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

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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).

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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.

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%	

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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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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	

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