from Users for whom the incremental transmission system is build, may lead to burdening of these users and hence presently followed system of postage stamp may help in socializing the cost among all the User of InSTS. However, STU can check effect of booking incremental cost to specific user by evaluating the transmission alternatives.

5.7. The Return on investment from perspective of Users/ society is considerable, as the Value of Lost Load (VoLL) is nearly 4-times (capping price of power exchange is Rs. 20/kWh, power purchased at this price under power shortage condition) of average cost power Rs. 5/kWh. Addition of transmission system will reduce the Loss of Load Probability (LOLP), reduce congestion and transmission constraints and as such results in huge benefits in terms of cost saving.

Example – The transactions through power exchange are considered to be most desirable from the perspective of both buyers and sellers as price discovery takes place in Power Exchange. However, market splitting due to transmission congestion is highly frequent in the country and congestion control is done through market splitting into two markets one importing area and other for the exporting area across the congestion interface. Assuming for example the prices cleared in both markets are Rs. 5/kWh and Rs. 3/kWh respectively and the transmission curtailment was 100MW, the congestion cost works out (Rs 5/kWh – Rs. 3/kWh) * (100MW * 1000 * 24 for one day RTC) equal to Rs. 48 lakhs/day. The additional ATC of 100MW in transmission would have saved Rs 175.2 Cr (365 days* 0.48Cr) to the society.

5.8. The effective gain to society is VoLL minus average cost of generation per kWh multiplied by additional energy met (kWh) due to transmission augmentation. In case of congestion removal between two areas the benefit accrued due to transmission augmentation is equal to additional energy supplied multiplied by difference in cost of power in importing and exporting regions.

5.9. To implement economic despatch on state wise MOD requires congestion free network as cheaper generator can generate 'X' kWh/year of additional energy due to transmission augmentation and replace energy generated from costlier generator. The benefit accrued due to transmission augmentation shall be equal to 'X' kWh multiplied by difference of cost in generation.

5.10. For implementation of Security Constrained Economic Despatch (SCED) by incrementing / decrementing schedules of cheaper/ costlier generators requires congestion free transmission. For each of the transmission element planned by STU, one of benefits like removal of congestion, reducing LOLP or enable SCED to accrue the benefits due to transmission augmentation. It can be evaluated over the life of the transmission project and computed at Net present value (NPV) to assess the economic benefits of transmission projects.

5.11. In compliance with the various provisions of MEGC, 2020 more specifically Regulations 13.2.2, the methodology for computing zone-wise "Transmission Capacity Utilization Index (TCUI)" as well as" Voltage Variation Index (VVI)" is formulated by STU. Detailed methodology for computing 'TCUI' and 'VVI' is enclosed as **Annexure-2** of this guidebook.

5.12. While developing transmission system plan, capacity unutilized in the existing transmission line is required to be considered in order to plan for augmentation of the capacity for addition of new transmission system element or addition of transmission element. TCUI can reflect incremental usage and also reserve transmission capacity for Reliability and future load growth.

5.13. In order to improve power quality, grid security, Reliability and efficient planning of network for augmentation or addition of transmission element. STU have formulated TCUI and VVI in compliance with MEGC.

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6. Planning data for purpose of developing Transmission Plan

6.1. To enable STU to discharge its responsibilities relating to planning Intra-State Transmission System under Electricity Act, 2003, all the Users are required to furnish Planning Data to STU in the prescribed formats appended herewith and at prescribed time.

6.2. To enable the Users to co-ordinate planning, design and operation of their own plants and systems with InSTS, STU may seek certain data of the Transmission System as applicable to them. Transmission Licensee shall provide the said data from time to time.

6.3. Transmission Licensees and Users shall provide Standard Planning data to the STU for purpose of developing transmission plan. Standard Planning Data with necessary formats are enclosed as **Annexure-3** of this guidebook.

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MANUAL

ON

TRANSMISSION PLANNING CRITERIA

CENTRAL ELECTRICITY AUTHORITY

NEW DELHI

JANUARY 2013

Annexure-1

MANUAL

ON

TRANSMISSION PLANNING CRITERIA

CENTRAL ELECTRICITY AUTHORITY

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MANUAL ON TRANSMISSION PLANNING CRITERIA

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PREAMBLE

Manual on transmission planning criteria was first brought out by CEA in 1985 setting the planning philosophy of regional self sufficiency. The manual was revised in 1994 taking into account the experience gained on EHV systems. Technological advancements and institutional changes during last ten years have necessitated review of Transmission Planning Criteria. The regional electrical grids of Northern, Western, Eastern and North-Eastern regions have been synchronously interconnected to form one of the largest electrical grids in the world. The country has moved from the concept of regional self-sufficiency to bulk inter-regional transfer of power through high capacity AC and HVDC corridors forming an all-India National Grid.

The Electricity Act, 2003 has brought profound changes in electricity supply industry of India leading to unbundling of vertically integrated State Electricity Boards, implementation of Open Access in power transmission and liberalisation of generation sector. The phenomenal growth of private sector generation and the creation of open market for electricity have brought its own uncertainties. Large numbers of generation projects are coming up with no knowledge of firm beneficiaries. The situation is compounded by uncertainty in generation capacity addition, commissioning schedules and fuel availability. All these factors have made transmission planning a challenging task. Adequate flexibility may be built in the transmission system plan to cater to such uncertainties, to the extent possible. However, given the uncertainties, the possibility of stranded assets or congestion cannot be entirely ruled out.

In the creation of very large interconnected grid, there can be unpredictable power flows leading to overloading of transmission lines due to imbalance in load-generation balance in different pockets of the grid in real time operation. Reliable transmission planning is basically a trade-off between the cost and the risk involved. There are no widely adopted uniform guidelines which determine the criteria for transmission planning vis-à-vis acceptable degree of adequacy and security. Practices in this regard vary from country to country. The common theme in the various approaches is "acceptable system performance".

However, recent grid incidents of July 2012 have underlined the importance of grid security. As the grid grows in size and complexity, grid security has to be enhanced because the consequences of failure of a large grid are severe. The transmission planning criteria has been reviewed accordingly. The transmission planning criteria has also considered large scale integration of renewable energy sources.

MANUAL ON TRANSMISSION PLANNING CRITERIA

Scope and planning philosophy (Paragraph 1 to 3)

1. Scope

1.1 The Central Electricity Authority is responsible for preparation of perspective generation and transmission plans and for coordinating the activities of planning agencies as provided under Section 73(a) of the Electricity Act 2003. The Central Transmission Utility (CTU) is responsible for development of an efficient and coordinated inter-state transmission system (ISTS). Similarly, the State Transmission Utility (STU) is responsible for development of an efficient and coordinated intra-state transmission system (Intra-STS). The ISTS and Intra-STS are interconnected and together constitute the electricity grid. It is therefore imperative that there should be a uniform approach to transmission planning for developing a reliable transmission system.

1.2 The planning criteria detailed herein are primarily meant for planning of Inter-State Transmission System (ISTS) down to 132kV level and Intra-State Transmission System (Intra-STS) down to 66kV level, including the dedicated transmission lines.

1.3 The manual covers the planning philosophy, the information required from various entities, permissible limits, reliability criteria, broad scope of system studies, modeling and analysis, and gives guidelines for transmission planning.

2. Applicability

2.1 These planning criteria shall be applicable from the date it is issued by Central Electricity Authority i.e. 1st February 2013.

2.2 These criteria shall be used for all new transmission systems planned after the above date.

2.3 The existing and already planned transmission systems may be reviewed with respect to the provisions of these planning criteria. Wherever required and possible, additional system may be planned to strengthen the system.

Till implementation of the additional system, suitable defense mechanisms may have to be put into place.

3. Planning philosophy and general guidelines

3.1 The transmission system forms a vital link in the electricity supply chain. Transmission system provides 'service' of inter-connection between the source (generator) and consumption (load centers) of electricity. In the Indian context, the transmission system has been broadly categorised as Inter-State Transmission System(ISTS) and Intra-State Transmission system(Intra-STS). The ISTS is the top layer of national grid below which lies the Intra-STS. The smooth operation of power system gets adversely affected on account of any of these systems. Therefore, the criteria prescribed here are intended to be followed for planning of both ISTS and Intra-STS.

3.2 The transmission system is generally augmented to cater to the long term requirements posed by eligible entities, for example, for increase in power demand, generation capacity addition etc. Further, system may also be augmented considering the feedback regarding operational constraints and feedback from drawing entities.

3.3 The long term applicants seeking transmission service are expected to pose their end-to-end requirements well in advance to the CTU/STUs so as to make-available the requisite transmission capacity, and minimise situations of congestion and stranded assets.

3.4 The transmission customers as well as utilities shall give their transmission requirement well in advance considering time required for implementation of the transmission assets. The transmission customers are also required to provide a reasonable basis for their transmission requirement such as - size and completion schedule of their generation facility, demand based on EPS and their commitment to bear transmission service charges.

3.5 Planning of transmission system for evacuation of power from hydro projects shall be done river basin wise considering the identified generation projects and their power potential.

3.6 In case of highly constrained areas like congested urban / semi-urban area, very difficult terrain etc., the transmission corridor may be planned by taking long term perspective of optimizing the right-of-way and cost. This may be done by adopting higher voltage levels for final system and operating one level below in the initial stage, or by using multi-circuit towers for stringing circuits in the future, or using new technology such as HVDC, GIS etc.

3.7 In line with Section 39 of the Electricity Act, the STU shall act as the nodal agency for Intra-STS planning in coordination with distribution licensees and intra-state generators connected/to be connected in the STU grid. The STU shall be the single point contact for the purpose of ISTS planning and shall be responsible on behalf of all the intra-State entities, for evacuation of power from their State's generating stations, meeting requirements of DISCOMS and drawing power from ISTS commensurate with the ISTS plan.

3.8 Normally, the various intra-State entities shall be supplied power through the intra-state network. Only under exceptional circumstances, the load serving intra-State entity may be allowed direct inter-connection with ISTS on recommendation of STU provided that such an entity would continue as intra-State entity for the purpose of all jurisdictional matters including energy accounting. Under such situation, this direct interconnection may also be used by other intra-State entity(s).

Further, State Transmission Utilities (STUs) shall coordinate with urban planning agencies, Special Economic Zone (SEZ) developers, industrial developers etc. to keep adequate provision for transmission corridor and land for new substations for their long term requirements.

3.9 The system parameters and loading of system elements shall remain within prescribed limits. The adequacy of the transmission system should be tested for different feasible load-generation scenarios as detailed subsequently in Paragraph: 9-11 of this manual.

3.10 The system shall be planned to operate within permissible limits both under normal as well as after more probable credible contingency(ies) as detailed in subsequent paragraphs of this manual. However, the system may experience extreme contingencies which are rare, and the system may not be planned for such rare contingencies. To ensure security of the grid, the extreme/rare but credible contingencies should be identified from time to time and suitable defense mechanism, such as - load shedding, generation rescheduling, islanding, system protection schemes, etc. may be worked out to mitigate their adverse impact.

3.11 The following options may be considered for strengthening of the transmission network. The choice shall be based on cost, reliability, right-of-way requirements, transmission losses, down time (in case of up-gradation and re-conductoring options) etc.

- Addition of new transmission lines/ substations to avoid overloading of existing system including adoption of next higher voltage.
- Application of Series Capacitors, FACTS devices and phase-shifting transformers in existing and new transmission systems to increase power transfer capability.
- Up-gradation of the existing AC transmission lines to higher voltage using same right-of-way.
- Re-conductoring of the existing AC transmission line with higher ampacity conductors.
- Use of multi-voltage level and multi-circuit transmission lines.
- Use of narrow base towers and pole type towers in semi-urban / urban areas keeping in view cost and right-of-way optimization.
- Use of HVDC transmission – both conventional as well as voltage source convertor (VSC) based.
- Use of GIS / Hybrid switchgear (for urban, coastal, polluted areas etc)

3.12 Critical loads such as - railways, metro rail, airports, refineries, underground mines, steel plants, smelter plants, etc. shall plan their interconnection with the grid, with 100% redundancy and as far as possible from two different sources of supply, in coordination with the concerned STU.

3.13 The planned transmission capacity would be finite and there are bound to be congestions if large quantum of electricity is sought to be transmitted in direction not previously planned.

3.14 Appropriate communication system for the new sub-stations and generating stations may be planned by CTU/STUs and implemented by CTU/STUs/generation developers so that the same is ready at the time of commissioning.

<u>Criteria for steady-state and transient-state behavior</u> (Paragraph 4 to 6)

4. General principles

The transmission system shall be planned considering following general principles:

4.1 In normal operation ('N-0') of the grid, with all elements to be available in service in the time horizon of study, it is required that all the system parameters like voltages, loadings, frequency should remain within permissible normal limits.

4.2 The grid may however be subjected to disturbances and it is required that after a more probable disturbance i.e. loss of an element ('N-1' or single contingency condition), all the system parameters like voltages, loadings, frequency shall be within permissible normal limits.

4.3 However, after suffering one contingency, grid is still vulnerable to experience second contingency, though less probable ('N-1-1'), wherein some of the equipments may be loaded up to their emergency limits. To bring the system parameters back within their normal limits, load shedding/re-scheduling of generation may have to be applied either manually or through automatic system protection schemes (SPS). Such measures shall generally be applied within one and a half hour(1½) after the disturbance.

5. Permissible normal and emergency limits

5.1 Normal thermal ratings and normal voltage limits represent equipment limits that can be sustained on continuous basis. Emergency thermal ratings and emergency voltage limits represent equipment limits that can be tolerated for a relatively short time which may be one hour to two hour depending on design of the equipment. The normal and emergency ratings to be used in this context are given below:

5.2 (a) The loading limit for a transmission line shall be its thermal loading limit. The thermal loading limit of a line is determined by design parameters based on ambient temperature, maximum permissible conductor temperature, wind speed, solar radiation, absorption coefficient, emissivity coefficient etc. In India, all the above factors and more particularly ambient temperatures in various parts of the country are different and vary considerably during various seasons of the year. However, during planning, the ambient temperature and other factors are assumed to be fixed, thereby permitting margins during operation. Generally, the ambient temperature may be taken as 45 deg Celsius; however, in some areas like hilly areas where ambient temperatures are less, the same may be taken. The maximum permissible thermal line loadings for different types of line configurations, employing various types of conductors, are given in Table-II of Annexure-V.

(b) Design of transmission lines with various types of conductors should be based on conductor temperature limit, right-of-way optimization, losses in the line, cost and reliability considerations etc.

(c) The loading limit for an inter-connecting transformer (ICT) shall be its name plate rating. However, during planning, a margin as specified in Paragraph: 13.2 and 13.3 shall be kept in the above lines/transformers loading limits.

(d) The emergency thermal limits for the purpose of planning shall be 110% of the normal thermal limits.

5.3 Voltage limits

a) The steady-state voltage limits are given below. However, at the planning stage a margin as specified at Paragraph: 13.4 may be kept in the voltage limits.

Voltages (kV_{rms})				
	Normal rating		Emergency rating	
Nominal	**Maximum**	**Minimum**	**Maximum**	**Minimum**
765	800	728	800	713
400	420	380	420	372
230	245	207	245	202
220	245	198	245	194
132	145	122	145	119
110	123	99	123	97
66	72.5	60	72.5	59

b) Temporary over voltage limits due to sudden load rejection:

i) 800kV system 1.4 p.u. peak phase to neutral (653 kV = 1 p.u.)

ii) 420kV system 1.5 p.u. peak phase to neutral (343 kV = 1 p.u.)

iii) 245kV system 1.8 p.u. peak phase to neutral (200 kV = 1 p.u.)

iv) 145kV system 1.8 p.u. peak phase to neutral (118 kV = 1 p.u.)

v) 123kV system 1.8 p.u. peak phase to neutral (100 kV = 1 p.u.)

vi) 72.5kV system 1.9 p.u. peak phase to neutral (59 kV = 1 p.u.)

c) **Switching over voltage limits**

i) 800kV system 1.9 p.u. peak phase to neutral (653 kV = 1 p.u.)

ii) 420kV system 2.5 p.u. peak phase to neutral (343 kV = 1 p.u.)

6. Reliability criteria

6.1 Criteria for system with no contingency ('N-0')

a) The system shall be tested for all the load-generation scenarios as given in this document at Paragraph: 9 -11.

b) For the planning purpose all the equipments shall remain within their normal thermal loadings and voltage ratings.

c) The angular separation between adjacent buses shall not exceed 30 degree.

6.2 Criteria for single contingency ('N-1')

6.2.1 Steady-state :

a) All the equipments in the transmission system shall remain within their normal thermal and voltage ratings after a disturbance involving loss of any one of the following elements (called single contingency or 'N-1' condition), but without load shedding / rescheduling of generation:

- Outage of a 132kV or 110kV single circuit,
- Outage of a 220kV or 230kV single circuit,
- Outage of a 400kV single circuit,
- Outage of a 400kV single circuit with fixed series capacitor(FSC),
- Outage of an Inter-Connecting Transformer(ICT),
- Outage of a 765kV single circuit
- Outage of one pole of HVDC bipole.

b) The angular separation between adjacent buses under ('N-1') conditions shall not exceed 30 degree.

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6.2.2 Transient-state :

Usually, perturbation causes a transient that is oscillatory in nature, but if the system is stable the oscillations will be damped. The system is said to be stable in which synchronous machines, when perturbed, will either return to their original state if there is no change in exchange of power or will acquire new state asymptotically without losing synchronism. The transmission system shall be stable after it is subjected to one of the following disturbances:

a) The system shall be able to survive a permanent three phase to ground fault on a 765kV line close to the bus to be cleared in 100 ms.

b) The system shall be able to survive a permanent single phase to ground fault on a 765kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.

c) The system shall be able to survive a permanent three phase to ground fault on a 400kV line close to the bus to be cleared in 100 ms.

d) The system shall be able to survive a permanent single phase to ground fault on a 400kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.

e) In case of 220kV / 132 kV networks, the system shall be able to survive a permanent three phase fault on one circuit, close to a bus, with a fault clearing time of 160 ms (8 cycles) assuming 3-pole opening.

f) The system shall be able to survive a fault in HVDC convertor station, resulting in permanent outage of one of the poles of HVDC Bipole.

g) Contingency of loss of generation: The system shall remain stable under the contingency of outage of single largest generating unit or a critical generating unit (choice of candidate critical generating unit is left to the transmission planner).

6.3 Criteria for second contingency ('N-1-1')

6.3.1 Under the scenario where a contingency as defined at Paragraph: 6.2 has already happened, the system may be subjected to one of the following subsequent contingencies (called 'N-1-1' condition):

a) The system shall be able to survive a temporary single phase to ground fault on a 765kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and successful re-closure (dead time 1 second) shall be considered.

b) The system shall be able to survive a permanent single phase to ground fault on a 400kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.

c) In case of 220kV / 132kV networks, the system shall be able to survive a permanent three phase fault on one circuit, close to a bus, with a fault clearing time of 160 ms (8 cycles) assuming 3-pole opening.

6.3.2 (a) In the 'N-1-1' contingency condition as stated above, if there is a temporary fault, the system shall not loose the second element after clearing of fault but shall successfully survive the disturbance.

(b) In case of permanent fault, the system shall loose the second element as a result of fault clearing and thereafter, shall asymptotically reach to a new steady state without losing synchronism. In this new state the system parameters (i.e. voltages and line loadings) shall not exceed emergency limits, however, there may be requirement of load shedding / rescheduling of generation so as to bring system parameters within normal limits.

6.4 Criteria for generation radially connected with the grid

For the transmission system connecting generators or a group of generators radially with the grid, the following criteria shall apply:

6.4.1 The radial system shall meet 'N-1' reliability criteria as given at Paragraph: 6.2 for both the steady-state as well as transient-state.

6.4.2 For subsequent contingency i.e. 'N-1-1' (of Paragraph: 6.3) only temporary fault shall be considered for the radial system.

6.4.3 If the 'N-1-1' contingency is of permanent nature or any disturbance/contingency causes disconnection of such generator/group of generators from the main grid, the remaining main grid shall asymptotically reach to a new steady-state without losing synchronism after loss of generation. In this new state the system parameters shall not exceed emergency limits, however, there may be requirement of load shedding / rescheduling of generation so as to bring system parameters within normal limits.

Criteria for simulation and studies (Paragraph 7 to 13)

7. System studies for transmission planning

7.1 The system shall be planned based on one or more of the following power system studies, as per requirements:

i) Power Flow Studies

ii) Short Circuit Studies

iii) Stability Studies (including transient stability ** and voltage stability)

iv) EMTP studies (for switching / dynamic over-voltages, insulation coordination, etc)

(** Note : *The candidate lines, for which stability studies may be carried out, may be selected through results of load flow studies. Choice of candidate lines for transient stability studies are left to transmission planner. Generally, the lines for which the angular difference between its terminal buses is more than 20 degree after contingency of one circuit may be selected for performing stability studies.)*

8. Power system model for simulation studies

8.1 Consideration of voltage level

8.1.1 For the purpose of planning of the ISTS:

a) The transmission network may be modeled down to 220kV level with exception for North Eastern Region and parts of Uttrakhand, Himachal and Sikkim which may be modeled down to 132kV level.

b) The generating units that are stepped-up at 132kV or 110kV may be connected at the nearest 220kV bus through a 220/132 kV transformer for simulation purpose. The generating units smaller than 50 MW size within a plant may be lumped and modeled as a single unit, if total lumped installed capacity is less than 200 MW.

c) Load may be lumped at 220kV or 132kV/110kV, as the case may be.

8.1.2 For the purpose of planning of the Intra-STS System, the transmission network may be modeled down to 66kV level or up to the voltage level which is not in the jurisdiction of DISCOM. The STUs may also consider modeling smaller generating units, if required.

8.2 Time Horizons for transmission planning

8.2.1 Concept to commissioning for transmission elements generally takes three to five years; about three years for augmentation of capacitors, reactors, transformers etc., and about four to five years for new transmission lines or substations. Therefore, system studies for firming up the transmission plans may be carried out with 3-5 year time horizon.

8.2.2 Endeavour shall be to prepare base case models corresponding to load-generation scenarios (referred in Paragraph: 10 and 11) for a 5 year time horizon. These models may be tested applying the relevant criteria mentioned in this manual.

9. Load - generation scenarios

9.1 The load-generation scenarios shall be worked out so as to reflect in a pragmatic manner the typical daily and seasonal variations in load demand and generation availability.

10. Load demands

10.1 Active power (MW)

10.1.1 The system peak demands (state-wise, regional and national) shall be based on the latest Electric Power Survey (EPS) report of CEA. However, the same may be moderated based on actual load growth of past three (3) years.

10.1.2 The load demands at other periods (seasonal variations and minimum loads) shall be derived based on the annual peak demand and past pattern of load variations. In the absence of such data, the season-wise variation in the load demand may be taken as given in Table-III at Annexure-III.

10.1.3 While doing the simulation, if the peak load figures are more than the peaking availability of generation, the loads may be suitably adjusted substation-wise to match with the availability. Similarly, while doing the simulation, if the peaking availability is more than the peak load, the generation dispatches may be suitably reduced, to the extent possible, such that, the inter-regional power transfers are high.

10.1.4 From practical considerations the load variations over the year shall be considered as under:

a. Annual Peak Load

b. Seasonal variation in Peak Loads for Winter, Summer and Monsoon

c. Seasonal Light Load (for Light Load scenario, motor load of pumped storage plants shall be considered)

10.1.5 The sub-station wise annual load data, both MW and MVAr shall be provided by the State Transmission Utilities as per the format given at Annexure -IV.

10.2 Reactive power (MVAr)

10.2.1 Reactive power plays an important role in EHV transmission system planning and hence forecast of reactive power demand on an area-wise or substation-wise basis is as important as active power forecast. This forecast would obviously require adequate data on the reactive power demands at the different substations as well as the projected plans for reactive power compensation.

10.2.2 For developing an optimal ISTS, the STUs must clearly spell out the substation-wise maximum and minimum demand in MW and MVAr on seasonal basis in the format given at Annexure - IV. In the absence of such data the load power factor at 220kV and 132kV voltage levels may be taken as 0.95 lag during peak load condition and 0.98 lag during light load condition. The STUs shall provide adequate reactive compensation to bring power factor as close to unity at 132kV and 220kV voltage levels.

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11. Generation dispatches and modeling

11.1 For the purpose of development of Load Generation scenarios on all India basis, the all India peaking availability may be calculated as per the norms given in Table-I and Table-II at Annexure-III.

11.2 For planning of new transmission lines and substations, the peak load scenarios corresponding to summer, monsoon and winter seasons may be studied. Further, the light load scenarios (considering pumping load where pumped storage stations exist) may also be carried out as per requirement.

11.3 For evolving transmission systems for integration of wind and solar generation projects, high wind/solar generation injections may also be studied in combination with suitable conventional dispatch scenarios. In such scenarios, the Intra-State generating station of the RES purchasing State may be backed-down so that impact of wind generation on the ISTS grid is minimum**. The maximum generation at a wind/solar aggregation level may be calculated using capacity factors as per the norms given in Table-II at Annexure - III.

***Note:*

1) *As per the grid code, it is the responsibility of each SLDC to balance its load and generation and stick to the schedule issued by RLDC. Accordingly, it follows that in case of variation in generation from Renewable Energy Source (RES) portfolio, the State should back-down/ramp-up its conventional (thermal/hydro) generation plants or revise their drawal schedule from ISGS plants and stick to the revised schedule. The Intra-State generating station should be capable of ramping-up/backing-down based on variation in RES generation so that impact of variability in RES on the ISTS grid is minimum.*
2) *Further to address the variability of the wind/solar projects, other aspects like reactive compensation, forecasting and establishment of renewable energy control centers may also be planned by STUs.*

11.4 Special area dispatches

a) Special dispatches corresponding to high agricultural load with low power factor, wherever applicable.

b) Complete closure of a generating station close to a major load centre.

11.5 In case of thermal units (including coal, gas/diesel and nuclear based) the minimum level of output (ex-generation bus, i.e. net of the auxiliary consumption) shall be taken as not less than 70% of the rated installed

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capacity. If the thermal units are encouraged to run with oil support, they may be modeled to run up to 25% of the rated capacity.

11.6 The generating unit shall be modeled to run as per their respective capability curves. In the absence of capability curve, the reactive power limits(Q_{max} and Q_{min}) for generator buses can be taken as :

a. Thermal Units : Q_{max} = 60% of P_{max}, and Q_{min} = (-) 50% of Q_{max}

b. Nuclear Units : Q_{max} = 60% of P_{max}, and Q_{min} = (-) 50% of Q_{max}

c. Hydro Units : Q_{max} = 48% of P_{max}, and Q_{min} = (-) 50% of Q_{max}

11.7 It shall be duty of all the generators to provide technical details such as machine capability curves, generator, exciter, governor, PSS parameters etc., for modeling of their machines for steady-state and transient-state studies, in the format sought by CTU/STUs. The CTU and STUs shall provide the information to CEA for preparation of national electricity plan.

12. Short circuit studies

12.1 The short circuit studies shall be carried out using the classical method with flat pre-fault voltages and sub-transient reactance (X''_d) of the synchronous machines.

12.2 MVA of all the generating units in a plant may be considered for determining maximum short-circuit level at various buses in system. This short-circuit level may be considered for substation planning.

12.3 Vector group of the transformers shall be considered for doing short circuit studies for asymmetrical faults. Inter-winding reactances in case of three winding transformers shall also be considered. For evaluating the short circuit levels at a generating bus (11kV, 13.8kV, 21kV etc.), the unit and its generator transformer shall be represented separately.

12.4 Short circuit level both for three phase to ground fault and single phase to ground fault shall be calculated.

12.5 The short-circuit level in the system varies with operating conditions, it may be low for light load scenario compared with for peak load scenario, as some of the plants may not be on-bar. For getting an understanding of system strength under different load-generation / export-import scenarios, the MVA of only those machines shall be taken which are on bar in that scenario.

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13. Planning margins

13.1 In a very large interconnected grid, there can be unpredictable power flows in real time due to imbalance in load-generation balance in different pockets of the grid. This may lead to overloading of transmission elements during operation, which cannot be predicted in advance at the planning stage. This can also happen due to delay in commissioning of a few planned transmission elements, delay/abandoning of planned generation additions or load growth at variance with the estimates. Such uncertainties are unavoidable and hence some margins at the planning stage may help in reducing impact of such uncertainties. However, care needs to be taken to avoid stranded transmission assets. Therefore, at the planning stage following planning margins may be provided:

13.2 Against the requirement of Long Term Access sought, the new transmission lines emanating from a power station to the nearest grid point may be planned considering overload capacity of the generating stations in consultation with generators.

13.3 The new transmission additions required for system strengthening may be planned keeping a margin of 10% in the thermal loading limits of lines and transformers (refer Paragraph: 5.2, above). Further, the margins in the inter-regional links may be kept as 15%.

13.4 At the planning stage, a margin of about ± 2% may be kept in the voltage limits (as given at Paragraph: 5.3(a), above) and thus the voltages under load flow studies (for 'N-0' and 'N-1' steady-state conditions only) may be maintained within the limits given below:

Voltage (kV_{rms}) (after planning margins)		
Nominal	**Maximum**	**Minimum**
765	785	745
400	412	388
230	240	212
220	240	203
132	142	125
110	119	102
66	70	62

13.5 In planning studies all the transformers may be kept at nominal taps and On Load Tap Changer (OLTC) may not be considered. The effect of the taps should be kept as operational margin.

13.6 For the purpose of load flow studies at planning stage, the nuclear generating units shall normally not run at leading power factor. To keep some margin at planning stage, the reactive power limits (Q_{max} and Q_{min}) for generator buses may be taken as:

Type of generating unit	Q_{max}	Q_{min}
Nuclear units	Q_{max}= 0.50 x P_{max}	Q_{min}= (-)0.10 x P_{max}
Thermal Units (other than Nuclear)	Q_{max}= 0.50 x P_{max}	Q_{min}= (-)0.10 x P_{max}
Hydro units	Q_{max}= 0.40 x P_{max}	Q_{min}= (-)0.20 x P_{max}

Notwithstanding above, during operation, following the instructions of the System Operator, the generating units shall operate at leading power factor as per their respective capability curves.

Additional planning criteria and guidelines (Paragraph 14 to 20)

14. Reactive power compensation

14.1 Requirement of reactive power compensation like shunt capacitors, shunt reactors(bus reactors or line reactors), static VAr compensators, fixed series capacitor, variable series capacitor(thyristor controlled) or other FACTS devices shall be assessed through appropriate studies.

14.2 Shunt capacitors

14.2.1 Reactive Compensation shall be provided as far as possible in the low voltage systems with a view to meet the reactive power requirements of load close to the load points, thereby avoiding the need for VAr transfer from high voltage system to the low voltage system. In the cases where network below 132kV/220 kV voltage level is not represented in the system planning studies, the shunt capacitors required for meeting the reactive power requirements of loads shall be provided at the 132kV/220kV buses for simulation purpose.

14.2.2 It shall be the responsibility of the respective utility to bring the load power factor as close to unity as possible by providing shunt capacitors at appropriate places in their system. Reactive power flow through 400/220kV or 400/132kV or 220/132(or 66) kV ICTs, shall be minimal. Wherever voltage on HV side of such an ICT is less than 0.975 pu no reactive power shall flow down through the ICT. Similarly, wherever voltage on HV side of the ICT is more than 1.025 pu no reactive power shall flow up through the ICT. These criteria shall apply under the 'N-0' conditions.

14.3 Shunt reactors

14.3.1 Switchable bus reactors shall be provided at EHV substations for controlling voltages within the limits (defined in the Paragraph: 5.3) without resorting to switching-off of lines. The bus reactors may also be provided at generation switchyards to supplement reactive capability of generators. The size of reactors should be such that under steady state condition, switching on and off of the reactors shall not cause a voltage change exceeding 5%. The standard sizes (MVAr) of reactors are:

Voltage Level	Standard sizes of reactors (in MVAr)
400kV (3-ph units)	50, 63, 80 and 125 (rated at 420kV)
765kV (1-ph units)	80 and 110 (rated at 800kV)

14.3.2 Fixed line reactors may be provided to control power frequency temporary over-voltage(TOV) after all voltage regulation action has taken place within the limits as defined in Paragraph: 5.3(b) under all probable operating conditions.

14.3.3 Line reactors (switchable/ controlled/ fixed) may be provided if it is not possible to charge EHV line without exceeding the maximum voltage limits given in Paragraph: 5.3(a). The possibility of reducing pre-charging voltage of the charging end shall also be considered in the context of establishing the need for reactors.

14.3.4 Guideline for switchable line reactors: The line reactors may be planned as switchable wherever the voltage limits, without the reactor(s), remain within limits specified for TOV conditions given at Paragraph: 5.3(b).

14.4 Static VAr compensation (SVC)

14.4.1 Static VAr Compensation (SVC) shall be provided where found necessary to damp the power swings and provide the system stability under conditions defined in the Paragraph: 6 on 'Reliability Criteria'. The dynamic range of static compensators shall not be utilized under steady state operating condition as far as possible.

15. Sub-station planning criteria

15.1 The requirements in respect of EHV sub-stations in a system such as the total load to be catered by the sub-station of a particular voltage level, its MVA capacity, number of feeders permissible etc. are important to the planners so as to provide an idea to them about the time for going in for the adoption of next higher voltage level sub-station and also the number of substations required for meeting a particular quantum of load. Keeping these in view the following criteria have been laid down for planning an EHV substation:

15.2 The maximum short-circuit level on any new substation bus should not exceed 80% of the rated short circuit capacity of the substation. The 20% margin is intended to take care of the increase in short-circuit levels as the system grows. The rated breaking current capability of switchgear at different voltage levels may be taken as given below:

Voltage Level		**Rated Breaking Capacity**
132 kV	-	25 kA / 31.5 kA
220 kV	-	31.5 kA / 40 kA
400 kV	-	50 kA / 63 kA
765 kV	-	40 kA / 50 kA

Measures such as splitting of bus, series reactor, or any new technology may also be adopted to limit the short circuit levels at existing substations wherever they are likely to cross the designed limits.

15.3 Rating of the various substation equipments shall be such that they do not limit the loading limits of connected transmission lines.

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15.4 Effort should be to explore possibility of planning a new substation instead of adding transformer capacity at an existing substation when the capacity of the existing sub-station has reached as given in column (B) in the following table. The capacity of any single sub-station at different voltage levels shall not normally exceed as given in column (C) in the following table:

Voltage Level	**Transformer Capacity**	
(A)	**Existing capacity (B)**	**Maximum Capacity (C)**
765 kV	6000 MVA	9000 MVA
400 kV	1260 MVA	2000 MVA
220 kV	320 MVA	500 MVA
132 kV	150 MVA	250 MVA

15.5 While augmenting the transformation capacity at an existing substation or planning a new substation the fault level of the substation shall also be kept in view. If the fault level is low the voltage stability studies shall be carried out.

15.6 Size and number of interconnecting transformers (ICTs) shall be planned in such a way that the outage of any single unit would not over load the remaining ICT(s) or the underlying system.

15.7 A stuck breaker condition shall not cause disruption of more than four feeders for the 220kV system and two feeders for the 400kV system and 765kV system.

Note – In order to meet this requirement it is recommended that the following bus switching scheme may be adopted for both AIS and GIS and also for the generation switchyards:

220kV – 'Double Main' or 'Double Main & Transfer' scheme with a maximum of eight(8) feeders in one section

400kV and 765kV – 'One and half breaker' scheme

16. Additional criteria for wind and solar projects

16.1 The capacity factor for the purpose of maximum injection to plan the evacuation system, both for immediate connectivity with the ISTS/Intra-STS and for onward transmission requirement, may taken as given in Table-II at Annexure – III.

16.2 The 'N-1' criteria may not be applied to the immediate connectivity of wind/solar farms with the ISTS/Intra-STS grid i.e. the line connecting the farm to the grid and the step-up transformers at the grid station.

16.3 As the generation of energy at a wind farm is possible only with the prevalence of wind, the thermal line loading limit of the lines connecting the wind machine(s)/farm to the nearest grid point may be assessed considering 12 km/hour wind speed.

16.4 The wind and solar farms shall maintain a power factor of 0.98 (absorbing) at their grid inter-connection point for all dispatch scenarios by providing adequate reactive compensation and the same shall be assumed for system studies.

17. Additional criteria for nuclear power stations

17.1 In case of transmission system associated with a nuclear power station there shall be two independent sources of power supply for the purpose of providing start-up power. Further, the angle between start-up power source and the generation switchyard should be, as far as possible, maintained within 10 degrees.

17.2 The evacuation system for sensitive power stations viz., nuclear power stations, shall generally be planned so as to terminate it at large load centres to facilitate islanding of the power station in case of contingency.

18. GUIDELINES FOR PLANNING HVDC TRANSMISSION SYSTEM

18.1 The option of HVDC bipole may be considered for transmitting bulk power (more than 2000 MW) over long distance (more than 700 km). HVDC transmission may also be considered in the transmission corridors that have AC lines carrying heavy power flows (total more than 5000 MW) to control and supplement the AC transmission network.

18.2 The ratio of fault level in MVA at any of the convertor station (for conventional current source type), to the power flow on the HVDC bipole shall not be less than 3.0 under any of the load-generation scenarios given under Paragraph:9 to 11 and contingencies given at Paragraph: 6, above. Further, in areas where multiple HVDC bipoles are feeding power (multi in

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feed), the appropriate studies be carried at planning stage so as to avoid commutation failure.

19. Guidelines for voltage stability

19.1 Voltage Stability Studies: These studies may carried out using load flow analysis program by creating a fictitious synchronous condenser at critical buses which are likely to have wide variation in voltage under various operating conditions i.e. bus is converted into a PV bus without reactive power limits. By reducing desired voltage of this bus, MVAr generation/ absorption is monitored. When voltage is reduced to some level it may be observed that MVAr absorption does not increase by reducing voltage further instead it also gets reduced. The voltage where MVAr absorption does not increase any further is known as Knee Point of Q-V curve. The knee point of Q-V curve represents the point of voltage instability. The horizontal 'distance' of the knee point to the zero-MVAr vertical axis measured in MVAr is, therefore, an indicator of the proximity to the voltage collapse.

19.2 Each bus shall operate above Knee Point of Q-V curve under all normal as well as the contingency conditions as discussed above. The system shall have adequate margins in terms of voltage stability.

20. Guidelines for consideration of zone – 3 settings

20.1 In some transmission lines, the Zone-3 relay setting may be such that it may trip under extreme loading condition. The transmission utilities should identify such relay settings and reset it at a value so that they do not trip at extreme loading of the line. For this purpose, the extreme loading may be taken as 120% of thermal current loading limit and assuming 0.9 per unit voltage (i.e. 360 kV for 400kV system, 689 kV for 765kV system). In case it is not practical to set the Zone-3 in the relay to take care of above, the transmission licensee/owner shall inform CEA, CTU/STU and RLDC/SLDC along with setting (primary impendence) value of the relay. Mitigating measures shall be taken at the earliest and till such time the permissible line loading for such lines would be the limit as calculated from relay impedance assuming 0.95 pu voltage, provided it is permitted by stability and voltage limit considerations as assessed through appropriate system studies.

Annexure- I

DEFINITIONS

1. **Peak Load:** It is the simultaneous maximum demand of the system being studied under a specific time duration(e.g. annual, monthly, daily etc).

2. **Light Load:** It is the simultaneous minimum demand of the system being studied under a specific time duration(e.g. annual, monthly, daily etc).

3. **System Stability:** A stable power system is one in which synchronous machines, when perturbed, will either return to their original state if there is no change in exchange of power or will acquire new state asymptotically without losing synchronism. Usually the perturbation causes a transient that is oscillatory in nature, but if the system is stable the oscillations will be damped.

4. **Temporary over-voltages:** These are power frequency over-voltages produced in a power system due to sudden load rejection, single phase to ground faults, etc.

5. **Switching over-voltages:** These over-voltages generated during switching of lines, transformers and reactors etc. having wave fronts 250/2500 micro sec.

6. **Surge Impedance Loading:** It is the unit power factor load over a resistance line such that series reactive loss (I^2X) along the line is equal to shunt capacitive gain (V^2Y). Under these conditions the sending end and receiving end voltages and current are equal in magnitude but different in phase position.

Annexure - II

ABBREVIATIONS

AC	:	Alternating Current
CEA	:	Central Electricity Authority
CTU	:	Central Transmission Utility
D/c	:	Double Circuit
DISCOM	:	Distribution Company
EHV	:	Extra High Voltage
EMTP	:	Electro Magnetic Transient Program
EPS	:	Electric Power Survey
FACTS	:	Flexible Alternating Current Transmission System
HV	:	High Voltage
HVDC	:	High Voltage Direct Current
ICT	:	Inter-Connecting Transformer
ISGS	:	Inter-State Generating Station
ISTS	:	Inter State Transmission System
Intra-STS	:	Intra-State Transmission System
kA	:	kilo Ampere
km	:	kilo meter
kV	:	kilo Volt
ms	:	millisecond
MVA	:	Million Volt Ampere
MVAr	:	Mega Volt Ampere reactive
MW	:	Mega Watt
NR/WR/SR/ ER/NER	:	Northern / Western / Southern / Eastern/North Eastern Region (s)
NLDC	:	National Load Dispatch Centre
P, Q	:	P - Active Power, Q - Reactive Power
P_{max}, Q_{max}, Q_{min}	:	P_{max} – Maximum Active Power, Q_{max} – Maximum Reactive Power Supplied i.e. lagging, Q_{min} – Maximum Reactive Power Absorbed i.e. leading

POSOCO	:	Power System Operation Corporation
POWERGRID or PGCIL	:	Power Grid Corporation of India Limited
p u	:	per unit
RES	:	Renewable Energy Source
RLDC	:	Regional Load Dispatch Centre
S/c	:	Single Circuit
SLDC	:	State Load Dispatch Centre
STU	:	State Transmission Utility (Generally Transmission Company of the State)
SVC	:	Static VAr Compensation
X, Y, Z	:	X - Reactance, Y - Admittance, Z - Impedance

Annexure- III

GENERATION AND LOAD FACTORS

Table – I

(Generation Availability Factors – for conventional generation)**

Actual data, wherever available, should be used. In cases where data is not available the generation availability may be calculated using following factors:

(a) Thermal Generation

Sl. No.	Type of Generation	Availability Factor (at Peak Load)	Availability Factor (at Light Load)
1.	Nuclear	80 %	80 %
2.	Thermal (Coal based)	80 %	80 %
3.	Thermal (Lignite based)	78 %	78 %
4.	Gas based (CCGT type)	85 %	50 %
5.	Diesel / or Gas based (open cycle)	90 %	50 %

(b) Hydro Generation

Sl. No.	Season	Availability Factor (at Peak Load)	Availability Factor (at Light Load)
1.	Summer	70 %	40 %
2.	Monsoon	90 %	60 %
3.	Winter	50 %	10 %

- The above availability factors are net of auxiliary consumption and considering planned/forced outages.
- The above availability factors may be used for working out generation availability at State/Regional/National level.
- These factors are not for modeling dispatch from individual units; the dispatch from a unit can be modeled up to its maximum capacity (net of Auxiliary consumption).

Table- II

(Capacity Factors – for Renewable Energy Source (wind/solar) generation) **

Capacity factor, considering diversity in wind/solar generation, is the ratio of maximum generation available at an aggregation point to the algebraic sum of capacity of each wind machine / solar panel connected to that grid point. Actual data, wherever available, should be used. In cases where data is not available the Capacity factor may be calculated using following factors:

Voltage level/ Aggregation level	132kV / Individual wind/solar farm	220kV	400kV	State (as a whole)
Capacity Factor (%)	80 %	75 %	70 %	60 %

Table- III

(Region-wise Demand Factors for seasonal variation of load) **

Actual data, wherever available, should be used. In cases where data is not available following Region-wise factors for seasonal variation of peak and light load demand may be assumed:

Sl. No.	Season / Scenario	Region-wise Demand Factors (%)				
		NR	**WR**	**SR**	**ER**	**NER**
1.	Summer Peak Load (S-PL)	**100**	**95**	**98**	**100**	**100**
2.	Summer Light Load (S-LL)	70	70	70	70	70
3.	Monsoon Peak Load (M-PL)	**96**	**90**	**90**	**95**	**95**
4.	Monsoon Light Load (M-LL)	70	70	70	70	70
5.	Winter Peak Load (W-PL)	**95**	**100**	**100**	**95**	**95**
6.	Winter Light Load (W-LL)	70	70	70	70	70

(Where 100% is for the annual peak load of a region)

** - The above factors may be revised from time to time.

Annexure- IV

LOAD DATA FROM STUs

STUs to provide sub-station wise load data as per following format:

(Please refer to Paragraph: 8 and Paragraph: 10)

Sl. No.	Name of Substation	Voltage Level	Peak Load		Light Load	
			MW	MVAR	MW	MVAR

The STUs may provide above information/data at least once a year (preferably by 31st March of every year.

CE (STU) MSETCL

Annexure- V

DATA FOR TRANSMISSION PLANNING STUDIES

Table- I(a)

(Line parameters (per unit / km / circuit, at 100 MVA base)

Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed:

Voltage (kV)	Config.	Type of conductor	Ckt	Positive sequence			Zero sequence		
				R	X	B	R_0	X_0	B_0
765	Quad	ACSR Bersimis	S/C	1.951E-6	4.880E-5	2.35E-2	4.500E-5	1.800E-4	1.406E-2
765	Hexa	ACSR Zebra	D/C	2.096E-6	4.360E-5	2.66E-2	3.839E-5	1.576E-4	1.613E-2
400	Twin	ACSR Moose	S/C	1.862E-5	2.075E-4	5.55E-3	1.012E-4	7.750E-4	3.584E-3
400	Twin	ACSR Moose	D/C	1.800E-5	1.923E-4	6.02E-3	1.672E-4	6.711E-4	3.669E-3
400	Twin	ACSR Lapwing	S/C	1.230E-5	1.910E-4	6.08E-3	6.685E-5	7.134E-4	3.926E-3
400	Twin	ACSR Lapwing	D/C	1.204E-5	1.905E-4	6.08E-3	1.606E-4	6.651E-4	3.682E-3
400	Twin	Moose eq. AAAC	S/C	1.934E-5	2.065E-4	5.67E-3	1.051E-4	7.730E-4	3.660E-3
400	Triple	ACSR Zebra	S/C	1.401E-5	1.870E-4	5.86E-3	7.616E-3	6.949E-4	3.783E-3
400	Quad	ACSR Zebra	S/C	1.050E-5	1.590E-4	6.60E-3	5.708E-3	5.940E-4	4.294E-3
400	Quad	ACSR Bersimis	S/C	7.416E-6	1.560E-4	7.46E-3	4.031E-3	5.828E-4	4.854E-3
400	Quad	ACSR Moose	S/C	9.167E-6	1.580E-4	7.32E-3	1.550E-4	6.250E-4	4.220E-3
400	Quad	ACSR Moose	D/C	9.177E-6	1.582E-4	7.33E-3	1.557E-4	6.246E-4	4.237E-3
400	Quad	Moose eq. AAAC	S/C	9.790E-6	1.676E-4	6.99E-3	5.320E-3	6.260E-4	4.510E-3
220	Twin	ACSR Moose	S/C	4.304E-5	5.819E-4	1.98E-3	4.200E-4	2.414E-3	1.107E-3
220	Single	ACSR Zebra	S/C	1.440E-4	8.220E-4	1.41E-3	4.231E-4	2.757E-3	8.843E-4
220	Single	ACSR Drake	S/C	1.800E-4	8.220E-4	1.41E-3	6.1E-4	2.56E-3	8.050E-4
220	Single	ACSR Moose	S/C	1.547E-4	8.249E-4	1.42E-3	4.545E-4	2.767E-3	8.906E-4
220	Single	ACSR Kunda	S/C	1.547E-4	8.249E-4	1.42E-3	4.545E-4	2.767E-3	8.906E-4
220	Single	AAAC Zebra	S/C	1.547E-4	8.249E-4	1.42E-3	4.545E-4	2.767E-3	8.906E-4
132	Single	ACSR Panther	S/C	9.310E-4	2.216E-3	5.10E-4	2.328E-3	9.310E-3	
66	Single	ACSR Dog	S/C	3.724E-3	8.864E-3	1.28E-4			

Table- I(b)

For some new conductors** the resistance data (in Ω/km) for **Zebra equivalent** size is given in following Table. The reactance(X) and susceptance (B) values of line mainly depend on the tower configuration, and therefore the X and B values (in per unit / km / circuit) may be taken from Table I(a) above for similar configuration.

Name of Conductor	DC Resistance	AC Resistance values at different temperatures (in Ω/km)							
	20° C	20° C	75° C	85° C	95° C	120° C	150° C	175° C	200° C
ACSR	0.06868	0.6868	0.08479	0.0875	NA	NA	NA	NA	NA
AAAC	0.06921	0.0704	0.08541	0.08814	0.09093	NA	NA	NA	NA
TACSR	0.07560	0.07668	0.09315	0.09613	0.09912	0.10662	0.11565	NA	NA
AL59	0.07805	0.0791	0.09610	0.09918	0.10230	NA	NA	NA	NA
ACSS	0.08430	0.08527	0.10366	0.1070	0.11034	0.11872	0.12878	0.13718	0.14557
STACIR	0.08000	0.08105	0.09847	0.10163	0.10479	0.11274	0.12229	0.13025	0.13822
ACCC	0.05510	0.05656	0.06844	0.07062	0.07279	0.07821	0.08475	0.09021	NA

Table- I(c)

For some new conductors** the resistance data (in Ω/km) for **Moose equivalent** size is given in following Table. The reactance(X) and susceptance (B) values of line mainly depend on the tower configuration, and therefore the X and B values (in per unit / km / circuit) may be taken from Table I(a) above for similar configuration.

Name of Conductor	DC Resistance	AC Resistance values at different temperatures (in Ω/km)							
	20° C	20° C	75° C	85° C	95° C	120° C	150° C	175° C	200° C
ACSR	0.05552	0.05699	0.069	0.07112	NA	NA	NA	NA	NA
AAAC	0.05980	0.06116	0.074	0.07646	0.07882	NA	NA	NA	NA
TACSR	0.05460	0.05609	0.068	0.07001	0.07213	0.07753	0.08398	NA	NA
AL59	0.05070	0.05231	0.063	0.06518	0.06714	NA	NA	NA	NA
ACSS	0.05210	0.05368	0.065	0.06691	0.06896	0.07409	0.08023	0.08537	0.09057
STACIR	0.06820	0.06941	0.084	0.08689	0.08960	0.09636	0.10445	0.11124	0.11802
ACCC	0.04340	0.04527	0.055	0.05618	0.05788	0.06211	0.06720	0.07148	NA

Table- I(d)

Name of Conductor	DC Resistance	AC Resistance values at different temperatures (in Ω/km)							
	20 ° C	20° C	75 ° C	85 ° C	95 ° C	120 ° C	150 ° C	175 ° C	200 ° C
ACSR Bersimis	0.0419	0.04384	0.0527	0.05435	NA	NA	NA	NA	NA
AAAC Bersimis	0.0494	0.05104	0.06164	0.06358	0.06548	NA	NA	NA	NA
ACSR Lapwing	0.0383	0.0404	0.04844	0.04995	NA	NA	NA	NA	NA
ACSR Snowbird	0.055	0.0565	0.06832	0.07049	NA	NA	NA	NA	NA

**

ACSR - Aluminum Conductor Steel Reinforced

AAAC - All Aluminum Alloy Conductor

TACSR - Thermal Alloy Conductor Steel Reinforced

ACSS - Aluminum Conductor Steel Supported

STACIR - Super Thermal Alloy Conductor, Invar Reinforced

ACCC - Aluminum Conductor Composite Core

AL 59 - Alloy conductor (of Aluminum, Magnesium and Silicon)

Table- II

(Thermal Loading Limits of Transmission Lines)

Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed. Data for some new conductors which are equivalent to ACSR Zebra/Moose are also given in following tables:

Conductor type and dimension	Ambient Temperature (°C)	AMPACITY FOR Maximum Conductor Temperature (°C)	
		65	75
ACSR PANTHER 210 sq mm	40	312	413
	45	244	366
	48	199	334
	50		311

Thermal Loading Limits for ACSR Zebra equivalent Conductors

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	95	120	150
ACSR Zebra (484 Sq.mm) Dia:28.62mm	40	473	643	769	NA	NA	NA
	45	346	560	703	NA	NA	NA
	48	240	503	661	NA	NA	NA
	50	128	462	631	NA	NA	NA

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	90	95	120
AAAC (479.00 sq mm) Dia:28.42 mm	40	471	639	765	818	866	NA
	45	345	557	700	758	811	NA
	48	240	501	657	720	776	NA
	50	130	460	627	693	751	NA

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	90	95	120
AL59 (383.00 sq mm) Dia:25.41 mm	40	440	590	702	750	793	NA
	45	329	516	643	696	743	NA
	48	240	466	605	661	711	NA
	50	154	429	578	637	689	NA

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
TACSR (462.63 sq mm) Dia:27.93mm	40	730	826	1010	1173	NA	NA
	45	667	773	971	1142	NA	NA
	48	627	740	946	1124	NA	NA
	50	599	717	930	1111	NA	NA

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
STACIR (419.39 sq mm) Dia:26.61mm	40	701	793	969	1124	1228	1318
	45	642	743	931	1094	1203	1296
	48	604	711	908	1076	1188	1283
	50	577	689	892	1064	1177	1274

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
ACSS (413.69 sq mm) Dia:26.40mm	40	682	771	942	1093	1193	1281
	45	625	722	905	1064	1169	1260
	48	587	691	882	1046	1154	1247
	50	561	67	867	1035	1144	1238

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
ACCC (588.30 sq mm) Dia:28.14 mm	40	853	965	1182	1374	1502	NA
	45	780	904	1136	1338	1472	NA
	48	733	865	1107	1316	1453	NA
	50	700	837	1088	1301	1440	NA

Thermal Loading Limits for ACSR Moose equivalent Conductors

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	95	120	150
ACSR Moose (597 Sq.mm) Dia:31.77mm	40	528	728	874	**NA**	**NA**	**NA**
	45	378	631	798	**NA**	**NA**	**NA**
	48	247	565	749	**NA**	**NA**	**NA**
	50	83	516	714	**NA**	**NA**	**NA**

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	90	95	120
AAAC (570.00 sq mm) Dia:31.05 mm	40	509	699	839	898	952	NA
	45	366	606	766	831	890	NA
	48	243	543	719	789	851	NA
	50	96	497	686	759	825	NA

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	95	120	150
AL59 (586.59 sq mm) Dia:31.50 mm	40	551	759	912	976	1035	NA
	45	395	658	832	904	968	NA
	48	260	589	781	857	926	NA
	50	94	539	745	825	896	NA

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
TACSR (596.90 sq mm) Dia:31.77mm	40	881	1001	1230	1433	NA	NA
	45	805	936	1182	1396	NA	NA
	48	755	895	1152	1372	NA	NA
	50	720	867	1132	1357	NA	NA

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
STACIR (483.85 sq mm) Dia:28.63 mm	40	772	874	1070	1244	1360	1461
	45	706	818	1028	1211	1333	1437
	48	663	783	1003	1191	1316	1423
	50	633	758	985	1178	1304	1413

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
ACSS (597 sq mm) Dia:31.77mm	40	902	1024	1258	1466	1606	1727
	45	823	957	1209	1428	1573	1699
	48	772	915	1178	1404	1554	1682
	50	736	886	1158	1388	1540	1670

Conductor Type (metallic area) and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		85	95	120	150	175	200
ACCC (729.41 sq mm) Dia:31.55 mm	40	982	1115	1371	1599	1606	NA
	45	897	1043	1318	1557	1573	NA
	48	841	998	1284	1531	1554	NA
	50	802	966	1262	1514	1540	NA

Thermal Loading Limits for Snowbird conductor

ACSR SNOWBIRD							
Conductor Type and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	95	120	150
ACSR Snowbird 552.23sq.mm Dia:30.57mm	40	529	726	870	NA	NA	NA
	45	382	630	795	NA	NA	NA
	48	256	565	746	NA	NA	NA
	50	110	517	712	NA	NA	NA

Thermal Loading Limits for Bersimis equivalent conductors

ACSR Bersimis							
Conductor Type and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	95	120	150
ACSR Bersimis 724.69sq.mm Dia:35.04 mm	40	606	848	1024	NA	NA	NA
	45	423	732	933	NA	NA	NA
	48	256	653	874	NA	NA	NA
	50		594	833	NA	NA	NA

AAAC BERSIMIS							
Conductor Type and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	90	95	120
AAAC Bersimis 766.86Sq.mm Dia:36 mm	40	562	788	953	1022	1085	NA
	45	388	679	868	945	1014	NA
	48	228	605	813	896	969	NA
	50		550	774	861	938	NA

Thermal Loading Limits for Lapwing conductor

ACSR LAPWING							
Conductor Type and Dimension	Ambient Temperature (deg C)	AMPACITY FOR Maximum Conductor Temperature (deg C)					
		65	75	85	95	120	150
ACSR Lapwing 863.47Sq.mm Dia:38.22 mm	40	635	899	1090	NA	NA	NA
	45	430	773	992	NA	NA	NA
	48	234	686	928	NA	NA	NA
	50		622	883	NA	NA	NA

The above data has been calculated based on following assumptions:

- Solar radiations = 1045 W/m^2.
- Wind Speed = 2 km/hour
- Absorption Coefficient = 0.8
- Emissivity Coefficient = 0.45
- Age > 1 year

Table-III

(Sag of conductor on Transmission Lines)

Indicative sag values for various types of conductors, assuming a ruling span of 400m and considering that tension for conductor is less than that for ACSR conductor, are given below:

For Zebra equivalent conductors:

Name of CONDUCTOR	Sag(in meter) at different temperatures				
	85 ° C	95 ° C	120 ° C	150 ° C	200 ° C
ACSR	9.66	NA	NA	NA	NA
TACSR	8.11	8.3	8.78	9.36	NA
ACSS*	7.53	7.73	8.23	8.85	9.86
STACIR	8.71	8.95	9.09	9.27	9.57
ACCC	8.77	8.79	8.84	8.90	NA
AAAC	10.37	NA	NA	NA	NA
AL59	10.16	10.60	NA	NA	NA

For Moose equivalent conductors:

Name of CONDUCTOR	Sag(in meter) at different temperatures				
	85 ° C	95 ° C	120 ° C	150 ° C	200 ° C
ACSR	13.26	N/A	N/A	N/A	N/A
TACSR	10.78	10.95	11.40	11.95	N/A
ACSS*	10.98	11.17	11.65	12.22	13.17
STACIR	11.47	11.84	12.22	12.41	12.72
ACCC	12.61	12.63	12.69	12.76	NA
AAAC	14.15	NA	NA	NA	NA
AL59	14.52	14.96	NA	NA	NA

* Workings of ACSS done under pre-tensioned condition of max Wind Load

Table- IV

(Transformer Reactance)

Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed:

Type of Transformer	Transformer reactance X_t (at its own base MVA)
Generator transformer (GT)	14 – 15 %
Inter-Connecting Transformer (ICT)	12.5 %

Data for Transient Stability Studies

Table- V

(Voltage and Frequency Dependency of Load)

Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed:

Load	**Voltage Dependency of the system loads**	**Frequency Dependency of the system loads**
Active loads (P)	$P = P_0\left(V/V_0\right)$	$P = P_0\left(f/f_0\right)$
Reactive loads (Q)	$Q = Q_0\left(V/V_0\right)^2$	Q can be taken as independent of frequency. However, if appropriate relationship is known, Q may also be simulated as dependent on frequency, on case to case basis.
(where P_o, Q_o, V_o and f_o are values at the initial system operating conditions)		

Table- VI (Modeling for Machines)

Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed:

Table- V(a) : 'Typical parameters for Thermal and Hydro Machines'

MACHINE PARAMETERS	MACHINE RATING (MW)				
	THERMAL				HYDRO
	800 (Mundra)	660 (Sipat-I)	500 (Simhadri-II)	210	200
Rated Voltage (kV)	26.00	24.00	21.00	15.75	13.80
Rated MVA	960.00	776.50	588.00	247.00	225.00
Inertia Constant (H)	4.50	4.05	4.05	2.73	3.50
Reactance					
Leakage (X_L)	0.18	0.188	0.147	0.18	0.16
Direct axis (X_d)	2.07	2.00	2.31	2.23	0.96
Quadrature axis (X_q)	2.04	1.89	2.19	2.11	0.65
Transient Reactance					
Direct axis (X'_d)	0.327	0.265	0.253	0.27	0.27
Quadrature axis (X'_q)	0.472	0.345	0.665	0.53	0.65
Sub-transient Reactance					
Direct axis (X''_d)	0.236	0.235	0.191	0.214	0.18
Quadrature axis (X''_q)	0.236	0.235	0.233	0.245	0.23
Open Circuit Time Const.					
Transient					
Direct axis (T'_{do})	8.60	6.20	9.14	7.00	9.70
Quadrature axis (T'_{qo})	1.80	2.50	2.50	2.50	0.50
Sub-transient					
Direct axis (T''_{do})	0.033	0.037	0.04	0.04	0.05
Quadrature axis (T''_{qo})	0.05	0.20	0.20	0.20	0.10

Table: V(b) - 'Typical parameters for Exciters'

Typical Parameters	Hydro	Thermal	
		< 210 MW	> 210 MW
Transdu. Time Const. (TR)	0.040	0.040	0.015
Amplifier gain (KA)	25 – 50	25 – 50	50 -200

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Typical Parameters	Hydro	Thermal	
		< 210 MW	> 210 MW
Amplif.Time Const.(TA)	0.04 – 0.05	0.04 – 0.05	0.03 – 0.05
Regulator limiting voltage			
Maximum (VR_{max})	4.0	6.0	5.0
Minimum (VR_{min})	-4.0	-5.0	-5.0
Feedback signal			
Gain (KF)	0.01	0.01	0.01
Time Constant (TF)	1.00	1.00	1.00
Exciter			
Gain(KE)	1.0	1.00	1.00
Time Constant (TE)	0.7	0.3	0.3

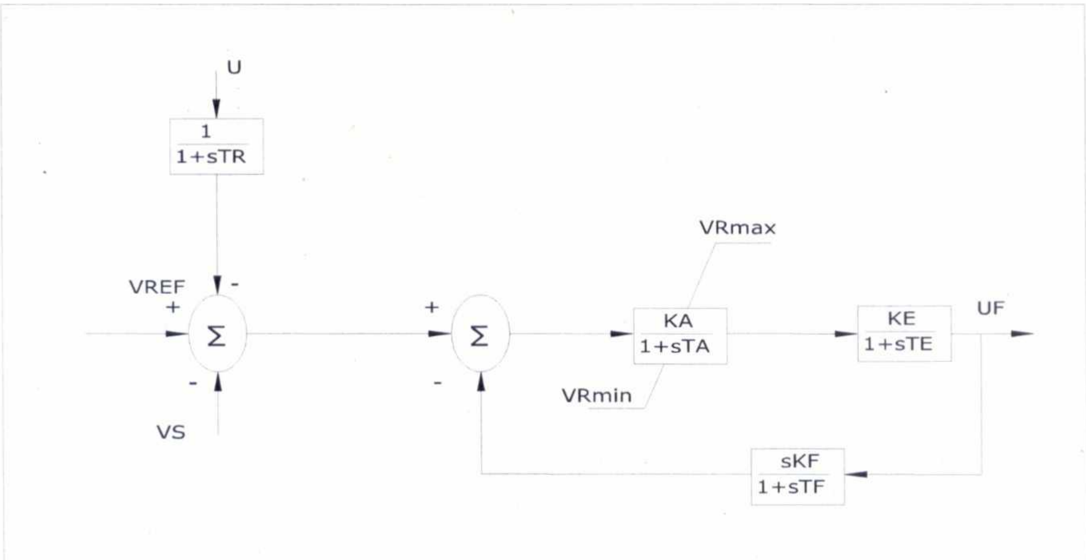
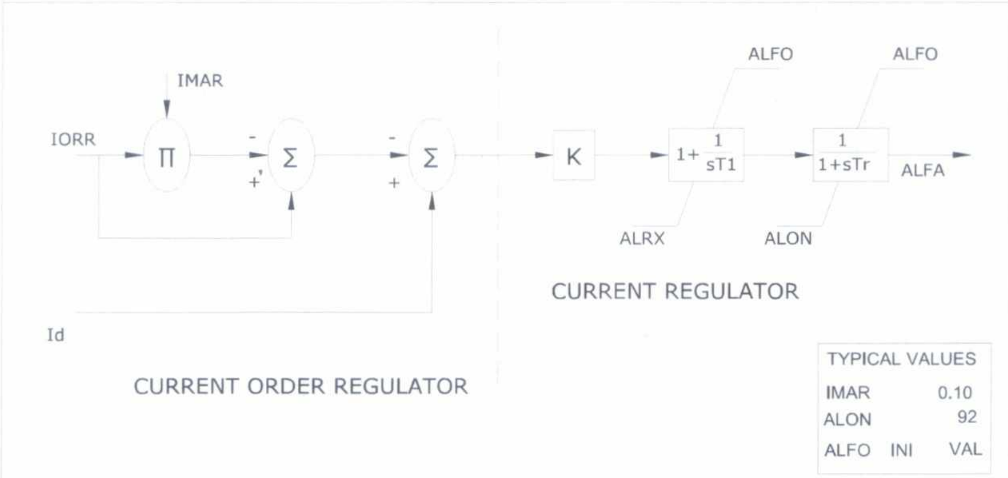


Table- VII (Modeling for HVDC)

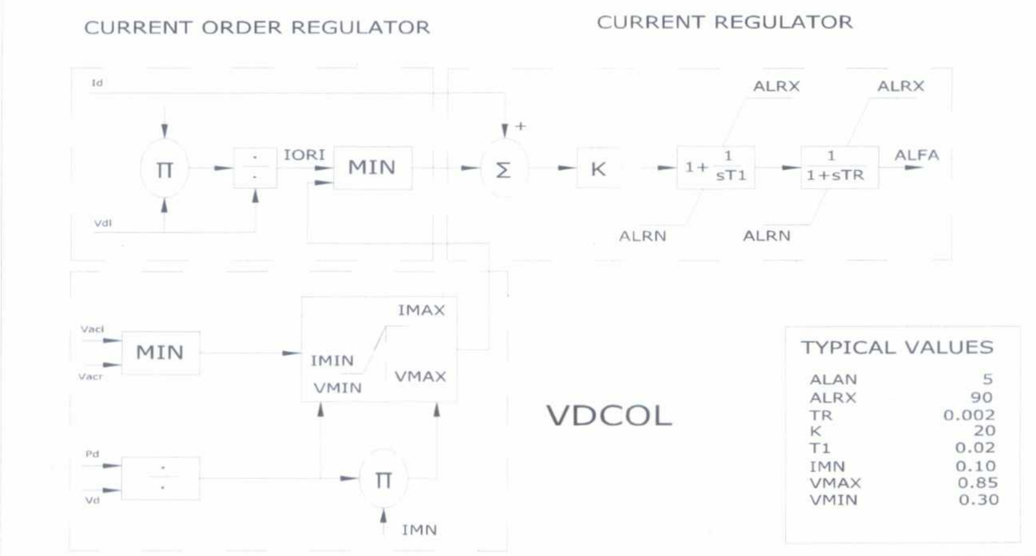
Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed:

HVDC Data: No standardized DC control model has been developed so far as this model is usually built to the load requirements of the DC terminals. Based on the past experience in carrying out stability studies, the following models are suggested for Rectifier and Invertor terminals.



D C CONTROL MODEL FOR INVERTOR

D C CONTROL MODEL FOR RECTIFIER (POWER CONTROL)



References:

1. Manual on Transmission Planning Criteria – 1994, CEA
2. Indian Electricity Act, 2003
3. Grid Standards, CEA
4. Indian Electricity Grid Code, CERC
5. CERC regulations for long term access
6. Planning Methodology and Criteria report, 1995 of M/s PTI
7. Transmission Reliability Criteria, Alberta Electric System Operator, Canada
8. Reliability Standards for the Bulk Electric Systems of North America, NERC
9. Transmission Planning Criteria - 1998, ESB National Grid
10. National Electricity Transmission System Security and Quality of Supply, National Grid, UK
11. Power System Stability and Control – Book by P. Kundur
12. Definition and Classification of Power System Stability, IEEE/CIGRE Joint Task Force -2004

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Explanatory Notes

I. At the time of the earlier Transmission Planning Criteria, published in 1994, the Indian grid was in a developing stage with skeletal 400kV lines and no 765kV line. In the present criteria, the reliability requirements have been formulated considering growth of 400kV and 765kV network. For the 765kV level the earlier criteria required the system to be able to survive a temporary single phase to ground fault, and in the present criteria the system should be able to survive a permanent 3 phase fault with normal clearing (100 ms) or a permanent single phase to ground fault with dead time of one second. As regards steady state operation, the earlier manual on transmission planning, the criteria required secure operation of grid without necessitating generation rescheduling or load shedding following loss of one element i.e. 'N-1'. The manual was silent about subsequent fault. This has been elaborated by providing criteria for 'N-1-1'.

II. Inter-state and Intra-state transmission system and the dedicated lines are all interconnected and together constitute the transmission grid. The concept of dedicated line has come after the Electricity Act, 2003. The dedicated line allowed under Section 10 of the Act connects a generating station to the grid. There is a notion that since the dedicated line is a private line, the owner is free to plan and operate it as per his choice. The dedicated line operates as part of the integrated grid and affects the grid security like any other line. Therefore, for avoidance of doubt it has been mentioned at para 1.2 that the Transmission Planning Criteria shall also apply to the dedicated lines.

III. With the passage of time, getting R-o-W for transmission lines is becoming increasingly difficult. In the meanwhile a number of high capacity conductors have come to the market. They can be used to build new lines as well as for re-conductoring. They can be particularly useful in urban/semi urban areas, on multi-circuit towers, in hilly areas and even for normal usage. Comparative technical data (Resistance, Ampacity and Sag) has been tabulated in the Manual for easy selection.

IV. After the emergence of electricity market, there is an expectation that the planners should suo motu plan the expansion of the transmission system based on load forecast and generation development plans without waiting for the specific information to pour in. The above expectation is based on simplistic assumption that transmission system is similar to a plug and play device or an optic fibre backbone. The fact is that transmission system is a highly tailor made infrastructure. For instance, take the case of a 3000 MW hydro generation developer who has applied for connectivity to the CTU and is expecting the CTU to take care of its transmission needs. The fact is that no serious planning or implementation is possible simply by knowing the location of a large generation project. A 3000 MW project would require ±800 kV HVDC bi-pole from Arunachal Pradesh to the load centres in NR/WR/SR and would cost about Rs. 15,000 crore. Even on the basis of target region it would be too risky to build such an expensive system. Firm knowledge of the buying DISCOMs/States based on long term PPAs is a pre-requisite to decide the landing point of HVDC bi-pole and then to branch out to various firm buyers. Atleast 85% power should be tied up in long term PPAs at least five years in advance so that transmission can be properly planned and implemented. It has also to be realized that margins for short term open access are limited. This aspect has been highlighted in the preamble as well as at para 3.3 and 3.13.

V. For the reliability consideration, single contingency is the most probable grid event. Para 6.2 interalia specifies that after single contingency (N-1) resulting in outage of an element :

- the system will remain stable during transition
- there will be no need to readjust generation or load
- the elements of the depleted system shall remain within normal operating limits (current, voltage and angular separation)

The above shall apply to AC network, AC/DC hybrid network as well as to stand alone HVDC bi-poles and radial AC feeders. It may be clarified that if after N-1 contingency, generation/load has to be re-dispatched through special protection scheme or through manual intervention of the operator, it means that the system is not N-1 compliant. This requirement of N-1 compliance was also specified in the 1994 Manual. But this time it has been restated in a more elaborate manner. This is also in line with international practice. Feeders emanating from wind/solar farms and terminating at the grid pooling stations and transformers at the above pooling stations have been exempted from 'N-1' criteria. (Para 16.2).

VI. Para 6.3 provides that system should successfully pass through the transient state and remain stable in the event of a subsequent contingency (N-1-1). During the N-1-1 condition the system parameters should remain within emergency limits. The intervention of the operator may be required to bring the parameters back to the normal operating limits. Generating stations with radial double circuit lines or HVDC bi-poles connecting to the main grid may get separated in the event of N-1-1 contingency but the main grid should reach a new state after the separation. Further, corrective actions to normalize the grid frequency (such as load shedding through under frequency or df/dt relays, turbine governor response, SPS, activating spinning resources, activating load back down contracts etc.) fall in the realm of IEGC and the same have not been touched upon. Planning criteria for simulating 'N-1-1' contingency has been included to improve system reliability.

VII. To reduce the impact of uncertainties at the planning stage, i.e. deviation in actual growth of the power system (generation, load demand and transmission network) from the projected growth of power system known at the time of planning, some margins have been provided under para 13. The transmission system shall be planned keeping aside these margins. These planning margins may also improve reliability of the grid.

VIII. Criteria for providing dynamic compensation through Static Var Compensators in order to damp the power swings and to enhance system stability during disturbances has been included at para 14.4.

IX. In order to minimize the impact of stuck breaker condition, it has been specified that 400 kV and 765 kV substations shall have one and a half breaker switching scheme.

X. Additional planning criteria for wind and solar projects has been included at para 16.

XI. Guidelines for carrying out voltage stability studies have been added at para 19.

XII. Guidelines have been provided at para 20 so that the Zone 3 distance protection settings of transmission lines do not foul with thermal rating of the lines.

XIII. In the discussion paper published by CEA it was mentioned that :

"*The present planning criteria mentions the following for assessing permissible line loading limits :*

Permissible line loading limit depend on many factors such as voltage regulation, stability and current carrying capacity (thermal capacity) etc. While Surge Impedance Loading (SIL) gives a general idea of the loading capability of the line, it is usual to load the short lines above SIL and long lines lower than SIL (because of the stability limitations). SIL at different voltage levels is given at Annex – II. Annex –II also shows line loading (in terms of surge impedance loading of uncompensated line) as a function of line length assuming a voltage regulation of 5% and phase angular

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difference of 30⁰ between the two ends of the line. In case of shunt compensated lines, the SIL will get reduced by a factor k, where

$$k = \sqrt{1 - \text{degree of compensation}}$$

For lines whose permissible line loading as determined from the curve higher than the thermal loading limit, permissible loading limit shall restricted to thermal loading limit ....

The above methodology needs to be reviewed so as to incorporate assessment of line loadabilities through simulation studies instead of using thumb-rule based assessment using St. Clair curve (Annex II of the Manual). As fast system study /analysis software is available to planners and dispatcher (in comparison to the time when St. Clair curve was proposed in 1953), the appropriate simulation studies and analysis (load flow/ voltage stability / transient stability etc) can be used to allow line loadings up to thermal ampacity limit if permitted by stability and voltage regulation considerations. Therefore, it is proposed to drop the St. Clair curve as guiding criteria, and instead use the studies to check violation of thermal, voltage and stability criteria."

There was consensus on the proposal to dispense with St. Clair curve as a general guidance for transmission line loading. Instead, the transmission line loadings are required to be decided based on the studies which is also as per the international practice.

XIV. The machine data for 660 MW and 800 MW units required for simulation studies have been added.

XV. It has been specified at Para 3.14 that all new substations and generating stations should commission their communication systems along with the main facilities. SLDC/RLDC may disallow commissioning of the substation/ generating substations in case requisite communication system is not ready. The above provision has been added because effective communication system and telemetering are essential for secure grid operation.

Annexure-2

Methodology for Computing 'Transmission Capacity Utilization Index' and 'Voltage Variation Index'

In accordance with the

Maharashtra Electricity Regulatory Commission

(Electricity Grid Code) Regulations, 2020

MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.

Prepared by

STATE TRANSMISSION UTILITY

MAHARASHTRA STATE ELECTRICITY TRANSMISSION

COMPANY LIMITED

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LIST OF ABBREVIATIONS

Abbreviation/Acronym	Expanded Form
ATC	Available Transfer Capacity
CBM	Capacity Benefit Margin
GCC	Grid Coordination Committee
InSTS	Intra-State Transmission System
kV	Kilovolt
MEGC	Maharashtra Electricity Grid Code, 2020
MERC	Maharashtra Electricity Regulatory Commission
MW	Megawatt
OCC	Operation Coordination Committee
SGS	State Generating Station
SIL	Surge Impedance Loading
SLDC/MSLDC	Maharashtra State Load Despatch Centre
STU	State Transmission Utility
TCUI	Transmission Capacity Utilization Index
TTC	Total Transfer Capacity
TRM	Transmission Reliability Margins
V	Voltage
Vi	RMS value of hourly measured voltage (in kV) at i^{th} hour
Vs	RMS value of the nominal system voltage
VVI	Voltage Variation Index

1. Definitions

1. '**Basic Network**' means the power system at voltage levels of 110 kV and above containing all the power system elements including generating stations and transmission system;

2. '**Available Transfer Capability (ATC)**' means the transfer capability of the inter-control area transmission system available for scheduling commercial transactions (through long term access, medium term open access and short-term open access) in a specific direction, taking into account the network security. Mathematically ATC is the Total Transfer Capability less Transmission Reliability Margin.

3. '**Capacity Benefit Margin (CBM)**' means the amount of transmission transfer capability reserved by load serving entities to ensure access to generation from interconnected systems to meet generation reliability requirements.

4. **'Peak Block'** means a single 15 minute time block in a month in which the drawal by all Distribution Licensees and full Open Access Consumers connected to InSTS is maximum.

5. '**SIL**' means loading on transmission line for various configurations as per Table-1 of this document.

6. '**Total Transfer Capability (TTC)**' means the amount of electric power that can be transferred reliably over the inter-control area transmission system under a given set of operating conditions considering the effect of occurrence of the worst credible contingency.

7. '**Transmission Reliability Margin (TRM)**' means the amount of margin kept in the total transfer capability necessary to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions.

2. Background

2.1. In compliance with the various provisions of Maharashtra Electricity Regulatory Commission (Electricity Grid Code) Regulations, 2020 more specifically Regulations 13.2.2, the methodology for computing zone-wise 'Transmission Capacity Utilization Index' as well as 'Voltage Variation Index' is to be formulated by State Transmission Utility (STU).

2.2. The Planning Criteria specified in MEGC 2020 emphasizes on grid security philosophy on which the InSTS has been planned considering past experience of STU and Users and future plan of various State Government agencies.

2.3. While developing Transmission System Plan, capacity unutilized in the existing transmission line is required to be considered in order to plan for augmentation of the capacity for addition of new transmission system element or addition of transformer or bay.

2.4. STU shall have to consider the commercial aspect and cost implication thereof arising on account of addition/augmentation of any transmission system element, for which STU have to consider the following commercial principle and parameters:

a) Optimum utilisation of the existing capacity and planned capacity addition of the transmission system element

b) Economical and efficient development of transmission system element(s) to economise overall Return of Investment for transmission system

c) Equitable and fairness in recovery of the cost from the transmission system users

d) Coordinated development of transmission system elements, particularly with reference to inter-state/inter-regional transmission system elements vis-à-vis InSTS elements

2.5. For operationalization of the Financial Planning Criteria in Transmission system planning, STU has proposed the methodology to calculate the Transmission Capacity Utilization Index and Voltage Variation Index for various elements of transmission system (HVDC, 765kV, 400kV, 22, kV, 132kV and below).

3. Computation of Transmission Capacity Utilization Index

3.1. Load Flow (Base Case) studies shall be done by the STU for Peak Block of month for the following:

a) Basic Network for the power system corresponding to the Peak Block of the previous month; and

b) Actual generation (in MW and MVAR) and actual demand (in MW and MVAR), at each node of the basic network corresponding to the peak block.

3.2. SLDC shall declare the Peak block on the first day of every month for the previous month and submit the details of the same to STU.

3.3. STU in consultation with SLDC shall finalize the data required for the Load Flow studies (base case) for the Peak Block. If required, Transmission licensees, State Generating station (SGS), Distribution licensee (s) located in the State and full Open Access Consumers connected to InSTS shall be asked to submit following data to the STU:

a) MW and MVAR data for actual injection or actual drawal at various nodes or a group of nodes for Peak Block.

b) Any other information as required by the STU.

3.4. In the event of information required by the STU is not available within 7 days, the STU shall compute TCUI based on such information from the available sources.

3.5. Surge Impedance Loading (SIL) to be considered for determination of utilization of transmission line.

3.6. SIL Loading for various voltage levels are conductor configuration as given for "CEA Transmission Planning Criterion 2013" as given below:

Table -1 SIL loading as per CEA Transmission Planning Criterion 2013

Voltage Level	Conductor Type	R	X	B	Characteristics Impedance (Surge Impedance) Zc = Sqrt (X/B)	SIL = 1^1/Zc (in PU)	SIL in MW=100*SIL (in PU)
765 kV	Quad Bersimis	1.95E-06	4.48E-05	2.40E-02	0.04	23.158	2316
765 kV at 400 kV	Quad Bersimis (Kishenpur - Moga)	7.14E-06	1.64E-04	6.56E-03	0.16	6.331	633
400 kV	Quad Bersimis Delhi Ring	7.42E-06	1.56E-04	7.46E-03	0.14	6.915	692
400 kV	Quad Moose (Tata transmission System)	9.13E-06	1.57E-04	7.40E-03	0.15	6.867	687
400 kV	Quad AAAC	9.79E-06	1.68E-04	6.99E-03	0.15	6.458	646
400 kV	Quad Zebra	1.05E-05	1.59E-04	6.65E-03	0.15	6.467	647
400 kV	Triple Snowbird	1.21E-05	1.72E-04	6.74E-03	0.16	6.254	625
400 kV	Triple Zebra	1.40E-05	1.87E-04	5.86E-03	0.18	5.598	560
400 kV	Twin Moose	1.86E-05	2.08E-04	5.55E-03	0.19	5.172	517
400 kV	Twin AAAC	1.93E-05	2.07E-04	5.67E-03	0.19	5.240	524
400 kV	Twin ACAR	1.65E-05	1.94E-04	6.02E-03	0.18	5.574	557
220 kV	Single Zebra	1.55E-04	8.25E-04	1.42E-03	0.76	1.312	131
220 kV	AAAC zebra	6.87E-02	4.17E-01	1.33E-06	0.56	1.785	178
220kV	Twin AAAC moose	3.33E-02	3.32E-01	1.76E-06	0.43	2.30	230
132 kV	Single Panther	9.31E-04	2.22E-03	5.10E-04	2.08	0.480	48

The SIL loading as computed by CEA is based on technical parameters (Inductance and Capacitance of transmission line in per km), and same has to be considered for computing TCUI.

3.7. The STU shall run load flow studies on the base case in accordance with this procedure to determine power flow on each transmission line:

Provided that while carrying out load flow studies, the STU may make minor adjustment in generation and demand data, if required, to ensure load-generation balance.

3.8. STU shall calculate the loading on each transmission line with respect to SIL values as given in Table-1. Formula to compute Transmission Capacity Utilization Index is as follows:

$$\textbf{Tranmission Capacity Utilization Index} = \frac{Base\ case\ line\ loading}{SIL} X100$$

3.9. In case, if line loading as per base case load flow is equal to or higher than SIL loading given in Table-1 (3.3.2), then Transmission Capacity Utilization Index is 100% and in case if line loading is less than SIL loading then Transmission Capacity Utilization Index shall be less than 100%.

3.10. All the line with loading below SIL can be grouped in the form of a report on PSS/E by considering SIL loading as Rate A. Then as given in 3.7, the transmission capacity utilization index can be computed. PSS/E would give results in report form and displays Transmission Capacity Utilization Index.

3.11. STU shall study and compute impact of MOD and RE generation by using the Re-despatching criteria and some of the transmission lines in the base case may be excluded from the list of lines whose transmission capacity utilization index is lower than 100%.

3.12. The commercial transactions or load up to ATC only and power flow exceeding ATC leads to congestion (As per CERC Measure to relieve congestion in real time operation, Regulation 2009). For transfer capacity estimation viz TTC/ATC /TRM, N-1 criteria is inbuilt / considered and further 2%-5% Reliability Margin (RM) required to handle uncertainties in grid operations. Accordingly, it is prudent to keep margin for TRM (Transmission Reliability Margin) as 2% and CBM (Capacity Benefit Margin) of 3%.

3.13. STU shall exclude following elements from computation as these lines are required for interconnecting in synchronous grids–

a) Transmission lines emanating from ISTS substation

b) Interstate transmission lines

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c) HVDC lines and Lines with FACT devices*

**HVDC lines and lines with FACT devices have capability to control the Active and Reactive Power flow. Active power flow can be controlled in case of HVDC lines and Active and Reactive power flow as the case may be can be controlled in case of lines with FACT devices and hence their importance needs to be evaluated from the considerations other than Transmission Capacity Utilization index.*

3.14. The lines loaded below SIL need to be further examined in respect of

a) N-1 and N-1-1 compliance fulfilment

b) Capacity built in future load growth considering five years forward horizon (25% growth)

c) Reserve capacity built in considering ROW considerations (10%)

d) Consideration of annual peak load conditions

e) Margins to be left for TRM in the TTC/ATC computations and Capacity Benefit Margin (5%)

f) Design margins and forecasting errors

The above factors are required for any transmission system to the extent of margin of around 50%. Based on this criterion, the Transmission Capacity Utilization Index (for individual line / Zone wise) to be multiplied by a factor of 1.5, before comparing with SIL.

3.15. Transmission systems operate in parallel with national grid and InSTS has to maintain transmission line loadings to comply with static and dynamic security requirements. All transmission lines shall be loaded at minimum of

a) Thermal Loading

b) Voltage Limits

c) Stability Limits

Even though stability limit computation requires elaborate dynamic modelling and simulations, the simple criterion of keeping 50% margin in thermal loading (by ensuring voltage angle difference equal to or less than 30 degrees for any two successive buses) can take care of the stability issues. Hence any line loaded up to 50% of thermal loading can be considered as fully utilized.

3.16. STU shall calculate zone-wise voltage level wise transmission capacity utilization index as given below:

3.17. Zone wise list of lines can be segregated in the load flow case of PSS/E by declaring zone of each line. Zonal indices calculated for each voltage level.

$$Zonal\ Transmission\ capacity\ utilization\ Index\ (\%) = \frac{\sum_{line=1}^{N} Line\ Length\ X\ Transmission\ line\ Utilization\ Index}{\sum_{i=1}^{N} Line\ length} x\ 100$$

Example – Consider two transmission lines in a zone of 400kV, Line A-B has length of 200km with Transmission capacity utilization index of 1.0 and Line C-D has length of 400km with Transmission capacity utilization index of 0.6

$$Zonal\ Transmission\ capacity\ utilization\ Index\ (\%) = \frac{200x0.1+400x0.6}{200+400} x100$$

Zonal Transmission capacity utilization Index (%) = 73.33%

3.18. Considering the importance of margins to be built in the transmission capacity while planning, it is prudent to consider a safety factor multiplier of 1.5 in the estimation of both individual and zonal transmission utilization indices

3.19. The zonal transmission utilization indices computed in 3.10 is multiplied by 1.5 to arrive at the Zonal Transmission Capacity Utilization Index.

Zonal Transmission Capacity Utilization Index (%) = 73.33 x 1.5= 110%

3.20. STU shall publish the data on its website by 25th of every month for the previous month as per format given in Annexure -1.

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4. Voltage Variation Index

4.1. Voltage Variation is defined as the deviation of the root-mean-square (RMS) value of the voltage from its nominal value, expressed in terms of percentage. Voltage Variation may be either of short duration not exceeding one minute or long duration for a time greater than one minute. For the purpose of these standards, the sustained variation in voltage exceeding hourly duration shall be considered.

4.2. Transmission Licensee shall ensure that the grid voltage on real time basis remain within the specified limits at all EHV sub-stations of Transmission System, provided that voltage at inter-connection points of generation and inter-state regional transmission is within the limits applicable as specified in CERC and MEGC and CEA Grid Standard Regulation.

Voltage levels	CEA- Grid Standard Regulation and CERC – Indian Electricity Grid Code		Upper Limit	Lower Limit	CEA- Technical Standard for Grid Connectivity
	Maximum Voltage in kV	Minimum Voltage in kV			Upper and Lower Limit
765 kV	800	728	5%	-5%	
400 kV	420	380	5%	-5%	
220 kV	245	198	11%	-10%	
132 kV	145	122	10%	-8%	
110 kV	121	99	10%	-10%	
66 kV	72	60	9%	-9%	
33 kV	36	30	9%	-9%	

5. Methodology for Computation of Voltage Variation Index

5.1. Voltage Variation Index represents the degree of voltage variation from nominal value over a specified period of time expressed as a standard deviation.

5.2. The VVI is computed for all interconnection points of G<>T and T<>D interconnection points.

5.3. STU shall collect hourly log sheet data on first day of the month from each Transmission Licensee, wherein substation bus voltage is measured (for 100kV and above) and reported in daily log sheet.

Provided that data from defective metering or any abnormal data shall be discarded from calculations.

5.4. The formula to calculate the VVI is as follows:

$$Voltage\ Variation\ Index = \frac{100}{Vs}\ x\ Square\ root\ of\ \frac{\sum_{i=1}^{N}(Vi - Vs)^2}{N}$$

Where,

Vi = RMS value of hourly measured voltage (in kV) at ith hour in the period for which VVI is computed

Vs = RMS value of the nominal system voltage i.e., 765kV, 400kV, 220kV and 132 kV as may be applicable at the interconnection point

N = Number of hourly measurements over the specified period of time

5.5. STU shall compute zone-wise voltage wise Voltage Variation Index from hourly log sheet data recorded at sub-stations (Interconnection points).

5.6. STU shall keep the record of month-wise Voltage Variation Index and submit the report for the past six-monthly performance during the GCC meeting.

5.7. GCC shall review and deliberate on the cause of the significant variation from the normal range and may suggest the remedial actions for the improvements.

5.8. Since the voltage is local phenomenon for each sub-station, it is not appropriate to compute zone-wise VVI. However, a simple indicative zone-wise VVI is computed as below:

$$Zone\ wise\ Voltage\ Variation\ Index = \frac{\sum_{i=1}^{N} VVI}{N}$$

Where, N = *Number of substations*

5.9. STU shall publish the data on its website by 25th of every month for the previous month as per format given in Annexure -1.

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SUBSTATION WISE AND ZONEWISE VOLTAGE VARIATION INDEX
MONTH -

765kV Substation		
Sr. No.	Name of Substation in Zone A	VVI
1		
2		
3		
4	Zone A	
	Name of Substation in Zone B	VVI
5		
6		
7		
8	Zone B	
	Name of Substation in Zone Z	VVI
9		
10		
11		
12	Zone Z	

400kV Substation		
Sr. No.	Name of Substation in Zone A	VVI
1		
2		
3		
4	Zone A	
	Name of Substation in Zone B	VVI
5		
6		
7		
8	Zone B	
	Name of Substation in Zone Z	VVI
9		
10		
11		
12	Zone Z	

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220kV Substation		
Sr. No.	Name of Substation in Zone A	VVI
1		
2		
3		
4	Zone A	
	Name of Substation in Zone B	VVI
5		
6		
7		
8	Zone B	
	Name of Substation in Zone Z	VVI
9		
10		
11		
12	Zone Z	

132kV Substation		
Sr. No.	Name of Substation in Zone A	VVI
1		
2		
3		
4	Zone A	
	Name of Substation in Zone B	VVI
5		
6		
7		
8	Zone B	
	Name of Substation in Zone Z	VVI
9		
10		
11		
12	Zone Z	

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Maharashtra State Electricity Transmission Co. Ltd.

LINE and ZONEWISE TRANSMISSION CAPACITY UTILIZATION INDEX (TCUI)

Month -

765 kV Line		
Sr. No.	**Name of Zone A**	**TCUI**
1	Line-1	
2	Line-2	
3	.... Line-n	
4	Zone A	
	Name of Zone B	**TCUI**
5	Line-1	
6	Line-2	
7	.... Line-n	
8	Zone B	
	Name of Zone Z	**TCUI**
9	Line-1	
10	Line-2	
11	.... Line-n	
12	Zone Z	

400 kV Line		
Sr. No.	**Name of Zone A**	**TCUI**
1	Line-1	
2	Line-2	
3	.... Line-n	
4	Zone A	
	Name of Zone B	**TCUI**
5	Line-1	
6	Line-2	
7	.... Line-n	
8	Zone B	
	Name of Zone Z	**TCUI**
9	Line-1	
10	Line-2	
11	.... Line-n	
12	Zone Z	

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220 kV Line		
Sr. No.	Name of Zone A	TCUI
1	Line-1	
2	Line-2	
3	.... Line-n	
4	Zone A	
	Name of Zone B	TCUI
5	Line-1	
6	Line-2	
7	.... Line-n	
8	Zone B	
	Name of Zone Z	TCUI
9	Line-1	
10	Line-2	
11	.... Line-n	
12	Zone Z	

132 kV Line		
Sr. No.	Name of Zone A	TCUI
1	Line-1	
2	Line-2	
3	.... Line-n	
4	Zone A	
	Name of Zone B	TCUI
5	Line-1	
6	Line-2	
7	.... Line-n	
8	Zone B	
	Name of Zone Z	TCUI
9	Line-1	
10	Line-2	
11	.... Line-n	
12	Zone Z	

Annexure -3

STANDARD PLANNING DATA

(Pursuant to Section 14.2.2 of the MEGC 2020)

In accordance with the

Maharashtra Electricity Regulatory Commission

(Electricity Grid Code) Regulations, 2020

MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.

Prepared by

STATE TRANSMISSION UTILITY

MAHARASHTRA STATE ELECTRICITY TRANSMISSION COMPANY LIMITED

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List Of Abbreviations

Abbreviation/Acronym	Expanded Form
BESS	Battery Energy Storage System
CEA	Central Electricity Authority
CHP	Combined Heat and Power
CPP	Captive Power Producer
CTU	Central Transmission Utility
EPS	Electric Power Survey
FACT	Flexible Alternating Current Transmission
IEEE	The Institute of Electrical and Electronics Engineers
InSTS	Intra-State Transmission System
IPP	Independent Power Producer
ISTS	Inter-State Transmission System
kV	Kilovolt
LTA	Long-term Access
MEGC	Maharashtra Electricity Grid Code, 2020
MERC	Maharashtra Electricity Regulatory Commission
MTOA	Medium-term Open Access
MVAr	Mega volt ampere (reactive)
MW	Megawatt
PSS/E	Power System Simulator for Engineering
QCA	Qualified Coordinating Agency
RE	Renewable Energy
SLDC/MSLDC	Maharashtra State Load Despatch Centre
STU	Maharashtra State Transmission Utility
WR	Western Region
RLDC	Regional load Dispatch Centre

Standard Planning Data

1. Introduction:

To enable State Transmission Utility (STU) to discharge its responsibilities relating to planning of Intra-State Transmission System (InSTS) under Electricity Act, 2003, the Users are required to furnish data relating to their systems to STU. In accordance with clause 14.2.2 and other relevant clauses of MEGC 2020, the Transmission Licensee and Users shall supply planning data to the State Transmission Utility for purpose of developing the transmission plan.

This document describes the procedure, format and periodicity of submission of data required by STU from the Transmission Licensees and Users for development of transmission plan on long term basis.

2. Definitions

1. Connectivity: The state of getting connected to the InSTS by a generating station, including captive generating plant or User or an Intra-State Transmission Licensee.
2. Flexible Alternating Current Transmission (FACT): A power electronics-based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase in power transfer capability;
3. Intra State Transmission System (InSTS) means any system for conveyance of electricity by transmission lines within the area of the State and includes all transmission lines, sub-stations, and associated equipment of transmission licensees in the State excluding ISTS.
4. Inter State Transmission System (ISTS):

   i) Any system for the conveyance of electricity by means of a main transmission line from the territory of one State to another State.

   ii) The conveyance of electricity across the territory of an intervening State as well as conveyance within the State which is incidental to such inter-State transmission of energy.

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iii) The transmission of electricity within the territory of State on a system built, owned, operated, maintained, or controlled by CTU.

5. Licensee: A person who has been granted a licence or deemed licensee under Section 14 of the Act.
6. Maharashtra State Load Despatch Centre (MSLDC or SLDC): The Centre established under sub-section (1) of Section 31 of the Act.
7. Open Access: The non-discriminatory provision for the use of transmission lines or distribution system or associated facilities with such lines or system by any licensees or consumer or a person engaged in generation in accordance with Regulations of the appropriate Commission.
8. Qualified Coordinating Agency (QCA): The agency appointed by the Wind or Solar Energy Generators connected to a Pooling Sub-Station, or by an individual Generator connected directly to a Sub-Station, to perform the functions and discharge the obligations specified in the MERC (Forecasting, Scheduling and Deviation Settlement for Solar and Wind Generation) Regulations, 2018.
9. Regional Load Despatch Centre (RLDC): The Centre established under sub-section (1) of Section 27 of the Act.
10. Transmission Licence: A licence granted under Section 14 of the Act to transmit electricity.
11. User or InSTS User: A person such as State owned generator including, CPP, Renewable Energy Generators or Distribution Licensee or Consumers connected to the InSTS.

3. Objective and Scope

The objective of this procedure is to prescribe formats for submission of all the data required to be provided by the Transmission Licensees and the Users to STU in accordance with the provisions of MEGC 2020 and periodicity for submission of such data.

All existing grid users (including InSTS Transmission Licensees, Generators (State

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owned Generators, IPPs, CPPs, RE generator), Distribution Licensees and Open Access consumers connected to InSTS and those Users seeking Connectivity, LTOA or MTOA to InSTS shall furnish the data.

4. Responsibility

4.1. All Users are responsible for submitting up-to-date data to STU as per Annexure-1 in accordance with the provisions of the MEGC 2020.

4.2. All Users shall provide STU with the name, designation, address and contact details of the nodal officer who will be responsible for sending the data.

4.3. STU shall inform all Users of the name, designation, address and contact details of the nodal officer who will be responsible for receiving data.

4.4. STU shall provide up to date data to Users as they may require for planning their system.

4.5. Responsibility for the correctness of data rests with concerned User providing the data.

5. Planning Philosophy and Cycle

5.1. A robust, strong and flexible InSTS network acts as an enabler for seamless transfer of power from any generator to load centres anywhere in the State in an efficient, reliable and economic manner. Such a network shall facilitate the ease of interconnection of generators to the InSTS and also the end consumers to purchase power at competitive rates along with promoting the development of vibrant power market. An adequate InSTS network is essential for ensuring continuity of power supply to state utilities and distribution companies under various emergency situations including disaster management.

5.2. The STU shall draw up plan for InSTS for up to next five years on rolling basis, every year identifying specific transmission projects which are required to be taken up

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along with their implementation timelines, after considering the plans made by Central Electricity Authority (CEA) and studying the progress in generation capacity and demand in different parts of the State. The STU transmission plans shall consider the quarterly feedbacks provided by SLDC and RLDC to affect system strengthening, to remove transmission congestion. The STU plan shall be in accordance with perspective plan of CEA, planning of Inter-State Transmission System (ISTS) substation and transmission elements in the State by Central Transmission Utility (CTU), the decision taken in the Western Region (WR) standing committee so as to ensure building of evacuation system from ISTS substation in the State.

5.3. State Distribution Licensees shall furnish demand forecast for one year ahead and five years ahead. The long-term forecast for the state can also be taken from Electric Power Survey (EPS) of CEA.

6. Planning Data Requirement:

6.1. To enable STU to discharge its responsibilities relating to planning Intra-State Transmission System under Electricity Act, 2003. All the Users are required to furnish Planning Data to STU in the prescribed formats appended herewith and at prescribed time.

6.2. To enable the Users to co-ordinate planning, design and operation of their own plants and systems with InSTS they may seek certain salient data of the Transmission System as applicable to them. STU/ Transmission Licensee shall supply these data from time to time.

6.3. The data shall be submitted by concerned Users to STU as per standard formats given in Section -1 for General and Connection data, Section – 2 for Load flow data and Section – 3 for Dynamic data within three (3) months of uploading of the format on website of STU and as when changes occur in case of existing stations, however any other data as required by STU for transmission planning shall be made available to STU by all the Users and InSTS Transmission Licensees as per the timelines and in a format provided by the STU.

6.4. Transmission Licensees and Users shall submit the Standard Planning Data to the State Transmission Utility for purpose of developing transmission plan.

7. Standard Planning Data

7.1. Standard Planning Data shall consist of details which are expected to be normally sufficient for the State Transmission Utility to investigate the impact on the InSTS due to User/Transmission Licensees development in their systems.

Standard Planning Data shall consist of following:

a) Preliminary project planning data

b) Committed project planning data

c) Connected planning data

7.2. Preliminary project planning data comprise location of Generating station, Pooling Substation, type of fuel and various stages approvals concerning land acquisition, fuel supply agreement, various clearances from statutory authorities, timelines for various activity including schedule date of commissioning, start-up power arrangement, etc.

7.3. Committed project planning data comprise connectivity details, power purchase agreements, LTA and MTOA details, No. of units, Size/Capacity of units, Rating of equipments, etc.

7.4. Connected planning data comprise of equipment details, Load Flow (Static) data and Dynamic data.

8. Format for Standard Planning Data

Standard Planning Data shall be provided by the Generating Companies including IPPs, CPPs, RE generators, Transmission Licensees, Distribution Licensees and Open Access

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consumers connected to InSTS in the formats prescribed in Section -1, Section-2 and Section-3 of this document.

9. Changes to Users Data

9.1. Whenever any User becomes aware of a change to any items of data that is registered with STU, the User must promptly notify STU of the changes. STU on receipt of intimation of the changes shall promptly correct the database accordingly. This shall also apply to any data compiled by STU regarding to its own system.

9.2. In case of Distribution Licensees the load data (substation wise data - MW/ MVAr) need to be updated at least once in a year. Similarly, Transmission Licensees shall update the planning data base on quarterly basis to incorporate new transmission lines and new substation added in the network. As and when a generation unit/ station is added SLDC shall inform STU for updating the planning data base.

9.3. However, STU can create base cases using the planning data of the existing system and by incorporating data for those generators, transmission elements and load centers expected to be commissioned for planning horizon such as one year ahead and five year ahead.

10. Methods of Submitting Data

10.1. The data shall be furnished in the standard formats for data submission and such format must be used for the written submission of data to STU.

10.2. All data to be submitted under the Schedule(s) must be submitted to STU. The name of the Person who is submitting each schedule of data must be indicated.

10.3. In case the Users / Transmission Licensees of InSTS are using PSS/E software for system studies, they can submit the planning data in the PSS/E files as indicated below.

A. For load flow data ".sav", ".sld", ".raw" files need to be furnished

B. For dynamic model data can be furnished in ".dyre" file.

11. Preparation of Transmission Plan for new InSTS

11.1. Load-generation scenarios shall be worked out as per the requirements so as to reflect the daily and seasonal variations in load demand and generation availability (such as cases for peak, off-peak and other than peak / off-peak hours for different seasons considering low, moderate and high renewable/other generation capacity).

11.2. In addition to this, varying import / export requirements of load centers and scheduling of various generating stations under economic dispatch for which variable cost of existing and upcoming generating stations may also be considered.

11.3. While planning the transmission system, options of upgrading the existing InSTS in place of building new transmission lines (such as increasing line loading through use of compensation, reconductoring, etc.) shall be explored for optimally utilizing the existing assets.

11.4. To avoid bottling up of power, STUs shall also plan to strengthen their downstream networks based on the evolved Inter-State Transmission System in similar time-frame. Based on progress of implementation of generating stations and upstream/downstream systems, mid-course correction for transmission system to the extent possible should be made in terms of (i) Re-configuration of planned transmission system, (ii) Phasing of transmission elements and (iii) Rescheduling of some of the transmission elements.

11.5. STU shall carry out joint studies with CTU in order to avoid duplication of substation and transmission elements in the plans of CTU and STU and also to plan evacuation networks from CTU substations. The integration of CTU and STU plans shall be coordinated through WR standing committee meetings of CEA.

12. Data not supplied

Users are obliged to supply data as referred to in the individual formats. In case any data is missing and not supplied by any User, STU may, acting reasonably, if and when necessary, estimates such data depending upon the urgency of the situation preferably from Standard IEEE, PSS/E, etc. models shall be used in case of non-available data.

13. Special Considerations

STU and any other User may at any time make reasonable request for extra data as necessary.

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Annexure-1

All existing grid users (including InSTS Transmission Licensees, Generators (State owned Generators, IPPs, CPPs, RE), Distribution Licensees and Open Access consumers connected to InSTS and those users seeking Connectivity, LTOA or MTOA to InSTS shall furnish the data as per formats given under sections 1, 2 and 3.

Details of State-owned Generator, IPPs and CPPs, RE generator and QCA on behalf of RE Generator, Transmission licensee and Distribution Licensee

Nodal Officer and Designation	
Contact Number and Email address	
Name of the data submitting Agency	
Whether State owned Generator, IPPs and CPPs, RE generator and QCA on behalf of RE Generator, Transmission licensee and Distribution Licensee	
User registration details with SLDC	
Address	

Detailed Planning Data shall be provided by the Generating Companies including IPPs, CPPs, RE generators, Transmission Licensees, Distribution Licensees, Open Access users connected to InSTS as and when requested by the State Transmission Utility in the formats prescribed hereunder:

Sr. No.	Formats No.	Data submission by	Data to be submitted to	Data relating to	Periodicity of data submission
	Section :1 - General Information and Connectivity Details Formats				
1	Format No. - General/Gen/thermal/1	Generating Company/ CPP	STU	Each thermal power station	
2	Format No. - General/Gen/hydro/1	Generating Company/CPP/	STU	Each Hydro power station	

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Sr. No.	Formats No.	Data submission by	Data to be submitted to	Data relating to	Periodicity of data submission
		Hydro Power generator			occur in case of existing stations
3	Format No. - General/Gen/Cogen/1	Cogeneration or CHP Company/ CPP	STU	Each Cogeneration station	For upcoming generating station seeking connectivity, LTOA or MTOA along with application. If placement of orders for main and balance equipment is not done at the time of seeking connectivity, the balance data need to be furnished at the earliest or in within one month of placing order for equipments.
4	Format No. - General/Gen/RE/1	Wind / Solar Generating Company/CPP and QCA on behalf of RE Generators	STU	Each Wind / Solar station	
5	Format No. - General/Storage/BESS/1	BESS	STU	BESS	
6	Format No. - General/Transmission/1	Transmission Licensee/TSU	STU	Each line and sub-station	
7	Format No. - General//Distribution/1	Distribution Licensee/ Discom	STU	Entire Distribution system	
	Section: 2 - Load Flow Studies Formats				
8	Format No. - LF/Bus/1		STU	Bus Data	
9	Format No. - LF/Generator/1		STU	Generator	
10	Format No. - LF/Transmission Line/2		STU	Transmission Line	

Sr. No.	Formats No.	Data submission by	Data to be submitted to	Data relating to	Periodicity of data submission
11	Format No. - LF/Transformer/3		STU	Transmission Line / Transformer	
12	Format No. - LF/HVDC/1	Transmission Licensee	STU	HVDC Lines	
13	Format No. - LF/FACT/1	Transmission Licensee	STU	FACT Devices	
14	Format No. - LF/FACT/2	Transmission Licensee	STU	FACT Devices	
15	Format No. - LF/STATCOM/1	Transmission Licensee	STU	STATCOM	
	Section: 3 - Dynamic Studies Formats				
16	Format No. - Dyn/Generation / Thermal-Coal Fired/1	Generating Company /CPP	STU	Coal Fired thermal Generation details	
17	Format No. - Dyn/Generation / Thermal-Gas/1	Generating Company /CPP	STU	Each Gas based thermal power station	
18	Format No. - Dyn/Generation /Hydro/1	Generating Company/CPP/ Hydro Power generator	STU	Each hydro station	
19	Format No. - Dyn/Generation /Wind/1	Wind Power Generator /CPP	STU	Wind Mill	
20	Format No. - Dyn/Generation /Solar/1	Solar Power Generator /CPP	STU	Solar Generation Plant	
21	Format No. - Dyn/Storage/BESS/1	BESS	STU	BESS	
22	Format No. - Dyn/Transmission/HVDC/1	Transmission Licensee	STU	HVDC Link	

Section - 1
General information and Connectivity Details Formats

14. General Information and Connectivity Details Format

14.1.Generation: Thermal (Coal/Gas/Liquid Fuel)

Format No.:	General/Gen/thermal/1
Data Submission By:	Generating Company / CPP
Data related to:	Each thermal power station
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	Three months after uploading of the formats on the website of STU and as when changes occur in case of existing stations For upcoming generating station seeking connectivity, LTA or MTOA along with application. If placement of orders for main and balance equipment is not done at the time of seeking connectivity, the balance data need to be furnished at the earliest or in within one month of placing order for equipments.

GENERAL		
1	Name of Generating Company	
2	Name of Power Station	
3	Name of Pooling Station	
4	Site Map	Showing area required for Power Station coal linkage, coal yard, water pipe lines, ash disposal area, colony etc.
5	Approximate period of construction and Date of Commercial Operation date (COD)	
6	Proof of Land Acquisition	
7	Fuel Supply Arrangement	
8	Statutory clearance from various authority	
9	Startup power Arrangement details	
CONNECTION		
1	Point of Connection/ Interface Point	Furnish single line diagram of the proposed Connection with the Transmission system with clear indication of possibility for right of way for unobstructed outlet.
2	Step up voltage for Connection (kV)	
STATION CAPACITY		
1	Total Power Station capacity (MW)	Give details whether development will be carried out in phases and if so, furnish details.
2	No. of units & unit size (MW)	
GENERATING UNIT DATA FOR EACH TYPE		
1	Generator	

	(a) Make and Type	
	(b) Rating (MVA)	
	(c) Terminal Voltage (kV)	
	(d) Rated Power Factor	
	(e) Reactive Power capability (MVAr) in the range 0.95 leading and 0.85 lagging.	
	(f) Short Circuit Ratio	
	(g) Direct axis transient reactance (% on MVA rating)	
	(h) Direct axis sub-transient reactance (% on MVA rating)	
	(i) Auxiliary Power requirement	
2	Generator Transformer	
	(a) Type	
	(b) Rated Capacity (MVA)	
	(c) Voltage Ratio (HV/LV)	
	(d) Tap change range (+% to -%)	
	(e) Percentage Impedance (Positive Sequence at Full load).	
3	Steam Generating Unit	Give details of type, capacity, steam pressure, stream temperature etc.
4	Steam turbine	Give details of type, capacity.

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14.2. Generation: Hydro

Format No. :	General/Gen/hydro/1
Data Submission By:	Generating Company / CPP / Hydro Power Generator
Data related to:	Each hydro station
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission	Three months after uploading of the formats on the website of STU and as when changes occur in case of existing stations For upcoming generating station seeking connectivity, LTA or MTOA along with application. If placement of orders for main and balance equipment is not done at the time of seeking connectivity, the balance data need to be furnished at the earliest or in within one month of placing order for equipments.

GENERAL		
1	Name of Generating Company	
2	Name of Power Station	
3	Name and location of Pooling Station	
4	Site	Give location map to scale showing roads, railway lines, and transmission lines.
5	Site map (To scale)	Showing proposed canal, reservoir area, water conductor system, fore-bay, power house etc.
6	Submerged Area	Give information on area submerged, villages submerged, submerged forest land, agricultural land etc
7	Whether storage type or run of river type or pumped storage	
8	Whether catchments receiving discharges from other reservoir or power plant.	
9	Full reservoir level	
10	Minimum draw down level.	
11	Tail race level	
12	Design Head	
13	Reservoir level v/s energy potential curve	
14	Restraint, if any, in water discharges	
15	Approximate period of construction.	
16	Proof of Land Acquisition	

17	Statutory clearance from various authorities	
18	Startup power arrangement details	
CONNECTION		
1	Point of Connection/ Interface Point	Furnish single line diagram of the proposed Connection with the Transmission system with clear indication of possibility for right of way for unobstructed outlet.
2	Step up voltage for Connection (kV)	
STATION CAPACITY		
1	Total Power Station capacity (MW)	Give details whether development will be carried out in phases and if so, furnish details.
2	No. of units & unit size (MW)	
GENERATING UNIT DATA FOR EACH TYPE		
		a. Maximum b. Minimum c. Average.
2	Hydro Unit	
a	Capability to operate as synchronous condenser	
b	Water head versus discharges curve (at full and part load)	
c	Power requirement or water discharge while operating as synchronous condenser	
3	Turbine	State Type and capacity
4	Generator	
a	Type	
b	Rating (MVA)	
c	Speed (RPM)	
d	Terminal Voltage (kV)	
e	Rated Power Factor	
f	Reactive Power Capability (MVAr) in the range 0.95 of leading and 0.85 of lagging	
g	MW & MVAr capability curve of generating unit	
h	Short Circuit Ratio	
i	Direct axis transient (saturated) reactance (% on rated MVA)	

j	Direct axis sub-transient (saturated) reactance (% on rated MVA)	
k	Auxiliary Power Requirement (MW)	

14.3. Generation: Cogeneration or Combined Heat and Power (CHP)

Format No.:	General/Gen/Cogen/1
Data Submission By:	Generating Company / CPP
Data related to:	Each Cogeneration or Combined Heat and Power (CHP) power station
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	Three months after uploading of the formats on the website of STU and as when changes occur in case of existing stations For upcoming generating station seeking connectivity, LTA or MTOA along with application. If placement of orders for main and balance equipment is not done at the time of seeking connectivity, the balance data need to be furnished at the earliest or in within one month of placing order for equipments.

GENERAL	
Name of Generating Company	
Name of Power Station	
Name of Pooling Station	
Site Map	Showing area required for Power Station coal linkage, coal yard, water pipe lines, ash disposal area, colony etc.
Approximate period of construction and Date of Commercial Operation date (COD)	
Proof of Land Acquisition	
Type of Fuel and Fuel Supply Arrangement	
Statutory clearance from various authority	
Startup power Arrangement details	
Type of Cogeneration Power Plants	Combined Cycle CGP Plant / Steam Turbine CHP Plant / Internal Combustion / others (details to be added)
CONNECTION	
Point of Connection/ Interface Point	Furnish single line diagram of the proposed Connection with the Transmission system with clear indication of possibility for right of way for unobstructed outlet.
Step up voltage for Connection (kV)	
STATION CAPACITY	

1	Total Power Station capacity (MW)	Give details whether development will be carried out in phases and if so, furnish details.
2	No. of units & unit size (MW)	
GENERATING UNIT DATA FOR EACH TYPE		
1	Generator	
	(a) Make and Type	
	(b) Rating (MVA)	
	(c) Terminal Voltage (kV)	
	(d) Rated Power Factor	
	(e) Reactive Power capability (MVAr) in the range 0.95 leading and 0.85 lagging	
	(f) Short Circuit Ratio	
	(g) Direct axis transient reactance (% on MVA rating)	
	(h) Direct axis sub-transient reactance (% on MVA rating)	
	(i) Auxiliary Power requirement	
2	Generator Transformer	
	(a) Type	
	(b) Rated Capacity (MVA)	
	(c) Voltage Ratio (HV/LV)	
	(d) Tap change range (+% to -%)	
	(e) Percentage Impedance (Positive Sequence at Full load)	
3	Steam Generating Unit	Give details of type, capacity, steam pressure, stream temperature etc.
4	Steam turbine / Gas Turbine/ Reciprocating engine	Give details of type, capacity, equipment configuration (Back-pressure steam turbine, Extraction & condensing steam turbine, Extraction & back-pressure steam turbine, Single/double extraction & condensing, Gas turbine with unfired Waste Heat Recovery Boiler (WHRB), and etc.) details

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14.4. Generation: Wind/Solar

Format No. :	General/Gen/RE/1
Data Submission By:	Wind / Solar Generating Company/CPP and QCA on behalf of RE Generators
Data related to:	Each Wind / Solar station
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission	Three months after uploading of the formats on the website of STU and as when changes occur in case of existing stations For upcoming generating station seeking connectivity, LTA or MTOA along with application. If placement of orders for main and balance equipment is not done at the time of seeking connectivity, the balance data need to be furnished at the earliest or in within one month of placing order for equipments.

GENERAL		
1	Name of Generating Company	
2	Type Wind/Solar Generator	
3	Name and location of pooling station	
4	If applying on behalf of group of generators details of agreement to be attached	
5	Name of QCA/ Lead Generator	
6	Registered with SLDC	
7	Converter/Inverter details	
8	Details of dedicated lines (Including ownership)	
9	Total Installed Capacity of Generating Station	
10	Total Number of Units with details	
11	Physical Address of the RE Generating Station	
12	Whether any PPA has been signed: (Y/N)	If yes, then attach details
13	Name of Pooling substation /Connectivity Details	Location/Voltage Level
14	Metering Details	Meter No. 1. Main Meter No. 2. Check
15	Connectivity Diagram	(Please Enclose)
16	Proof of Land Acquisition	
17	Statutory clearance from various authority	

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(a) General Data of Wind Generating Station

Sr. No	Particulars
1	Type (Type 1/Type 2/ Type 3/Type 4) *
2	Manufacturer
3	Make
4	Model
5	Capacity
6	Commission date
7	Hub height
8	Total height
9	RPM Range
10	Rated wind speed
11	Performance Parameter
12	Rated electrical power at Rated wind speed
13	Cut in speed
14	Cut out speed
15	Survival speed (Max wind speed)
16	Ambient temperature for out of operation
17	Ambient temperature for in operation
18	Survival temperature
19	Low Voltage Ride Through (LVRT) setting
20	High Voltage Ride Through (HVRT) setting
21	Lightning strength (kA & in coulombs)
22	Noise power level (db)
23	Rotor
24	Hub type
25	Rotor diameter
26	Number of blades
27	Area Swept by blades
28	Rated rotational speed
29	Rotational Direction
30	Coning angle
31	Tilting angle
32	Design tip speed ratio
33	Blade
34	Length
35	Diameter
36	Material
37	Twist angle
38	Generator
39	Generator Type
40	Generator No. of poles
41	Generator speed
42	Winding type
43	Rated Gen. Voltage
44	Rated Gen. Frequency
45	Generator current

46	Rated Temperature of generator
47	Generator cooling
48	Generator power factor
49	KW/MW at Rated Wind speed
50	KW/MW at Rated peak continuous
51	Frequency Converter
52	Filter generator side
53	Filter grid side
54	Transformer
55	Transformer Capacity
56	Transformer cooling type
57	Voltage
58	Winding configuration
59	Weight
60	Rotor Weight
61	Nacelle Weight
62	Tower weight
63	Over speed Protection
64	Design life
65	Design Standard
66	Latitude
67	Longitude
68	COD Details
69	Past Generation History from the COD to the date on which DAS facility provided at SLDC, if applicable
70	Distance above mean sea level

*Type 1 – Squirrel cage induction generator

Type 2 – Wound rotor induction generator

Type 3 – Doubly fed induction generator (DFID)

Type 4 – Full Converter type

(b) General Data of Solar Generating Station

1. Latitude
2. Longitude
3. Inverter Power Curve
4. Elevation and orientation angles of arrays or concentrators
5. The generator capacity of the Generating Facility
6. Distance above mean sea level etc.
7. COD details
8. Rated voltage
9. Details of type of Mounting: (Tracking Technology if used, single axis or dual axis, auto or manual)

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10. Manufacturer and Model (of important Components, Concentrators, Inverter, Cable, PV Module, Transformer, Cables)
11. DC installed Capacity
12. Module Cell Technology
13. I-V Characteristics of the Module
14. Inverter Rating at different temperature
15. Inverter Efficiency Curve
16. Transformer Capacity & Rating, Evacuation voltage, distance from injection point

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14.5. Storage: BESS

Format No.:	General/Storage/BESS/1
Data Submission By:	BESS
Data related to:	Each BESS
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	Three months after uploading of the formats on the website of STU and as when changes occur in case of existing stations. For upcoming generating station seeking connectivity, LTA or MTOA along with application. If placement of orders for main and balance equipment is not done at the time of seeking connectivity, the balance data need to be furnished at the earliest or in within one month of placing order for equipments.

GENERAL		
1	Name of BESS Utility	
2	Name and location of BESS Station	
3	Name and location of Pooling Station	
4	Approximate period of construction and Date of Commercial Operation date (COD)	
5	Registered with SLDC	
6	Statutory clearance from various authority	
7	Point of Connection / Interface Point	Furnish single line diagram of the proposed Connection with the Transmission system with clear indication of possibility for right of way for unobstructed outlet.
BASIC TECHNICAL DETAILS		
A	Battery	
1	Make/Manufacturer	
2	Type / Chemistry	
3	Design capacity of battery in terms of KWh	
4	Self-Discharge rate	
5	Depth of Discharge (DoD)	
	Life cycle of battery	

	Round trip efficiency	
	Dimensions and weight of battery	
	Test certificate available for battery cell/module (IEC Standards)	
	Number of series & parallel connected cells and modules	
	Power/energy rating cells and modules	
	BESS favourable operating temperature	
POWER CONDITIOINING UNIT		
	Make/manufacturer	
	Type of charge controller(DC-DC converter)	
	Inverter- power rating & efficiency	
	Inverter minimum response time	
	Test certificate available (IEC Standards)	

General Data of Battery Parameters:

Details	Technical Requirement
AC ratings	
Total rated output power to load @ nominal voltage (charge) MW to (discharge) MW	
Apparent power @ nominal voltage	
No of units	
Rate output power of each unit	
Real and reactive power control accuracy (%)	
Voltage range	
Type of output	
Frequency (Nominal Frequency and the tolerance band)	
VAR production (full MVAR production at rated Voltage)	
Harmonics (as per CEA standards)	
DC input ratings	
Voltage range	
Ripple voltage Ripple current (% of full current peak to Peak)	
Environmental ratings	
Operating temperature	
Humidity	
Functions/Features	

Power flow operation (, Support four - quadrant control)	Yes / No
Real power control (Positive and negative)	Yes / No
Reactive power control (capacitiveand inductive)	Yes / No
Combination of real and reactive power control(priority real power)	Yes / No
Load following (renewable smoothing)	Yes / No
Low-voltage ride through	Yes / No
Synchro-check function	Yes / No
Operation modes	
Black start (external command)	Yes / No
Commanded power (external command)	Yes / No
Commanded VAR (external command)	Yes / No
Frequency regulation	Yes / No
Frequency response (Automatic)	Yes / No
Islanding	Yes / No
Renewable smoothing (if applicable , automatic)	Yes / No
Scheduled power (preconfigured time/date of work power profiles	Yes / No
Voltage regulation	Yes / No
Response time of PCS to the command received (Milli seconds)	Yes / No
Communications	
Communications with SLDC (main /standby)	Yes / No
Battery technologies	
Battery technologies supported(Ex Li-Ion etc ..)	
Battery Cycle life	> 4,000 at 20-80% SOC
Voltage Regulation (%)	
Reactive Power Regulation (Var flow level Range +/- example +/- 5%)	
Frequency Regulation (+/_ cycle /second)	
Capacity (Ah)	
Power factor	
Battery temperature (average/extreme)	
Overload capability (%) and Switching frequency(in kHz) State of Charge (SOC)	
Protection system	
Under/over voltage (DC and AC)	
Under/over frequency	
Over current protection	
Ground fault protection	
Over heat protection	
Surge protection (DC and AC)	
Automatic AC & DC open circuit when fault detection	

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14.6. Transmission: Transmission Licensee

Format No. :	General/Transmission/1
Data Submission By:	Transmission Licensee/TSU
Data related to:	Each line and sub-station
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission	Three months after uploading of the formats on the website of STU and as when changes occur in case of existing stations.

GENERAL		
1	Name of Transmission Licensee	
2	Name of line (indicating Generating Station and sub-stationsto be connected)	Proposed route showing existing power lines and telecommunication lines.
3	Voltage of Line	
4	Number of Circuit	
5	Route length(Ckt – KM)	
6	Conductor Size (Name and area insq mm)	
7	Line parameters (PU on 100 MVAbase or ohmic value)	
	(a) Resistance/KM	
	(b) Reactance /KM	
	(c) Susceptance/KM	
8	Approximate power flow	MW MVAr
9	Terrain of the route TopographicSheet	Give information regarding nature of terrain i.e. forest land, fallow land, agricultural and river basin, hill slope etc.
10	Route map (to scale)	Furnish topographical map showing the proposed route showing existing power lines and telecommunication lines
11	Purpose of connection	Reference to schemes
12	Approximate period of construction	

14.7. Distribution: Distribution Licensee

Format No. :	General//Distribution/1
Data Submission By:	Distribution Licensee/ Discom
Data related to:	Entire Distribution System
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission	Three months after uploading of the formats on the website of STU and as when changes occur in case of existing stations.

Format-1

GENERAL		
1	Name of Distributing Company	
2	Name of Divisions /sub-divisionpresently in charge of the Distribution.	
3	Area Map (to scale)	Marking the area in the map of area for which Distribution License is applicable
4	Consumer Data	Furnish categories of consumers, their numbers and connected loads.
CONNECTION		
1	Points of Connection	Furnish single line diagram showing points of connection
2	Voltage of supply at points of Connection / interface point	
3	Names of Grid Sub-Station feeding the Connection/ interface	
LINES AND SUBSTATIONS		
1	Line Data	Furnish lengths of line and voltages within the area
2	Sub-station Data	Furnish details of 33/11kV sub-station,11/0.4 kV sub-stations, capacitor installations
LOADS		
1	Loads drawn at connection/interface points.	If the Distribution Licensee receive power at a number of connection point in a compact area, which are interconnected in a ring, then such Distribution Licensee shall forward the overall load drawn for overall Area of Supply as well as at each connection point with variation or tolerance as mutually discussed and agreed upon with the STU

2	Details of loads fed at EHV, if any.	Give name of consumer, voltage of supply,contract demand and name of Grid Sub- station from which line is drawn, length of EHV line from Grid Sub-station to consumer's premises
3	Reactive Power compensation installed	Give details of capacitors and capacitor banks installed at various sub-station andconsumers' premises
DEMAND DATA (FOR ALL LOADS 1 MW AND ABOVE)		
1	Type of load	Give details of furnace loads, rolling mills,traction loads, other industrial loads, pumping loads etc.
2	Rated voltage and phase	
3	Electrical loading of equipment	Give number and size of motors, types ofdrive and control arrangements.
4	Power Factor	
5	Sensitivity of load to voltage and frequency of supply.	
6	Maximum Harmonic content of load	
7	Average and maximum phase unbalance of load.	
8	Nearest sub-station from whichload is to be fed.	
9	Location map to scale	Showing location of load with reference tolines and sub-stations in the vicinity.
LOAD FORECAST DATA		
1	Peak load and energy forecast for each category of loads for each of the succeeding 5 years.	
2	Details of methodology and assumptions on which forecasts are based.	
3	If supply is received from more than one substation, the sub-stationwise break up of peak load and energy projections for each category of loads for each of the succeeding 5 years along with estimated Daily load curve.	
4	Details of loads 1 MW and above. a. Name of prospective consumer. b. Location and nature of load/complex. c. Sub-Station from which to be fed. d. Voltage of supply. e. Phasing of load.	

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Format - 2

Distribution licensee - To provide details information of Power Purchase from outside state through ISTS Network

Sr. No.	Name of Generating Station outside the state	Generating Station Situated State & Region	Name of Pooling ISTS Substation	Total installed capacity of Generating Station (in MW)	Maximum Contracted Capacity (in MW) using ISTS	Voltage level at POC (kV)	Type of Open Access (LTA / MTOA / STOA)
A	**Central Sector (Conventional)**						
1							
2							
3							
N							
B	**IPP (Conventional)**						
1							
2							
3							
N							
C	**Others (Conventional)**						
1							
2							
3							
N							
D	**Non-Conventional**						
1							
2							
3							
N							

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Section – 2
Load Flow Studies Formats

Source-PSS/E Model Library

15. Load Flow Studies Format

Network data for Load Flow Studies

Data Submission By:	Transmission licensee, Generating Company, CPPs, RE Generators and QCA on behalf of RE Generators
Data related to:	Bus data / Transformer /HVDC Lines/ FACT Devices / STATCOM
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission	As and When requested by STU.

15.1.Format for Bus data

Format No. :	LF/Bus/1
Data Submission By:	Transmission licensee, Generating Company, CPPs, RE Generators and QCA on behalf of RE Generators

Date of Commercial Operation	Bus Name	Base Voltage (kV)	Bus Type *	Shunt Admittance		In service/ Out of service during Peak Block
				Conductance (MW)	Susceptance (MVAR)	

*Note – Bus Type

1. Load Bus
2. Generator Bus
3. Swing Bus

15.2.Format for Generator

Format No.:	LF/Generator/1
Data Submission By:	Generating Company, CPPs, RE Generators and QCA on behalf of RE Generators

Date of Commercial Operation	Bus Name	Machine Identifier (ID)	MW Output (PG)	Max MW (PT)	Min MW (PB)	MVAR Output (QG)	Max MVAR (QT)	Min MVAR (QB)	Voltage Set point (VS)	Remote Controlled Bus Index (IREG)	MVA Base (MBASE)	In service/ Out of service during peak block	Machine Impedance (PU on MBASE)		Step up Transformer Impedance (PU on MBASE)		Off Nominal Tap Ratio	RMPCT
													Resistance (ZR)	Reactance (ZX)	Resistance (R T)	Reactance (XT)		

15.3. Format for Transmission Line

Format No.:	LF/Transmission Line/2
Data Submission By:	Transmission licensee

Date of Commercial Operation	From Bus Name	To Bus Name	Ckt ID	Length	Owner	Type of Line (InSTS)	Line configuration	Shunt Admittance				Operational Limits			Electrical Parameters (In Per Unit)			In service/ Out of service during peak block	Remarks
								From Bus		To Bus									
								G	B	G	B								

15.4. Format for Transformer-3

Format No.:	LF/Transformer/3
Data Submission By:	Transmission licensee, Generating Company, CPPs, RE Generators and QCA on behalf of RE Generators

Date of Commercial Operation	From Bus Name	To Bus Name	Ckt ID	In Service/ Out of service during Peak Block	Rate A	Rate B	Rate C	Nominal Tap Ratio	Transformer Phase shift angle	Resistance (R)	Reactance (X)	Controlled Bus	Max. Turns Ratio	Min. Turns Ratio	Max Controlled Volts	Min Controlled Volts	Turns Ration Step Increment	Table

15.5. Format for HVDC Lines

Format No.:	LF/HVDC/1
Data Submission By:	Transmission licensee

A. Format For LCC based HVDC

Date of commercial operation	DC Line Number	TR (R, I)	TAP (R, I)	NB (R,I)	EBASE (R, I)	XC (R, I)	RC (R, I)	XCAP (R, I)	IC (R, I)	IF (R, I)	IT (R,I)	ID (R,I)	ALFMIN	GAMMIN	ALFMAX	GAMMIN	ALFMAX	GAMMAX	MDC	RDC	SETVAL	TAPMX (R,I)	TAPMN (R,I)	TSTP (R,I)	VSCHED	RCOMP	DELTI	VCMODE	DCVMIN	CCCITMX	CCCACC

Description of nomenclature of dc line data items are as follows, with (R,I) indicating rectifier and inverter respectively -

TR (R, I) – Actual open circuit voltage ratio (i.e., nominal turns ratio for line to line voltage on primary and secondary windings of converter transformer. Secondary voltage divided by primary voltage.	**TAP (R, I) –** per unit variation of actual voltage ratio from nominal due to off-nominal tap setting
NB (R, I) – Number of three phase converter bridges in series, with respect to the dc side of converter	**EBASE (R, I) –** Line to Line base rms voltage at primary ac system bus (kV)

XC (R, I) – Converter transformer secondary commutating reactance in ohms per bridge	**RC (R, I) -** Converter transformer secondary commutating resistance in ohms per bridge
XCAP (R, I) – Commutating capacitor reactance magnitude in ohms per bridge. Enter the value greater than zero to represent a commutation capacitor	**IC (R, I) –** Angle measuring bus if not converter ac bus
IF (R, I) – Tapped side (from bus) number of an ac transformer branch	**IT (R, I) –** Untapped side (to bus) number of an ac transformer branch
ID (R, I) – Circuit identifier of transformer	**ALFMIN** - Minimum firing (delay) angle of rectifier in degrees
GAMMIN – Minimum margin angle of inverter in degrees	**ALFMAX –** Maximum firing (delay) angle objective for rectifier degrees
GAMMAX – Maximum margin angle objective for inverter in degrees	**MDC –** DC line mode (0 = blocked line, 1 = constant power, 2 = constant current)
RDC - dc line resistance, ohm	**SETVAL –** Desired DC power in MW or desired dc current in amps. Positive value specifies current or rectifier power, negative specifies inverter power
TAPMX (R, I) – Maximum value of converter transformer tap ratio, per unit	**TAPMN (R, I)** – Minimum value of converter transformer tap ratio, per unit
TSTP (R,I) – Converter transformer tap-step, per unit	**VSCHED** – Scheduled dc voltage, kV
RCOMP – Compensating resistance for voltage control, ohm	**DELTI –** Current margin measured per unit of current setpoint
VCMODE - Minimum inverter dc voltage for power control mode, kV	**DCVMIN –** Minimum compounded DC voltage kV

B. Format for VSC based HVDC

Date of Commercial operation	Type	MODE	DCSET	ACSET	Aloss	Bloss	Minloss	SMAX	IMAX	MAXQ	MINQ	PWF

Description of nomenclature of dc line data items are as follows

Type - Code for the type of converter dc control:1 for dc control or 2 for MW control. Exactly one converter for each VSC dc line must be of Type – 1	**MODE –** Converter ac control mode :1 for ac voltage control or 2 for fixed ac power factor
DCSET – Converter dc setpoint. For TYPE=1, DCSET is the schedule dc voltage on the dc side of the converter, entered in kV. For Type = 2, DCSET is power demand, MW.	**ACSET –** Converter AC set point. For MODE = 1, ACSET is the regulated AC set point For MODE = 2, ACSET is the power factor set point
Aloss, Bloss – Coefficient of the linear approximation used to calculate converter losses	
Minloss – Minimum converter losses, kW	**SMAX –** MVA rating of converter, MVA
IMAX – Converter current, amp	**MAXQ –** Reactive power upper limit
MINQ = Reactive power lower limit	**PWF –** Power weighing factor fraction (0=<PWF=<1)

15.6. Format for FACT devices - 1

Format No.:	LF/FACT/1
Data Submission By:	Transmission Licensee

Date of Commercial Operation	Bus Name	Mode	In Service/ Out of service during Peak Block	Voltage Upper Limit	Voltage Lower Limit	Voltage Set point	N1	B1	N2	B2

N: Steps for Block N
B: Admittance Increment of Block 1 in MVAR at 1.0 pu

15.7. Format for FACT devices - 2

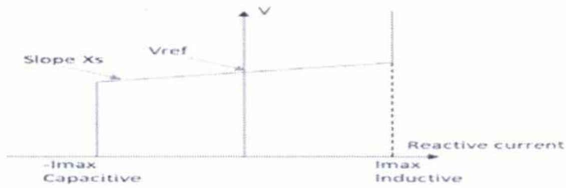
Format No.:	LF/FACT/2
Data Submission By:	Transmission Licensee

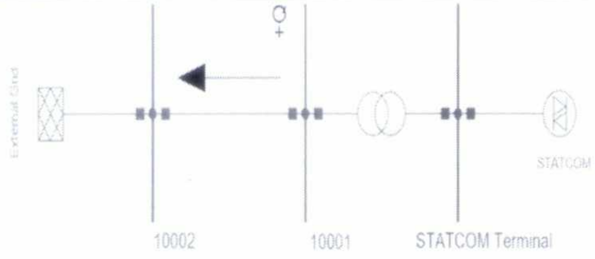
Voltage Level (kV)	Substation Name	FACT Device Type	Sub Device Name	Voltage level of Sub Device	Total Number of Sub Devices	MVAR/ MVA Rating	In Voltage	Out Voltage	Slope (%)	Impedance (%)	Connection Type (Star, Delta), Vector Group

15.8. Format for STATCOM

Format No.:	LF/STATCOM/1
Data Submission By:	Transmission Licensee

Steady State STATCOM model parameters with example value for voltage droop control

Parameter	Example value
STATCOM rating (MVA) This is the MVA base for all control parameters.	
Continuous current limit (kA)	0.175 kA
Nominal voltage at the controlled remote bus (kV)	33 kV
Nominal voltage at the converter terminal (kV)	0.5 kV
Temperature and voltage dependence of STATCOM rating (e.g. 90% of MVA base when voltage is at 90%)	9 MVAr when terminal voltage is at 90% of nominal voltage.
Overload capacity	+25% of nominal current for 1second
Modulation limit	1
No-load loss (kW)	100 kW
Switching loss factor (kW/A)	5 kW/A
Resistive loss factor (ohm)	0 ohm
Negative sequence impedance r2, x2	998 + j1503 pu
Typical control mode (Voltage control, voltage droop, reactive power, or power factor)	
Typical setpoint (Voltage, reactive power, or power factor)	1.0 pu
	4% Or V-I curve as shown below 
Voltage deviation dead band for reducing controller sensitivity (pu)	

Parameter	Example value
	
Remote bus for voltage measurement	10001/Bus Name & Voltage Level
Remote bus for branch / line for reactive power measurement – sending end (where reactive current injection convention to this bus is positive)	
Remote bus for branch / line for reactive power measurement – receiving end (where reactive current injection convention to this bus is negative	10002/Bus Name & Voltage Level

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Section - 3
Dynamic Studies Format

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Source-PSS/E Model Library

16. Dynamic Studies Format

16.1. Generation: Thermal (Coal Fired)

Format No.:	Dyn/Generation/ Thermal-Coal Fired/1
Data Submission By:	Generating Company / CPP
Data related to:	Coal Fired thermal Generator
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and when requested by STU

16.1.1. Details of models in PSS/E for modelling coal fired thermal generation:

(a) Synchronous Machine

Category	Parameter Description	Data
Generator Nameplate	Rated apparent power in MVA	
	Rated terminal voltage	
	Rated power factor	
	Rated frequency (in Hz)	
	Rated speed (in RPM)	
	Rated excitation (in Amperes and Volts)	
Type of synchronous machine	Round rotor or salient pole No. of Poles:	
	The generator capability curve shows the reactive capability of the machine and should include any restrictions on the real or reactive power range like under/over excitation limits, stability limits, etc. Capability curve should have properly labelled axis and legible data	
	Graph of excitation current versus terminal voltage and stator current	
	No load excitation current	
	Excitation current at rated stator current	
	Otherwise referred to as "V-curve". A plot of the terminal (armature) current versus the generating unit field voltage.	
Resistance values	Resistance measurements of field winding and stator winding to a known temperature	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated)	

Category	Parameter Description	Data
	Stator leakage reactance Xa in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq' in p.u. (Unsaturated or saturated)	
	Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Direct axis open circuit transient time constant Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit transient time constant Tqo' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass (generator, AVR, turbo-governor set) H in MW.s/MVA	
	Speed Damping D	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	
Generator step up transformer (GSUT)	Nameplate Rating - Rated primary and secondary voltage - Vector group - Impedance - Tap changer details (Number of taps, tap position, tap ratio etc.)	

(b) Site Load

	Low Output			High Output		
	kW	kVAr	kVA	kW	kVAr	kVA
Auxiliary Load						

(c) Excitation System

Category	Parameter Description	Data
Type of Automatic Voltage Regulator (AVR)	Manufacturer and product details	
	Type of control system:- Analogue or digital	
	Year of commissioning / Year of manufacture	

Category	Parameter Description	Data
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
Type of excitation system		
	Rated excitation current (converter rating in Amperes)	
	Six pulse thyristor bridge or PWM converter	
	Excitation transformer or auxiliary supply (Details thereof)	
	If excitation transformer, nameplate information such as type of transformer, HV and HV winding ratings, positive and zero sequence impedance, tap positions, voltage step per tap is required.	
	Saturation curves of the exciter (if applicable – see Type AC and DC)	
	Drawings of excitation system, typically prepared and supplied by the OEM	
	Single line diagram (i.e. one-line diagram) for the excitation system	
	What excitation limiters are commissioned?	
	Under Excitation Limiters settings	
	Over Excitation Limiters settings	
	Voltage/frequency limiter	
	Stator current limiter	
	Minimum excitation current limiter	
	Is the AVR equipped with a PSS?	
	How many input Channels does the PSS have? (Speed, real power output or both	
	If the PSS uses speed, is this a derived speed signal (i.e. synthesized speed signal) or measured directly (i.e. actual rotor speed)?	
	Type of PSS Block Diagram of PSS and as commissioned parameters value (Gain, time constants, filter coefficients, output limits of the PSS)	

(d) Turbine Details

Category	Parameter Description	Data
Manufacturer of turbine	Manufacturer and name plate details Rating of turbine	
	Electro-mechanical governor	
	Digital electric governor	
	Block diagram of the speed governor	
Ramp rates	How fast can the turbine increase and/or decrease load, specified in MW/min	
	Stroke limits of speed changer (values of full stroke, full load and no-load in mm)	
Droop		
Dead band	Details of frequency dead band (typically in Hz)	
	Tandem compound: all sections on one shaft with a single generator	
	Cross compound: consists of two shafts, each connected to a generator and driven by one or more turbine section	
	Turbine sections: High pressure (HP), intermediate pressure (IP) and low pressure (LP)	
	Reheat or non-reheat: In a reheat, steam upon leaving HP section returns to boiler where it passed through reheater before entering IP section	
	Valves: - Main inlet stop valve (MSV) - Governor control valve (CV) - Reheater stop valve (RSV) - Intercept valves (IV)	
	Turbine control action:	
	- Boiler follow mode - Turbine follow mode - Coordinated control	
	Fast valving /bypass operation	
	Block diagram of the turbine load control	

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Category	Parameter Description	Data
	Reheater volume (m^3), volume flow (kg/s), and average specific volume (m^3/kg)	

16.1.2. Generic Models for synchronous machine

There are two typical groups of synchronous machine models, depending upon the type of machine:

- Round rotor machine (2 poles):
  - GENROU – Round rotor machine model with quadratic saturation function
  - GENROE – Round rotor machine model with exponential saturation function
- Salient pole machine (more than two poles):
  - GENSAL – Salient pole machine with quadratic saturation function
  - GENSAE – Salient pole machine with exponential saturation function

Category	Parameter Description	Data
Generator Model		
	Direct axis open circuit transient time constant Tdo′ in sec	
	Direct axis open circuit sub-transient time constant Tdo″ in sec	
	Quadrature axis open circuit transient time constant Tqo′ in sec	
	Quadrature axis open circuit sub-transient time constant Tqo″ in sec	
	Inertia constant of total rotating mass H in MWs/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd′ in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq′ in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd″ in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq″ in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	
	Direct axis open circuit transient time constant Tdo′ in sec	
	Direct axis open circuit sub-transient time constant Tdo″ in sec	
	Quadrature axis open circuit sub-transient time constant Tqo″ in sec	
	Inertia constant of total rotating mass H in MW/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd′ in p.u. (Unsaturated	

	or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

While entering the values in above table, following relationship must be kept:

Xd>Xq>Xq'≥Xd'>Xq''≥Xd''

Tdo'>Td'>Tdo''>Td''

Tqo''>Tq'>Tqo''>Tq''

16.1.3. Excitation system model:

If a generic model is used, the first step must be to identify what type of exciter is present in the excitation system. The IEEE Std 421.5 (IEEE Recommended Practice for Excitation System Models for Power System Stability Studies published on 26th Aug 2016) has published several generic models, which are classified into three groups:

- Type DC: for excitation systems with a DC exciter
- Type AC: for excitation systems with an AC exciter
- Type ST: for excitation systems with a static exciter

The following table shows the types of models separated into their respective groups.

DC exciter	AC exciter	Static excitation system
Type DC1A	Type AC1A	Type ST1A
Type DC2A	Type AC2A	Type ST2A
Type DC3A	Type AC4A	Type ST3A
Type DC4B	Type AC5A	Type ST4B
	Type AC6A	Type ST5B
	Type AC7B	Type ST6B
	Type AC8B	Type ST7B

DC Exciter, AC Exciter and Static Excitation System

Category	Parameter Description	Data
	DC Exciter	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	

Category	Parameter Description	Data
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (> 0) rate feedback time constant (sec)	
	Switch	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KV (pu) limit on fast raise/lower contact setting	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	TRH (> 0) Rheostat motor travel time (sec)	
	TE (> 0) exciter time-constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	VEMIN (pu) exciter minimum limit	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KP (pu) (> 0) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KD (pu) voltage regulator derivative gain	
	TD voltage regulator derivative channel time constant (sec)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KA (> 0) (pu) voltage regulator gain	
	TA voltage regulator time constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	

Category	Parameter Description	Data
	AC Exciter	
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	VRMAX (pu) regulator output maximum limit	
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KB, Second stage regulator gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	KH, Exciter field current feedback gain	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	

Category	Parameter Description	Data
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	KR (>0), Constant associated with regulator and alternator field power supply	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KN, Exciter feedback gain	
	EFDN, A parameter defining for which value of UF the feedback gain shall change from KF to KN	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	VIMAX, Maximum value of limitation of the integrator signal VI in p.u	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	TB (s), lag time constant	
	TC (s), lead time constant	

Category	Parameter Description	Data
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC, rectifier regulation factor (pu)	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (sec), Regulator stabilizing circuit time constant in seconds	
	TF2 (sec), Regulator stabilizing circuit time constant in seconds	
	TF3 (sec), Regulator stabilizing circuit time constant in seconds	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TK (sec), Lead time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFELIM, Exciter field current limit reference	
	KH, Damping module gain	
	VHMAX, damping module limiter	
	TH (sec), damping module lag time constant	
	TJ (sec), damping module lead time constant	

Category	Parameter Description	Data
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KPA (pu) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KP (pu)	
	KL (pu)	
	KF1 (pu)	
	KF2 (pu)	
	KF3 (pu)	
	TF3 (sec) time constant (> 0)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactance	
	KE (pu) exciter constant related for self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) exciter field current limit (> 0)	
	VEMIN (pu)	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	

Category	Parameter Description	Data
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VPIDMAX (pu) PID maximum limit	
	VPIDMIN (pu) PID minimum limit	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) max exciter field current limit (> 0)	
	VEMIN (pu),	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	Static Exciter	
	TR (sec) regulator input filter time constant	
	VIMAX, Controller Input Maximum	
	VIMIN, Controller Input Minimum	
	TC (s), Filter 1st Derivative Time Constant	
	TB (s), I Filter 1st Delay Time Constant	
	TC1 (s), Filter 2nd Derivative Time Constant	
	TB1 (s), Filter 2nd Delay Time Constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KF (pu) rate feedback gain	

Category	Parameter Description	Data
	TF (> 0) rate feedback time constant (sec)	
	KLR, Current Input Factor	
	ILR, Current Input Reference	
	TR (sec) regulator input filter time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	EFDMAX	
	TR (sec) regulator input filter time constant	
	VIMAX, Maximum value of limitation of the signal VI in p.u.	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	KM, Forward gain constant of the inner loop field regulator	
	TC (s), lag time constant	
	TB (s), lead time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KG, Feedback gain constant of the inner loop field regulator	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX, Maximum value of limitation of the signal VB in p.u.	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL, Reactance associated with potential source	
	VGMAX, Maximum value of limitation of the signal VG in p.u	
	Θ_P (degrees)	
	TM (sec), Forward time constant of the inner loop field regulator	

Category	Parameter Description	Data
	VMMAX, Maximum value of limitation of the signal VM in p.u	
	VMMIN, Minimum value of limitation of the signal VM in p.u.	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TA (sec) voltage regulator time constant	
	KPM, Regulator gain	
	KIM, Regulator gain	
	VMMAX, Maximum value of limitation of the signal in p.u.	
	VMMIN, Minimum value of limitation of the signal in p.u.	
	KG	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL	
	Θ_P (degrees)	
	TR regulator input filter time constant (sec)	
	TC1 lead time constant of first lead-lag block (voltage regulator channel) (sec)	
	TB1 lag time constant of first lead-lag block (voltage regulator channel) (sec)	
	TC2 lead time constant of second lead-lag block (voltage regulator channel) (sec)	
	TB2 lag time constant of second lead-lag block (voltage regulator channel) (sec)	
	KR (>0) (pu) voltage regulator gain	
	VRMAX (pu) voltage regulator maximum limit	
	VRMIN (pu) voltage regulator minimum limit	
	T1 voltage regulator time constant (sec)	
	KC (pu)	
	TUC1 lead time constant of first lead-lag block (under-excitation channel) (sec)	
	TUB1 lag time constant of first lead-lag block (under-excitation channel) (sec)	
	TUC2 lead time constant of second lead-lag block (under-excitation channel) (sec)	
	TUB2 lag time constant of second lead-lag block (under-excitation channel) (sec)	

Category	Parameter Description	Data
	TOC1 lead time constant of first lead-lag block (over-excitation channel) (sec)	
	TOB1 lag time constant of first lead-lag block (over-excitation channel) (sec)	
	TOC2 lead time constant of second lead-lag block (over-excitation channel) (sec)	
	TOB2 lag time constant of second lead-lag block (over-excitation channel) (sec)	
	TR regulator input filter time constant (sec)	
	KPA (pu) (> 0) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	KDA (pu) voltage regulator derivative gain	
	TDA voltage regulator derivative channel time constant (sec)	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KFF (pu) pre-control gain of the inner loop field regulator	
	KM (pu) forward gain of the inner loop field regulator	
	KCI (pu) exciter output current limit adjustment gain	
	KLR (pu) exciter output current limiter gain	
	ILR (pu) exciter current limit reference	
	VRMAX (pu) voltage regulator output maximum limit	
	VRMIN (pu) voltage regulator output minimum limit	
	KG (pu) feedback gain of the inner loop field voltage regulator	
	TG (> 0) feedback time constant of the inner loop field voltage regulator (sec)	
	TR regulator input filter time constant (sec)	
	TG lead time constant of voltage input (sec)	
	TF lag time constant of voltage input (sec)	
	Vmax (pu) voltage reference maximum limit	
	Vmin (pu) voltage reference minimum limit	
	KPA (pu) (>0) voltage regulator gain	
	VRMAX (pu) voltage regulator output maximum limit	
	VRMIN (pu) voltage regulator output minimum limit	
	KH (pu) feedback gain	
	KL (pu) feedback gain	
	TC lead time constant of voltage regulator (sec)	
	TB lag time constant of voltage regulator (sec)	
	KIA (pu) (>0) gain of the first order feedback block	
	TIA (>0) time constant of the first order feedback block (sec)	

16.1.4. Power system stabilizer:

The function of the PSS is to add to the unit's characteristic electromechanical oscillations. This is achieved by modulating excitation to develop a component in electrical torque in phase with rotor speed deviations.

The most important aspect when considering a PSS model is the number of inputs. The following table shows the type of models separated based on the inputs:

Type	Inputs	Remarks
PSS1A	Single input	Two lead-lags Input can either be speed, frequency or power
PSS2B	Dual input	Integral of accelerating power Speed and Power Most common type Supersedes PSS2A (three versus two lead lags)
PSS3B	Dual input	Power and rotor angular frequency deviation Stabilizing signal is a vector sum of processed signals Not very common

Category	Parameter Description	Data
Stabilizer Models		
	A1, Filter coefficient	
	A2, Filter coefficient	
	TR, transducer time constant	
	0	
	0	
	0	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	Tw, Washout Time Constant	
	Tw, Washout Time Constant	
	Ks, input channel gain	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	
	0	
	0	
	TW1, 1st Washout 1th Time Constant	
	TW2, 1st Washout 2th Time Constant	
	T6, 1st Signal Transducer Time Constant	
	TW3, 2nd Washout 1th Time Constant	
	TW4, 2nd Washout 2th Time Constant	
	T7, 2nd Signal Transducer Time Constant	
	KS2, 2nd Signal Transducer Factor	

PSS2B	KS3, Washouts Coupling Factor	
	T8, Ramp Tracking Filter Deriv. Time Constant	
	T9, Ramp Tracking Filter Delay Time Constant	
	KS1, PSS Gain	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	T10, 3rd Lead-Lag Derivative Time Constant	
	T11, 3rd Lead-Lag Delay Time Constant	
	VS1MAX, Input 1 Maximum limit	
	VS1MIN, Input 1 Minimum limit	
	VS2MAX, Input 2 Maximum limit	
	VS2MIN, Input 2 Minimum limit	
	VSTMAX, Controller Maximum Output	
	VSTMIN, Controller Minimum Output	
	KS1 (pu) (≠0), input channel #1 gain	
	T1 input channel #1 transducer time constant (sec)	
	Tw1 input channel #1 washout time constant (sec)	
	KS2 (pu) (≠0), input channel #2 gain	
	T2 input channel #2 transducer time constant (sec)	
	Tw2 input channel #2 washout time constant (sec)	
	Tw3 (0), main washout time constant (sec)	
	A1, Filter coefficient	
	A2, Filter coefficient	
	A3, Filter coefficient	
	A4, Filter coefficient	
	A5, Filter coefficient	
	A6, Filter coefficient	
	A7, Filter coefficient	
	A8, Filter coefficient	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	

16.1.5. Generic models for turbine-governor

The following table is a list for generic models of steam turbines:

Type	Name	Remarks
BBGOV1	Brown-Boveri turbine governor model	Mainly used for steam turbine with electrical damping feedback
TGOV1	Steam-turbine governor	Mainly used for steam turbine with reheater
CRCMGV	Cross-compound turbine	-

Type	Name	Remarks
IEEEG1	IEEE type 1 Speed-Governor Model	Used to represent non-reheat, tandem compound, and cross compound types.
IEEEG2	IEEE Type 2 Speed-Governing Model	Linearized model for representing a hydro turbine-governor and penstock dynamics
IEEEG3	IEEE type 3 turbine-governor model	Includes a more complex representation of the governor controls than IEEEG2 does
IEESGO	IEEE Standard Model	Simple model of reheat steam turbine
TGOV2	Steam –turbine governor with fast valving	Fast valving model of steam turbine
TGOV3	Modified IEEE Type 1 Speed-Governing Model with fast valving	Modification of IEEEG! For fast valving studies
TGOV4	Modified IEEE Type 1 Speed-GoverningModel with PLU and EVA	Model of steam turbine and boiler, explicit action for both control valve (CV) and inlet valve (IV), main reheat and LP steam effects,and boiler
TGOV5	IEEE Type 1 Speed-Governor Model Modified to Include Boiler Controls	Most common type of governor model, based on TGOV1 with boiler controls
TURCZT	Czech hydro or steam turbine governormodel	General-purpose hydro and thermal turbine-governor model. Penstock dynamic is notincluded in the model

Category	Parameter Description	Data
Turbine Governor Model		
	fcut (>=0) (pu), cut off frequency	
	KS, frequency gain	
	KLS (> 0)	
	KG	
	KP, power regulator gain	
	TN (sec) (> 0)	
	KD, damping gain	
	TD (sec) (> 0), damping time constant	
	T4 (sec), high pressure time constant	
	K2, intermediate pressure time constant	
	T5 (sec), intermediate re-heater time constant	
	K3, high pressure time constant	
	T6 (sec), re-heater time constant	
	T1 (sec), measuring transducer time constant	
	SWITCH	
	PMAX, maximum power output limiter	
	PMIN, minimum power output limiter	
	R, Permanent Droop	
	T1 (>0) (sec), Steam bowl time constant	

Category	Parameter Description	Data
TGOV1	VMAX, Maximum valve position	
	VMIN, Minimum valve position	
	T2 (sec), Time constant	
	T3 (>0) (sec), reheater time constant	
	Dt, Turbine damping coefficient	
	VMAX, VMIN, Dt and R are in per unit on generator MVA base.T2/T3 = high-pressure fraction.	
	PMAX (HP)1, maximum HP value position (on generator base)	
	R (HP), HP governor droop	
	T1 (HP) (>0), HP governor time constant	
	T3 (HP) (>0), HP turbine time constant	
	T4 (HP) (>0), HP turbine time constant	
	T5 (HP) (>0), HP reheater time constant	
	F (HP), fraction of HP power ahead of reheater	
	DH (HP), HP damping factor (on generator base)	
	PMAX (LP), maximum LP value position (on generator base)	
	R (LP), LP governor droop	
	T1 (LP) (>0), LP governor time constant	
	T3 (LP) (>0), LP turbine time constant	
	T4 (LP) (>0), LP turbine time constant	
	T5 (LP) (>0), LP turbine time constant	
	F (LP), fraction of LP power ahead of reheater	
	DH (LP), LP damping factor (on generator base)	
	K, Governor gain, (1/droop) pu	
	T1 (sec), Lag time constant (sec)	
	T2 (sec), Lead time constant (sec)	
	T3 (> 0) (sec), valve position time constant	
	Uo (pu/sec), maximum valve opening rate	
	Uc (< 0) (pu/sec), maximum valve closing rate	
	PMAX (pu on machine MVA rating)	
	PMIN (pu on machine MVA rating)	
	T4 (sec), time constant for steam inlet	
	K1, HP fraction	
	K2, LP fraction	
	T5 (sec), Time Constant for Second Boiler Pass [s]	
	K3, HP Fraction	
	K4, LP fraction	
	T6 (sec), Time Constant for Third Boiler Pass [s]	
	K5, HP Fraction	
	K6, LP fraction	
	T7 (sec), Time Constant for Fourth Boiler Pass [s]	
	K7, HP Fraction	
	K8, LP fraction	
	K, Governor gain	
	T1 (sec), Governor lag time constant	
	T2 (sec), Governor lead time constant	

Category	Parameter Description	Data
IEEEG2	T3 (>0) (sec), Gate actuator time constant	
	PMAX (pu on machine MVA rating), gate maximum	
	PMIN (pu on machine MVA rating), gate minimum	
	T4 (>0) (sec), water starting time	
	TG, (>0) (sec), gate servomotor time constant	
	TP (>0) (sec), pilot value time constant	
	Uo (pu per sec), opening gate rate limit	
	Uc (pu per sec), closing gate rate limit (< 0)	
	PMAX maximum gate position (pu on machine MVA rating)	
	PMIN minimum gate position (pu on machine MVA rating)	
	σ, permanent speed droop coefficient	
	δ, transient speed droop coefficient	
	TR, (>0) (sec), Dashpot time constant	
	TW (>0) (sec), water starting time	
	a11 (>0), Turbine coefficient	
	a13, Turbine coefficient	
	a21, Turbine coefficient	
	a23 (>0), Turbine coefficient	
	T1, Controller Lag	
	T2, Controller Lead Compensation	
	T3, Governor Lag (> 0)	
	T4, Delay Due To Steam Inlet Volumes	
	T5, Reheater Delay	
	T6, Turbine, pipe, hood Delay	
	K1, 1/Per Unit Regulation	
	K2, Fraction	
	K3, fraction	
	PMAX, Upper Power Limit	
	PMIN, Lower Power Limit	
	R (pu), permanent droop	
	T1 (>0) (sec), Steam bowl time constant	
	VMAX (pu), Maximum valve position	
	VMIN (pu), Minimum valve position	
	K (pu), Governor gain	
	T3 (>0) (sec), Time constant	
	Dt (pu), Turbine damping coefficient	
	Tt (>0) (sec), Valve time constant	
	TA, Valve position at time 2 (fully closed after fast valving initialization)	
	TB, Valve position at time 3 (start to reopen after fast valving initialization)	
	TC, Valve position at time 4 (again fully open after fast valving initializations)	
	K, Governor gain	

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Category	Parameter Description	Data
TGOV3	T1 (sec), Governor lead time constant	
	T2 (sec), Governor lag time constant	
	T3 (>0) (sec), Valve positioner time constant	
	Uo, Maximum valve opening velocity	
	Uc (< 0), Maximum valve closing velocity	
	PMAX, Maximum valve opening	
	PMIN, Minimum valve opening	
	T4 (sec), Inlet piping/steam bowl time constant	
	K1, Fraction of turbine power developed after first boiler pass	
	T5 (> 0) (sec), Time constant of second boiler pass	
	K2, Fraction of turbine power developed after second boiler pass	
	T6 (sec), Time constant of crossover or third boiler pass	
	K3, Fraction of hp turbine power developed after crossover or third boiler pass	
	TA (sec), Valve position at time 2 (fully closed after fast valving initializations)	
	TB (sec), Valve position at time 3 (start to reopen after fast valving initializations)	
	TC (sec), Valve position at time 4 (again fully open after fast valving initializations)	
	PRMAX (pu), Max. pressure in reheater	
	K, The inverse of the governor speed droop	
	T1 (sec), The governor controller lag time constant	
	T2 (sec), The governor controller lead time constant	
	T3 (>0) (sec), The valve servomotor time constant for the control valves	
	Uo, The control valve open rate limit	
	Uc (<0), The control valve close rate limit	
	KCAL	
	T4 (sec), The steam flow time constant	
	K1	
	T5 (> 0) (sec)	
	K2	
	T6 (sec)	
	PRMAX	
	KP	
	KI	
	TFuel (sec)	
	TFD1 (sec)	
	TFD2 (sec)	
	Kb	
	Cb (> 0) (sec)	
	TIV (> 0) (sec)	
	UOIV	

Category	Parameter Description	Data
	UCIV	
	R (>0)	
	Offset	
	CV position demand characteristic	
	CV #2 offset	
	CV #3 offset	
	CV #4 offset	
	IV position demand characteristic	
	IV #2 offset	
	CV valve characteristic	
	IV valve characteristic	
	CV starting time for valve closing (sec)	
	CV closing rate (pu/sec)	
	Time closed for CV #1 (sec)	
	Time closed for CV #2	
	Time closed for CV #3	
	Time closed for CV #4	
	IV starting time for valve closing (sec)	
	IV closing rate (pu/sec)	
	Time closed for IV #1 (sec)	
	Time closed for IV #2 (sec)	
	TRPLU (>0) (sec)	
	PLU rate level	
	Timer	
	PLU unbalance level	
	TREVA (>0) (sec)	
	EVA rate level	
	EVA unbalance level	
	Minimum load reference (pu)	
	Load reference ramp rate (pu/sec)	
	K, The inverse of the governor speed droop	
	T1 (sec), The governor controller lag time constant	
	T2 (sec), The governor controller lead time constant	
	T3 (>0) (sec), The valve servomotor time constant for the control valves	
	Uo, The control valve open rate limit	
	Uc (<0), The control valve close rate limit	
	VMAX, The maximum valve area	
	VMIN, The minimum valve area	
	T4 (sec), The steam flow time constant	
	K1, The fractions of the HP	
	K2, fractions of the LP	
	T5 (sec), The first reheater time constant	
	K3, The fractions of the HP	
	K4, fractions of the LP	

Category	Parameter Description	Data
TGOV5	T6 (sec), second reheater time constant	
	K5, The fractions of the HP	
	K6, fractions of the LP	
	T7 (sec), crossover time constant	
	K7, The fractions of the HP	
	K8, fractions of the LP	
	K9, The adjustment to the pressure drop coefficient as a function of drum pressure	
	K10, The gain of anticipation signal from main stream flow	
	K11, The gain of anticipation signal from load demand	
	K12, The gain for pressure error bias	
	K13, The gain between MW demand and pressure set point	
	K14, Inverse of load reference servomotor time constant (= 0.0 if load reference does not change).	
	RMAX, The load reference positive rate of change limit	
	RMIN, The load reference negative rate of change limit	
	LMAX, The maximum load reference	
	LMIN, The minimum load reference	
	C1, The pressure drop coefficient	
	C2, The gain for the pressure error bias	
	C3, The adjustment to the pressure set point	
	B, The frequency bias for load reference control	
	CB (>0) (sec), The boiler storage time constant	
	KI, The controller integral gain	
	TI (sec), The controller proportional lead time constant	
	TR (sec), The controller rate lead time constant	
	TR1 (sec), The inherent lag associated with lead TR (usually about TR/10)	
	CMAX, The maximum controller output	
	CMIN, The minimum controller output	
	TD (sec), The time delay in the fuel supply system	
	TF (sec), The fuel and air system time constant	
	TW (sec), The water wall time constant	
	Psp (initial) (>0), The initial throttle pressure set point	
	TMW (sec), The MW transducer time constant	
	KL (0.0 or 1.0), The feedback gain from the load reference	
	KMW (0.0 or 1.0), The gain of the MW transducer	
	DPE (pu pressure), The dead band in the pressure error signal for load reference control	
	• *The fractions of the HP unit's mechanical power developed by the various turbine stages. The sum of K1,*	

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Category	Parameter Description	Data
	K3, K5 andK7 constants should be one for a non-cross-compound unit. • *Similarly fractions of the LP unit's mechanical power should be zero for a non-cross- compound unit. For a cross-compound unit, the sum of K1 through K8 should equal one.*	
	fDEAD (pu), Frequency Dead Band	
	fMIN (pu), Frequency Minimum Deviation	
	fMAX (pu), Frequency Maximum Deviation	
	KKOR (pu), Frequency Gain	
	KM > 0 (pu), Power Measurement Gain	
	KP (pu), Regulator Proportional Gain	
	SDEAD (pu), Speed Dead Band	
	KSTAT (pu), Speed Gain	
	KHP (pu), High Pressure Constant	
	TC (sec), Measuring transducer time constant	
	T 1 (sec), Regulator Integrator Time Constant	
	TEHP (sec), Hydro Converter Time Constant	
	TV > 0 (sec), Regulation Valve Time Constant	
	THP (sec), High Pressure Time Constant	
	TR (sec), Reheater time constant	
	TW (sec), Water Time Constant	
	NTMAX (pu), Power Regulator-Integrator Maximum Limiter	
	NTMIN (pu), Power Regulator-Integrator Minimum Limiter	
	GMAX (pu), Valve Maximum Open	
	GMIN (pu), Valve Minimum Open	
	VMIN (pu/sec), Valve Maximum Speed Close	
	VMAX (pu/sec), Valve Maximum Speed Open	

16.2. Generation: Thermal (Gas)

Format No.	Dyn/Generation/ Thermal-Gas/1
Data Submission By:	Generating Company / CPP
Data related to:	Each Gas based thermal power station
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and when required by STU

16.2.1. Details of models in PSS/E for modelling Gas power generation:

(a) Synchronous Machine – To be filled separately for Gas turbine (GT) and steam turbine (ST)

Category	Parameter Description	Data
	Rated apparent power in MVA	

Category	Parameter Description	Data
	Rated terminal voltage	
	Rated power factor	
	Rated speed (in RPM)	
	Rated frequency (in Hz)	
	Rated excitation (in Amperes and Volts)	
Type of Synchronous Machine	Round rotor or salient pole No. of poles	
	The generator capability curve shows the reactive capability of the machine and should include any restrictions on the real or reactive power range like under/over excitation limits, stability limits, etc. Capability curve should have properly labelled axis and legible data	
	Graph of excitation current versus terminal voltage and stator current	
	No load excitation current – used to derive per unit values	
	Excitation current at rated stator current	
	Otherwise referred to as "V-curve". A plot of the terminal (armature) current versus the generating unit field voltage.	
Resistance values	Resistance measurements of field winding and stator winding to a known temperature	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd′ in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd′′ in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xa in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq′ in p.u. (Unsaturated or saturated)	
	Quadrature axis sub-transient synchronous reactance Xq′′ in p.u. (Unsaturated or saturated)	
	Direct axis open circuit transient time constant Tdo′ in sec	
	Direct axis open circuit sub-transient time constant Tdo′′ in sec	
	Quadrature axis open circuit transient time constant Tqo′ in sec	

Category	Parameter Description	Data
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass (generator, AVR, turbo-governor set) H in MW/MVA	
	Speed Damping D	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	
	Nameplate Rating - Rated primary and secondary voltage - Vector group - Impedance - Tap changer details (Number of taps, tap position, tap ratio etc.)	
	Value of auxiliary load (MW and MVAr) at rated power of the generating unit.	
	Whether or not the load trips if the generating unit trips.	
Test Reports	Factory acceptance test (FAT) reports	

(b) Site Load

	Low Output			High Output		
	kW	kvar	kVA	kW	kvar	kVA
Auxiliary Load						

(c) Excitation System

Category	Parameter Description	Data
	Manufacturer and product details (for example ABB UNITROL or GE EX2100e)	
	Type of control system :- Analogue or digital	
	Year of commissioning / Year of manufacture	
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
	Static excitation system OR	
	Indirect excitation system (i.e. rotating exciter)	
	- AC exciter, or	
	- DC exciter	
	Rated excitation current (converter rating in Amperes)	
	Six pulse thyristor bridge or PWM converter	
	Excitation transformer or auxiliary supply (Details thereof)	
	If excitation transformer, nameplate information required	
	Saturation curves of the exciter (if applicable – see Type AC and DC)	

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Category	Parameter Description	Data
	Drawings of excitation system, typically prepared and supplied by the OEM	
	Single line diagram (i.e. one-line diagram) for the excitation system	
	What excitation limiters are commissioned?	
	Under Excitation Limiters settings	
	Over Excitation Limiters settings	
	Voltage/frequency limiter	
	Stator current limiter	
	Minimum excitation current limiter	

(d) Excitation System

Category	Parameter Description	Data
Type of prime mover	- Open cycle gas turbine - Aero-derivative (twin shaft) gas turbine - Combined cycle plant (closed cycle gas turbine)	
Manufacturer of turbine	Manufacturer and name plate details	
	Electro-mechanical governor (including settings and drawings)	
	Digital electric governor (including settings and drawings)	
	Frequency influence limiters - Maximum frequency deviation limiter (eg +/-2 Hz) - Maximum influence limiter (eg 10% of rating)	
Dead band	Details of frequency dead band (typically in Hz or RPM)	
	- Open cycle	
	- Close cycle	
	Does turbine operate in dual fuel (gas and liquid fuel)	
	Inlet guide vane (IGV) characteristic	
	Limit for exhaust gas temperature (EGT)	
	Base load/frequency control	
	Power output versus ambient temperature	
	No load fuel flow and turbine gain (determined by relationship of active power versus fuel valve position or fuel stroke reference)	
	Size of steam turbine	
	Frequency control of ST	
	Time lag and relationship of GT and ST	
	Is the combined cycle plant a single shaft plant – i.e. the gas and steam turbine are on same shaft and drive same generator	

16.2.2. Generic Models for synchronous machine

Gas turbine (GT) or steam turbines (ST) are generally round rotor machines however, salient pole Gas turbine (aero-derivative) with synchronous machine having four poles has also been installed at some of the places. Depending upon the saturation characteristic of the machine they are classified further:

- Round rotor machine (2 poles):
    - GENROU – Round rotor machine model with quadratic saturation function
    - GENROE – Round rotor machine model with exponential saturation function
- Salient pole machine (more than two poles):
    - GENSAL – Salient pole machine with quadratic saturation function
    - GENSAE – Salient pole machine with exponential saturation function

Category	Parameter Description	Data
	Generator Model	
	Direct axis open circuit transient time constant Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit transient time constant Tqo' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	
	Direct axis open circuit transient time constant Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo'' in sec	
	Quadrature axis open circuit sub-transient time constant Tqo'' in sec	
	Inertia constant of total rotating mass H in MW.s/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u.	

	(Unsaturated or saturated)	
	Stator leakage reactance Xl in p.u.	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

16.2.3. Excitation system model:

If a generic model is used, the first step must be to identify what type of exciter is present in the excitation system. The IEEE Std 421.5 (IEEE Recommended Practice for Excitation System Models for Power System Stability Studies published on 26th Aug 2016) has published several generic models, which are classified into three groups:

- Type DC: for excitation systems with a DC exciter
- Type AC: for excitation systems with an AC exciter
- Type ST: for excitation systems with a static exciter

The following table shows the types of models separated into their respective groups.

DC exciter	AC exciter	Static excitation system
Type DC1A	Type AC1A	Type ST1A
Type DC2A	Type AC2A	Type ST2A
Type DC3A	Type AC4A	Type ST3A
Type DC4B	Type AC5A	Type ST4B
	Type AC6A	Type ST5B
	Type AC7B	Type ST6B
	Type AC8B	Type ST7B

Category	Parameter Description	Data
	DC Exciter	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (> 0) rate feedback time constant (sec)	
	Switch	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	

Category	Parameter Description	Data
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KV (pu) limit on fast raise/lower contact setting	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	TRH (> 0) Rheostat motor travel time (sec)	
	TE (> 0) exciter time-constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	VEMIN (pu) exciter minimum limit	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KP (pu) (> 0) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KD (pu) voltage regulator derivative gain	
	TD voltage regulator derivative channel time constant (sec)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KA (> 0) (pu) voltage regulator gain	
	TA voltage regulator time constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	

Category	Parameter Description	Data
ESAC1A	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KB, Second stage regulator gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	KH, Exciter field current feedback gain	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
AC Exciter		
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	

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Category	Parameter Description	Data
ESAC3A	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	KR (>0), Constant associated with regulator and alternator field power supply	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KN, Exciter feedback gain	
	EFDN, A parameter defining for which value of UF the feedback gain shall change from KF to KN	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	VIMAX, Maximum value of limitation of the integrator signal VI in p.u	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC, rectifier regulation factor (pu)	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	

Category	Parameter Description	Data
ESAC5A	KF (pu) rate feedback gain	
	TF1 (sec), Regulator stabilizing circuit time constant in seconds	
	TF2 (sec), Regulator stabilizing circuit time constant in seconds	
	TF3 (sec), Regulator stabilizing circuit time constant in seconds	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TK (sec), Lead time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFELIM, Exciter field current limit reference	
	KH, Damping module gain	
	VHMAX, damping module limiter	
	TH (sec), damping module lag time constant	
	TJ (sec), damping module lead time constant	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	

Category	Parameter Description	Data
AC7B	KPA (pu) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KP (pu)	
	KL (pu)	
	KF1 (pu)	
	KF2 (pu)	
	KF3 (pu)	
	TF3 (sec) time constant (> 0)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) exciter field current limit (> 0)	
	VEMIN (pu)	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VPIDMAX (pu) PID maximum limit	
	VPIDMIN (pu) PID minimum limit	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) max exciter field current limit (> 0)	
	VEMIN (pu),	
	E1, exciter flux at knee of curve (pu)	

Category	Parameter Description	Data
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
Static Exciter		
	Static Exciter	
	TR (sec) regulator input filter time constant	
	VIMAX, Controller Input Maximum	
	VIMIN, Controller Input Minimum	
	TC (s), Filter 1st Derivative Time Constant	
	TB (s), I Filter 1st Delay Time Constant	
	TC1 (s), Filter 2nd Derivative Time Constant	
	TB1 (s), Filter 2nd Delay Time Constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KLR, Current Input Factor	
	TR (sec) regulator input filter time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	EFDMAX	
	TR (sec) regulator input filter time constant	
	VIMAX, Maximum value of limitation of the signal VI in p.u.	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	

Category	Parameter Description	Data
	KM, Forward gain constant of the inner loop field regulator	
	TC (s), lag time constant	
	TB (s), lead time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KG, Feedback gain constant of the inner loop field regulator	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX, Maximum value of limitation of the signal VB in p.u.	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL, Reactance associated with potential source	
	VGMAX, Maximum value of limitation of the signal VG in p.u	
	Θ_P (degrees)	
	TM (sec), Forward time constant of the inner loop field regulator	
	VMMAX, Maximum value of limitation of the signal VM in p.u	
	VMMIN, Minimum value of limitation of the signal VM in p.u.	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TA (sec) voltage regulator time constant	
	KPM, Regulator gain	
	KIM, Regulator gain	
	VMMAX, Maximum value of limitation of the signal in p.u.	
	VMMIN, Minimum value of limitation of the signal in p.u.	
	KG	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL	
	Θ_P (degrees)	
	TR regulator input filter time constant (sec)	
	TC1 lead time constant of first lead-lag block (voltage regulator channel) (sec)	

Category	Parameter Description	Data
	TB1 lag time constant of first lead-lag block (voltage regulator channel) (sec)	
	TC2 lead time constant of second lead-lag block (voltage regulator channel) (sec)	
	TB2 lag time constant of second lead-lag block (voltage regulator channel) (sec)	
	KR (>0) (pu) voltage regulator gain	
	VRMAX (pu) voltage regulator maximum limit	
	VRMIN (pu) voltage regulator minimum limit	
	T1 voltage regulator time constant (sec)	
	KC (pu)	
	TUC1 lead time constant of first lead-lag block (under-excitation channel) (sec)	
	TUB1 lag time constant of first lead-lag block (under-excitation channel) (sec)	
	TUC2 lead time constant of second lead-lag block (under-excitation channel) (sec)	
	TUB2 lag time constant of second lead-lag block (under-excitation channel) (sec)	
	TOC1 lead time constant of first lead-lag block (over-excitation channel) (sec)	
	TOB1 lag time constant of first lead-lag block (over-excitation channel) (sec)	
	TOC2 lead time constant of second lead-lag block (over-excitation channel) (sec)	
	TOB2 lag time constant of second lead-lag block (over-excitation channel) (sec)	
	TR regulator input filter time constant (sec)	
	KPA (pu) (> 0) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	KDA (pu) voltage regulator derivative gain	
	TDA voltage regulator derivative channel time constant (sec)	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KFF (pu) pre-control gain of the inner loop field regulator	
	KM (pu) forward gain of the inner loop field regulator	
	KCI (pu) exciter output current limit adjustment gain	
	KLR (pu) exciter output current limiter gain	
	ILR (pu) exciter current limit reference	
	VRMAX (pu) voltage regulator output maximum limit	
	VRMIN (pu) voltage regulator output minimum limit	
	KG (pu) feedback gain of the inner loop field voltage regulator	
	TG (> 0) feedback time constant of the inner loop field voltage regulator (sec)	
	TR regulator input filter time constant (sec)	

Category	Parameter Description	Data
	TG lead time constant of voltage input (sec)	
	TF lag time constant of voltage input (sec)	
	Vmax (pu) voltage reference maximum limit	
	Vmin (pu) voltage reference minimum limit	
	KPA (pu) (>0) voltage regulator gain	
	VRMAX (pu) voltage regulator output maximum limit	
	VRMIN (pu) voltage regulator output minimum limit	
	KH (pu) feedback gain	
	KL (pu) feedback gain	
	TC lead time constant of voltage regulator (sec)	
	TB lag time constant of voltage regulator (sec)	
	KIA (pu) (>0) gain of the first order feedback block	
	TIA (>0) time constant of the first order feedback block (sec)	

16.2.4. Power system stabilizer:

The function of the PSS is to add to the unit's characteristic electromechanical oscillations. This is achieved by modulating excitation to develop a component in electrical torque in phase with rotorspeed deviations.

The most important aspect when considering a PSS model is the number of inputs. The following tableshows the type of models separated based on the inputs:

Type	Inputs	Remarks
PSS1A	Single input	Two lead-lags Input can either be speed, frequency or power
PSS2B	Dual input	Integral of accelerating power type stabilizer Speed and Power Most common type Supersedes PSS2A (three versus two lead lags)
PSS3B	Dual input	Power and rotor angular frequency deviation Stabilizing signal is a vector sum of processed signalsNot very common

Category	Parameter Description	Data
	Stabilizer Models	
	A1, Filter coefficient	
	A2, Filter coefficient	
	TR, transducer time constant	
	0	
	0	
	0	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	

Category	Parameter Description	Data
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	Tw, Washout Time Constant	
	Tw, Washout Time Constant	
	Ks, input channel gain	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	
	0	
	0	
	TW1, 1st Washout 1th Time Constant	
	TW2, 1st Washout 2th Time Constant	
	T6, 1st Signal Transducer Time Constant	
	TW3, 2nd Washout 1th Time Constant	
	TW4, 2nd Washout 2th Time Constant	
	T7, 2nd Signal Transducer Time Constant	
	KS2, 2nd Signal Transducer Factor	
	KS3, Washouts Coupling Factor	
	T8, Ramp Tracking Filter Deriv. Time Constant	
	T9, Ramp Tracking Filter Delay Time Constant	
	KS1, PSS Gain	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	T10, 3rd Lead-Lag Derivative Time Constant	
	T11, 3rd Lead-Lag Delay Time Constant	
	VS1MAX, Input 1 Maximum limit	
	VS1MIN, Input 1 Minimum limit	
	VS2MAX, Input 2 Maximum limit	
	VS2MIN, Input 2 Minimum limit	
	VSTMAX, Controller Maximum Output	
	VSTMIN, Controller Minimum Output	
	KS1 (pu) (≠0), input channel #1 gain	
	T1 input channel #1 transducer time constant (sec)	
	Tw1 input channel #1 washout time constant (sec)	
	KS2 (pu) ([1]0), input channel #2 gain	
	T2 input channel #2 transducer time constant (sec)	
	Tw2 input channel #2 washout time constant (sec)	

Category	Parameter Description	Data
	Tw3 (0), main washout time constant (sec)	
	A1, Filter coefficient	
	A2, Filter coefficient	
	A3, Filter coefficient	
	A4, Filter coefficient	
	A5, Filter coefficient	
	A6, Filter coefficient	
	A7, Filter coefficient	
	A8, Filter coefficient	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	

16.2.5. Generic models for gas turbine-governor:

The following table is a list for common generic models of gas turbines:

Type	Name	Remarks
GAST	Gas turbine governor	Simplified model for industrial gas turbine (i.e. OCGT)
GAST2A	Gas turbine governor	More detailed GT from GAST. Governor can be configured for droop or isochronous control. Includes temperature control
GASTWD	Woodward Gas Turbine-Governor model	Same detail of turbine dynamics as GAST2A but with a Woodward governor controls
WESGOV	Westinghouse Digital governor for GasTurbine	Westinghouse 501 combination turbine governor
GGOV1	GE General Governor/Turbine model	General purpose GE GT model (neglects ICV control)
PWTBD1	Pratt & Whitney Turboden turbine-governor	Turbine load PI control with valve and look-up table
URCSCT	Combined cycle, single shaft turbine-governor model	
URGS3T	WECC gas turbine governor	

Category	Parameter Description	Data
Turbine Governor Model		
	R, permanent droop	
	T1 (>0) (sec), Governor mechanism time constant	
	T2 (>0) (sec), Turbine power time constant	
	T3 (>0) (sec), Turbine exhaust temperature time constant	
	Ambient temperature load limit, AT	
	KT, Temperature limiter gain	
	VMAX, Maximum turbine power	
	VMIN, Minimum turbine power	
	Dturb, Turbine damping factor	

Category	Parameter Description	Data
GAST2A	W, governor gain (1/droop) (on turbine rating)	
	X (sec) governor lead time constant	
	Y (sec) (> 0) governor lag time constant	
	Z, governor mode:1 Droop or 0 ISO	
	ETD (sec), Turbine exhausts time constant	
	TCD (sec), Gas turbine dynamic time constant	
	TRATE turbine rating (MW)	
	T (sec), Fuel control time constant	
	MAX (pu) limit (on turbine rating)	
	MIN (pu) limit (on turbine rating)	
	ECR (sec), Combustor time constant	
	K3, Fuel control gain	
	a (> 0) valve positioner	
	b (sec) (> 0) valve positioner	
	c valve positioner	
	Tf (sec) (> 0), Fuel system time constant	
	Kf, feedback gain	
	K5, Radiation shield	
	K4, Radiation shield	
	T3 (sec) (> 0), Radiation shield time constant	
	T4 (sec) (> 0), Thermocouple time constant, seconds	
	Tt (> 0), Temperature control time constant	
	T5 (sec) (> 0), Temperature control time constant	
	af1, describes the turbine characteristic	
	bf1, describes the turbine characteristic	
	af2, describes the turbine characteristic	
	bf2, describes the turbine characteristic	
	cf2, describes the turbine characteristic	
	TR (degree), Rated temperature	
	K6 (pu), Minimum fuel flow	
	TC (degree), Temperature control	
	KDROOP (on turbine rating)	
	KP, Proportional gain	
	KI, Integral gain	
	KD, Derivative gain	
	ETD (sec), Turbine exhaust time constant	
	TCD (sec), Gas turbine dynamic time constant	
	TRATE turbine rating (MW)	
	T (sec), Fuel control time constant	
	MAX (pu) limit (on turbine rating)	
	MIN (pu) limit (on turbine rating)	
	ECR (sec), Combustor time constant	
	K3, Fuel control gain	
	a (> 0) valve positioner	
	b (sec) (> 0) valve positioner	
	c valve positioner	

Category	Parameter Description	Data
GASTWD	tf (sec) (> 0), Fuel system time constant	
	Kf, feedback gain	
	K5, Radiation shield	
	K4, Radiation shield	
	T3 (sec) (> 0), Radiation shield time constant	
	T4 (sec) (> 0), Thermocouple time constant, seconds	
	tt (> 0), Temperature control time constant	
	T5 (sec) (> 0), Temperature control time constant	
	af1, describes the turbine characteristic	
	bf1, describes the turbine characteristic	
	af2, describes the turbine characteristic	
	bf2 (>0), describes the turbine characteristic	
	cf2, describes the turbine characteristic	
	TR(degree), Rated temperature1	
	K6 (pu), Minimum fuel flow	
	TC (degree), Temperature control1	
	TD (sec) (> 0), Power transducer	
	ΔTC (sec), Δt sample for controls	
	ΔTP (sec), Δt sample for PE	
	Power Droop	
	Kp, Trubine proportional gain	
	TI (> 0) (sec), Integral time constant	
	T1 (sec), Constant time	
	T2 (sec), Constant time	
	ALIM	
	Tpe (sec), Power time constant	
	R, Permanent droop, pu	
	Tpelec, Electrical power transducer time constant, sec	
	maxerr, Maximum value for speed error signal	
	minerr, Minimum value for speed error signal	
	Kpgov, Governor proportional gain	
	Kigov, Governor integral gain	
	Kdgov, Governor derivative gain	
	Tdgov, Governor derivative controller time constant, sec	
	vmax, Maximum valve position limit	
	vmin, Minimum valve position limit	
	Tact, Actuator time constant, sec	
	Kturb, Turbine gain	
	Wfnl, No load fuel flow, pu	
	Tb, Turbine lag time constant, sec	
	Tc, Turbine lead time constant, sec	
	Teng, Transport lag time constant for diesel engine, sec	
	Tfload, Load Limiter time constant, sec	
	Kpload, Load limiter proportional gain for PI controller	

Category	Parameter Description	Data
GGOV1	Kiload, Load limiter integral gain for PI controller	
	Ldref, Load limiter reference value pu	
	Dm, Mechanical damping coefficient, pu	
	Ropen, Maximum valve opening rate, pu/sec	
	Rclose, Maximum valve closing rate, pu/sec	
	Kimw, Power controller (reset) gain	
	Aset, Acceleration limiter setpoint, pu/sec	
	Ka, Acceleration limiter gain	
	Ta, Acceleration limiter time constant, sec (> 0)	
	Trate, Turbine rating (MW)1	
	db, Speed governor deadband	
	Tsa, Temperature detection lead time constant, sec	
	Tsb, Temperature detection lag time constant, sec	
	Rup, Maximum rate of load limit increase	
	Rdown, Maximum rate of load limit decrease	
	Trate (MW), Turbine rating (MW)	
	K (pu), Proportional gain	
	Ki (pu), Integral gain	
	Vrmax (pu), Upper Limit of PI controller	
	Vrmin (pu), Lower Limit of PI controller	
	Tv (s) (>0), Control valve Time Constant	
	Lo (pu/sec) (>0), Control valve open rate limit	
	Lc (pu/sec) (>0), Control valve close rate limit	
	Vmax (pu), Maximum valve position	
	Vmin (pu), Minimum valve position	
	Tb1 (s), steam buffer time constant	
	Tb2 (s), steam buffer time constant	
	v1 (pu), valve position 1	
	p1 (pu), power output for valve position v1	
	v2 (pu), valve position 2	
	p2 (pu), power output for valve position v2	
	v3 (pu), valve position 3	
	p3 (pu), power output for valve position v3	
	v4 (pu), valve position 4	
	p4 (pu), power output for valve position v4	
	v5 (pu), valve position 5	
	p5 (pu), power output for valve position v5	
	v6 (pu), valve position 6	
	p6 (pu), power output for valve position v6	
	v7 (pu), valve position 7	
	p7 (pu), power output for valve position v7	
	v8 (pu), valve position 8	
	p8 (pu), power output for valve position v8	

Category	Parameter Description	Data
	v9 (pu), valve position 9	
	p9 (pu), power output for valve position v9	
	v10 (pu), valve position 10	
	p11 (pu), power output for valve position v11	
	v11 (pu), valve position 11	
	p11 (pu), power output for valve position v11	
	W, governor gain (1/droop) (on turbine rating)	
	X (sec) governor lead time constant	
	Y (sec) (> 0) governor lag time constant	
	Z, governor mode:1 Droop or 0 ISO	
	ETD (sec), Turbine exhausts time constant	
	TCD (sec), Gas turbine dynamic time constant	
	TRATE turbine rating (MW)	
	T (sec), Fuel control time constant	
	MAX (pu) limit (on turbine rating)	
	MIN (pu) limit (on turbine rating)	
	ECR (sec), Combustor time constant	
	K3, Fuel control gain	
	a (> 0) valve positioner	
	b (sec) (> 0) valve positioner	
	c valve positioner	
	Tf (sec) (> 0), Fuel system time constant	
	Kf, feedback gain	
	K5, Radiation shield	
	K4, Radiation shield	
	T3 (sec) (> 0), Radiation shield time constant	
	T4 (sec) (> 0), Thermocouple time constant, seconds	
	Tt (> 0), Temperature control time constant	
	T5 (sec) (> 0), Temperature control time constant	
	af1, describes the turbine characteristic	
	bf1, describes the turbine characteristic	
	af2, describes the turbine characteristic	
	bf2, describes the turbine characteristic	
	cf2, describes the turbine characteristic	
	TR (degree), Rated temperature	
	K6 (pu), Minimum fuel flow	
	TC (degree), Temperature control	
	K, Governor gain, (1/droop) pu	
	T1 (sec), Lag time constant (sec)	
	T2 (sec), Lead time constant (sec)	
	T3 (> 0) (sec), valve position time constant	
	Uo (pu/sec), maximum valve opening rate	
	Uc (< 0) (pu/sec), maximum valve closing rate	
	PMAX (pu on machine MVA rating)	

Category	Parameter Description	Data
	PMIN (pu on machine MVA rating)	
	T4 (sec), time constant for steam inlet	
	K1, HP fraction	
	K2, LP fraction	
	T5 (sec), Time Constant for Second Boiler Pass [s]	
	K3, HP Fraction	
	K4, LP fraction	
	T6 (sec), Time Constant for Third Boiler Pass [s]	
	K5, HP Fraction	
	K6, LP fraction	
	T7 (sec), Time Constant for Fourth Boiler Pass [s]	
	K7, HP Fraction	
	K8, LP fraction	
	ST Rating, Steam turbine rating (MW)	
	POUT A, Plant total, point A (MW)	
	STOUT A, Steam turbine output, point A (MW)	
	POUT B, Plant total, point B (MW)	
	STOUT B, Steam turbine output, point B (MW)	
	POUT C, Plant total, point C (MW)	
	STOUT C, Steam turbine output, point C (MW)	
	R	
	T1 (> 0) (sec)	
	T2 (> 0) (sec)	
	T3 (> 0) (sec)	
	Lmax	
	Kt	
	Vmax	
	Vmin	
	Dturb	
	Fidle	
	Rmax	
	Linc (> 0)	
	Tltr (>0) (sec)	
	Ltrat	
	a	
	b (> 0)	
	db1, dead band width (p.u.)	
	Err, deadband hysteresis (p.u.)	
	db2, dead band width (p.u.)	
	GV1, coordinate of power-gate look-up table (p.u. gate)	
	PGV1, coordinate of power-gate look-up table (p.u. power)	
	GV2, coordinate of power-gate look-up table (p.u. gate)	
	PGV2, coordinate of power-gate look-up table (p.u. power)	

Category	Parameter Description	Data
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. power)	
	GV4, coordinate of power-gate look-up table (p.u. gate)	
	PGV4, coordinate of power-gate look-up table (p.u. power)	
	GV5, coordinate of power-gate look-up table (p.u. gate)	
	PGV5, coordinate of power-gate look-up table (p.u. power)	
	Ka	
	T4	
	T5	
	MWCAP	

16.3. Generation: Hydro

Format No.:	Dyn/Generation/Hydro/1
Data Submission By:	Generating Company/CPP/Hydro Power generator
Data related to:	Each hydro station
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and when requested by STU.

16.3.1. Details of models in PSS/E for modelling hydro power generator:

(a) Synchronous Machine – HPP and PSP types

Category	Parameter Description	Data
	Rated apparent power in MVA	
	Rated terminal voltage	
	Rated power factor	
	Rated speed (in RPM)	
	Rated frequency (in Hz)	
	Rated excitation (in Amperes and Volts)	
Type of Synchronous Machine	Round rotor or salient pole No. of poles	
Generator capability curve	The generator capability curve shows the reactive capability of the machine and should include any restrictions on the real or reactive power range like under/over excitation limits, stability limits, etc. Capability curve should have properly labelled axis and legible data Graph of excitation current versus terminal voltage and stator current	
	No load excitation current – used to derive per unit values	
	Excitation current at rated stator current	

Category	Parameter Description	Data
Generator vee-curves	Otherwise referred to as "V-curve". A plot of the terminal (armature) current versus the generating unit field voltage.	
Resistance values	Resistance measurements of field winding and stator winding to a known temperature	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Direct axis transient synchronous reactance Xd′ in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd″ in p.u. (Unsaturated or saturated)	
	Stator leakage reactance Xa in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	
	Quadrature axis transient synchronous reactance Xq′ in p.u. (Unsaturated or saturated)	
	Quadrature axis sub-transient synchronous reactance Xq″ in p.u. (Unsaturated or saturated)	
	Direct axis open circuit transient time constant Tdo′ in sec	
	Direct axis open circuit sub-transient time constant Tdo″ in sec	
	Quadrature axis open circuit transient time constant Tqo′ in sec	
	Quadrature axis open circuit sub-transient time constant Tqo″ in sec	
	Inertia constant of total rotating mass (generator, AVR, turbo-governor set) H in MW/MVA	
	Speed Damping D	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	
	Nameplate Rating - Rated primary and secondary voltage - Vector group - Impedance - Tap changer details (Number of taps, tap position, tap ratio etc.)	
	Value of auxiliary load (MW and Mvar) at rated power of the generating unit.	
	Whether or not the load trips if the generating unit trips.	
Test Reports	Factory acceptance test (FAT) reports	

(b) Site Load

	Low Output			High Output		
	kW	kVAr	kVA	kW	kVAr	kVA
Auxiliary Load						

CE (STU) MSETCL

(c) Excitation System

Category	Parameter Description	Data
	Manufacturer and product details (for example ABB UNITROL)	
	Type of control system :- Analogue or digital	
	Year of commissioning / Year of manufacture	
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
	Static excitation system OR	
	Indirect excitation system (i.e. rotating exciter) - AC exciter, or - DC exciter	
	Rated excitation current (converter rating in Amperes)	
	Six pulse thyristor bridge or PWM converter	
	Excitation transformer or auxiliary supply (Details thereof)	
	If excitation transformer, nameplate information required	
	Saturation curves of the exciter (if applicable – see Type AC and DC)	
	Drawings of excitation system, typically prepared and supplied by the OEM	
	Single line diagram (i.e. one-line diagram) for the excitation system	
	What excitation limiters are commissioned?	
	Under Excitation Limiters settings	
	Over Excitation Limiters settings	
	Voltage/frequency limiter	
	Stator current limiter	
	Minimum excitation current limiter	
	Is the AVR equipped with a PSS?	
	How many input Channels does the PSS have? (speed, real power output or both	
	If the PSS uses speed, is this a derived speed signal (i.e. synthesized speed signal) or measured directly (i.e. actual rotor speed)?	
	Type of PSS Block Diagram of PSS and as commissioned parameters value (Gain, time constants, filter coefficients, output limits of the PSS)	
Test Reports	Factory acceptance test (FAT) reports	

(d) Turbine Details (to be filled in for the HPP and PSP separately)

Category	Parameter Description	Data
Type of prime mover	Hydro-electric turbine Other (Pumped storage)	

Category	Parameter Description	Data
Manufacturer of turbine	Manufacturer and name plate details	
Modes of operation	Type of modes of operation capable: - Generator - Pump storage - Synchronous condenser	
Governor	- Electro-mechanical governor (including settings and drawings) - Digital electric governor (including settings and drawings) - PID governor details and settings - Transient droop (dashpot) governor details and settings - Tacho-accelerometric governor details and settings - Input transducer details - Transfer function data	
	Digital electric governor	
Ramp rates		
Droop		
	Frequency influence limiters - Maximum frequency deviation limiter (eg +/-2 Hz) - Maximum influence limiter (eg 10% of rating)	
Dead band	Details of frequency dead band (typically in Hz or RPM)	
Hydro-electric turbine		
	- Impulse turbines: typical with high head plants (Pelton wheel)	
	- Reaction turbine: typical with low and medium head plants (such as Francis and Kaplan turbine	
	Head, water flow, velocity and pressure (e.g. intake and outtake/draft tube)	
Penstock	Length (m)	
	Area (m^2)	
	Internal penstock diameter	
	Pipe thickness, material or other characteristics (such as tapering)	
	Non-elastic or elastic	
	Linear or non-linear model (with or without relief valve) or Kaplan model	
	Flow of water through turbine (m^3/s) – with gates fully open	
	Number of penstocks supplied from common tunnel	

Category	Parameter Description	Data
Pressure relief valve	Drawings/schematics	
	Settings	
	Operational descriptions	
	Vertical distance between the upper reservoir and level of turbine (in meters)	
	Head at turbine admission (lake head minus tailrace head) – (in meters)	
	Head loss due to friction in conduit (in meters)	
	Surge tank height, diameter and other characteristics (e.g. restricted inlet orifice)	
Pump characteristics	Active power draw vs head (table)	
	PSS status when pumping (on/off/not used)	
Synchronous condenser	Dewatered when operating as Syncon (yes/no)	
	Losses when operating as Sync on: · Mechanical loss (0 Mvar) : ...... MW · Copper loss (table) MW loss as a function of MVar output	
Other	Details of protection schemes that could influence dynamics (if any)	
	Details of resonance chamber for pipes (if any)	
	Temperature (e.g. water , ambient , unit)	
	Characteristic curve of blade versus gate (from 0MW to maximum MW)	

16.3.2. Generic Models for synchronous machine

Hydro machines are multi-pole machines and depending upon the saturation characteristic of the machine they are classified in two groups:

- GENSAL – Salient pole machine with quadratic saturation function
- GENSAE – Salient pole machine with exponential saturation function

Category	Parameter Description	Data
	Generator Model	
	Direct axis open circuit transient time constant Tdo' in sec	
	Direct axis open circuit sub-transient time constant Tdo" in sec	
	Quadrature axis open circuit sub-transient time constant Tqo" in sec	
	Inertia constant of total rotating mass H in MW/MVA	
	Speed Damping D	
	Direct axis synchronous reactance Xd in p.u. (Unsaturated or saturated)	
	Quadrature axis synchronous reactance Xq in p.u. (Unsaturated or saturated)	

	Direct axis transient synchronous reactance Xd' in p.u. (Unsaturated or saturated)	
	Direct axis sub-transient synchronous reactance Xd'' in p.u. (Unsaturated or saturated) = Quadrature axis sub-transient synchronous reactance Xq'' in p.u. (Unsaturated orsaturated)	
	Stator leakage reactance Xl	
	Saturation constant S (1.0) in p.u.	
	Saturation constant S (1.2) in p.u.	

16.3.3. Excitation system model:

If a generic model is used, the first step must be to identify what type of exciter is present in the excitation system. The IEEE Std 421.5 (IEEE Recommended Practice for Excitation System Models for Power System Stability Studies published on 26th Aug 2016) has published several generic models, which are classified into three groups:

- Type DC: for excitation systems with a DC exciter
- Type AC: for excitation systems with an AC exciter
- Type ST: for excitation systems with a static exciter

The following table shows the types of models separated into their respective groups.

DC exciter	AC exciter	Static excitation system
Type DC1A	Type AC1A	Type ST1A
Type DC2A	Type AC2A	Type ST2A
Type DC3A	Type AC4A	Type ST3A
Type DC4B	Type AC5A	Type ST4B
	Type AC6A	Type ST5B
	Type AC7B	Type ST6B
	Type AC8B	Type ST7B

Category	Parameter Description	Data
	DC Exciter	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (> 0) rate feedback time constant (sec)	
	Switch	
	E1, exciter flux at knee of curve (pu)	

Category	Parameter Description	Data
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KV (pu) limit on fast raise/lower contact setting	
	VRMAX (pu) regulator output maximum limit or Zero	
	VRMIN (pu) regulator output minimum limit	
	TRH (> 0) Rheostat motor travel time (sec)	
	TE (> 0) exciter time-constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	VEMIN (pu) exciter minimum limit	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KP (pu) (> 0) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KD (pu) voltage regulator derivative gain	
	TD voltage regulator derivative channel time constant (sec)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KA (> 0) (pu) voltage regulator gain	
	TA voltage regulator time constant (sec)	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
AC Exciter		
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	

Category	Parameter Description	Data
ESAC1A	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KB, Second stage regulator gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	KH, Exciter field current feedback gain	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VEMIN (pu) minimum exciter voltage output	
	KR (>0), Constant associated with regulator and alternator field power supply	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KN, Exciter feedback gain	

Category	Parameter Description	Data
	EFDN, A parameter defining for which value of UF the feedback gain shall change from KF to KN	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	VFEMAX, parameter of VEMAX, exciter field maximum output	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	VIMAX, Maximum value of limitation of the integrator signal VI in p.u	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	TB (s), lag time constant	
	TC (s), lead time constant	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KE (pu) exciter constant related to self-excited field	
	TE (> 0) rotating exciter time constant (sec)	
	KF (pu) rate feedback gain	
	TF1 (sec), Regulator stabilizing circuit time constant in seconds	
	TF2 (sec), Regulator stabilizing circuit time constant in seconds	
	TF3 (sec), Regulator stabilizing circuit time constant in seconds	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR regulator input filter time constant (sec)	
	KA (> 0) (pu) voltage regulator gain	
	TA (s), voltage regulator time constant	
	TK (sec), Lead time constant	
	TB (s), lag time constant	
	TC (s), lead time constant	

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Category	Parameter Description	Data
AC6A	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TE (> 0) rotating exciter time constant (sec)	
	VFELIM, Exciter field current limit reference	
	KH, Damping module gain	
	VHMAX, damping module limiter	
	TH (sec), damping module lag time constant	
	TJ (sec), damping module lead time constant	
	KC, rectifier regulation factor (pu)	
	KD, exciter regulation factor (pu)	
	KE (pu) exciter constant related to self-excited field	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KPA (pu) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KP (pu)	
	KL (pu)	
	KF1 (pu)	
	KF2 (pu)	
	KF3 (pu)	
	TF3 (sec) time constant (> 0)	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) exciter field current limit (> 0)	
	VEMIN (pu)	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	

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Category	Parameter Description	Data
AC8B	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	KDR (pu) regulator derivative gain	
	TDR (sec) regulator derivative block time constant	
	VPIDMAX (pu) PID maximum limit	
	VPIDMIN (pu) PID minimum limit	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KD (pu) demagnetizing factor, function of AC exciter reactances	
	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	VFEMAX (pu) max exciter field current limit (> 0)	
	VEMIN (pu),	
	E1, exciter flux at knee of curve (pu)	
	SE(E1), saturation factor at knee of curve	
	E2, maximum exciter flux (pu)	
	SE(E2), saturation factor at maximum exciter flux (pu)	
Static Exciter		
	TR (sec) regulator input filter time constant	
	VIMAX, Controller Input Maximum	
	VIMIN, Controller Input Minimum	
	TC (s), Filter 1st Derivative Time Constant	
	TB (s), I Filter 1st Delay Time Constant	
	TC1 (s), Filter 2nd Derivative Time Constant	
	TB1 (s), Filter 2nd Delay Time Constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KLR, Current Input Factor	
	ILR, Current Input Reference	
	TR (sec) regulator input filter time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	

Category	Parameter Description	Data
ST2A	KE (pu) exciter constant related fo self-excited field	
	TE (pu) exciter time constant (>0)	
	KF (pu) rate feedback gain	
	TF (> 0) rate feedback time constant (sec)	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	EFDMAX	
	TR (sec) regulator input filter time constant	
	VIMAX, Maximum value of limitation of the signal VI in p.u.	
	VIMIN, Minimum value of limitation of the signal VI in p.u.	
	KM, Forward gain constant of the inner loop field regulator	
	TC (s), lag time constant	
	TB (s), lead time constant	
	KA (pu) voltage regulator proportional gain	
	TA (sec) voltage regulator time constant	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	KG, Feedback gain constant of the inner loop field regulator	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX, Maximum value of limitation of the signal VB in p.u.	
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL, Reactance associated with potential source	
	VGMAX, Maximum value of limitation of the signal VG in p.u	
	Θ_P (degrees)	
	TM (sec), Forward time constant of the inner loop field regulator	
	VMMAX, Maximum value of limitation of the signal VM in p.u	
	VMMIN, Minimum value of limitation of the signal VM in p.u.	
	TR (sec) regulator input filter time constant	
	KPR (pu) regulator proportional gain	
	KIR (pu) regulator integral gain	
	VRMAX (pu) regulator output maximum limit	
	VRMIN (pu) regulator output minimum limit	
	TA (sec) voltage regulator time constant	
	KPM, Regulator gain	
	KIM, Regulator gain	
	VMMAX, Maximum value of limitation of the signal in p.u.	
	VMMIN, Minimum value of limitation of the signal in p.u.	
	KG	
	KP (pu) voltage regulator proportional gain	
	KI (pu) voltage regulator integral gain	
	VBMAX	

Category	Parameter Description	Data
	KC (pu) rectifier loading factor proportional to commutating reactance	
	XL	
	Θ_P (degrees)	
	TR regulator input filter time constant (sec)	
	TC1 lead time constant of first lead-lag block (voltage regulator channel) (sec)	
	TB1 lag time constant of first lead-lag block (voltage regulator channel) (sec)	
	TC2 lead time constant of second lead-lag block (voltage regulator channel) (sec)	
	TB2 lag time constant of second lead-lag block (voltage regulator channel) (sec)	
	KR (>0) (pu) voltage regulator gain	
	VRMAX (pu) voltage regulator maximum limit	
	VRMIN (pu) voltage regulator minimum limit	
	T1 voltage regulator time constant (sec)	
	KC (pu)	
	TUC1 lead time constant of first lead-lag block (under-excitation channel) (sec)	
	TUB1 lag time constant of first lead-lag block (under-excitation channel) (sec)	
	TUC2 lead time constant of second lead-lag block (under-excitation channel) (sec)	
	TUB2 lag time constant of second lead-lag block (under-excitation channel) (sec)	
	TOC1 lead time constant of first lead-lag block (over-excitation channel) (sec)	
	TOB1 lag time constant of first lead-lag block (over-excitation channel) (sec)	
	TOC2 lead time constant of second lead-lag block (over-excitation channel) (sec)	
	TOB2 lag time constant of second lead-lag block (over-excitation channel) (sec)	
	TR regulator input filter time constant (sec)	
	KPA (pu) (> 0) voltage regulator proportional gain	
	KIA (pu) voltage regulator integral gain	
	KDA (pu) voltage regulator derivative gain	
	TDA voltage regulator derivative channel time constant (sec)	
	VAMAX (pu) regulator output maximum limit	
	VAMIN (pu) regulator output minimum limit	
	KFF (pu) pre-control gain of the inner loop field regulator	
	KM (pu) forward gain of the inner loop field regulator	
	KCI (pu) exciter output current limit adjustment gain	
	KLR (pu) exciter output current limiter gain	
	ILR (pu) exciter current limit reference	
	VRMAX (pu) voltage regulator output maximum limit	
	VRMIN (pu) voltage regulator output minimum limit	

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Category	Parameter Description	Data
	KG (pu) feedback gain of the inner loop field voltage regulator	
	TG (> 0) feedback time constant of the inner loop field voltage regulator (sec)	
	TR regulator input filter time constant (sec)	
	TG lead time constant of voltage input (sec)	
	TF lag time constant of voltage input (sec)	
	Vmax (pu) voltage reference maximum limit	
	Vmin (pu) voltage reference minimum limit	
	KPA (pu) (>0) voltage regulator gain	
	VRMAX (pu) voltage regulator output maximum limit	
	VRMIN (pu) voltage regulator output minimum limit	
	KH (pu) feedback gain	
	KL (pu) feedback gain	
	TC lead time constant of voltage regulator (sec)	
	TB lag time constant of voltage regulator (sec)	
	KIA (pu) (>0) gain of the first order feedback block	
	TIA (>0) time constant of the first order feedback block (sec)	

16.3.4. Power system stabilizer:

The function of the PSS is to add to the unit's characteristic electromechanical oscillations. This is achieved by modulating excitation to develop a component in electrical torque in phase with rotor speed deviations.

The most important aspect when considering a PSS model is the number of inputs. The following tableshows the type of models separated based on the inputs:

Type	Inputs	Remarks
PSS1A	Single input	Two lead-lags Input can either be speed, frequency or power
PSS2B	Dual input	Integral of accelerating power Speed and Power Most common type Supersedes PSS2A (three versus two lead lags)
PSS3B	Dual input	Power and rotor angular frequency deviation Stabilizing signal is a vector sum of processed signals Not very common

Category	Parameter Description	Data
	Stabilizer Models	
	A1, Filter coefficient	
	A2, Filter coefficient	
	TR, transducer time constant	
	0	
	0	
	0	
	T1, 1st Lead-Lag Derivative Time Constant	

Category	Parameter Description	Data
PSS1A	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	Tw, Washout Time Constant	
	Tw, Washout Time Constant	
	Ks, input channel gain	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	
	0	
	0	
	TW1, 1st Washout 1th Time Constant	
	TW2, 1st Washout 2th Time Constant	
	T6, 1st Signal Transducer Time Constant	
	TW3, 2nd Washout 1th Time Constant	
	TW4, 2nd Washout 2th Time Constant	
	T7, 2nd Signal Transducer Time Constant	
	KS2, 2nd Signal Transducer Factor	
	KS3, Washouts Coupling Factor	
	T8, Ramp Tracking Filter Deriv. Time Constant	
	T9, Ramp Tracking Filter Delay Time Constant	
	KS1, PSS Gain	
	T1, 1st Lead-Lag Derivative Time Constant	
	T2, 1st Lead-Lag Delay Time Constant	
	T3, 2nd Lead-Lag Derivative Time Constant	
	T4, 2nd Lead-Lag Delay Time Constant	
	T10, 3rd Lead-Lag Derivative Time Constant	
	T11, 3rd Lead-Lag Delay Time Constant	
	VS1MAX, Input 1 Maximum limit	
	VS1MIN, Input 1 Minimum limit	
	VS2MAX, Input 2 Maximum limit	
	VS2MIN, Input 2 Minimum limit	
	VSTMAX, Controller Maximum Output	
	VSTMIN, Controller Minimum Output	
	KS1 (pu) (≠0), input channel #1 gain	
	T1 input channel #1 transducer time constant (sec)	
	Tw1 input channel #1 washout time constant (sec)	
	KS2 (pu) (≠0), input channel #2 gain	
	T2 input channel #2 transducer time constant (sec)	
	Tw2 input channel #2 washout time constant (sec)	
	Tw3 (0), main washout time constant (sec)	
	A1, Filter coefficient	
	A2, Filter coefficient	
	A3, Filter coefficient	
	A4, Filter coefficient	

Category	Parameter Description	Data
	A5, Filter coefficient	
	A6, Filter coefficient	
	A7, Filter coefficient	
	A8, Filter coefficient	
	VSTMAX, Controller maximum output	
	VSTMAX, Controller minimum output	

16.3.5. Generic models for turbine-governor:

The following table is a list for generic models of steam turbines:

Type	Name	Remarks
BBGOV1	Brown-Boveri turbine governor model	Mainly used for steam turbine with electrical damping feedback
TGOV1	Steam-turbine governor	Mainly used for steam turbine with reheater
CRCMGV	Cross-compound turbine	-
IEEEG1	IEEE type 1 Speed-Governor Model	Used to represent non-reheat, tandem compound, and cross compound types.
IEEEG2	IEEE Type 2 Speed-Governing Model	Linearized model for representing a hydro turbine-governor and penstock dynamics
IEEEG3	IEEE type 3 turbine-governor model	Includes a more complex representation of the governor controls than IEEEG2 does
IEESGO	IEEE Standard Model	Simple model of reheat steam turbine
TGOV2	Steam –turbine governor with fast valving	Fast valving model of steam turbine
TGOV3	Modified IEEE Type 1 Speed-Governing Model with fast valving	Modification of IEEEG! For fast valving studies
TGOV4	Modified IEEE Type 1 Speed-GoverningModel with PLU and EVA	Model of steam turbine and boiler, explicit action for both control valve (CV) and inlet valve (IV), main reheat and LP steam effects,and boiler
TGOV5	IEEE Type 1 Speed-Governor Model Modified to Include Boiler Controls	Most common type of governor model, based on TGOV1 with boiler controls
TURCZT	Czech hydro or steam turbine governormodel	General-purpose hydro and thermal turbine-governor model. Penstock dynamic is notincluded in the model

Category	Parameter Description	Data
Turbine Governor Model		
	R, permanent droop	
	r, temporary droop	
	Tr (>0) governor time constant	
	Tf (>0) filter time constant	
	Tg (>0) servo time constant	
	+ VELM, gate velocity limit	
	GMAX, maximum gate limit	
	GMIN, minimum gate limit	
	TW (>0) water time constant	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	R, permanent droop	
	r, temporary droop	
	Tr (>0) governor time constant	
	Tf (>0) filter time constant	
	Tg (>0) servo time constant	
	+ VELM, gate velocity limit	
	GMAX, maximum gate limit	
	GMIN, minimum gate limit	
	TW (>0) water time constant	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	DBH (pu), droop for over-speed, (> 0)	
	DBL (pu), droop for under-speed, (< 0)	
	TRate (MW), turbine rating, if zero, then MBASE used	
	Prated, rated turbine power (MW	
	Qrated, rated turbine flow (cfs or cms)	
	Hrated, rated turbine head (ft or m)	
	Grated, gate position at rated conditions (pu)	
	QNL, no power flow (pu of Qrated)	
	R, permanent droop (pu)	
	r, temporary droop (pu)	
	Tr, governor time constant (> 0) (sec)	
	Tf, filter time constant (> 0) (sec)	
	Tg, servo time constant (> 0) (sec)	
	MXGTOR, maximum gate opening rate (pu/sec)	
	MXGTCR, maximum gate closing rate (< 0) (pu/sec)	
	MXBGOR, maximum buffered gate opening rate (pu/sec)	
	MXBGCR, maximum buffered gate closing rate (< 0) (pu/sec)	

Category	Parameter Description	Data
HYGOVM	BUFLIM, buffer upper limit (pu)	
	GMAX, maximum gate limit (pu)	
	GMIN, minimum gate limit (pu)	
	RVLVCR, relief valve closing rate (< 0) (pu/sec) or MXJDOR, maximum jet deflector opening rate (pu/sec)	
	RVLMAX, maximum relief valve limit (pu) or MXJDCR, maximum jet deflector closing rate (< 0) (pu/sec)	
	HLAKE, lake head (ft or m)	
	HTAIL, tail head (ft or m)	
	PENL/A, summation of penstock, scroll case and draft tube lengths/ cross sections (> 0) (1/ft or 1/m)	
	PENLOS, penstock head loss coefficient (ft/cfs2 or m/cms2)	
	TUNL/A, summation of tunnel lengths/cross sections (>0) (1/ft or 1/m)	
	TUNLOS, tunnel head loss coefficient (ft/cfs^2 or m/cms^2)	
	SCHARE, surge chamber effective cross section (>0) (ft^2 or m^2)	
	SCHMAX, maximum water level in surge chamber (ft or m)	
	SCHMIN, minimum water level in surge chamber (ft or m)	
	SCHLOS, surge chamber orifice head loss coefficient (ft/cfs^2 or m/cms^2)	
	DAMP1, turbine damping under RPM1	
	RPM1, over speed (pu)	
	DAMP2, turbine damping above RPM2	
	RPM2, over speed (pu)	
	R-PERM-GATE (Feedback settings)	
	R-PERM-PE (Feedback settings)	
	TPE (sec), Power time constant	
	Kp, Proportional gain	
	KI, Integral gain	
	KD, Derivative gain	
	TD (sec), Derivative time constant	
	TP (sec), Gate servo time constant	
	TDV (sec), Time constant	
	Tg (sec), Gate servo time constant	
	GTMXOP (>0), Max gate opening velocity	
	GTMXCL (<0), Max gate closing velocity	
	GMAX, Maximum governor output	
	GMIN, Minimum governor output	
	DTURB, Turbine damping factor	
	TW (sec), Water inertia time constant	
	Speed Dead Band (DBAND)	
	DPV, Governor limit factor	
	DICN, Gate limiter modifier	
	GATE 1	
	GATE 2	
	GATE 3	
	GATE 4	

Category	Parameter Description	Data
WEHGOV	GATE 5	
	FLOW G1	
	FLOW G2	
	FLOW G3	
	FLOW G4	
	FLOW G5	
	FLOW P1	
	FLOW P2	
	FLOW P3	
	FLOW P4	
	FLOW P5	
	FLOW P6	
	FLOW P7	
	FLOW P8	
	FLOW P9	
	FLOW P10	
	PMECH1	
	PMECH2	
	PMECH3	
	PMECH4	
	PMECH5	
	PMECH6	
	PMECH7	
	PMECH8	
	PMECH9	
	PMECH10	
	Prated, rated turbine power (MW)	
	Qrated, rated turbine flow (cfs or cms)	
	Hrated, rated turbine head (ft or m)	
	Grated, gate position at rated conditions (pu)	
	QNL, no power flow (pu of Qrated)	
	R, permanent droop	
	r, temporary droop (pu)	
	Tr, governor time constant (> 0) (sec)	
	Tf, filter time constant (> 0) (sec)	
	Tg, servo time constant (> 0) (sec)	
	MXGTOR, maximum gate opening rate (pu/sec)	
	MXGTCR, maximum gate closing rate (< 0) (pu/sec)	
	MXBGOR, maximum buffered gate opening rate (pu/sec)	
	MXBGCR, maximum buffered gate closing rate (< 0) (pu/sec)	
	BUFLIM, buffer upper limit (pu)	
	GMAX, maximum gate limit (pu)	
	GMIN, minimum gate limit (pu)	
	RVLVCR, relief valve closing rate (< 0) (pu/sec) or MXJDOR, maximum jet deflector opening rate (pu/sec)	

Category	Parameter Description	Data
	RVLMAX, maximum relief valve limit (pu) or MXJDCR, maximum jet deflector closing rate (< 0) (pu/sec)	
	HLAKE, lake head (ft or m)	
	HTAIL, tail head (ft or m)	
	PENLGTH, penstock length (ft or m)	
	PENLOS, penstock head loss coefficient (ft/cfs2 or m/cms2)	
	TUNLGTH, tunnel length (ft or m)	
	TUNLOS, tunnel head loss coefficient (ft/cfs2 or m/cms2)	
	SCHARE, surge chamber effective cross section (>0) (ft2 or m2)	
	SCHMAX, maximum water level in surge chamber (ft or m)	
	SCHMIN, minimum water level in surge chamber (ft or m)	
	SCHLOS, surge chamber orifice head loss coefficient (ft/cfs2 or m/cms2)	
	DAMP1, turbine damping under RPM1	
	RPM1, overspeed (pu)	
	DAMP2, turbine damping above RPM2	
	RPM2, overspeed (pu)	
	PENSPD, penstock wave velocity (>0) (ft/sec or m/sec)	
	PENARE, penstock cross section (>0) (ft2 or m2)	
	TUNSPD, tunnel wave velocity (>0) (ft/sec or m/sec)	
	TUNARE, tunnel cross section (>0) (ft2 or m2)	
	Rperm, permanent drop, pu	
	Treg (sec), speed detector time constant	
	Kp, proportional gain, pu/sec	
	Ki, reset gain, pu/sec	
	Kd, derivative gain, pu	
	Ta (sec) > 0, controller time constant	
	Tb (sec) > 0, gate servo time constant	
	Dturb, turbine damping factor, pu	
	G0, gate opening at speed no load, pu	
	G1, intermediate gate opening, pu	
	P1, power at gate opening G1, pu	
	G2, intermediate gate opening, pu	
	P2, power at gate opening G2, pu	
	P3, power at full opened gate, pu	
	Gmax, maximum gate opening, pu	
	Gmin, minimum gate opening, pu	
	Atw > 0, factor multiplying Tw, pu	
	Tw (sec) > 0, water inertia time constant	
	Velmax, minimum gate opening velocity, pu/sec	
	Velmin < 0, minimum gate closing velocity, pu/sec	
	db1, Intentional dead band width, Hz	
	Err, deadband hysteresis (p.u.)	
	Td (sec), Input filter time constant, s	
	T1 (sec), Lead time constant 1, s	
	T2 (sec) q, Lag time constant 1, s	

Category	Parameter Description	Data
HYGOVR1	T3 (sec), Lead time constant 2, s	
	T4 (sec), Lag time constant 2, s	
	T5 (sec), Lead time constant 3, s	
	T6 (sec), Lag time constant 3, s	
	T7 (sec), Lead time constant 4, s	
	T8 (sec), Lag time constant 4, s	
	KP, proportional gain	
	R, Steady-state droop, p.u.	
	Tt, Power feedback time constant, s	
	KG, Gate servo gain, p.u.	
	TP (sec), Gate servo time constant, s	
	VELOPEN, Maximum gate opening velocity, p.u./s	
	VELCLOSE, Maximum gate closing velocity, p.u./s (<0)	
	PMAX, Maximum gate opening, p.u. of mwcap	
	PMIN, Minimum gate opening, p.u. of mwcap	
	db2, Unintentional deadband, MW	
	TW (>0) water time constant	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	Trate (Turbine MW rating)	
	fDEAD (pu), Frequency Dead Band	
	fMIN (pu), Frequency Minimum Deviation	
	fMAX (pu), Frequency Maximum Deviation	
	KKOR (pu), Frequency Gain	
	KM > 0 (pu), Power Measurement Gain	
	KP (pu), Regulator Proportional Gain	
	SDEAD (pu), Speed Dead Band	
	KSTAT (pu), Speed Gain	
	KHP (pu), High Pressure Constant	
	TC (sec), Measuring transducer time constant	
	T 1 (sec), Regulator Integrator Time Constant	
	TEHP (sec), Hydro Converter Time Constant	
	TV > 0 (sec), Regulation Valve Time Constant	
	THP (sec), High Pressure Time Constant	
	TR (sec), Reheater time constant	
	TW (sec), Water Time Constant	
	NTMAX (pu), Power Regulator-Integrator Maximum Limiter	
	NTMIN (pu), Power Regulator-Integrator Minimum Limiter	
	GMAX (pu), Valve Maximum Open	
	GMIN (pu), Valve Minimum Open	
	VMIN (pu/sec), Valve Maximum Speed Close	
	VMAX (pu/sec), Valve Maximum Speed Open	
	R, permanent droop	
	r, temporary droop	

Category	Parameter Description	Data
TWDM1T	Tr, governor time constant (>0)	
	Tf, filter time constant (>0)	
	Tg, servo time constant (>0)	
	VELMX, open gate velocity limit (pu/sec)	
	VELMN, close gate velocity limit (pu/sec) (<0)	
	GMAX, maximum gate limit	
	GMIN, minimum gate limit	
	TW, water time constant (sec) (>0)	
	At, turbine gain	
	Dturb, turbine damping	
	qNL, no power flow	
	F1, frequency deviation (pu)	
	TF1, time delay (sec)	
	F2, frequency deviation (pu)	
	sF2, frequency (pu/sec)	
	TF2, time delay (sec)	
	GMXRT, rate with which GMAX changes when TWD is tripped (pu/sec)	
	NREF, setpoint frequency deviation (pu)	
	Tft, frequency filter time constant (>0	
	TREG (sec), governor time constant (s)	
	Reg, permanent droop (p.u. on generator MVA rating)	
	KP, controller proportional gain (p.u.)	
	KI, controller integral gain (p.u./s)	
	KD, controller derivative gain (p.u.-s)	
	TA (sec) (> 0), controller time constant (s)	
	TB (sec) (> 0), controller time constant (s)	
	VELMX (pu/sec), open gate velocity limit (p.u./s)	
	VELMN (pu/sec) (> 0), close gate velocity limit (p.u./s)	
	GATMX (pu), maximum gate limit (p.u.)	
	GATMN (pu), minimum gate limit (p.u.)	
	TW (sec) (> 0), water time constant (s)	
	At, turbine gain	
	qNL, flow rate at no load (p.u.)	
	Dturb, turbine damping factor	
	F1, frequency deviation (pu)	
	TF1, time delay (sec)	
	F2, frequency deviation (pu)	
	sF2, frequency (pu/sec)	
	TF2, time delay (sec)	
	PREF, power reference (pu)	
	Tft, frequency filter time constant (sec) (>0)	
	TREG (sec), governor time constant (s)	
	REG1, permanent droop (p.u. on generator MVA base)	
	KP, controller proportional gain (p.u.)	

Category	Parameter Description	Data
WPIDHY	KI, controller integral gain (p.u./s)	
	KD, controller derivative gain (p.u./s)	
	TA (>0) (sec), controller time constant (s)	
	TB (>0) (sec), controller time constant (s)	
	VELMX (>0), open gate velocity limit (p.u./s)	
	VELMN (<0), close gate velocity limit (p.u./s)	
	GATMX, maximum gate limit (p.u.)	
	GATMN, minimum gate limit (p.u.)	
	TW (>0) (sec), water time constant (s)	
	PMAX, maximum gate position (p.u.)	
	PMIN, minimum gate position (p.u.)	
	D	
	G0, gate position at no load (p.u.)	
	G1, first gate intermediate position (p.u.)	
	P1, power at gate position G1 (p.u. on generator MVA rating)	
	G2, second gate intermediate position (p.u.)	
	P2, power at gate position G2 (p.u. on generator MVA rating)	
	P3, power at fully open gate (p.u. on generator MVA rating)	
	db1, deadband width (p.u.)	
	Err, deadband hysteresis (p.u.)	
	Td (sec), input filter time constant (s)	
	K1, derivative gain (p.u.)	
	Tf (sec), derivative time constant (s)	
	KD, double derivative gain (p.u.)	
	KP, integral gain (p.u.)	
	R, droop (p.u. on Trate)	
	Tt, power feedback time constant (s)	
	KG, gate servo gain (p.u.)	
	TP (sec), gate servo time constant (s)	
	VELOPEN (>0), maximum gate opening rate (p.u./s)	
	VELCLOSE (>0), maximum gate closing rate (p.u./s)	
	PMAX, maximum gate opening (p.u.)	
	PMIN, minimum gate opening (p.u.)	
	db2, deadband (p.u.)	
	GV1, coordinate of power-gate look-up table (p.u. gate)	
	PGV1, coordinate of power-gate look-up table (p.u. power)	
	GV2, coordinate of power-gate look-up table (p.u. gate)	
	PGV2, coordinate of power-gate look-up table (p.u. power)	
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. power)	
	GV4, coordinate of power-gate look-up table (p.u. gate)	
	PGV4, coordinate of power-gate look-up table (p.u. power)	
	GV5, coordinate of power-gate look-up table (p.u. gate)	
	PGV5, coordinate of power-gate look-up table (p.u. power)	
	Aturb, turbine lead time constant multiplier	
	Bturb (> 0), turbine lag time constant multiplier	

Category	Parameter Description	Data
	Tturb (> 0) (sec), turbine time constant (s)	
	Trate, turbine rating (MW)	
	db1, deadband width (p.u.)	
	Err, deadband hysteresis (p.u.)	
	Td (sec), input filter time constant (s)	
	K1, derivative gain (p.u.)	
	Tf (sec), derivative time constant (s)	
	KD, double derivative gain (p.u.)	
	KP, integral gain (p.u.)	
	R, droop (p.u. on Trate)	
	Tt, power feedback time constant (s)	
	KG, gate servo gain (p.u.)	
	TP (sec), gate servo time constant (s)	
	VELOPEN (>0), maximum gate opening rate (p.u./s)	
	VELCLOSE (>0), maximum gate closing rate (p.u./s)	
	PMAX, maximum gate opening (p.u.)	
	PMIN, minimum gate opening (p.u.)	
	db2, deadband (p.u.)	
	GV1, coordinate of power-gate look-up table (p.u. gate)	
	PGV1, coordinate of power-gate look-up table (p.u. power)	
	GV2, coordinate of power-gate look-up table (p.u. gate)	
	PGV2, coordinate of power-gate look-up table (p.u. power)	
	GV3, coordinate of power-gate look-up table (p.u. gate)	
	PGV3, coordinate of power-gate look-up table (p.u. power)	
	GV4, coordinate of power-gate look-up table (p.u. gate)	
	PGV4, coordinate of power-gate look-up table (p.u. power)	
	GV5, coordinate of power-gate look-up table (p.u. gate)	
	PGV5, coordinate of power-gate look-up table (p.u. power)	
	Aturb, turbine lead time constant multiplier	
	Bturb (> 0), turbine lag time constant multiplier	
	Tturb (> 0) (sec), turbine time constant (s)	
	Trate, turbine rating (MW)	

16.4. Generation: Wind

Format No.	Dyn/Generation/Wind/1
Data Submission By:	Wind Power Generator / CPP
Data related to:	Wind Mills
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and when requested by STU.

16.4.1. Details of models in PSS/E for modelling Wind plants/ farms/ parks:

Category	Parameter Description	Data
	Connection point voltage (kV)	
	Terminal voltage (kV)	
	Wind Farm - Rated active power (sent out) in MW	
	Turbine - Rated MVA	
	Turbine - Rated active power (PMAX) in MW	
	Number of wind turbines (Type wise)	
	Capability chart at connection point [If not available, then for each	
	individual wind turbine, and mode of operation of Power Plant Controller)	
	QMAX	
	QMIN	
Single Line Diagram	Single line diagram of the wind farm/park showing number and location of turbines, cable run, transformers, feeders (including type of cables and electrical R,X,B parameters), and connection to transmission system Preferable : Electrical Single Line Diagram including details between individual WTGs and b/w WTGs and aggregation points	
	Manufacturer and product details (include Year of Manufacture)	
	Year of commissioning	
	Fixed speed or variable speed	
	Type of turbine: stall control, pitch control , active stall control , limited variable speed, variable speed with partial or full-scale frequency	
	converter	

Category	Parameter Description	Data
	Hub height (in metre)	
	Rotor diameter (in metre)	
	Number of blades	
	Rotor speed (in rpm)	
	Gearbox ratio	
	Type of generator: Type 1/ Type 2 / Type 3 / Type 4	
	Number of pole pairs	
	Stator resistance (in Ohms)	
	Rotor resistance (in Ohms)	
	Details of speed controller in wind turbine	
	Efficiency (Cp) curves	
	Cut-in wind speed	
	Wind speed at which full power is attained Cut-out wind speed	
	Pitch angle at low wind speed	
	Voltage of the reticulation system	
	Number of feeders	
	Cable schedules (lengths, cable size, conductor material, rating info)	
	Details of the turbine transformer, including vector group, impedance, and number of taps, tap position, tap ratio	
	Nameplate details	
	Details of the main wind farm step up transformer, including vector	
	group, impedance, and tap position	
	Nameplate ; OLTC?	
	Controlled bus	
	Voltage setpoint	
	Dead band	
	Number of taps	
	Tap ratio range	
	Voltage influence (maximum change etc)	
	Short circuit ratio (SCR)	
	Min	
	Max	
	Harmonic filters	
	STATCOM	
	Synchronous condensers	
	Battery Energy Storage System (if applicable)	

Category	Parameter Description	Data
	What is the method of control -voltage regulation, power factor control, reactive power control?	
	Voltage control strategy (operating mode)	
	- Controls MV Bus	
	- Controls HV Bus	
	- PF control	
	- Q control	
	- Voltage control	
	Is there a droop setting?	
	- Voltage control	
	- Frequency Control	
	- Is there line drop compensation?	
	Is reactive power limited?	
	Temperature dependency	
	Active power ramp rate limiters	
	FRT protocols and setpoints	
	- LVRT	
	- HVRT	
	Provide settings from controller.	

16.4.2. Generic Models for Type-1 and Type-2 Wind turbine generators:

Category	Parameter Description	Data
Generator Model		
	Synchronous reactance (ohms or pu) Xs	
	Transient reactance (ohms or pu) X'	
	Wound rotor induction generator (WRIG) with a variable resistor in the rotor circuit, and typically employs pitch control	
	Leakage reactance , XL	
	Saturation curve (El, S(El), E2, S(E2)	
	XA, stator reactance (pu)	
	Doubly fed induction generator (DFIG) wind turbines ; Variable speed with rotor side converter	
	Xl rotor reactance (put)	
	R_Rot_Mach, rotor resistance (pu)	
	R_Rot_Max (sum of R_Rot_Mach + total external resistance) in pu	
	Saturation curve (El, S (El), E2, S(E2)	
	Power - slip curve (Top 5 points in the T-s curve)	
Electrical Control Model		
	TsP, rotor speed filter time constant, sec.	

Rotor Resistance Control: Type-2 (WT2EI)	Tpe, power filter time constant, sec.	
	Ti, PI-contro ller integrator time constant, sec.	
	Kp, PI-controller proportional gain, pu	
	ROTRV_MAX, Output MAX limit	
	ROTRV_MIN, Output MIN limit	
Drive Train Model		
	H, Total inertia constant, sec	
	DAMP, Machine damping factor, pu P/pu speed	
	Htfrac , Turbine inertia fraction (Hturb/H)I	
	Freq1, First shaft torsional resonant frequency, Hz	
	Dshaft, Shaft damping factor (pu)	

16.4.3. Generic Models for Type-3 and Type-4 Wind turbine generators:

Category	Parameter Description	Data
Generator Model		
	Tg, Converter time constant (s)	
	Rrpwr, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)	
	Wound rotor induction generator (WRIG) with a variable resistor inthe rotor circuit, and typically employs pitch control	
	Zerox, LVPL characteristic voltage 1 (pu)	
	Lvpll, LVPL gain (pu)	
	Volim, Voltage limit (pu) for high voltage reactive current manage-	
	Doubly fed induction generator (DFIG) wind turbines; Variable speed with rotor side converter	
	Lvpntl, High voltage point for low voltage active current manage-	
	ment (pu)	
	LvpntO, Low voltage point for low voltage active current manage-	
	ment (pu)	
	lolim, Current limit (pu) for high voltage reactive current manage-	
	ment (specified as a negative value)	
	Tfltr, Voltage filter time constant for low voltage active current man-	
	agement (s)	
	Khv, Overvoltage compensation gain used in the high voltage reac-	
	tive current management	
	lqrmax, Upper limit on rate of change for reactive current (pu)	
	lqrmin, Lower limit on rate of change for reactive current (pu)	
	Accel, acceleration factor (O < Accel <= 1)	
Electrical Control Model		

Category	Parameter Description	Data
	Vdip (pu), low voltage threshold to activate reactive current injection logic	
	Vup (pu), Voltage above which reactive current injection logic is activated	
	Trv (s), Voltage filter time constant	
	dbdl (pu), Voltage error dead band lower threshold (:50)	
	dbd2 (pu), Voltage error dead band upper threshold (2::0)	
	Kqv (pu), Reactive current injection gain during over and undervoltage conditions	
	lqhl (pu), Upper limit on reactive current injection lqinj	
	lqll (pu), Lower limit on reactive current injection lqinj	
	VrefO (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	lqfrz (pu), Value at which lqinj is held for Thld seconds following a voltage dip if Thld > 0	
Type-3 and Type-4Wind turbines: (REECAl)	Thld (s), Time for which lqinj is held at lqfrz after voltage dip returns to zero (see Note 1)	
	Thld2 (s) (2::0), Time for which the active current limit (IPMAX) is held at the faulted value after voltage dip returns to zero	
	Tp (s), Filter time constant for electrical power	
	QMax (pu), limit for reactive power regulator	
	QMin (pu) limit for reactive power regulator	
	VMAX (pu), Max. limit for voltage control	
	VMIN (pu), Min. limit for voltage control	
	Kqp (pu), Reactive power regulator proportional gain	
	Kqi (pu), Reactive power regulator integral gain	
	Kvp (pu), Voltage regulator proportional gain	
	Kvi (pu), Voltage regulator integral gain	
	Vbias (pu), User-defined bias (normally O)	
	Tiq (s), Time constant on delay s4	
	dPmax (pu/s) (>O) Power reference max. ramp rate	
	dPmin (pu/s) (<O) Power reference min. ramp rate	
	PMAX (pu), Max. power limit	
	PMIN (pu), Min. power limit	
	Imax (pu), Maximum limit on total converter current	
	Tpord (s), Power filter time constant	
	VQ-IQ characteristic (at least two pairs, up to 4 pairs of voltage and current in pu)	
	VP-IP characteristic (at least two pairs, up to 4 pairs, of voltage and current in pu)	

Category	Parameter Description	Data
	Is turbine in PF control or Q control (including controlled by external signal)?	
	Is the turbine controlling voltage (directly, not than through PPC)?	
	If controlling voltage directly what bus does it control?	
	Is the turbine in P or Q priority mode?	
	Drive Train Model	
	H, Total inertia constant, sec	
	DAM P, Machine damping factor, pu P/pu speed	
	Ht frac, Turbine inertia fraction (Hturb/H)l	
	Freq1, First shaft torsional resonant frequency, Hz	
	Dshaft, Shaft damping factor (pu)	
	Pitch Control Model [for Type-3 only]	
	Kiw, Pitch-control Integral Gain (pu)	
	Kpw, Pitch-control proportional gain (pu)	
	Kie, Pitch-compensation integral gain (pu)	
	Kpc, Pitch-compensation proportional gain (pu)	
	Kee, Gain (pu)	
	Tp, Blade response time constant (s)	
	TetaMax, Maximum pitch angle (degrees)	
	TetaMin, Minimum pitch angle (degrees)	
	RTetaMax, Maximum pitch angle rate (degrees/s)	
	RTetaMin, Minimum pitch angle rate (degrees/s) (< O)	
	Aerodynamic Model [For Type-3 only]	
	Ka, Aerodynamic gain factor (pu/degrees)	
	Theta O Initial pitch angle (degrees)	
	Torque Controller Model [For Type-3 only]	
	Kpp, Proportional gain in torque regulator (pu)	
	KIP, Integrator gain in torque regulator (pu)	
	Tp, Electrical power filter time constant (s)	
	Twref, Speed-reference time constant (s)	
	Temax, Max limit in torque regulator (pu)	
	Temin, Min limit in torque regulator (pu)	
	pl, power (pu)	
	spdl, shaft speed for power pl (pu)	
	p2, power (pu)	
	spd2, shaft speed for power p2 (pu)	
	p3, power (pu)	
	spd3, shaft speed for power p3 (pu)	
	p4, power (pu)	
	spd4, shaft speed for power p3 (pu)	
	TRATE, Total turbine rating (MW)	

Category	Parameter Description	Data
Power Plant Controller (PPC) Model		
	Tfltr, Voltage or reactive power measurement filter time constant (s)	
	Kp, Reactive power PI control proportional gain (pu)	
	Ki, Reactive power PI control integral gain (pu)	
	Tft, Lead time constant (s)	
	Tfv, Lag time constant (s)	
	Vfrz, Voltage below which State s2 is frozen (pu)	
	Re, Line drop compensation resistance (pu)	
	Xe, Line drop compensation reactance (pu)	
	Kc, Reactive current compensation gain (pu)	
	emax, upper limit on deadband output (pu)	
	emin, lower limit on deadband output (pu)	
	dbdl, lower threshold for reactive power control deadband (<=O)	
	dbd2, upper threshold for reactive power control deadband (>=O)	
	Qmax, Upper limit on output of V/Q control (pu)	
	Qmin, Lower limit on output of V/Q control (pu)	
	Kpg, Proportional gain for power control (pu)	
	Kig, Proportional gain for power control (pu)	
	Tp, Real power measurement filter time constant (s)	
	fdbdl, Deadband for frequency control, lower threshold (<=O)	
	Fdbd2, Deadband for frequency control, upper threshold (>=O)	
	femax, frequency error upper limit (pu)	
	femin, frequency error lower limit (pu)	
	Pmax, upper limit on power reference (pu)	
	Pmin, lower limit on power reference (pu)	
	Tg, Power Controller lag time constant (s)	
	Ddn, droop for over-frequency conditions (pu)	
	Dup, droop for under-frequency conditions (pu)	

16.5. Generation: Solar

Format No.	Dyn/Generation/Solar/1
Data Submission By:	Solar Generating Company / CPP
Data related to:	Solar Generation Plant
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and When requested by STU

CE (STU) MSETCL

16.5.1. Details of models in PSS/E for modelling Solar plants / farms/ parks:

Category	Parameter Description	Data
	Manufacturer, model number and product details	
	Year of commissioning	
	As found settings (obtained either from HMI or downloaded from controller in digital systems)	
	• Grid following • Grid forming (viz. Assist in regulation of Voltage and Frequency) • Reactive power priority (Controls Pf or Voltage? Point of control?)	
Single Line Diagram	Single line diagram of the solar farm showing number and location of inverters and PV arrays behind each inverter, cable run, transformers, feeders (including type of cables and electrical R,X,B parameters), and connection to transmission system Preferable: Electrical Single Line Diagram including details between PV array to Inverters, Inverters to MV reticulation system, MV reticulation system till Point of Interconnection (POI) at EHV level (220 kV/400 kV)	
	DC/AC ratio	
	Number of inverters	
	Panel type	
	Number of modules per string	
	Tracking in 0/1/2 axes	
	Capability diagram at nominal (STC) and typical temperature	
	Does the solar farm have a PPC? If yes, whether PPC controls all or part of the inverters in Solar farm	
	What is the method of control -voltage regulation, power factor control, reactive power control?	
	Voltage control strategy (operating mode) • Controls MV bus • Controls HV bus • PF control • Q control	
	Is there a droop setting? • Voltage control • Frequency control	
	Is reactive power limited? Details thereof	
	Is active power limited below MPPT at high output? Details thereof	
	Temperature dependency details	

Category	Parameter Description	Data
	Active power ramp rate limiters	
	Fault Ride Through (FRT) protocols and setpoints • LVRT • HVRT	
	Provide settings from controller	
	Voltage of the reticulation system	
	Number of feeders	
	Cable schedules (lengths, cable size, conductor material, rating info)	
	Details of the turbine transformer, including vector group, impedance, and number of taps, tap position, tap ratio	
	Nameplate details	
	Details of the main solar farm step up transformer, including vector group, impedance, and tap position	
	Nameplate ; OLTC?	
	Controlled bus	
	Voltage setpoint	
	Dead band	
	Number of taps	
	Tap ratio range	
	Voltage influence (maximum change etc)	
	Short circuit ratio (SCR)	
	Min	
	Max	
	Harmonic filters	
	STATCOM	
	Synchronous condensers	
	Battery Energy Storage System (if applicable)	
	What is the method of control -voltage regulation, power factor control , reactive power control?	
	Voltage control strategy (operating mode)	
	- Controls MV Bus - Controls HV Bus - PF control - Q control	

CE(TU) MSETCL

Category	Parameter Description	Data
	- Voltage control	
	Is there a droop setting? - Voltage control - Frequency Control - Is there line drop compensation?	
	Is reactive power limited?	
	Temperature dependency	
	Active power ramp rate limiters	
	FRT protocols and setpoints - LVRT - HVRT	
	Provide settings from controller.	

16.5.2. Generic Models for utility Scale Solar – PV generation:

Category	Parameter Description	Data
Generator Model		
	Tg, Converter time constant (s)	
	Rrpwr, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)	
	Brkpt, LVPL characteristic voltage 2 (pu)	
	Zerox, LVPL characteristic voltage 1 (pu)	
	Lvpll, LVPL gain (pu)	
	Volim, Voltage limit (pu) for high voltage reactive current manage-	
	Lvpntl, High voltage point for low voltage active current management (pu)	
	LvpntO, Low voltage point for low voltage active current management (pu)	
	Iolim, Current limit (pu) for high voltage reactive current management (specified as a negative value)	
	Tfltr, Voltage filter time constant for low voltage active current management (s)-	
	Khv, Overvoltage compensation gain used in the high voltage reactive current management	
	Iqrmax, Upper limit on rate of change for reactive current (pu)	
	Iqrmin, Lower limit on rate of change for reactive current (pu)	
	Accel, acceleration factor (0 < Accel <= 1)	
Electrical Control Model		
	Vdip (pu), low voltage threshold to activate reactive current injection logic	
	Vup (pu), Voltage above which reactive current injection logic isactivated	
	Trv (s), Voltage filter time constant	
	dbdl (pu), Voltage error dead band lower threshold (0)	
	dbd2 (pu), Voltage error dead band upper threshold (;::0)	

Category	Parameter Description	Data
(REECBI)	Kqv (pu), Reactive current injection gain during over and undervoltage conditions	
	Iqhl (pu), Upper limit on reactive current injection Iqinj	
	Iqll (pu), Lower limit on reactive current injection Iqinj	
	Vref0 (pu), User defined reference (if 0, model initializes it toinitial terminal voltage)	
	Tp (s), Filter time constant for electrical power	
	QMax (pu), limit for reactive power regulator	
	QMin (pu) limit for reactive power regulator	
	VMAX (pu) , M ax. limit for voltage control	
	VMIN (pu) , Min. limit for voltage control	
	Kqp (pu), Reactive power regulator proportional gain	
	Kqi (pu), Reactive power regulator integral gain	
	Kvp (pu) , Voltage regulator proportional gain	
	Kvi (pu), Voltage regulator integral gain	
	Tiq (s), Time constant on delay s4	
	dPmax (pu/s) (>O) Power reference max. ramp rate	
	dPmin (pu/s) (<O) Power reference min. ramp rate	
	PMAX (pu), Max. power limit	
	PMIN (pu), Min. power limit	
	Imax (pu), Maximum limit on total converter current	
	Tpord (s), Power filter time constant	
	Tfltr, Voltage or reactive power measurement filter time constant (s)	
	Kp, Reactive power PI control proportional gain (pu)	
	Ki, Reactive power PI control integral gain (pu)	
	Tft, Lead time constant (s)	
	Tfv, Lag time constant (s)	
	Vfrz, Voltage below which State s2 is frozen (pu)	
	Re, Line drop compensation resistance (pu)	
	Xe, Line drop compensation reactance (pu)	
	Kc, Reactive current compensation gain (pu)	
	emax, upper limit on deadband output (pu)	
	emin, lower limit on deadband output (pu)	
	dbdl, lower threshold for reactive power control deadband (<=O)	
	dbd2, upper threshold for reactive power control deadband (>=O)	
	Qmax, Upper limit on output of V/Q control (pu)	
	Qmin, Lower limit on output of V/Q control (pu)	
	Kpg, Proportional gain for power control (pu)	
	Kig, Proportional gain for power control (pu)	
	Tp, Real power measurement filter time constant (s)	

Category	Parameter Description	Data
	fdbdl , Deadband for frequency control, lower threshold (<=O)	
	Fdbd2, Deadband for frequency control, upper threshold (>=O)	
	femax, frequency error upper limit (pu)	
	femin, frequency error lower limit (pu)	
	Pmax, upper limit on power reference (pu)	
	Pmin, lower limit on power reference (pu)	
	Tg, Power Controller lag time constant (s)	
	Ddn, droop for over-frequency conditions (pu)	
	Dup, droop for under-frequency conditions (pu)	

16.6. Storage: BESS

Format No.	Dyn/Storage/BESS/1
Data Submission By:	BESS
Data related to:	BESS
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and when requested by STU.

Details of PSS/E model for modelling BESS:

Category	Parameter Description	Data
	Electrical Control Model: BESS	
	Vdip (pu), low voltage threshold to activate reactive current injection logic	
	Vup (pu),Voltage above which reactive current injection logic is activated	
	Trv 9s), Voltage filter time constant	
	Dbd1 (pu), Voltage error dead band lower threshold (<= 0)	
	Dbd1 (pu), Voltage error dead band upper threshold (>= 0)	
	Kqv (pu), Reactive current injection gain during over and undervoltage conditions	
	Iqh1 (pu), upper limit in reactive current injection Iqinj	
	Iqh1 (pu), lower limit in reactive current injection Iqinj	
	Vref0 (pu), user defined reference (if , model initialized it to initial terminal voltage)	
	Tp (s), Filter time constant for electrical power	
	Qmax (pu), limit for reactive power regulator	
	Qmin (pu), limit for reactive power regulator	
	VMAX (pu), Max. limit for voltage control	

	VMIN(pu), Min. limit for voltage control	
	Kqp (pu), Reactive power regulator proportional gain	
	Kqi (pu), Reactive power regulator integral gain	
	Kvp (pu), Voltage regulator proportional gain	
	Kvi (pu), Voltage regulator integral gain	
	Tiq (s), Time constant on delay s4	
	dPmax (pu/s) (>0) power reference max. ramp rate	
	dPmin (pu/s) (>0) power reference min. ramp rate	
	PMAX (pu), Max. power limit	
	PMIN (pu), Min. power limit	
	Imax (pu), Maximum limit on total converter current	
	Tpord (s), Power filter time constant	
	Vq and Iq curve (Reactive Power V-I pair in p.u): 4 points	
	Vq and Iq curve (Active Power V-I pair in p.u): 4 points	
	T, battery discharge time (s) (<0)	
	SOCini (pu), initial state of charge	
	SOCmax(pu), Maximum allowable state of charge	
	SOCmin(pu), Minimum allowable state of charge	

Note: 1) SOCini represents the initial state of charge on the battery and is a user entered value. This is entered in pu; with 1 pu meaning that the battery is fully charged and 0 means the battery is completely discharged.

2) If BESS have other PSS/E model / user model, same can be shared with STU.

16.7. Transmission: HVDC Links

Format No.	Dyn/Transmission/HVDC/1
Data Submission By:	Transmission Licensee
Data related to:	HVDC Link
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and when requested by STU

16.6.1. Details of models in PSS/E for modelling HVDC Links:

Category	Parameter Description	Data
	Manufacturer and product details (for example Siemens, Areva, ABB, etc)	
	Year of commissioning	
	Rated DC voltage	
	Length of the link	
	Conductor Type (of DC lines)	
	Number of Poles	
	Rating of Each Pole (Power-MW, and Current-Amperes)	

Category	Parameter Description	Data
	Minimum Power flow on DC link (per pole) in MW	
	Overload capability of DC link (per pole) in MW and no. of hours	
	LCC, Rectifier controls maintain - constant DC power or DC current?	
	LCC, Inverter controls maintain - constant DC voltage or extinction angle?	
	LCC, For DC voltage control, whether any compensation is utilized?	
	LCC, Inverter current margin	
	VSC, converter controls DC voltage or DC power?	
	VSC, converter controls AC voltage or power factor?	
Technology	Converters: - LCC (Conventional) - Voltage Source Converter (VSC) - Multi-terminal	
	Smoothing Reactors	
	DC Line resistance (Rdc) in Ohms	
	Minimum inverter dc voltage for power control mode (in kV)	
	Make	
	MVA rating	
	Two winding transformer or three winding transformer?	
	If three winding, any auxiliary equipment connected to tertiary winding?	
	AC side base voltage	
	DC side base voltage	
	Impedance (in Ohms, in % on 100 MVA base and mention Voltage reference side)	
	Converter transformer secondary commutating reactance in ohms per bridge[Star point to Secondary]	
	Converter transformer secondary commutating resistance in ohms per bridge [Star point to Secondary]	
	Primary to Star-point impedance of Converter transformer (R+jX)	
	Tertiary to Star-point impedance of Converter transformer (R+jX)	
	Maximum value of converter transformer tap ratio (in p.u. of Voltage)	

Category	Parameter Description	Data
	Minimum value of converter transformer tap ratio (in p.u. of Voltage)	
	Converter transformer tap-step (in pu of voltage)	
	Minimum firing (delay) angle of rectifier in degrees (Alpha-min)	
	Maximum firing (delay) angle objective for rectifier in degrees (Alpha-max)	
	Minimum margin angle of inverter in degrees (Gamma-min)	
	Maximum margin angle objective for inverter in degrees (Gamma-max)	
	Number of Pulses (Ex. 12 pulse bridge, with 2 nos. 6 pulse bridge in series)	
	Alpha-min, actual absolute minimum firing angle during transients	
	Gamma-min, actual absolute minimum extinction angle during transients	
	AC side MVA rating	
	Q limits	
	Converter Losses	
	Voltage Control Settings	
AC Filters	Details of AC filters (Switching sequence w.r.t. Power order, MVAR values at nominal voltage and fundamental frequency	

16.6.2. Transient simulation model (Dynamics):

For representation of the electromechanical transient behavior of HVDC links, standard models areavailable in PSS/E library. A list of standard models are listed below:

Generic Models for HVDC links

Category	Type	Model Description
CDC4T	LCC	Two-terminal dc line model
CDC7T	LCC	DC line model
HVDCPL1	VSC	Siemens HVDC plus model
VSCDCT	VSC	Two-terminal VSC dc line model
MTDC1T	MTDC	Multiterminal (five converter) dc line model
MTDC2T	MTDC	Multiterminal (five converter) dc line model

Category	Parameters	Data
LCC based HVDC		
	ALFDY, minimum alpha for dynamics (degrees)	

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Category	Parameters	Data
CDC4T	GAMDY, minimum gamma for dynamics (degrees)	
	TVDC, dc voltage transducer time constant (sec)	
	TIDC, dc current transducer time constant (sec)	
	VBLOCK, rectifier ac blocking voltage (pu)	
	VUNBL, rectifier ac unblocking voltage (pu)	
	TBLOCK, minimum blocking time (sec)	
	VBYPAS, inverter dc bypassing voltage (kV)	
	VUNBY, inverter ac unbypassing voltage (pu)	
	TBYPAS, minimum bypassing time (sec)	
	RSVOLT, minimum dc voltage following block (kV)	
	RSCUR, minimum dc current following block (amps	
	VRAMP, voltage recovery rate (pu/sec)	
	CRAMP, current recovery rate (pu/sec)	
	C0, minimum current demand (amps)	
	V1, voltage limit point 1 (kV)	
	C1, Current limit point 1 (amps); >C0	
	V2, voltage limit point 2 (kV)	
	C2, current limit point 2 (amps)	
	V3, voltage limit point 3 (kV)	
	C3, current limit point 3 (amps)	
	TCMODE, minimum time stays in switched mode (sec)	
	dc voltage sensor time constant, sec.	
	dc current sensor time constant, sec.	
	Rectifier smoothing reactor inductance, mH	
	Rectifier smoothing reactor resistance, ohm	
	Inverter smoothing reactor inductance, mH	
	Inverter smoothing reactor resistance, ohm	
	Inductance of O/H dc line from rectifier side, mH	
	Resistance of O/H dc line from rectifier side, ohm	
	Inductance of O/H dc line from inverter side, mH	
	Resistance of O/H dc line from inverter side, ohm	
	Inductance of dc cable line, mH	
	Damping resistance of dc cable line, ohm	
	dc line capacitance, µF	
	dc fault shunt inductance, rectifier side, mH	
	dc fault shunt resistance, rectifier side, ohm	
	dc fault shunt inductance, mid-line, mH	
	dc fault shunt resistance, mid-line, ohm	
	dc fault shunt inductance, inverter side, mH	
	dc fault shunt resistance, inverter side, ohm	
	dc cable damping resistor	
	Rated dc current, A	
	Rated dc voltage, kV	
	VDComp down time constant for VDCL, rectifier, sec	

Category	Parameters	Data
CDC7T	VDComp up time constant for VDCL, rectifier, sec	
	VDComp down time constant for VDCL, inverter, sec	
	VDComp up time constant for VDCL, inverter, sec	
	Current margin, rectifier, pu	
	Current margin, inverter, pu	
	Voltage margin, rectifier, pu	
	Voltage margin, inverter, pu	
	Gamma margin, rectifier, pu	
	Gamma margin, inverter, pu	
	IDC error to V-control gain, rectifier	
	IDC error to V-control gain, inverter	
	IDC error to Gamma-control gain, inverter	
	VDComp filter gain, rectifier, pu	
	VDComp filter gain, inverter, pu	
	VDComp filter time constant, rectifier, sec.	
	VDComp filter time constant, inverter, sec.	
	Selected controller output gain, rectifier	
	Selected controller output gain, inverter	
	PI-controller proportional gain, rectifier	
	PI-controller integrator time constant, rectifier, sec.	
	PI-controller proportional gain, inverter	
	PI-controller integrator time constant, inverter, sec.	
	Max Alfa limit, rectifier	
	Min Alfa limit, rectifier	
	Max Alfa limit, inverter	
	Min Alfa limit, inverter	
	Control configuration 1	
	Control configuration 3	
	Min GAMA in dynamics	
	Rate of current order change when blocking, A/sec	
	Rate of current order change when unblocking, A/sec	
	VDC filter time constant for Pordr calculation, sec.	
	5 pairs of rectifier VDCL coordinates (Vd1, Id1) ... (Vd5, Id5)1	
	5 pairs of inverter VDCL coordinates (Vd1, Id1) ... (Vd5, Id5)1	
	VSC based HVDC	
	Rated AC voltage on DC side of converter Xfmr [kV]	
	Rectifier transformer impedance [pu of SBASE]	
	Inverter transformer impedance [pu of SBASE]	
	DC line total inductance [H]	
	DC line total capacitance [F]	
	Gain GQr of the rectifier reactive power controller	
	Lead time constant TLeadQr of the rectifier reactive power controller [s]	
	Lag time constant TLagQr of the rectifier reactive power controller [s]	
	Gain GQi of the inverter reactive power controller	
	Lead time constant TLeadQi of the inverter reactive power controller [s]	
	Lag time constant TLagQi of the inverter reactive power controller [s]	
	Gain G1Ud of the DC voltage controller	
	Lead time constant TLead1Ud of the DC voltage controller [s]	

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Category	Parameters	Data
HVDCPL1	Lag time constant TLag1Ud of the DC voltage controller [s]	
	Gain G2Ud of the DC voltage controller	
	Lead time constant TLead2Ud of the DC voltage controller [s]	
	Lag time constant TLag2Ud of the DC voltage controller [s]	
	Ramp rate of the inverter active power setting value [p.u./s] (used for interconnected application)	
	Gain G1P of the inverter active power controller (interconnected application)	
	Lead time constant TLead1P of the inverter active power controller [s] (interconnected application)	
	Lag time constant TLag1P of the inverter active power controller [s] (interconnected application)	
	Gain G2P of the inverter active power controller (interconnected application)	
	Lead time constant TLead2P of the inverter active power controller [s] (interconnected application)	
	Lag time constant TLag2P of the inverter active power controller [s] (interconnected application)	
	TIntQr (s); Rectifier Q controller integrator time constant	
	LMXQr (pu); Rectifier Q controller integrator upper limit	
	LMNQr (pu); Rectifier Q controller integrator lower limit	
	TIntQi (s); Inverter Q controller integrator time constant	
	LMXQi (pu); Inverter Q controller integrator upper limit	
	LMNQi (pu); Inverter Q controller integrator lower limit	
	TIntUd (s); Inverter dc voltage controller integrator time constant	
	LMXIUd (pu); Inverter dc voltage controller integrator upper limit	
	LMNIUd(pu); Inverter dc voltage controller integrator lower limit	
	TIntP (s); Inverter P controller integrator time constant	
	LMXP (pu); Inverter P controller integrator upper limit	
	LMNP (pu); Inverter P controller integrator lower limit	
	Tsync (s); Inverter POI Angle measurement delay	
	LMX1Ud (deg.); Rectifier dc voltage controller first lead-lag upper limit	
	LMN1Ud (deg.); Rectifier dc voltage controller first lead-lag lower limit	
	LMX2Ud (deg.); Rectifier dc voltage controller second lead-lag upper limit	
	LMN2Ud (deg.); Rectifier dc voltage controller second lead-lag lower limit	
	LMX1P (deg.); Inverter P controller first lead-lag upper limit	
	LMN1P (deg.); Inverter P controller first lead-lag lower limit	
	LMX2P (deg.); Inverter P controller second lead-lag upper limit	
	LMN2P (deg.); Inverter P controller second lead-lag lower limit	
	C_Module (F), Converter module capacitor	
	V_Module (kV), Converter module rated capacitor voltage	
	Protection threshold peak current of the IGBTs, kA	
	Model Acceleration factor(>0 and <=1)	
	Undervoltage characteristics, X1 (measured AC-voltage in pu)	
	Undervoltage characteristics, Y1 (AC-voltage reference in pu)	
	Undervoltage characteristics, X2	
	Undervoltage characteristics, Y2	
	Undervoltage characteristics, X3	
	Undervoltage characteristics, Y3	

Category	Parameters	Data
HVDCPL1	Undervoltage characteristics, X4	
	Undervoltage characteristics, Y4	
	Undervoltage characteristics, X5	
	Undervoltage characteristics, Y5	
	Undervoltage characteristics, X6	
	Undervoltage characteristics, Y6	
	Undervoltage characteristics, X7	
	Undervoltage characteristics, Y7	
	Undervoltage characteristics, X8	
	Undervoltage characteristics, Y8	
	Undervoltage characteristics, X9	
	Undervoltage characteristics, Y9	
	Undervoltage characteristics, X10	
	Undervoltage characteristics, Y10	
	Power-Voltage characteristics, X1 (measured AC-voltage in pu)	
	Power-Voltage characteristics, Y1 (maximum active power in pu of MVA rating of second converter)	
	Power-Voltage characteristics, X2	
	Power-Voltage characteristics, Y2	
	Power-Voltage characteristics, X3	
	Power-Voltage characteristics, Y3	
	Power-Voltage characteristics, X4	
	Power-Voltage characteristics, Y4	
	Power-Voltage characteristics, X5	
	Power-Voltage characteristics, Y5	
	Power-Voltage characteristics, Y6	
	DC Chopper characteristics, X1 (Direct voltage in pu)	
	DC Chopper V-I characteristics, Y1 (chopper current in kA)	
	DC Chopper characteristics, X2	
	DC Chopper characteristics, Y2	
	DC Chopper characteristics, X3	
	DC Chopper characteristics, Y3	
	DC Chopper characteristics, X4	
	DC Chopper characteristics, Y4	
	DC Chopper characteristics, X5	
	DC Chopper characteristics, X6	
	DC Chopper characteristics, Y6	
	DC Chopper characteristics, X7	
	DC Chopper characteristics, X7	
	DC Chopper characteristics, X8	
	DC Chopper characteristics, X8	
	DC Chopper characteristics, X9	
	DC Chopper characteristics, X9	
	DC Chopper characteristics, X10	
	DC Chopper characteristics, X10	
	Tpo_1, Time constant of active power order controller, sec (For VSC # 1).	
	AC_VC_Limits_1, Reactive power limit for ac voltage control, pu on converter MVA	

Category	Parameters	Data
VSCDCT	rating. When 0, it is not used and Qmax/Qmin pair is used instead (For VSC # 1).	
	AC_Vctrl_kp_1, AC Voltage control proportional gain, converter MVA rating/BASEKV (For VSC # 1).	
	Tac_1 > 0.0, Time constant for AC voltage PI integral, sec (For VSC # 1). When 0, VSC#1 is ignored.	
	Tacm_1, Time constant of the ac voltage transducer, sec (For VSC # 1).	
	Iacmax_1, Current Limit, pu on converter MVA rating (For VSC # 1).	
	Droop_1, AC Voltage control droop, converter MVA rating/BASEKV (For VSC # 1).	
	VCMX_1, Maximum VSC Bridge Internal Voltage (For VSC # 1).	
	XREACT_1 > 0.0, Pu reactance of the ac series reactor on converter MVA rating (For VSC # 1). When 0.0, default value 0.17 is used.	
	QMAX_1, Maximum system reactive limits in Mvars (For VSC # 1). When AC- VC_Limits_1 >0, QMAX_1 is not used.	
	QMIN_1, Minimum system reactive limits in MVARs (For VSC # 1). When AC- VC_Limits_1 >0, QMIN_1 is not used.	
	AC_VC_KT_1, Adjustment Parameter for the feedback from reactive power limiter to ac voltage controller (For VSC #1).	
	AC_VC_KTP_1, Adjustment Parameter for the feedback from current order limiter to ac voltage controller (For VSC #1).	
	Tpo_2, Time constant of active power order controller, sec (For VSC # 2).	
	AC_VC_Limits_2, Reactive power limit for ac voltage control, pu on converter MVA rating. When 0, it is not used and Qmax/Qmin pair is used instead (For VSC # 2).	
	AC_Vctrl_kp_2, AC Voltage control proportional gain, converter MVA rating/BASEKV (For VSC # 2).	
	Tac_2 > 0.0, Time constant for AC voltage PI integral, sec (For VSC # 2). When 0, VSC#2 is ignored.	
	Tacm_2, Time constant of the ac voltage transducer, sec (For VSC # 2).	
	Iacmax_2, Current Limit, pu on converter MVA rating (For VSC # 2).	
	Droop_2, AC Voltage control droop, converter MVA rating/BASEKV (For VSC # 2).	
	VCMX_2, Maximum VSC Bridge Internal Voltage (For VSC # 2).	
	XREACT_2 > 0.0, Pu reactance of the ac series reactor on converter MVA rating (For VSC # 2). When 0.0, default value 0.17 is used.	
	QMAX_2, Maximum system reactive limits in MVARs (For VSC # 2). When AC-VC_Limits_2 >0, QMAX_2 is not used.	
	QMIN_2, Minimum system reactive limits in MVARs (For VSC # 2). When AC- VC_Limits_2 >0, QMIN_2 is not used.	
	AC_VC_KT_2, Adjustment Parameter for the feedback from reactive power limiter to ac voltage controller (For VSC #2).	

Category	Parameters	Data
	AC_VC_KTP_2, Adjustment Parameter for the feedback from current order limiter to ac voltage controller (For VSC #2).	
	Tpo_DCL, Time constant of the power order controller, sec (For DC Line).	
	Tpo_lim, Time constant of the power order limit controller, sec (For DC Line).	
	MTDC	
	DY1, minimum angle converter 1 (degrees)	
	TVAC1, ac voltage transducer converter 1 (sec)	
	TVDC1, dc voltage transducer converter 1 (sec)	
	TIDC1, current transducer converter 1 (sec)	
	RSVLT1, minimum dc voltage following block, converter 1 (kV)1	
	RSCUR1, minimum dc current following block, converter 1 (amps)2	
	VRMP1, voltage recovery rate, converter 1 (pu/sec)1	
	CRMP1, current recovery rate, converter 1 (pu/sec)2	
	C0-1, minimum current demand converter 1 (amps)3	
	V1-1, voltage limit point 1, converter 1 (kV)2	
	C1-1, current limit point 1, converter 1 (amps)2	
	V2-1, voltage limit point 2, converter 1 (kV)2	
	C2-1, current limit point 2, converter 1 (amps)2	
	V3-1, voltage limit point 3, converter 1 (kV)2	
	C3-1, current limit point 3, converter 1 (amps)2	
	DY2, minimum angle converter 2 (degrees)	
	TVAC2, ac voltage transducer converter 2 (sec)	
	TVDC2, dc voltage transducer converter 2 (sec)	
	TIDC2, current transducer converter 2 (sec)	
	RSVLT2, minimum dc voltage following block, converter 2 (kV)1	
	RSCUR2, minimum dc current following block, converter 2 (amps)2	
	VRMP2, voltage recovery rate, converter 2 (pu/sec)1	
	CRMP2, current recovery rate, converter 2 (pu/sec)2	
	C0-2, minimum current demand converter 2 (amps)3	
	V1-2, voltage limit point 1, converter 2 (kV)2	
	C1-2, current limit point 1, converter 2 (amps)2	
	V2-2, voltage limit point 2, converter 2 (kV)2	
	C2-2, current limit point 2, converter 2 (amps)2	
	V3-2, voltage limit point 3, converter 2 (kV)2	
	C3-2, current limit point 3, converter 2 (amps)2	
	DY3, minimum angle converter 3 (degrees)	
	TVAC3, ac voltage transducer converter 3 (sec)	
	TVDC3, dc voltage transducer converter 3 (sec)	
	TIDC3, current transducer converter 3 (sec)	
	RSVLT3, minimum dc voltage following block, converter 3 (kV)1	
	RSCUR3, minimum dc current following block, converter 3 (amps)2	
	VRMP3, voltage recovery rate, converter 3 (pu/sec)1	
	CRMP3, current recovery rate, converter 3 (pu/sec)2	
	C0-3, minimum current demand converter 3 (amps)3	
	V1-3, current limit point 1, converter 3 (kV)2	
	C1-3, current limit point 1, converter 3 (amps)2	

Category	Parameters	Data
MTDC1T	V2-3, voltage limit point 2, converter 3 (kV)2	
	C2-3, current limit point 2, converter 3 (amps)2	
	V3-3, voltage limit point 3, converter 3 (kV)2	
	C3-3, current limit point 3, converter 3 (amps)2	
	DY4, minimum angle converter 4 (degrees)	
	TVAC4, ac voltage transducer converter 4 (sec)	
	TVDC4, dc voltage transducer converter 4 (sec)	
	TIDC4, current transducer converter 4 (sec)	
	RSVLT4, minimum dc voltage following block, converter 4 (kV)1	
	RSCUR4, minimum dc current following block, converter 4 (amps)2	
	VRMP4, voltage recovery rate, converter 4 (pu/sec)1	
	CRMP4, current recovery rate, converter 4 (pu/sec)2	
	C0-4, minimum current demand converter 4 (amps)3	
	V1-4, voltage limit point 1, converter 4 (kV)2	
	C1-4, current limit point 1, converter 4 (amps)2	
	V2-4, voltage limit point 2, converter 4 (kV)2	
	C2-4, current limit point 2, converter 4 (amps)2	
	V3-4, voltage limit point 3, converter 4 (kV)2	
	C3-4, current limit point 3, converter 4 (amps)2	
	DY5, minimum angle converter 5 (degrees)	
	TVAC5, ac voltage transducer converter 5 (sec)	
	TVDC5, dc voltage transducer converter 5 (sec)	
	TIDC5, current transducer converter 5 (sec)	
	RSVLT5, minimum dc voltage following block, converter 5 (kV)1	
	RSCUR5, minimum dc current following block, converter 5 (amps)2	
	VRMP5, Voltage recovery rate, converter 5 (pu/sec)1	
	CRMP5, current recovery rate, converter 5 (pu/sec)2	
	C0-5, minimum current demand converter 5 (amps)3	
	V1-5, voltage limit point 1, converter 5 (kV)2	
	C1-5, current limit point 1, converter 5 (amps)2	
	V2-5, voltage limit point 2, converter 5 (kV)2	
	C2-5, current limit point 2, converter 5 (amps)2	
	V3-5, voltage limit point 3, converter 5 (kV)2	
	C3-5, current limit point 3, converter 5 (amps)2	
	TCMODE (sec)	
	DY1, minimum angle converter 1 (degrees)	
	TVAC1, ac voltage transducer converter 1 (sec)	
	TVDC1, dc voltage transducer converter 1 (sec)	
	TIDC1, current transducer converter 1 (sec)	
	RSVLT1, minimum dc voltage following block, converter 1 (kV)1	
	RSCUR1, minimum dc current following block, converter 1 (amps)	
	VRMP1, voltage recovery rate, converter 1 (pu/sec)1	
	CRMP1, current recover rate, converter 1 (pu/sec)	
	C0-1, minimum current demand converter 1 (amps)	
	V1-1, minimum current demand converter 1	
	C1-1, minimum current demand converter 1 (amps)	
	V2-1, minimum current demand converter 1	
	C2-1, minimum current demand converter 1 (amps)	

Category	Parameters	Data
MTDC2T	V3-1, minimum current demand converter 1	
	C3-1, minimum current demand converter 1 (amps)	
	DY2, minimum angle converter 2 (degrees)	
	TVAC2, ac voltage transducer converter 2 (sec)	
	TVDC2, dc voltage transducer converter 2 (sec)	
	TIDC2, current transducer converter 2 (sec)	
	RSVLT2, minimum dc voltage following block, converter 2 (kV)1	
	RSCUR2, minimum dc current following block, converter 2 (amps)	
	VRMP2, voltage recovery rate, converter 2 (pu/sec)1	
	CRMP2, current recover rate, converter 2 (pu/sec)	
	C0-2, minimum current demand converter 2 (amps)	
	V1-2, minimum current demand converter 2	
	C1-2, minimum current demand converter 2 (amps)	
	V2-2, minimum current demand converter 2	
	C2-2, minimum current demand converter 2 (amps)	
	V3-2, minimum current demand converter 2	
	C3-2, minimum current demand converter 2 (amps)	
	DY3, minimum angle converter 3 (degrees)	
	TVAC3, ac voltage transducer converter 3 (sec)	
	TVDC3, dc voltage transducer converter 3 (sec)	
	TIDC3, current transducer converter 3 (sec)	
	RSVLT3, minimum dc voltage following block, converter 3 (kV)1	
	RSCUR3, minimum dc current following block, converter 3 (amps)	
	VRMP3, voltage recovery rate, converter 3 (pu/sec)1	
	CRMP3, current recover rate, converter 3 (pu/sec)	
	C0-3, minimum current demand converter 3 (amps)	
	V1-3, minimum current demand converter 3	
	C1-3, minimum current demand converter 3 (amps)	
	V2-3, minimum current demand converter 3	
	C2-3, minimum current demand converter 3 (amps)	
	V3-3, minimum current demand converter 3	
	C3-3, minimum current demand converter 3 (amps)	
	DY4, minimum angle converter 4 (degrees)	
	TVAC4, ac voltage transducer converter 4 (sec)	
	TVDC4, dc voltage transducer converter 4 (sec)	
	TIDC4, current transducer converter 4 (sec)	
	RSVLT4, minimum dc voltage following block, converter 4 (kV)1	
	RSCUR4, minimum dc current following block, converter 4 (amps)	
	VRMP4, voltage recovery rate, converter 4 (pu/sec)1	
	CRMP4, current recovery rate, converter 4 (pu/sec)	
	C0-4, minimum current demand converter 4 (amps)	
	V1-4, minimum current demand converter 4	
	C1-4, minimum current demand converter 4 (amps)	
	V2-4, minimum current demand converter 4	
	C2-4, minimum current demand converter 4 (amps)	
	V3-4, minimum current demand converter 4	
	C3-4, minimum current demand converter 4 (amps)	
	DY5, minimum angle converter 5 (degrees)	

Category	Parameters	Data
	TVAC5, ac voltage transducer converter 5 (seconds)	
	TVDC5, dc voltage transducer converter 5 (seconds)	
	TIDC5, current transducer converter 5 (seconds)	
	RSVLT5, minimum dc voltage following block, converter 5 (kV)1	
	RSCUR5, minimum dc current following block, converter 5 (amps)	
	VRMP5, voltage recovery rate, converter 5 (pu/sec)1	
	CRMP5, current recovery rate, converter 5 (pu/sec)	
	C0-5, minimum current demand converter 5 (amps)	
	V1-5, minimum current demand converter 5	
	C1-5, minimum current demand converter 5 (amps)	
	V2-5, minimum current demand converter 5	
	C2-5, minimum current demand converter 5 (amps)	
	V3-5, minimum current demand converter 5	
	C3-5, minimum current demand converter 5 (amps)	
	TVF, power control VDC transducer time constant (sec)	
	VDCOLUP, voltage transducer time constants (sec)	
	VDCOLON, voltage transducer time constants (sec)	
	Current margin (amps)	
	Converter 1 DV/DI multiplier (pu)2	
	Converter 2 DV/DI multiplier (pu)2	
	Converter 3 DV/DI multiplier (pu)2	
	Converter 4 DV/DI multiplier (pu)2	
	Converter 5 DV/DI multiplier (pu)2	

16.8. Transmission: STATCOM

Format No.:	Dyn/Transmission/STATCOM/1
Data Submission By:	Transmission Licensee
Data related to:	STATCOM
Data to be submitted to:	State Transmission Utility
Periodicity & prescribed date for data submission:	As and when requested by STU

16.7.1. Details of models in PSS/E for modelling HVDC Links:

(a) Transient simulation model (Dynamics):

For representation of the RMS behaviour of STATCOMs, two standard models are available in the PSS/E library, namely SVSMO3T2 and CSTCNT. Details for SVSMO3T2 are given in Table 1 and Table 2 and the CSTCNT model are given in Table 3 and Table 4. The SVSMO3T2 has been described as STATCOM based SVC with logic to trip mechanically switched shunts (MSS). In comparison, the CSTCNT is a simpler representation of STATCOM with no dependence on shunt devices.

Table 1: Parameters of SVSMO3T2 generic STATCOM model

CE (STU) MSETCL

Parameter (Controller parameters or PSS/E CON)	Value
Xc0, linear droop	
Tc1, voltage measurement lead time constant (sec)	
Tb1, voltage measurement lag time constant (sec)	
Kp, proportional gain	
Ki, integral gain	
Vemax, voltage error max. (pu)	
Vemin, voltage error min. (pu)	
T0, firing sequence control delay (sec)	
Imax1, max. continuous current rating (pu on STBASE)	
dbd, deadband range for voltage control (pu)	
Kdbd, ratio of outer to inner deadband	
Tdbd, deadband time (sec)	
Kpr, proportional gain for slow-reset control	
Kir, integral gain for slow-reset control	
Idbd, deadband range for slow-reset control (pu on STBASE)	
Vrmax, max. limit on slow-reset control output (pu)	
Vrmin, min. limit on slow-reset control output (pu)	
Ishrt, max. short-term current rating as a multiplier of max. cont. current rating (pu)	
UV1, voltage at which STATCOM limit starts to be reduced linearly (pu)	
UV2, voltage below which STATCOM is blocked (pu)	
OV1, voltage above which STATCOM limit linearly drops (pu)	
OV2, voltage above which STATCOM blocks (pu)	
Vtrip, voltage above which STATCOM trips after time delay Tdelay2 (pu)	
Tdelay1, short-term rating time(sec)	
Tdelay2, trip time for V .GT. Vtrip(sec)	
Vrefmax, max. limit on voltage reference (pu)	
Vrefmin, min. limit on voltage reference (pu)	
Tc2, lead time constant(sec)	
Tb2, lag time constant(sec)	
I2t, short-term limit	
Reset, reset rate for I2t limit	
hyst, width of hysteresis loop for I2t limit	
Xc1, non-linear droop slope 1	
Xc2, non-linear droop slope 2	
Xc3, non-linear droop slope 3	
V1, non-linear droop upper voltage (pu)	
V2, non-linear droop lower voltage (pu)	
Tmssbrk, time for MSS breaker to operate (sec)	
Tout, time MSC should be out before switching back in (sec)	
TdelLC, Time delay for switching in a MSS (sec)	
Iupr, Upper threshold for switching MSS (pu on STBASE)	
Ilwr, Lower threshold for switching MSS (pu on STBASE)	

CE (STU) MSETCL

Parameter (Controller parameters or PSS/E CON)	Value
Sdelay, time STATCOM should remain blocked before being unblocked	
STBASE (>0), STATCOM BASE MVA	

Table 2: Parameters of SVSMO3T2 generic STATCOM model – additional information

Parameter (Other relevant information or PSS/E ICON)	Value
Remote bus number for voltage regulation	Bus Name & Voltage Level
Disable or enable coordinated MSS switching, 0 - no MSS switching, 1 - MSS switching based on STATCOM current	
flag1, slow-reset off/on, flag1 (0/1)	
flag2, non-linear droop off/on, flag2 (0/1)	
1st MSS bus #	
1st MSS Id (to be entered within single quotes)	
2nd MSS bus #	
2nd MSS Id (to be entered within single quotes)	
3rd MSS bus #	
3rd MSS Id (to be entered within single quotes)	
4th MSS bus #	
4th MSS Id (to be entered within single quotes)	
5th MSS bus #	
5th MSS Id (to be entered within single quotes)	
6th MSS bus #	
6th MSS Id (to be entered within single quotes)	
7th MSS bus #	
7th MSS Id (to be entered within single quotes)	
8th MSS bus #	
8th MSS Id (to be entered within single quotes)	

Table 3: Parameters of CSTCNT generic STATCON model

Parameter (Controller parameters or PSS/E CON)	Value
T1 (>0)	
T2 (>0)	
T3 (>0)	
T4 (>0)	
K(Typical = 25/(dv/dei))	
Droop (typical = 0.03)	
VMAX (typical = 999)	
VMIN (typical = -999)	
ICMAX (typical = 1.25) Max capacitive current	
ILMAX (typical = 1.25) Max inductive current	
Vcutout (typical = 0.2)	
Elimit (typical = 1.2)	
Xt (>0) (transformer reactance, typical = 0.1)	
Acc (acceleration factor, typical = 0.5)	
STBASE (>0) STATCON base MVA	

Table 4: Parameters of CSTCNT generic STATCOM model – additional information

Parameter (Other relevant information or PSS/E ICON)	Value
IB, remotely regulated bus	Bus Name & Voltage Level