MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.

MAHARASHTRA STATE ELECTRICITY TRANSMISSION CO. LTD.

(CIN NO. U40109MH2005SGC153646)

PROTECTION MANUAL FOR MAHARASHTRA SYSTEM

OFFICE OF THE CHIEF ENGINEER (ACI & P) CO,

AIROLI, NAVI-MUMBAI

1.0. Background:

1.1. In pursuance of MERC Order dated 22nd October, 2020 in Case No. 202 of 2020, the High Level Committee was constituted for Enquiry into MMR Grid disturbance on dtd. 12.10.2021. Subsequently Hon. MERC has directed all the stakeholders in the state to implement the various recommendations of the HLC within prescribed time lines.

1.2. As per the HLC committee `the Protection Co-ordination Committee (PCC) under the aegis of GCC has to review the protection philosophy & relay co-ordination setting on distance protection & over-current and suggest the revision in the relay settings in consultation with WRPC protection committee`. A detailed action plan and changes in the protection philosophy may be taken up by STU and Transmissions Licensees in consultation with GCC.

1.3. Further Executive Director (MSLDC) & Member secretary of GCC vide letter No. MSLDC/TECH/OP/GCC - HLC/No. 01607 dtd. 26.07.2021 informed to take necessary step to carry out revision of the protection philosophy, review of tripping logic & relay co-ordination setting on distance protection & over-current by PCC and submit its reports to GCC core group for approval within specified time line i.e. within 6 months.

1.4. Also as per Maharashtra Electricity Grid Code (MEGC) 2020 dtd. 02.09.2020 pt. No. 66.7, protection manual is to be prepared by STU in consultation with PCC.

1.5. Accordingly vide letter No. MSETCL/CO/CE (ACI&P)/793 dtd. 20.12.2021 requested PCC member organization to nominate one expert engineer in the domain of protection for group to prepare protection manual.

1.6. Subsequently vide letter No. MSETCL/CO/CE (ACI&P)/GCC/PCC/87 dtd. 23.02.2022 formed the Protection Group/committee to review protection philosophy & preparation of protection manual consisting of the following members.

1. Shri. Jayant Kulkarni, Superintending Engineer (PAC Circle) MSETCL, Pune.
2. Shri. Deepak Patil, Executive Engineer (PAC Division) MSETCL, Nashik.
3. Shri. M. B. Dhore, Executive Engineer (PAC Division) MSETCL, Kalwa.
4. Shri. Girish Malode, Executive Engineer (Telecom Division) MSETCL, Kalwa.
5. Shri M. B. Pande, Executive Engineer (Operation), SLDC, Airoli.

6. Shri. Girish Dhok, Executive Engineer MSPGCL, Nagpur.
7. Shri. Abhijeet Gore, Dy. General Manager AEML - Transmission, Mumbai
8. Shri. Girish Tukaram Jawale, Group Head (Protection & System Studies), Tata Mumbai.

1.7. The tasked assigned to the Protection Group are as follows:

- To review the protection philosophy & practices.
- To prepare protection manual.
- To review the SOP for preventative maintenance practices & testing activities for relaying.

2.0. Meetings & Discussions:

2.1. Three meeting of Protection group was conducted & one meeting of Protection co-ordination committee (PCC) including Protection group members. The details are tabulated below:

Sr. No.	Meeting No.	Date & Time	Group Members	Physical/On-line
1.	1	24.03.2022 at 11.00hrs	Protection Group	Physical & On-line
2.	2	12.10.2022 at 11.00hrs	Protection Group	On-line
3	3	01.12.2022 at 11.30hrs	PCC & Protection Group	On-line

2.2. 1st Meeting of the Committee:

The 1st meeting of the Protection Group was convened vide letter no. MSETCL/CO/CE (ACI&P)/GCC/PCC/PGM/145 dtd. 22.03.2022 on 24.03.2022 at 11:00 hrs at `office of the Chief Engineer (ACI&P), Old load despatch centre building, Thane-Belapur road, Airoli Sector-1, Navi-Mumbai.

The brief discussions are as follows:

2.2.1. The Chief Engineer (ACI&P), Chairperson of PCC briefed the present Power System network of Maharashtra & challenges to protection system co-ordination. He further stated that Power System network of Maharashtra has seen a large growth in recent years with different licensee owned transmission systems interconnected to each other. There are now 9 number of transmission licensees which are interconnected.

Further, the Intrastate Transmission System (InSTS) of Maharashtra is also connected to the national grid. The InSTS has now more that 800 EHV substations, more than 50,000 km of lines and more than 1,40,000 MVA transformation capacity. It caters a peak demand of 28,000 MW and will have to cater more and more demand in future.

Due the complexity of the network and also fault levels in the network have also risen to very high levels. Protection of network elements like lines, transformers, reactors, capacitor banks, bus bars plays a vital role in ensuring security of the system.
The protection system has to be reliable, selective & fast for isolation of faulty element in the system and has to ensure that the faults do not penetrate further into the network and cause

harm to the stability of the grid. Due to complexity of the grid, coordination of protection system has also become complex and challenging.

2.2.2. The protection group has considered these requirements and challenges. The protection philosophy and practices followed by each other was also discussed and it was decided to bring out the best out of it for preparing the general guidelines.

2.2.3. The protection group decided to referred CBIP manual & Ramakrishna Committee report on protection philosophy, setting & guidelines while reviewing practices adopted by utilities in Maharashtra and making recommendation thereof.

2.2.4. The protection group also suggests that these documents be adopted as part of protection manual.

2.2.5. Based on the CBIP manual & Ramakrishna Committee report, the general guidelines sheets of Protection & SOP for Testing of Equipments & Relay is attached as **Annexure-I.**

2.2.6. Correspondence & Reply:

2.2.6.1. Vide e-mail dtd. 25.03.2022, the general guidelines sheets prepared by protection group during the meeting held on dtd. 24.03.2022 & adding the bus-bar & LBB sheets circulated to all protection group members for addition & suggestion of parameters if any.

2.2.6.2. M/s Tata & AEML vide their e-mail dtd. 05.04.2022 submitted updated general guidelines sheets.

2.2.6.3. Updated general guidelines sheets of Protection & SOP for Testing of Equipments & Relay is attached as **Annexure-II**.

2.3. 2nd Meeting of the Committee:

The 2nd meeting of the Protection Group was convened on 07.10.2022 at 11:00 hrs through Microsoft - VC. However the scheduled meeting for finalization of protection manual on dtd. 07.10.2022 had been canceled due to unavoidable circumstances. The meeting was rescheduled again on dtd. 12.10.2022 at 15.00Hrs. through Microsoft - VC.

The brief discussions are as follows:

2.3.1. Protection philosophy & practices adopted for different voltage level transmission lines, ICT, Power TF, busbar & LBB protection at Tata, Adani & MSETCL were compared, discussed & suggestions for proposed best practice are worked out.

2.3.2. The main protections viz. Distance, differential, backup, bus-bar & LBB etc. functions/parameters, setting adopted at Tata, Adani & MSETCL & its significance were compared and discussed.

2.3.3. Protection group has decided to refer CBIP guidelines for transmission system protection, CEA Ramakrishna Committee guidelines & CEA Sub-committee report on relay/protection also.

2.3.4. Based on the CBIP manual, Ramakrishna Committee report & protection philosophy and practices followed by different utilities, **final draft of Protection Group recommendation on Protection Guidelines** is attached as **Annexure-III.**

2.3.5. Correspondence & Reply:

2.3.5.1. Review of Protection Philosophy in the state & finalization of Protection Manual was discussed during the PCC meeting held on dtd. 20.10.2022.

2.3.5.2. Shri. J.R.Kulkarni SE PAC Pune MSETCL, Protection Group Member presented the draft of protection manual. The existing philosophy followed by different utilities & recommendation of the committee were discussed in details.

2.3.5.3. After deliberation it was decided that the draft of protection manual to be finalized after the perusal by PCC members & circulating the draft to all.

2.3.5.4. Accordingly vide e-mail dtd. 07.11.2022, final draft of protection manual was circulated to all PCC members for suggestions & comments as decided during the PCC meeting dtd. 20.10.2022.

2.3.5.5. Vide e-mail dtd. 10.11.2022, AEML submitted the minor changes / correction as highlighted in the sheets. No comments received from other PCC members.

2.3.5.6. Vide e-mail dtd. 24.11.2022, again requested all PCC members to offer their comments on draft protection manual or else communicate the acceptance on or before 28.11.2022. However no comments received.

2.4. Special Protection Co-ordination Committee Meeting:

The Special Protection co-ordination committee meeting was convened vide e-mail dtd. 24.11.2022, for finalization of Protection Manual on dtd. 01.12.2022 at 11.30hrs. through Microsoft VC.

The brief discussions are as follows:

2.4.1. Chief Engineer (ACI&P), Chairperson, PCC welcomed all the PCC members and other participants for Special PCC Meeting & informed that the special Protection co-ordination committee meeting was called for finalization of Protection manual draft prepared by Protection manual Group members & approval of PCC committee.

2.4.2. The comments were received from AEML having difference of opinion with committee recommendations was discussed & put up for committee acceptance and approval.

2.4.3. Accordingly the following AEML comments were discussed,

Load Enchrochment: AEML representative informed that the present practise of setting of Resistive Reach is as per OEM's Technical Manual. However there is no issue of accepting the Ramakrishana committee recommendation as recommended by protection manual group members.

The PCC committee has accepted the recommendation of Protection manual group members i.e. Resistive reach setting as per Ramakrishana committee.

Auto Recloser (AR): AEML representative suggested to include the `keeping of AR in Non auto for all Cable Feeders` in the recommendation made by protection manual group members.

The PCC committee has accepted the suggestion made by AEML & will be included in the protection manual.

Standalone AR: AEML representative agreed with protection manual group members recommendation.

Dead Line charging, Live line charging, Synchronizing: AEML representative agreed with protection manual group members recommendation.

Bus bar (220kV and Below): AEML representative agreed with protection manual group members recommendation.

2.4.4. AEML representative informed that the comments given for correctly representing the AEML practices documented in the draft only and agreed with the overall recommendations in the draft.

2.4.5. The PCC committee has accepted suggestions / corrections as above & approved the protection manual and recommended for onward submission to GCC for acceptance & approval.

2.4.6. Protection Guidelines & SOP for Testing of Equipments & Relay is attached as below,

Protection Guidelines

765KV & 400KV TRANSMISSION LINE	
Parameter	**Committee Recommendation**
Main 1 Protection	Differential cum Distance Relay
Main 2 Protection	Differential cum Distance Relay
B/U Protection	No
DC system	2 Nos. DC Source for Main-I & Main-II Protection.
Communication	OPGW/FOTE + PLCC
Relay GPS synchronization	Yes
Short Line	1. As per system requirement POTT can be adopted or 2. POTT for line length less than 5kM.
Long Line	PUTT
Make of relays for M1 & M2	Main-I & Mani-II Protection should be of different make.
Relay Characteristics	Quadrilateral for distance relay
Nos. of Zones	Z1, Z2, Z3: Forward and Z4: Reverse
OTHER FUNCTIONS:	
Power Swing Blocking (PSB)	Block all except Z1
Load Encroachment	As per load impedance (Ramakrishana committee recommendation)
VT Supervision	Yes
Auto Recloser Function (AR)	Single phase, Single shot
Standalone AR	Standalone AR for Tie CB for one & half CB scheme
Dead time	1 Sec for Main CB, 1.5 or 2 Sec for Tie CB.
Reclaim time	25 Sec
Dead Line charging, Live line charging, Synchronizing	Synchro check required at all locations (Through BCU or M1 , M2)
Disturbance Recorder (DR)	Total Length: 2 Sec Pre-fault Length: 0.5 Sec Post-fault Length: 1.5 sec
Trip Log	Yes
Event Log	Yes
Broken Conductor Alarm (BCA)	Alarm mode, 5 Sec
Parallel Line Compensation	Yes (For double circuit lines, special considerations are as per Ramakrishna Committee Report)
Travelling Wave fault locator (standalone)	Yes (standalone)

220KV TRANSMISSION LINE	
Parameter	**Committee Recommendation**
Main 1 Protection	Main 1 distance protection
Main 2 Protection	Main 2 differential cum distance (For all Sub-stations in Mumbai & Mumbai Metropolitan Region (MMR)/For other region excluding Mumbai & MMR, Critical/Grid connected sub-station)
B/U Protection	Inbuilt in M1 & M2 or standalone
DC system	Double source philosophy may be adopted for Critical /Grid substation.
Communication	OPGW/FOTE + PLCC
Relay GPS synchronization	Yes
Short Line	POTT may be adopted
Long Line	PUTT
Make of relays for M1 & M2	Main-I & Mani-II Protection should be of different make
Relay Characteristics	Quadrilateral for distance relay
Nos. of Zones	Z1,Z2,Z3 Forward Z4 Reverse
OTHER FUNCTIONS:	
Power Swing Blocking (PSB)	Block all except Z1
Load Encroachment	As per load impedance ((Ramakrishana committee recommendation.)
VT Supervision	Yes
Auto Recloser Function (AR)	1. Single ph, single shot for overhead lines at both ends. 2. For hybrid lines, Single ph, Single shot at Overhead end only or AR in Non auto for all Cable Feeders.
Standalone AR	Inbuilt in M1 or M2 or Standalone Relay
Dead time	1 sec
Reclaim time	25 Sec
Dead Line charging, Live line charging, Synchronizing	Synchro check required at strategic locations (Through BCU or M1 , M2)
Disturbance Recorder (DR)	Total Length: 2 Sec Pre-fault Length: 0.5 Sec Post-fault Length: 1.5 sec
Trip Log	Yes
Event Log	Yes
Broken Conductor Alarm (BCA)	Alarm mode, 5 Sec
Parallel Line Compensation	No
Travelling Wave fault locator (standalone)	For Critical hybrid lines

132KV/110KV/100KV TRANSMISSION LINE	
Parameter	**Committee Recommendation**
Main 1 Protection	Main 1 distance protection
Main 2 Protection	Main 2 differential cum distance (for critical/grid lines or short lines having OPGW)
B/U Protection	BU OC & EF (Standalone - on Separate core)
DC system	Double source philosophy may be adopted for Critical /Grid substation.
Communication	OPGW/FOTE + PLCC
Relay GPS synchronization	Yes
Short Line	POTT may be adopted
Long Line	PUTT
Make of relays for M1 & M2	Main-I & Mani-II Protection should be of different make
Relay Characteristics	Quadrilateral for distance relay
Nos. of Zones	Z1,Z2,Z3 Forward Z4 Reverse
OTHER FUNCTIONS:	
Power Swing Blocking (PSB)	Block all except Z1
Load Encroachment	As per load impedance (Ramakrishana committee recommendation)
VT Supervision	Yes
Auto Recloser Function (AR)	3-phase, single shot
Standalone AR	Inbuilt in M1 or M2 or Standalone Relay
Dead time	1 sec
Reclaim time	25 Sec
Dead Line charging, Live line charging, Synchronizing	No
Disturbance Recorder (DR)	Total Length: 2 Sec Pre-fault Length: 0.5 Sec Post-fault Length: 1.5 sec
Trip Log	Yes
Event Log	Yes
Broken Conductor Alarm (BCA)	Alarm mode, 5 Sec
Parallel Line Compensation	No
Travelling Wave fault locator (standalone)	No

ICT & POWER TRANSFORMER (TF)	
Parameter	**Committee Recommendation**
Differential protection	Yes
Slope	2 Slopes
Differential HS	Yes
Overfluxing	Yes, Alarm
2nd Harmonics Restrain	Yes
5th Harmonics Restrain	Yes
DR	1 to 2 Sec
Back up Protection (HV & LV)	Yes
REF	Yes
Buchholz	Yes
WTI	Yes
OTI	Yes
PRV	Yes
OLTC Buchholz	Yes
Sudden PRV	Yes
Sensitive Earth fault	No
Online DGA	No
NIFPS	Yes for above 50 MVA capacity

LOCAL BREAKER BACKUP (LBB) PROTECTION	
Voltage level	**Committee Recommendation**
765kV, 400kV, 220kV, 132kV, 110kV & 100 kV	Standalone
	Two stage: Stage I :(Re-Trip) time delay of 100ms to trip own CB Stage II : time delay of 200ms to trip all CBs connected to the respective bus
	Phase segregation feature in LBB used.
	Built-in LBB feature in BB relay not used.
	Stand alone LBB relay is used.
	Current Setting- 0.8 pu.
33 & 22 kV Incomer	No

BUS BAR (BB) PROTECTION	
Voltage level	**Committee Recommendation**
765kV & 400kV	Main I &Main II (centralized /decentralized)
220kV & below	Main (centralized /decentralized)
	Diff. relay setting: Highest CT ratio
	CT Supervision setting- 30 mA (sec), 5 sec
33 & 22 kV Incomer	No

SOP FOR TESTING OF EHV & 765KV/400KV EQUIPMENTS GUIDELINES

Sr. No.	Equipments	Testing activity	Committee recommendation (Test frequency)
1.	**ICT / Transformers / Reactors**	Bushings - C & tan-delta (765kV, 400kV & 220kV)	Yearly
		Bushings - C & tan-delta (132kV &below)	Yearly
		Winding - C & tan-delta (765kV, 400kV & 220kV)	2 Yearly
		Winding - C & tan-delta (132kV &below)	2 Yearly
		Winding Resistance Measurement at all tap position	4 Yearly & As and when required
		SFRA	5 Yearly & As and when required
		Winding (With Bushing)- IR / PI	Yearly
		DGA - ICT & Reactor	Quarterly for first year on commissioning & then subsequently half Yearly
		DGA - Power TF	Quarterly for first year on commissioning & then subsequently half Yearly
		Oil Parameter Test	Yearly
		Excitation Current test @10kV	2 Yearly
		Cooling System Trial	Half Yearly
		Device Auxiliary Protection Trials	Yearly
		Transformer all low voltage Test	As and when required
		Furan Analysis	As and when required
		Dielectric Frequency Response (DFR)	2 Yearly
		Tap Changer (OLTC) Continuity Test	2 Yearly
2.	**LA**	Leakage Current (Third Harmonic Resistive Current) Measurement	Half Yearly (Before & After monsoon)
		Insulation Resistance (IR) measurement	As and when required
		Capacitance & tan-d measurement	As and when required
3.	**CT**	Capacitance & tan-d of 765kV/400kV	2 Yearly
		Capacitance & tan-d of 220kV major/important s/s	Yearly
		Capacitance & tan-d of all other EHV CT (66kV to 220kV)	2 Yearly
		Insulation Resistance measurement	2 Yearly
		DGA & testing of other parameters	As and when required
		Ratio test, Knee point measurement	As and when required

Sr. No.	Equipments	Testing activity	Committee recommendation (Test frequency)
4.	**CVT**	Capacitance & tan-d	3 Yearly
		Measurement of secondary voltage at C & R Panels	1. Quarterly or 2. Online Monitoring in SCADA
5.	**PT**	Capacitance & tan-d	3 Yearly
		IR Value, Magnetizing Current & Primary Winding Resistance Measurement	During Bus outage
6.	**Circuit Breaker (CB)**	CB operating timing (Main, PIR) of EHV CB	2 Yearly
		CB operating timing of HV CB	Yearly
		Static Contact Resistance Measurement (CRM) of EHV CB	2 Yearly
		Static Contact Resistance Measurement (CRM) of HV CB	Yearly
		Dynamic Contact Resistance Measurement (DCRM) of 765kV/400kV	During Commissioning & then 2 Yearly
		Dynamic Contact Resistance Measurement (DCRM) of 220kV Major/important s/s	During Commissioning & then as and when required
		Dynamic Contact Resistance Measurement (DCRM) of all other EHV s/s	During Commissioning & then as and when required
		Capacitance & tan-d measurement of Grading Capacitor	2 Yearly
		Measurement of due point in SF6 gas	2 Yearly
		Insulation Resistance Measurement of EHV CB	2 Yearly
		Insulation Resistance Measurement of HV CB	2 Yearly
		1) Checking of Air Compressor/Hydraulic Pump operation 2) Checking of spring charging motor/ air compressor motor/ hydraulic compressor motor operation timing 3) Checking the pressure switch setting	Yearly
		All Electrical / Mechanical Tests (Pole, Mechanism, Drive O/H or Replacement)	As and when required

SOP FOR PROTECTIVE RELAYS & SCHEMES TESTING GUIDELINES

Sr. No.	Equipments	Testing activity	Committee recommendation (Test frequency)
Relays	Bus-bar	1 Year after commissioning & subsequently after 3 Year	1) The test procedure should include thorough functional scheme testing. 2) For Electromechanical & Static relays except bus-bar, yearly testing to be carried out. 3) Detail Testing after configuration change.
	LBB	1 Year after commissioning & subsequently after 3 Year	
	Distance / Line differential	2 Yearly	
	Differential /REF	2 Yearly	
	Backup	2 Yearly	
	Load Trimming Relay (LTS)	Yearly	Testing may be skipped in case of correct operation on fault.
	UFR & FTR	Yearly	
	Islanding Scheme	Yearly	
	Over voltage, NDR & Overfluxing	Yearly	

Annexure

Annexure-I

PROTECTION GUIDELINES SHEET

765kV, 400kV, 220kV & 132kV/110kV/100kV TRANSMISSION LINE	
Sr. No.	**Parameter**
1	Main 1
2	Main 2
3	B/U Prot
4	DC system
5	Communication
6	Relay GPS Synchro
7	Short Line
8	Long Line
9	Make of relays for M1 & M2
10	Characteristics
11	No of Zones
12	**Other functions**
13	PSB
14	Load Enchrochment
15	VT Supervision
16	AR
17	Standalone AR
18	Dead time
19	Reclaim time
20	Dead Line charging, Live line charging, Synchronizing
21	DR
22	Trip Log
23	Event Log
24	BRC
25	Parallel line compensation
26	Travelling Wave fault locator (standalone)

CE (STU) MSETCL

ICT & POWER TRANSFORMER (TF)	
Sr. No.	**Parameter**
1	Differential protection
2	Slope
3	Differential HS
4	Overfluxing
5	2nd Harmonics Restrain
6	5th Harmonics Restrain
7	DR
8	Back up Protection (HV & LV)
9	REF
10	Buchholz
11	WTI
12	OTI
13	PRV
14	OLTC Buchholz
15	Sudden PRV
16	Sensitive Earth fault
17	Online DGA
18	NIFPS

LOCAL BREAKER BACKUP (LBB) PROTECTION		
Sr. No.	**Voltage Level**	**Parameters**
1	765kV/400kV/220kV &132kV/ 110kV/100kV	Standalone
2		Single / Two Stages Stage I : Re-Trip of own CB Stage II : time delay to trip all CBs connected to the respective bus
3		Phase segregation feature
4		Built-in LBB feature in BB relay
5		Current Setting
6	33 & 22 kV Incomer	NA

BUS BAR PROTECTION		
Sr. No.	**Voltage level**	**Parameter**
1	765kV/400kV	Main I (centralized /decentralized) Main II
2	220kV & Below	Main
		Diff relay setting
		CT Supervision setting
3	33 & 22 kV	NA

Sr. No.	Equipment	Testing Activity	Test Frequency
1	**ICT/ Transformers / Reactors**	Bushings - C & tan-delta (765kV, 400kV & 220kV)	
		Bushings - C & tan-delta (132kV &below)	
		Winding - C & tan-delta (765kV, 400kV & 220kV)	
		Winding - C & tan-delta (132kV &below)	
		Winding Resistance Measurement at all tap position	
		SFRA	
		Winding (With Bushing) - IR / PI	
		DGA - ICT & Reactor	
		DGA - Power TF	
		Oil Parameter Test	
		Excitation Current test @10kV	
		Cooling System Trial	
		Device Auxiliary Protection Trials	
		Transformer all low voltage Test	
		Furan Analysis	
		Dielectric Frequency Response (DFR)	
		Tap Changer (OLTC) Continuity Test	
2	**LA**	Leakage Current (Third Harmonic Resistive Current) Measurement	
		Insulation Resistance (IR) measurement	
		Capacitance & tan-d measurement	
3	**CVT**	Capacitance & tan-d	
		Measurement of secondary voltage at C & R Panels	
4	**PT**	Capacitance & tan-d	
		IR Value, Magnetizing Current & Primary Winding Resistance Measurement	

CE (STU) MSETCL

Sr No	Equipment	Testing Activity	Test Frequency
5	**CT**	Capacitance & tan-d of 765kV & 400kV	
		Capacitance & tan-d of 220kV major/important	
		Capacitance & tan-d of all other EHV CT (66kV to 220kV)	
		Insulation Resistance measurement	
		DGA & testing of other parameters	
		Ratio test, Knee point measurement	
6	**Circuit Breaker**	CB operating timing (Main, PIR) of EHV CB	
		CB operating timing of HV CB	
		Static Contact Resistance Measurement (CRM) of EHV CB	
		Static Contact Resistance Measurement (CRM) of HV CB	
		Dynamic Contact Resistance Measurement (DCRM) of 765kV & 400kV	
		Dynamic Contact Resistance Measurement (DCRM) of 220kV Major/important s/s	
		Dynamic Contact Resistance Measurement (DCRM) of all other EHV s/s	
		Capacitance & tan-d measurement of Grading Capacitor	
		Measurement of due point in SF6 gas	
		Insulation Resistance Measurement of EHV CB	
		Insulation Resistance Measurement of HV CB	
		1) Checking of Air Compressor/Hydraulic Pump operation 2) Checking of spring charging motor/ air compressor motor/ hydraulic compressor motor operation timing 3) Checking the pressure switch setting	
		All Electrical/Mechanical Tests (Pole, Mechanism, Drive O/H or Replacement)	

Sr No	Equipment	Testing Activity	Test Frequency
1	Relay	Bus-bar	
2		LBB	
3		Distance / Line differential	
4		Differential /REF	
5		Backup	
6		Load Trimming Relay (LTS)	
7		UFR & FTR	
8		Islanding Scheme	
9		Over voltage, NDR & Overfluxing	

Annexure-II.

REVIEW OF PRACTICES

765kV & 400kV TRANSMISSION LINE					
Parameter	**MSETCL**	**TATA**	**AEML**	**Other utility**	**Recommendation**
Main 1	Distance	NA	NA		Diff . cum Distance
Main 2	Distance	NA	NA		Diff. cum Distance
B/U Prot	No	NA	NA		
DC system	2 nos. source for Main 1 & Main 2 protection	NA	NA		
Communication	OPGW, PLCC	NA	NA		OPGW
Relay GPS Synchro	Yes at few locations	NA	NA		Required
Short Line	PUTT, POTT at few locations	NA	NA		As per system requirement POTT can be adopted
Long Line	PUTT	NA	NA		
Make of relays for M1 & M2	NA	NA	NA		M1 & M2 should be different make
Characteristics	Quadrilateral for distance relay	NA	NA		
No of Zones	Z1,Z2,Z3 Forward Z4 Reverse (10% of short line or limited 2Km) Stage 1 : 200ms Trip Bus-coupler Stage 2 : 350ms, Trip own breaker	NA	NA		

CE (STU) MSETCL

Parameter	MSETCL	TATA	AEML	Other utility	Recommendation
Other functions					
PSB	Block all except Z1	NA	NA		
Load Enchrochment	As per load impedance (Ramkrishana formula)	NA	NA		
VT Supervision	Yes	NA	NA		
AR	Single ph, single shot	NA	NA		
Standalone AR	No	NA	NA		Standalone AR for Tie CB for one & half scheme
Dead time	1 Sec for Main CB, 1.5 or 2 Sec for Tie CB	NA	NA		
Reclaim time	25 Sec	NA	NA		
Dead Line charging, Live line charging, Synchronizing	No	NA	NA		Synchro. check required at all locations (Through BCU or M1 , M2)
DR	Length : 2 Sec Pre fault : 0.5 Post fault : 1.5 sec As per availability in relay	NA	NA		
Trip Log	Yes	NA	NA		
Event Log	Yes	NA	NA		
BRC	Alarm mode, 5 Sec	NA	NA		
Parallel line compensation	No	NA	NA		Required
Travelling Wave fault locator (standalone)	No	NA	NA		Required

220kV TRANSMISSION LINE					
Parameter	**MSETCL**	**Tata**	**AEML**	**Other utility**	**Recommendation**
Main 1	Distance	Diff Cum Distance + OC EF + LBB + Overload LTS + AR	Diff Cum Distance		Main 1
Main 2	NA	Diff Cum Distance + OC EF + LBB + Overload LTS + AR	Diff Cum Distance		Main 2 to be adopted
B/U Prot	OC EF on Separate core	Inbuilt in M1 & M2	O/C EF in series with M2		Inbuilt in M1 & M2
DC system	1 source for Main and Back Up	2 Source ,for M1 & M2	2 Source ,for M1 & M2		Double source philosophy may be adopted for critical substation
Communication	OPGW, PLCC	All OPGW Parallel redundant path available	All OPGW Parallel redundant path available Two channel for each line through different SDH panels		OPGW
Relay GPS Synchro.	Yes at few locations	Yes	Yes		Yes, Required
Short Line	PUTT, POTT at few locations	POTT	POTT		POTT may be adopted
Long Line	PUTT	PUTT	PUTT		
Make of relays for M1 & M2	NA	Different Make for M1 & M2	Different Make for M1 & M2		Different Make for M1 & M2
Characteristics	Quadrilateral for distance relay	Quadrilateral for Both M1 & M2	Quadrilateral for Both M1 & M2		

Parameter	MSETCL	Tata	AEML	Other utility	Recommendation
No of Zones	Z1,Z2,Z3 Forward Z4 Reverse (10% of short line or limited 2Km) Stage 1 : 200mS, Trip Bus coupler Stage 2 : 350ms , Trip own breaker	Z1,Z2,Z3 Forward Z4 forward , 51% of load impedance or 1.5 times of Z3 impedance whichever is less , 2sec Z5 reverse , 350 ms	Z1,Z2,Z3 Forward Z4 Reverse		
Other functions					
PSB	Block all except Z1	Block all except Z1	Block all except Z1		
Load Enchrochment	As per load impedance (Ramkrishana formula)	As per load impedance (Ramkrishana formula)	Resistive reach Setting calculated considering 250MVA		
VT Supervision	Yes	Yes	Yes		
AR	Single ph, single shot	3 pole Single shot , Few lines are 1 pole	Single ph, single shot		Single ph, single shot for overhead lines
Standalone AR	No	Inbuilt in M1 & M2	At Some locations		
Dead time	1 Sec	30 Sec (3phase for hybrid line) 10 Sec single pole overhead lines	1 Sec		
Reclaim time	25 Sec	35 sec 20 Sec	120 Sec		
Dead Line charging, Live line charging ,Synchronizing	No	Inbuilt in M1 & M2	Through BCU at GIS AIS dedicated relay used		Synchro. check required at strategic locations (Through BCU or M1 , M2)

Parameter	MSETCL	TATA	AEML	Other utility	Recommendation
DR	Length : 2 Sec Pre fault : 0.5 Post fault : 1.5 sec As per availability in relay	Length : 2 Sec Pre fault : 0.2 Post fault : 1.8 sec As per availability in relay	Length : 1.5 to 2 Sec Pre fault : 0.2 to 0.5 Post fault : 1 to 1.5 sec As per availability in relay		
Trip Log	Yes	Yes	Yes		
Event Log	Yes	Yes	Yes		
BRC	Alarm mode, 5 Sec	Disabled	Alarm for Overhead lines, 5 Sec		
Parallel line compensation	No	No	No		
Travelling Wave fault locator (standalone)	No	Available for Few lines	All overhead lines		for Critical hybrid lines

132kV/110kV/100kV TRANSMISSION LINE					
Parameter	**MSETCL**	**Tata**	**AEML**	**Other utility**	**Recommendation**
Main 1	Distance	Diff Cum Distance + OC EF + LBB + Overload LTS + AR	NA		Diff cum distance
Main 2	No	Diff Cum Distance + OC EF + LBB + Overload LTS + AR	NA		
B/U Prot	OC EF on Separate core	Inbuilt in M1 & M2	NA		
DC system	1 source for Main and Back Up	2 Source, for M1 & M2	NA		
Communication	PLCC	All OPGW Parallel redundant path available	NA		
Relay GPS Synchro.	Yes at few locations	Yes , Most of locations	NA		Required
Short Line	PUTT, POTT at few locations	POTT	NA		POTT to be adopted for short lines
Long Line	PUTT	PUTT	NA		
Make of relays for M1 & M2	NA	Different Make for M1 & M2	NA		
Characteristics	Quadrilateral for distance relay	Quadrilateral for Both M1 & M2	NA		
No of Zones	Z1,Z2,Z3 Forward Z4 Reverse (10% of short line or limited 2Km) Stage 1 : 200mS, Trip Bus coupler Stage 2 : 350ms , Trip own breaker	Z1, Z2, Z3 Forward Z4 forward , 51% of load impedance or 1.5 times of Z3 impedance whichever is less , 2sec Z5 reverse , 350 ms	NA		

Parameter	MSETCL	TATA	AEML	Other utility	Recommendation
Other functions					
PSB	Block all except Z1	Block all except Z1	NA		
Load Enchrochment	As per load impedance (Ramkrishana formula)	As per load impedance (Ramkrishana formula)	NA		
VT Supervision	Yes	Yes	NA		
AR	3ph ph, single shot	3 pole Single shot	NA		
Standalone AR	No	Inbuilt in M1 & M2	NA		
Dead time	1 Sec	30 Sec (3phase for hybrid line) 10 Sec single pole overhead lines	NA		
Reclaim time	25 Sec	35 sec 20 Sec	NA		
Dead Line charging, Live line charging, Synchronizing	No	Inbuilt in M1 & M2	NA		
DR	Length : 2 Sec Pre fault : 0.5 Post fault : 1.5 sec As per availability in relay	Length : 2 Sec Pre fault : 0.2 Post fault : 1.8 sec As per availability in relay	NA		
Trip Log	Yes	Yes	NA		
Event Log	Yes	Yes	NA		
BRC	Alarm mode, 5 Sec	Disabled	NA		
Parallel line compensation	No	No	NA		
Travelling Wave fault locator (standalone)	No	Available for Few lines	NA		

ICT & POWER TRANSFORMER (TF)					
Parameter	**MSETCL**	**TPC**	**AEML**	**Other utility**	**Recommendation**
765kV/400kV/220kV/132kV/110kV					
Differential protection	Yes	Yes	Yes		
Slope	2 Slopes	2 Slopes	2 Slopes		
Differential HS	Yes	Yes	Yes		
Overfluxing	Yes, Alarm	Yes, Alarm	Yes, Alarm		
2nd Harmonics Restrain	Yes	Yes	Yes		
5th Harmonics Restrain	Yes	Yes	No		
DR	1 to 2 Sec	2 Sec	0.5 sec		
Back up Protection (HV & LV)	Yes	Yes	Yes		
REF	Yes	Yes	Both HV&LV for transformer		
Buchholz	Yes	Yes	Yes		
WTI	Yes	Yes	Yes		
OTI	Yes	Yes	Yes		
PRV	Yes	Yes	Yes		
OLTC Buchholz	Yes	Yes	Yes		
Sudden PRV	No	Yes	Yes		
Sensitive Earth fault	No	Yes , IDMTL	Yes , DT 1 sec		
Online DGA	Yes for few	Yes for few	Yes for few		
NIFPS	Yes for above 50 MVA	Yes for few	Yes		

LOCAL BREAKER BACKUP (LBB) PROTECTION					
Voltage level	**MSETCL**	**TPC**	**AEML**	**Other utility**	**Recommendation**
765kV/400kV/ 220kV & 110 kV	Standalone	Inbuilt in Main 1 & 2			
	Two Stages Stage I :(Re-Trip) time delay of 100ms to trip own CB Stage II : time delay of 200ms to trip all CBs connected to the respective bus	Only stage II. i.e. No Re trip Time Delay - 150 ms for 220 kV and 200 ms for 110 kV System	Single stage , Time delay = 200 ms		
	Phase segregation feature in LBB used.				
	Built-in LBB feature in BB relay not used.	Built-in LBB in BB not used but as a permissive is taken at many locations	Built-in LBB feature in BB relay not used.		
	Stand alone LBB relay is used.		Single Stage Standalone LBB relay at all Locations (Except few feeders where inbuilt feature is used)		
	Current Setting- 0.8 pu.	Current Pick-up - 0.2 PU	Current Setting- 0.6 pu.		
33 & 22 kV Incomer	NA	Part of Overcurrent Protection	No		

BUS BAR PROTECTION					
Voltage level	**MSETCL**	**TPC**	**AEML**	**Utility**	**Recommendation**
765kV/400kV	Main I (centralized /decentralized) Main II				
220kV & Below	Main	Decentralized at maximum stations, Centralized at Few location where Bays are less	Main 1 & Main-2 (Biased differential) 1) Centralized Busbar at 2 AIS Substations 2) Decentralized busbar at 5 GIS locations 3) Both Centralized and Decentralized busbar at 1 AIS location		
	Diff relay setting: Highest CT ratio	Diff Relay setting - 1 PU	Diff relay setting: 1 p.u.		
	CT Supervision setting- 30 mA, 5 sec	CT Supervision - 100 Amp (Prim), 3.0 Sec	CT Supervision setting- 50 A (Prim), 5 sec		
33 & 22 kV	NA	**MV Feeders**: Reverse blocking scheme for GIS and High Impedance scheme for AIS	Reverse blocking scheme		

SOP FOR TESTING OF EHV, 765KV & 400KV EQUIPMENTS

Sr No	Equipment	Testing Activity	Testing Frequency				Remarks
			MSETCL	Tata	AEML	Other utility	
1	**ICT/ Transformers/ Reactors**	Bushings - C & tan-delta (765kV, 400kV & 220kV)	Yearly	2 Yearly	Yearly		
		Bushings - C & tan-delta (132kV &below)	Yearly	2 Yearly	Yearly		
		Winding - C & tan-delta (765kV, 400kV & 220kV)	2 Yearly	2 Yearly	2 Yearly		
		Winding - C & tan-delta (132kV &below)	2 Yearly	2 Yearly	2 Yearly		
		Winding Resistance Measurement at all tap position	4 Yearly & As and when required	6 Yearly	SOS		
		SFRA	5 Yearly & As and when required	6 Yearly	5 Yearly		
		Winding (With Bushing)- IR / PI	Yearly	2 Yearly	Yearly		
		DGA - ICT & Reactor	Quarterly for first year on commissioning & then subsequently half Yearly	0.5 Yearly	Half yearly		
		DGA - Power TF	Quarterly for first year on commissioning & then subsequently half Yearly	0.5 Yearly	Half yearly		
		Oil Parameter Test	Yearly	0.5 Yearly	Half yearly		
		Excitation Current test @10kV	2 Yearly	6 Yearly	SOS		

Sr No	Equipment	Testing Activity	Testing Frequency				Remarks
			MSETCL	Tata	AEML	Other utility	
1	ICT/ Transformers/ Reactors	Cooling System Trial	Half Yearly	2 Yearly	Yearly		
		Device Auxiliary Protection Trials	Yearly	2 Yearly	Yearly		
		Transformer all low voltage Test		6 Yearly	SOS		
		Furan Analysis	As and when required	SOS	SOS		
		Dielectric Frequency Response (DFR)	2 Yearly	NA	No		
		Tap Changer (OLTC) Continuity Test	2 Yearly	SOS	No		
2	LA	Leakage Current (Third Harmonic Resistive Current) Measurement	Half Yearly (Before & After monsoon)	Half Yearly (Before & After monsoon)	Half Yearly (Before & After monsoon)		
		Insulation Resistance (IR) measurement		SOS	SOS		
		Capacitance & tan-d measurement		NA	No		
3	CT	Capacitance & tan-d of 765kV & 400kV	2 Yearly	NA	NA		
		Capacitance & tan-d of 220kV major/important s/s	Yearly	2 Yearly	2 Yearly		
		Capacitance & tan-d of all other EHV CT (66kV to 220kV)		2 Yearly	NA		

Sr No	Equipment	Testing Activity	Testing Frequency				Remarks
			MSETCL	Tata	AEML	Other utility	
3	**CT**	Insulation Resistance measurement		2 Yearly	SOS		
		DGA & testing of other parameters		SOS	No		
		Ratio test, Knee point measurement		SOS	SOS		
4	**CVT**	Capacitance & tan-d	3 Yearly	2 Yearly	NA		
		Measurement of secondary voltage at C & R Panels	Quarterly	Online Monitoring in SCADA	NA		
5	**PT**	Capacitance & tan-d		2 Yearly	3 Yearly		
		IR Value, Magnetizing Current & Primary Winding Resistance Measurement	During Bus outage	2 Yearly, Magnetizing-SOS	SOS		
6	**Circuit Breaker**	CB operating timing (Main, PIR) of EHV CB	2 Yearly	6 Yearly	2 / 5 Yearly		
		CB operating timing of HV CB	Yearly	6 Yearly	NA		
		Static Contact Resistance Measurement (CRM) of EHV CB	2 Yearly	6 Yearly	2 / 5 Yearly		
		Static Contact Resistance Measurement (CRM) of HV CB	Yearly	6 Yearly	NA		
		Dynamic Contact Resistance Measurement (DCRM) of 765kV & 400kV	During Commissioning & then 2 Yearly	NA	NA		

Sr No	Equipment	Testing Activity	Testing Frequency				Remarks
			MSETCL	Tata	AEML	Other utility	
6	**Circuit Breaker**	Dynamic Contact Resistance Measurement (DCRM) of 220kV Major/important s/s	During Commissioning & then as and when required	SOS	2 / 5 Yearly		
		Dynamic Contact Resistance Measurement (DCRM) of all other EHV s/s	During Commissioning & then as and when required	SOS	NA		
		Capacitance & tan-d measurement of Grading Capacitor		NA	NA		
		Measurement of due point in SF6 gas	2 Yearly	SOS	1 / 5 Yearly		
		Insulation Resistance Measurement of EHV CB	2 Yearly	6 Yearly	SOS		
		Insulation Resistance Measurement of HV CB	2 Yearly	6 Yearly	NA		
		2) Checking of Air Compressor/Hydraulic Pump operation 2) Checking of spring charging motor/ air compressor motor/ hydraulic compressor motor operation timing 3) Checking the pressure switch setting		6 Yearly	Yearly		
		All Electrical/Mechanical Tests Pole, Mechanism, Drive O/H or Replacement)		6 Yearly	SOS		

SOP FOR TESTING OF PROTECTIVE RELAYS & SCHEMES

Sr No	Equipment	Testing Activity	Testing Frequency				Remarks
			MSETCL	Tata	AEML	Other utility	
1	Relay	Bus-bar	1 Year after commissioning & subsequently after 3 Year	2 & 6 Yearly	SOS		1) The test procedure should include thorough functional scheme testing. 2) For Electromechanical & Static relays except bus-bar, yearly testing to be carried out. 2) Detail Testing after configuration change, Protection Trial every 2 year & Detail testing every 6 years.-**M/s Tata**
2		LBB	1 Year after commissioning & subsequently after 3 Year	2 Yearly	Numerical relays - 5years Static Relays-1 year		
3		Distance / Line differential	2 Yearly	2& 6 Yearly	5 yearly		
4		Differential /REF	2 Yearly	2 & 6 Yearly	5 yearly		
5		Backup	2 Yearly	2 & 6 Yearly	5 yearly		
6		Load Trimming Relay (LTS)	Yearly	Yearly	NA		Testing may be skipped in case of correct operation on fault.

Annexure-III

PROTECTION GROUP/COMMITTEE RECOMMENDATIONS ON PROTECTION GUIDELINES

765KV & 400KV TRANSMISSION LINE		
Parameter	**Committee Recommendation**	**Remark**
Main 1 Protection	Differential cum Distance Relay	
Main 2 Protection	Differential cum Distance Relay	
B/U Protection	No	
DC system	2 Nos. DC Source for Main-I & Main-II Protection.	
Communication	OPGW/FOTE + PLCC	
Relay GPS synchronization	Yes	
Short Line	2. As per system requirement POTT can be adopted or 2. POTT for line length less than 5kM.	
Long Line	PUTT	
Make of relays for M1 & M2	Main-I & Mani-II Protection should be of different make.	
Relay Characteristics	Quadrilateral for distance relay	
Nos. of Zones	Z1, Z2, Z3: Forward and Z4: Reverse	
Other Functions:		
Power Swing Blocking (PSB)	Block all except Z1	
Load Encroachment	As per load impedance	Ramakrishana committee recommendation.
VT Supervision	Yes	
Auto Recloser Function (AR)	Single phase, Single shot	
Standalone AR	Standalone AR for Tie CB for one & half CB scheme	
Dead time	1 Sec for Main CB, 1.5 or 2 Sec for Tie CB.	
Reclaim time	25 Sec	
Dead Line charging, Live line charging, Synchronizing	Synchro check required at all locations (Through BCU or M1 , M2)	
Disturbance Recorder (DR)	Total Length: 2 Sec Pre-fault Length: 0.5 Sec Post-fault Length: 1.5 sec	
Trip Log	Yes	
Event Log	Yes	
Broken Conductor Alarm (BCA)	Alarm mode, 5 Sec	
Parallel Line Compensation	Yes	For double circuit lines, special considerations are as per Ramakrishna Committee Report

Travelling Wave fault locator (standalone)	Yes (standalone)	
220KV TRANSMISSION LINE		
Parameter	**Committee Recommendation**	**Remark**
Main 1 Protection	Main 1 distance protection	
Main 2 Protection	Main 2 differential cum distance	1. For all Sub-stations in Mumbai & Mumbai Metropolitan Region (MMR). 2. For other region excluding Mumbai & MMR, Critical/Grid connected sub-station.
B/U Protection	Inbuilt in M1 & M2 or standalone	
DC system	Double source philosophy may be adopted for Critical /Grid substation.	
Communication	OPGW/FOTE + PLCC	
Relay GPS synchronization	Yes	
Short Line	POTT may be adopted	
Long Line	PUTT	
Make of relays for M1 & M2	Main-I & Mani-II Protection should be of different make	
Relay Characteristics	Quadrilateral for distance relay	
Nos. of Zones	Z1,Z2,Z3 Forward, Z4 Reverse	
Other Functions:		
Power Swing Blocking (PSB)	Block all except Z1	
Load Encroachment	As per load impedance	RK committee recommendation.
VT Supervision	Yes	
Auto Recloser Function (AR)	1. Single ph, single shot for overhead lines at both ends. 2. For hybrid lines, Single ph, Single shot at Overhead end only.	
Standalone AR	Inbuilt in M1 or M2 or Standalone Relay	
Dead time	1 sec	
Reclaim time	25 Sec	
Dead Line charging, Live line charging, Synchronizing	Synchro check required at strategic locations (Through BCU or M1 , M2)	
Disturbance Recorder (DR)	Total Length: 2 Sec Pre-fault Length: 0.5 Sec Post-fault Length: 1.5 sec	
Trip Log	Yes	
Event Log	Yes	
Broken Conductor Alarm (BCA)	Alarm mode, 5 Sec	
Parallel Line Compensation	No	

Travelling Wave fault locator (standalone)	For Critical hybrid lines	
132KV/110KV/100KV TRANSMISSION LINE		
Parameter	**Committee Recommendation**	**Remark**
Main 1 Protection	Main 1 distance protection	
Main 2 Protection	Main 2 differential cum distance	Differential cum distance relay for critical/grid lines or short lines having OPGW.
B/U Protection	BU OC & EF	Standalone (on Separate core)
DC system	Double source philosophy may be adopted for Critical /Grid substation.	
Communication	PLCC or PLCC + FOTE	
Relay GPS synchronization	Yes	
Short Line	POTT to be adopted for short lines	
Long Line	PUTT	
Make of relays for M1 & M2	Main-I & Mani-II Protection should be of different make	
Relay Characteristics	Quadrilateral for distance relay	
Nos. of Zones	Z1,Z2,Z3 Forward Z4 Reverse	
Other Functions:		
Power Swing Blocking (PSB)	Block all except Z1	
Load Encroachment	As per load impedance	Ramakrishana committee recommendation.
VT Supervision	Yes	
Auto Recloser Function (AR)	3-phase, single shot	
Standalone AR	Inbuilt in M1 or M2 or Standalone Relay	
Dead time	1 sec	
Reclaim time	25 Sec	
Dead Line charging, Live line charging, Synchronizing	No	
Disturbance Recorder (DR)	Total Length: 2 Sec Pre-fault Length: 0.5 Sec Post-fault Length: 1.5 sec	
Trip Log	Yes	
Event Log	Yes	
Broken Conductor Alarm (BCA)	Alarm mode, 5 Sec	
Parallel Line Compensation	No	
Travelling Wave fault locator (standalone)	No	
ICT & POWER TRANSFORMER (TF)		
Parameter	**Committee Recommendation**	**Remark**
Differential protection	Yes	
Slope	2 Slopes	
Differential HS	Yes	

Overfluxing	Yes, Alarm	
2nd Harmonics Restrain	Yes	
5th Harmonics Restrain	Yes	
DR	1 to 2 Sec	
Back up Protection (HV & LV)	Yes	
REF	Yes	
Buchholz	Yes	
WTI	Yes	
OTI	Yes	
PRV	Yes	
OLTC Buchholz	Yes	
Sudden PRV	Yes	
Sensitive Earth fault	No	
Online DGA	No	
NIFPS	Yes for above 50 MVA capacity	
LOCAL BREAKER BACKUP (LBB) PROTECTION		
Voltage Level	**Committee Recommendation**	**Remark**
765kV, 400kV, 220kV, 132kV, 110kV & 100 kV	Standalone	
	Two stage: Stage I :(Re-Trip) time delay of 100ms to trip own CB Stage II : time delay of 200ms to trip all CBs connected to the respective bus	
	Phase segregation feature in LBB used.	
	Built-in LBB feature in BB relay not used.	
	Stand alone LBB relay is used.	
	Current Setting- 0.8 pu.	
33 & 22 kV Incomer	No	
BUS BAR (BB) PROTECTION		
Voltage Level	**Committee Recommendation**	**Remark**
765kV & 400kV	Main I &Main II (centralized /decentralized)	
220kV & below	Main (centralized /decentralized)	
	Diff. relay setting: Highest CT ratio	
	CT Supervision setting- 30 mA (sec), 5 sec	
33 & 22 kV Incomer	No	

SOP FOR TESTING OF EHV & 765KV/400KV EQUIPMENTS				
Sr. No.	**Eqipments**	**Testing Activity**	**Committee Recommendation (Test Frequency)**	**Remark**
1.	**ICT / Transformers/ Reactors**	Bushings - C & tan-delta (765kV, 400kV & 220kV)	Yearly	
		Bushings - C & tan-delta (132kV &below)	Yearly	
		Winding - C & tan-delta (765kV, 400kV & 220kV)	2 Yearly	
		Winding - C & tan-delta (132kV &below)	2 Yearly	
		Winding Resistance Measurement at all tap position	4 Yearly & As and when required	
		SFRA	5 Yearly & As and when required	
		Winding (With Bushing)-IR / PI	Yearly	
		DGA - ICT & Reactor	Quarterly for first year on commissioning & then subsequently half Yearly	
		DGA - Power TF	Quarterly for first year on commissioning & then subsequently half Yearly	
		Oil Parameter Test	Yearly	
		Excitation Current test @10kV	2 Yearly	
		Cooling System Trial	Half Yearly	
		Device Auxiliary Protection Trials	Yearly	
		Transformer all low voltage Test	As and when required	
		Furan Analysis	As and when required	
		Dielectric Frequency Response (DFR)	2 Yearly	
		Tap Changer (OLTC) Continuity Test	2 Yearly	
2.	**LA**	Leakage Current (Third Harmonic Resistive Current) Measurement	Half Yearly (Before & After monsoon)	
		Insulation Resistance (IR) measurement	As and when required	
		Capacitance & tan-d measurement	As and when required	

Sr. No.	Equipments	Testing Activity	Committee Recommendation (Test Frequency)	Remark
3.	**CT**	Capacitance & tan-d of 765kV/400kV	2 Yearly	
		Capacitance & tan-d of 220kV major/important s/s	Yearly	
		Capacitance & tan-d of all other EHV CT (66kV to 220kV)	2 Yearly	
		Insulation Resistance measurement	2 Yearly	
		DGA & testing of other parameters	As and when required	
		Ratio test, Knee point measurement	As and when required	
4.	**CVT**	Capacitance & tan-d	3 Yearly	
		Measurement of secondary voltage at C & R Panels	1. Quarterly or 2. Online Monitoring in SCADA	
5.	**PT**	Capacitance & tan-d	3 Yearly	
		IR Value, Magnetizing Current & Primary Winding Resistance Measurement	During Bus outage	
6.	**Circuit Breaker (CB)**	CB operating timing (Main, PIR) of EHV CB	2 Yearly	
		CB operating timing of HV CB	Yearly	
		Static Contact Resistance Measurement (CRM) of EHV CB	2 Yearly	
		Static Contact Resistance Measurement (CRM) of HV CB	Yearly	
		Dynamic Contact Resistance Measurement (DCRM) of 765kV/400kV	During Commissioning & then 2 Yearly	
		Dynamic Contact Resistance Measurement (DCRM) of 220kV Major/important s/s	During Commissioning & then as and when required	
		Dynamic Contact Resistance Measurement (DCRM) of all other EHV s/s	During Commissioning & then as and when required	
		Capacitance & tan-d measurement of Grading Capacitor	2 Yearly	

Sr. No.	Equipments	Testing Activity	Committee Recommendation (Test Frequency)	Remark
		Measurement of due point in SF6 gas	2 Yearly	
		Insulation Resistance Measurement of EHV CB	2 Yearly	
		Insulation Resistance Measurement of HV CB	2 Yearly	
		1) Checking of Air Compressor/Hydraulic Pump operation 2) Checking of spring charging motor/ air compressor motor/ hydraulic compressor motor operation timing 3) Checking the pressure switch setting	Yearly	
		All Electrical / Mechanical Tests (Pole, Mechanism, Drive O/H or Replacement)	As and when required	

SOP FOR PROTECTIVE RELAYS & SCHEMES TESTING

Sr. No.	Equipments	Testing Activity	Committee Recommendation (Test Frequency)	Remark
1.	**Relays**	Bus-bar	1 Year after commissioning & subsequently after 3 Year	2) The test procedure should include thorough functional scheme testing. 3) For Electromechanical & Static relays except bus-bar, yearly testing to be carried out. 3) Detail Testing after configuration change.
		LBB	1 Year after commissioning & subsequently after 3 Year	
		Distance / Line differential	2 Yearly	
		Differential /REF	2 Yearly	
		Backup	2 Yearly	
		Load Trimming Relay (LTS)	Yearly	Testing may be skipped in case of correct operation on fault.
		UFR & FTR	Yearly	
		Islanding Scheme	Yearly	
		Over voltage, NDR & Overfluxing	Yearly	

OFFICE COMMUNICATION

MAHARASHTRA STATE LOAD DESPATCH CENTER

CIN NO. U40109MH2005SGC153646

Office of The Executive Director
Office Address: Thane-Belapur Road, P.O. Airoli, Navi Mumbai Pin – 400 708.
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Ref: MSLDC/TECH/OP/GCC-HLC/ № 0 1 6 0 7 **Date:26.07.2021**

To,
The Chief Engineer (ACI&P) &
Chairman of the Protection Co-ordination Committee,
Corporate Office, MSETCL,
Bandra (E), Mumbai.

Sub: Implementation of the Recommendations issued by the High-Level Committee (HLC) Constituted by Hon'ble MERC for study of Grid Occurrence dated 12.10.2020__***Review of Protection Philosophy in the State***

Ref: 1. MERC Order and notification dated 28 May 2021 in Case No. 202 of 2020.
2. Meeting held by the Director (Operations) on 07.06.2021.

In reference to the above subject, it is to inform that Hon'ble MERC vide Order cited under ref (1) has directed all the Stakeholders in the State to implement various recommendations of the High-Level Committee (HLC) within prescribed timelines. Further, a Monitoring Committee has been constituted by Hon'ble MERC for regular review of these recommendations.

A review meeting was convened by the Director (Operations) ,MSETCL on 06.07.2021 in which discussions on various recommendations to be carried out by MSETCL & MSLDC were held. A detailed discussion on the recommendation viz , "**Revision of Protection philosophy of EHV lines, review of tripping logic of EHV lines, and revised relay settings**" which is to be implemented by the STU in coordination with GCC, PCC, MSLDC and WRPC within 6 months has also taken up.

Based on the above discussions as directed by the Chairman of the GCC, it is requested to take up through Protection Co-ordination Committee (PCC) the necessary steps to carry out *revision of Protection philosophy of EHV lines, review of tripping logic of EHV lines, and revised relay settings* and submit its report to GCC core Group for approval within specified timelines as mentioned above.

It is further requested to strictly adhere to the timelines as the progress of the implementation of the recommendations is being reviewed by the Monitoring Committee constituted by Hon'ble MERC.

Submitted for further needful please.

(Shrikant Jaltare)
Executive Director (MSLDC) & Member Secretary of GCC

Copy s.w.r.s. to:

- The Director (Operations), MSETCL, Prakashganga, Mumbai.

Copy f.w.c. to:

- The Executive Director (Trans O&M), MSETCL, Prakashganga, Mumbai

CE (STU) MSETCL

STATE TRANSMISSION UTILITY

No. O-1005
Date 23/11/2022

MSETCL/CO/STU/MEGC/

OFFICE NOTE

Sub: Implementation of Maharashtra State Grid Code 2020 – Preparation of Guidelines / Procedures thereof.

Ref: 1) MERC Notification of Maharashtra Electricity Grid Code 2020 (MEGC) dtd. 02.09.2020
2) MSETCL/CO/STU/Sys/SGC/1411 dtd. 28.02.2022
3) MSETCL/CO/STU/MERC/5395 dtd. 21.07.2022

****

In context to above subject, STU/SLDC is the nodal agency for Implementation of Maharashtra State Grid Code 2020. Hon. MERC in the MEGC, 2020 has entrusted responsibilities on various entities viz. STU, MSLDC, Transmission/Distribution licensees/ users etc. for development of various procedures/guidelines/manuals. In this regard, STU as per letter under ref. (2) has requested ACI&P to formulate the procedures/guidelines/manuals. Further as per letter under ref. (3), it was directed by Hon. Director (Operations) to prepare procedures/guidelines/manuals for the following activities in accordance with Maharashtra State Grid Code 2020.

Sr. No	Details of Procedure / Guidelines / Codes / Plans	Ref. Regulation
1	Protection Manual	66.7

As per Maharashtra State Grid Code 2020, these activities has to be completed within given timeline which is already exhausted. State Transmission Utility (STU) under Regulation 102 of MERC (State Grid Code) Regulations, 2020 filed petition seeking relaxation of timelines for completion of remaining activities under MEGC-2020. Hon. Commission has allowed time till December 2022 for submission of the balance activities including above. As such it is requested to forward the final document to this office duly approved by GCC on or before 15.12.2022.

In case of failure to submit the protection manual to Hon. Commission within extended timeline, the act may be seen as a breach of its order by Hon. Commission.

CE (STU)

Sub: Implementation of Maharashtra State Grid Code 2020 – Preparation of Guidelines Procedures thereof.

Hence it is requested to adhere to the timeline of Hon. Commission & do needful for completion & submission of the above activities by 15.12.2022.

Please treat this as **Most-Urgent.**

Chief Engineer
(Stat Transmission Utility)

Chief Engineer (ACI&P)

Copy s. w. rs. to:
1) The Director(Operations), CO, MSETCL, Mumbai

E-mail : ceaci@mahatransco.in

Tel. No: 022-27600405

MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.

Web: http://www.mahatransco.in

CIN 40109MH2005SGC153646

Office of the

Chief Engineer (ACI&P),

Old Load Despatch centre Building, Thane Belapur Road, Airoli Sector-1, Navi- Mumbai – 400708

MSETCL/CO/CE (ACI&P)/ 07 93 **Date:** 20 DEC 2021

To,
As per mailing list

Sub: Request for nomination of representative for preparation of Protection Manual as per MEGC 2020.

Ref: 1) T. O. L. No.MSETCL/CO/CE (ACI&P)/GCC/456 dtd 28.06.2021

2) MERC Notification of Maharashtra Electricity Grid Code 2020 (MEGC) dt.02.09.20

Dear Sir,

In context to the above subject, the Grid Co-ordination Committee (GCC) has been formed vide letter no. MSETCL/CO/STU/MEGC/2020/SLDC/05341 Dtd.11.12.2020. Accordingly, the Protection Coordination Committee (PCC) is formed vide this office letter under ref. (1)

As per Maharashtra Electricity Grid Code 2020, pt. No. 66.7 protection manual is to be prepared by STU in consultation with PCC. Hence nomination of one expert engineer in the domain of protection is requested for the group to prepare protection manual.

It is requested to nominate suitable representative from your organization as per the enclosed format by 25 Dec 2021.

(Shashank S. Jewalikar)
Chief Engineer (ACI&P)
(Chairman Protection Coordination Committee)

Copy s. w. r. s. to:

The Director (Operations), CO, MSETCL, Mumbai.

Copy s. w. c. to:

1. The Chief Engineer (STU), MSETCL, Mumbai.
2. The Chief Engineer (O&M) MSETCL, Mumbai.
3. The Chief Engineer (MSLDC), Airoli, Navi Mumbai.

CE (STU) MSETCL

Nomination format for Protection Manual.

Sr. No.	Name of Organisation	Name & Designation of Nominee	Contact No.	E-mail id
1	MSETCL			
2	State Transmission Utility (STU)			
3	SLDC, Airoli			
4	Maharashtra State Power Generation Co. Ltd.			
5	M/s AEML, Ahmadabad			
6	M/s AEML - Transmission, Mumbai			
7	M/s Tata Power Co. Ltd.- Mumbai - Transmission			

E-mail : ceaci@mahatransco.in
Tel. No: 022-27600405

MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.
Web: http://www.mahatransco.in
CIN 40109MH2005SGC153646

Office of the
Chief Engineer (ACI&P),
Old Load Despatch centre Building, Thane Belapur Road, Airoli Sector-1. Navi- Mumbai – 400708

MSETCL/CO/CE (ACI&P)/GCC/PCC/ 0087 **Date:** 23 FEB 2022

To,

The Director (Operations)

Maharashtra State Electricity Transmission Company Ltd.,

Chair person of GCC

CO, Mumbai.

SUB: Implementation of recommendation issued by the HLC Committee constituted by Hon`ble MERC for study of Grid occurrence dtd. 12.10.2020 - **Formation of Protection Group to review protection philosophy in the state & preparation of protection manual.**

REF: 1. MERC HLC Report dtd. 15.02.2021.
2. MERC order & notification dtd. 28.05.2021 in case no. 202 of 2020.
3. MSLDC/TECH/OP/GCC - HLC/No. 01607 dtd. 26.07.2021.
4. MERC Notification of Maharashtra Electricity Grid Code (MEGC) 2020 dtd. 02.09.2020.
5. T. O. L. No. MSETCL/CO/CE (ACI&P)/793 dtd. 20.12.2021.

Dear sir,

In pursuance of MERC Order dated 22nd October, 2020 in Case No. 202 of 2020, the High Level Committee was constituted for Enquiry into MMR Grid disturbance on dtd. 12.10.2021. Further Hon. MERC vide order dtd. 28.05.2021 under ref. (2), has directed all the stakeholders in the state to implement the various recommendations of the HLC within prescribed time lines.

As per the HLC committee `the Protection Co-ordination Committee (PCC) under the aegis of GCC has to review the protection philosophy & relay co-ordination setting on distance protection & over-current and suggest the revision in the relay settings in consultation with

Regd. Office: "Prakeshganga", Plot No.C-19, "E" Block, Bandra – Kurla Complex Bandra (E), Mumbai. 400 051

CE (STU)

WRPC protection committee'. A detailed action plan and changes in the protection philosophy may be taken up by STU and Transmissions Licensees in consultation with GCC.

Further Executive Director (MSLDC) & Member secretary of GCC vide letter under ref. (3) informed to take necessary step to carry out revision of the protection philosophy, review of tripping logic & relay co-ordination setting on distance protection & over-current by PCC and submit its reports to GCC core group for approval within specified time line i.e. within 6 months.

Also as per Maharashtra Electricity Grid Code (MEGC) 2020 pt. No. 66.7, protection manual is to be prepared by STU in consultation with PCC.

Accordingly this office vide letter under ref. (5) requested to nominate one expert engineer in the domain of protection for group to prepare protection manual.

Considering the nomination received from various organization, the Protection Group/committee has been formed to review protection philosophy & preparation of protection manual consisting of the members as per enclosed Annexure. The Group will review the protection practices and prepare protection manual.

Submitted for information please.

(Shashank S. Jewalikar)

Chief Engineer (ACI&P) & Chairperson of PCC

Copy s. w. r. to:

The Executive Director (MSLDC), Airoli, Navi-Mumbai.

Copy s. w. c. to:

1. The Chief Engineer (STU), MSETCL, Mumbai.
2. The Chief Engineer (O&M) MSETCL, Mumbai.
3. The Chief Engineer (MSLDC), Airoli, Navi Mumbai.
4. The Chief Engineer PC EHV O&M Zone, Aurangabad/Nashik/Pune.

CC to:

1. All PCC Members as per list
2. All Protection Group Members as per list (Annexure) - The group to review the protection philosophy and practices and prepare protection manual & submit the same to PCC by 15th April 2022.

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Regd. Office: "Prakeshganga", Plot No.C-19, "E" Block, Bandra – Kurla Complex Bandra (E), Mumbai. 400 051

Annexure: List of Protection Group Members

Sr. No.	Name of Organization	Name & Designation of Nominee	Contact No.	E-mail id
1	MSETCL	Shri. Jayant Kulkarni, Superintending Engineer TCC, Pune	9892718431	se6500@mahatransco.in
		Shri. Deepak Patil, Executive Engineer Testing, Nashik	8554005019	ee5140@mahatransco.in
		Shri. M. B. Dhore, Executive Engineer Testing, Kalwa	9930496209	ee7150@mahatransco.in
		Shri. Girish Malode, Executive Engineer, Telecom, Kalwa	9767103581	ee7270@mahatransco.in
2	SLDC, Airoli	Shri M. B. Pande, Executive Engineer (Operation)	9833608212	madhavbpande@gmail.com
3	Maharashtra State Power Generation Co. Ltd.	Shri. Girish Dhok, Executive Engineer	8408888664	gsdhok@rediffmail.com
4	M/s AEML - Transmission, Mumbai	Abhijeet Gore, Dy. General Manager	9324050031	abhijeet.gore@adani.com
5	M/s Tata Power Co. Ltd.- Mumbai - Transmission	Girish Tukaram Jawale, Group Head (Protection & System Studies)	922331419	gtjawale@tatapower.com

Task Assigned to Protection Group:

1. To Review the Protection Philosophy & Practices.
2. To Review the SOP for Preventive maintenance Practices & Testing Activities for relaying.
3. To Prepare Protection Manual.

Regd. Office: "Prakeshganga", Plot No.C-19, "E" Block, Bandra – Kurla Complex Bandra (E), Mumbai. 400 051

MAHARASHTRA STATE ELECTRICITY TRANSMISSION CO. LTD.

E-mail : ceaci@mahatransco.in
Tel.No: 022-27600405

MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.
Web: http://www.mahatransco.in
CIN 40109MH2005SGC153646

Office of the
Chief Engineer (ACI&P).
Old Load Despatch centre Building, Thane Belapur Road, Airoli Sector-1. Navi- Mumbai – 400708

MSETCL/CO/CE (ACI&P)/GCC/PCC/PGM/ 0145 **Date:** 22 MAR 2022

To,
The Protection Group Members.

Sub : 1st Meeting of Group Members to review the protection philosophy and preparation of protection manual

Ref : T.O.L No MSETCL/CO/CE(ACI&P)/GCC/PCC/0087dtd.23.02.2022

Dear Sir,

In context to the above subject, the protection group has been formed to review the protection philosophy and preparation of protection manual vide letter under ref (1). The 1st meeting of Protection group meeting is convened on 24.03.2022 at 11.00 Hrs. The venue for the meeting is " Office of the Chief Engineer (ACI&P) ,Old Load Despatch centre Building, Thane Belapur Road, Airoli Sector-1. Navi- Mumbai.

All Protection group members are to requested attend the meeting.

(Shashank Jewalikar)
Chief Engineer (ACI&P) & Chairman of PCC

Copy to :

All Protection Group Members as per list

CE (STU) MSETCL

List of Protection Group Members

Sr. No.	Name of Organization	Name & Designation of Nominee	Contact No.	E-mail id
1	MSETCL	Shri. Jayant Kulkarni, Superintending Engineer TCC, Pune	9892718431	se6500@mahatransco.in
		Shri. Deepak Patil, Executive Engineer Testing, Nashik	8554005019	ee5140@mahatransco.in
		Shri. M. B. Dhore, Executive Engineer Testing, Kalwa	9930496209	ee7150@mahatransco.in
		Shri. Girish Malode, Executive Engineer, Telecom, Kalwa	9767103581	ee7270@mahatransco.in
2	SLDC, Airoli	Shri M. B. Pande, Executive Engineer (Operation)	9833608212	madhavbpande@gmail.com
3	Maharashtra State Power Generation Co. Ltd.	Shri. Girish Dhok, Executive Engineer	8408888664	gsdhok@rediffmail.com
4	M/s AEML - Transmission, Mumbai	Abhijeet Gore, Dy. General Manager	9324050031	abhijeet.gore@adani.com
5	M/s Tata Power Co. Ltd.- Mumbai - Transmission	Girish Tukaram Jawale, Group Head (Protection & System Studies)	922331419	gtjawale@tatapower.com

CE (STU)

Protection Group Meeting _Review of protection Philosophy

Vilas Borle <ee1tel@mahatransco.in>

Fri 25-03-2022 15:36

To: Jayant Kulkarni <se6500@mahatransco.in>;Deepak Patil <ee5150@mahatransco.in>;Moreshwar Dhore <EE7150@mahatransco.in>;Kiran Shimpi <EE7270@mahatransco.in>;madhavbpande@gmail.com <madhavbpande@gmail.com>;gsdhok@rediffmail.com <gsdhok@rediffmail.com>;abhijeet.gore@adani.com <abhijeet.gore@adani.com>;gtjawale@tatapower.com <gtjawale@tatapower.com>
Cc: Anil Jaware <dyeeaci1@mahatransco.in>

1 attachments (38 KB)
Protection philosophy XLS Worksheet.xls;

Dear Sir,
The excel sheet prepared during the meeting 24.03.2022 is attached herewith. The LBB and Busbar sheet added in same. It is requested to fill the sheet & add points if any

With Regards,

Dilip S. Lende
Executive Engineer,
ACI&P, MSETCL,
C.O., NAVI-MUMBAI
Mob. No. 8554993474

RE: Protection Group Meeting _Review of protection Philosophy

Jawale Girish <gtjawale@tatapower.com>

Tue 4/5/2022 9:06 PM

To: Dilip Lende <ee1tel@mahatransco.in>

Cc: Anil Jaware <dyeeaci1@mahatransco.in>;Jayant Kulkarni <se6500@mahatransco.in>;Moreshwar Dhore <EE7150@mahatransco.in>;Girish Malode <EE7270@mahatransco.in>;gsdhok@rediffmail.com <gsdhok@rediffmail.com>;Deepak Patil <ee5150@mahatransco.in>;madhavbpande@gmail.com <madhavbpande@gmail.com>;ABHIJEET GORE <Abhijeet.Gore@adani.com>

Dear Sir,

Details of Tata Power is updated in the attached file

Regards,
Girish Tukaram Jawale
Group Head (Protection & System Studies)
The Tata Power Company Limited, Dharavi Receiving Station, Near Shalimar Industrial Estate, Matunga, Mumbai 400 019, Maharashtra, India
Tel: 3256 Mobile: 9223311419

From: ABHIJEET GORE <Abhijeet.Gore@adani.com>
Sent: 05 April 2022 17:32
To: Dilip Lende <ee1tel@mahatransco.in>
Cc: Anil Jaware <dyeeaci1@mahatransco.in>; Jayant Kulkarni <se6500@mahatransco.in>; Moreshwar Dhore <EE7150@mahatransco.in>; Girish Malode <EE7270@mahatransco.in>; gsdhok@rediffmail.com; Jawale Girish <gtjawale@tatapower.com>; Deepak Patil <ee5150@mahatransco.in>; madhavbpande@gmail.com
Subject: RE: Protection Group Meeting _Review of protection Philosophy

[EXTERNAL sender, Exercise caution..!]

Sir,

PFA file with AEML details updated.

Thanks & Regards,

Abhijeet D. Gore
Dy. General Manager, Protection / Metering / SAS - Transmission
Adani Electricity Mumbai Limited

4th Floor, 220kV Goregaon EHV Sub Station, Opp. Sahara India, S.V. Road, Goregaon(W), Mumbai-400062
Mobile: +91 93240 50031 | www.adanielectricity.com

RE: Protection Group Meeting _Review of protection Philosophy

ABHIJEET GORE <Abhijeet.Gore@adani.com>
Tue 4/5/2022 5:31 PM

To: Vilas Borle <ee1tel@mahatransco.in>

Cc: Anil Jaware <dyeeaci1@mahatransco.in>;Jayant Kulkarni <se6500@mahatransco.in>;Moreshwar Dhore <EE7150@mahatransco.in>;Kiran Shimpi <EE7270@mahatransco.in>;gsdhok@rediffmail.com <gsdhok@rediffmail.com>;gtjawale@tatapower.com <gtjawale@tatapower.com>;Deepak Patil <ee5150@mahatransco.in>;madhavbpande@gmail.com <madhavbpande@gmail.com>

1 attachments (37 KB)
Protection philosophy XLS Worksheet.xls;

Sir,

PFA file with AEML details updated.

Thanks & Regards,

Abhijeet D. Gore
Dy. General Manager, Protection / Metering / SAS - Transmission
Adani Electricity Mumbai Limited

4th Floor, 220kV Goregaon EHV Sub Station, Opp. Sahara India, S.V. Road, Goregaon(W), Mumbai-400062
Mobile: +91 93240 50031 | www.adanielectricity.com

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From: Jayant Kulkarni <se6500@mahatransco.in>
Sent: Tuesday, 05 April, 2022 4:46 PM
To: Dilip Lende <ee1tel@mahatransco.in>; Deepak Patil <ee5150@mahatransco.in>; Moreshwar Dhore <EE7150@mahatransco.in>; Girish Malode <EE7270@mahatransco.in>; madhavbpande@gmail.com; gsdhok@rediffmail.com; ABHIJEET GORE <Abhijeet.Gore@adani.com>; gtjawale@tatapower.com
Cc: Anil Jaware <dyeeaci1@mahatransco.in>
Subject: Re: Protection Group Meeting _Review of protection Philosophy

Thanks & Regards,
The Superintending Engineer,
Testing & Comm Circle,
MSETCL, Pune

From: Dilip Lende <ee1tel@mahatransco.in>
Sent: 25 March 2022 15:36

To: Jayant Kulkarni <se6500@mahatransco.in>; Deepak Patil <ee5150@mahatransco.in>; Moreshwar Dhore <EE7150@mahatransco.in>; Girish Malode <EE7270@mahatransco.in>; madhavbpande@gmail.com <madhavbpande@gmail.com>; gsdhok@rediffmail.com <gsdhok@rediffmail.com>; abhijeet.gore@adani.com <abhijeet.gore@adani.com>; gtjawale@tatapower.com <gtjawale@tatapower.com>
Cc: Anil Jaware <dyeeaci1@mahatransco.in>
Subject: Protection Group Meeting _Review of protection Philosophy

Dear Sir,
The excel sheet prepared during the meeting 24.03.2022 is attached herewith. The LBB and Busbar sheet added in same. It is requested to fill the sheet & add points if any

With Regards,

Dilip S. Lende

Executive Engineer,

ACI&P, MSETCL,

C.O., NAVI-MUMBAI

Mob. No. 8554993474

Meeting for finalization of protection manual

Shashank Jewalikar <ceaci@mahatransco.in>

Tue 10/11/2022 9:00 PM

To: Madhav Pande <EE1SLDCOP8000@mahatransco.in>;Deepak Patil <ee5150@mahatransco.in>;Moreshwar Dhore (Charge) <SE7500@mahatransco.in>;Jayant Kulkarni <se6500@mahatransco.in>;Moreshwar Dhore <EE7150@mahatransco.in>;Kiran Shimpi <EE7270@mahatransco.in>;gsdhok@rediffmail.com <gsdhok@rediffmail.com>;abhijeet.gore@adani.com <abhijeet.gore@adani.com>;gtjawale@tatapower.com <gtjawale@tatapower.com>

Cc: Vilas Borle <ee1tel@mahatransco.in>;Dilip Nandanwar <adee1protection@mahatransco.in>;Anil Jaware <dyeeaci1@mahatransco.in>;Rahul Ingle <aeaci5@mahatransco.in>

Dear Sir,

The scheduled meeting for finalization of protection manual on 07.10.2022 had been canceled due to unavoidable circumstances. The meeting is rescheduled on 12.10.2022 at 15.00Hrs. The link for the meeting will be sent separately.

Shashank Jewalikar
Chief Engineer (ACI&P)
Maharashtra State Electricity Transmission Co. Ltd.
C.O. Mumbai

Fw: Draft of Protection Manual for finalization

Shashank Jewalikar <ceaci@mahatransco.in>

Mon 11/7/2022 4:05 PM

To: Juelee Wagh(Charge) <CEOM@mahatransco.in>;Sanjeev Bhole <CESTU@mahatransco.in>;JUELEE WAGH <CESLDC@mahatransco.in>;DyCETesting KORADI <dycetestingkoradi@gmail.com>;Ashish Baviskar <ashish.baviskar@adani.com>;MOHAN WAINGANKAR <mohan.waingankar@adani.com>;KAILAS NERKAR <kailas.nerkar@adani.com>;Jawale Girish <gtjawale@tatapower.com>;kalyan.p@saiwardha.com <kalyan.p@saiwardha.com>;Amit Shioram Panchalwar <amit.panchalwar@rattanindia.com>;Ajay Khandelwal <ajay.Khandelwal@jsw.in>;Sanjeev Bhole <CESTU@mahatransco.in>

Cc: Madhav Pande <EE1SLDCOP8000@mahatransco.in>;Deepak Patil <ee5150@mahatransco.in>;Moreshwar Dhore (Charge) <SE7500@mahatransco.in>;Jayant Kulkarni <se6500@mahatransco.in>;Moreshwar Dhore <EE7150@mahatransco.in>;Kiran Shimpi <EE7270@mahatransco.in>;gsdhok@rediffmail.com <gsdhok@rediffmail.com>;abhijeet.gore@adani.com <abhijeet.gore@adani.com>;Jawale Girish <gtjawale@tatapower.com>;Vilas Borle <ee1tel@mahatransco.in>;Dilip Nandanwar <adee1protection@mahatransco.in>;Anil Jaware <dyeeaci1@mahatransco.in>

Dear Sir,
The draft Protection manual was discussed in detail during PCC meeting dtd 20.10.2020. During the meeting, It was decided to finalize the draft of Protection Manual after perusal of the PCC members. It is requested to go through the attached draft and submit comments if any.

Regards.

Shashank Jewalikar
Chief Engineer, ACI&P, Airoli,
Corporate Office, MSETCL,
Mumbai.

CE (STU)

Fw: Draft of Protection Manual for finalization

Shashank Jewalikar <ceaci@mahatransco.in>
Tue 11/15/2022 3:36 PM
To: Vilas Borle <ee1tel@mahatransco.in>;Dilip Nandanwar <adee1protection@mahatransco.in>;Anil Jaware <dyeeaci1@mahatransco.in>

Regards.

Shashank Jewalikar
Chief Engineer, ACI&P, Airoli,
Corporate Office, MSETCL,
Mumbai.

From: MOHAN WAINGANKAR <Mohan.Waingankar@adani.com>
Sent: 10 November 2022 10:18
To: Shashank Jewalikar <ceaci@mahatransco.in>
Cc: ABHIJEET GORE <Abhijeet.Gore@adani.com>; SURESH PATIL <Suresh.Patil@adani.com>; GANESH E PATIL <Ganesh.E.Patil@adani.com>; Dilip Nandanwar <adee1protection@mahatransco.in>
Subject: RE: Draft of Protection Manual for finalization

Sir,

- Minor changes / corrections are highlighted in attached files.

Thanks & Regards,

Mohan R Waingankar
Testing & Protection (T&D)
Adani Electricity Mumbai Limited

CTS 407/A (New), 408(Old), Village Eksar, Devidas Lane, Off. SVP Road, Borivali (West), Mumbai-400103
Mobile: +9324216664 | Direct Line: 50548303 | Extn:48303 | www.adanielectricity.com

From: Shashank Jewalikar <ceaci@mahatransco.in>
Sent: Monday, 07 November, 2022 4:05 PM
To: Juelee Wagh(Charge) <CEOM@mahatransco.in>; Sanjeev Bhole <CESTU@mahatransco.in>; JUELEE WAGH <CESLDC@mahatransco.in>; DyCETesting KORADI <dycetestingkoradi@gmail.com>; Ashish Baviskar <Ashish.Baviskar@adani.com>; MOHAN WAINGANKAR <Mohan.Waingankar@adani.com>; KAILAS NERKAR <Kailas.Nerkar@adani.com>; Jawale Girish <gtjawale@tatapower.com>; kalyan.p@saiwardha.com; Amit Shioram Panchalwar <amit.panchalwar@rattanindia.com>; Ajay Khandelwal <ajay.Khandelwal@jsw.in>; Sanjeev Bhole <CESTU@mahatransco.in>

Cc: Madhav Pande <EE1SLDCOP8000@mahatransco.in>; Deepak Patil <ee5150@mahatransco.in>; Moreshwar Dhore (Charge) <SE7500@mahatransco.in>; Jayant Kulkarni <se6500@mahatransco.in>; Moreshwar Dhore <EE7150@mahatransco.in>; Kiran Shimpi <EE7270@mahatransco.in>; gsdhok@rediffmail.com; ABHIJEET GORE <Abhijeet.Gore@adani.com>; Jawale Girish <gtjawale@tatapower.com>; Vilas Borle <ee1tel@mahatransco.in>; Dilip Nandanwar <adee1protection@mahatransco.in>; Anil Jaware <dyeeaci1@mahatransco.in>
Subject: Fw: Draft of Protection Manual for finalization

Dear Sir,
The draft Protection manual was discussed in detail during PCC meeting dtd 20.10.2020. During the meeting, It was decided to finalize the draft of Protection Manual after perusal of the PCC members. It is requested to go through the attached draft and submit comments if any.

Regards.

Shashank Jewalikar
Chief Engineer, ACI&P, Airoli,
Corporate Office, MSETCL,
Mumbai.

Call for Special Protection Co-ordination Committee meeting (PCC)

Shashank Jewalikar <ceaci@mahatransco.in>

Thu 11/24/2022 4:18 PM

To: Jayant Kulkarni <se6500@mahatransco.in>;Deepak Patil <ee5150@mahatransco.in>;Moreshwar Dhore <EE7150@mahatransco.in>;Kiran Shimpi <EE7270@mahatransco.in>;Madhav Pande <EE1SLDCOP8000@mahatransco.in>;dsdhok@rediffmail.com <dsdhok@rediffmail.com>;abhijeet.gore@adani.com <abhijeet.gore@adani.com>;gtjawale@tatapower.com <gtjawale@tatapower.com>;Juelee Wagh(Charge) <CEOM@mahatransco.in>;Sanjeev Bhole <CESTU@mahatransco.in>;JUELEE WAGH <CESLDC@mahatransco.in>;dycetestingkoradi@gmail.com <dycetestingkoradi@gmail.com>;ashish.baviskar@adani.com <ashish.baviskar@adani.com>;mohan.waingankar@adani.com <mohan.waingankar@adani.com>;kailas.nerkar@adani.com <kailas.nerkar@adani.com>;gtjawale@tatapower.com <gtjawale@tatapower.com>;prasadsanjay@tatapower.com <prasadsanjay@tatapower.com>;kalyan.p@saiwardha.com <kalyan.p@saiwardha.com>;amit.panchalwar@rattanindia.com <amit.panchalwar@rattanindia.com>;ajay.Khandelwal@jsw.in <ajay.Khandelwal@jsw.in>

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3 attachments (112 KB)

R2-Protection manual committee report(1)_AEML Comments.docx; V1_Protection philosophy XLS Worksheet _AEML Comments.xls; S1-SOP for testing activities for relaying_AEML Comments.xls;

Dear sir,

In context to the above subject, the PCC committee is established as per MEGC 2020 vide letter no. MSETCL/CO/CE(ACI&P)/GCC/456 dtd. 28.06.2021. As per the Sr. No. 18.3.3 of GCC procedure for conducting functional committee meeting , ``PCC shall meet separately also as & when needed to address urgent issues or specific issues if any``. Accordingly Special meeting is called for finalization of **Protection Manual** on dtd. **01.12.2022 at 11.30hrs.** through Microsoft VC. The link will be forwarded separately.

Further vide T. O. vide e-mail dtd. 07.11.2022, requested all members to offer their comments on draft protection manual. However, the comments from members are not received except from M/s Adani. The draft protection manual is again attached herewith. It is requested to offer your comments or else communicate the acceptance on or before 28.11.2022.

Regards.

Shashank Jewalikar
Chief Engineer (ACI&P)
Maharashtra State Electricity Transmission Co. Ltd.
C.O. Mumbai

MAHATRANSCO
Maharashtra State Electricity Transmission Co. Ltd.

OFFICE OF CHIEF ENGINEER (ACI&P), CO AIROLI

Minutes of the Special Protection Co-ordination Committee Meeting on 01.12.2022 held through Microsoft - VC

MSETCL/CO/CE (ACI&P)/SPCC/ 0598 **Date:** 06 DEC 2022

The Special Protection co-ordination committee meeting was held on dtd. 01.12.2022 through Microsoft - VC. The list of Members/Participants is enclosed as per Annexure-I.

Chief Engineer (ACI&P), Chairperson, PCC welcomed all the PCC members and other participants for Special PCC Meeting. He informed that the special Protection co-ordination committee meeting was called for finalization of Protection manual draft prepared by Protection manual Group members & approval of PCC committee. He further added that vide e-mail dtd. 07.11.2022 all PCC members were requested to offer their comments or else communicate the acceptance on or before 28.11.2022 on protection manual. However no comments received from PCC members except AEML. He further stated that the comments were received from AEML having difference of opinion with committee recommendations will be discussed & put up for committee acceptance and approval.

Accordingly the following AEML comments are discussed,

1. **Load Enchrochment**: AEML representative informed that the present practise of setting of Resistive Reach is as per OEM's Technical Manual. However there is no issue of accepting the Ramakrishana committee recommendation as recommended by protection manual group members.

The PCC committee has accepted the recommendation of Protection manual group members i.e. Resistive reach setting as per Ramakrishana committee.

2. **Auto Recloser (AR)**: AEML representative suggested to include the 'keeping of AR in Non auto for all Cable Feeders' in the recommendation made by protection manual group members.

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The PCC committee has accepted the suggestion made by AEML & will be included in the protection manual.

3. **Standalone AR**: AEML representative agreed with protection manual group members recommendation.

4. **Dead Line charging, Live line charging, Synchronizing**: AEML representative agreed with protection manual group members recommendation.

5. **Bus bar (220kV and Below)**: AEML representative agree with protection manual group members recommendation.

AEML representative informed that the comments given for correctly representing the AEML practices documented in the draft only and agreed with the overall recommendations in the draft.

The PCC committee has accepted suggestions / corrections as above & approved the protection manual and recommended for onward submission to GCC for acceptance & approval.

The Chief Engineer (ACI&P), Chairperson of committee thanked all the Protection manual group members for taking the sincere efforts for preparation of protection manual. He also thanks all PCC members & all other participants.

(Shashank S. Jewalikar)
Chief Engineer (ACI & P)
& Chairperson of PCC

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Annexure-I: list of Members/Participants.

Sr. No.	Name & Designation of Nominee	Contact No.	E-mail id
1	Sh. Sanjay Bhole, Chief Engineer (STU) MSETCL CO Mumbai	9588401698	cestu@mahatransco.in
2	Sh. Dinesh Patil, Executive Engineer (Op) MSLDC, Airoli	–	cesldc@mahatransco.in
3	Sh. Mohan Waingankar, M/s AEML - Transmission, Mumbai	9324216664	mohan.waingankar@adani.com
4	Sh. Kailas Nerkar – Addl. VP, Electrical M/s Adani Dhanu Thermal Power ltd.	9325118240	kailas.nerkar@adani.com
5	Sh. Abhijeet Gore, Dy. Gen. Manager M/s AEML - Transmission, Mumbai	9324050031	Abhijeet.gore@adani.com
6	Sh. Prasad Sanjay, Transmission & Distribution M/s Tata Power Co. Ltd.- Mumbai.	9223501465	prasadsanjay@tatapower.com

CE (STU) MSETCL

Annexure-II: List of Protection Group Members

Sr. No.	Name of Organization	Name & Designation of Nominee	Contact No.	E-mail id
1	MSETCL	Shri. Jayant Kulkarni, Superintending Engineer TCC, Pune	9892718431	se6500@mahatransco.in
		Shri. Deepak Patil, Executive Engineer Testing, Nashik	8554005019	ee5140@mahatransco.in
		Shri. M. B. Dhore, Executive Engineer Testing, Kalwa	9930496209	ee7150@mahatransco.in
		Shri. Girish Malode, Executive Engineer, Telecom, Kalwa	9767103581	ee7270@mahatransco.in
2	SLDC, Airoli	Shri M. B. Pande, Executive Engineer (Operation)	9833608212	madhavbpande@gmail.com
3	Maharashtra State Power Generation Co. Ltd.	Shri. Girish Dhok, Executive Engineer	8408888664	gsdhok@rediffmail.com
4	M/s AEML - Transmission, Mumbai	Abhijeet Gore, Dy. General Manager	9324050031	abhijeet.gore@adani.com
5	M/s Tata Power Co. Ltd.- Mumbai - Transmission	Girish Tukaram Jawale, Group Head (Protection & System Studies)	922331419	gtjawale@tatapower.com

Task Assigned to Protection Group:

1. To Review the Protection Philosophy & Practices.
2. To Review the SOP for Preventive maintenance Practices & Testing Activities for relaying.
3. To Prepare Protection Manual.

Ramakrishana Committee Report

PROTECTIVE RELAY SETTING GUIDELINES FOR 220kV, 400kV AND 765kV TRANSMISSION LINES

Table of Contents

PROTECTIVE RELAY SETTING GUIDELINES FOR 220kV, 400kV AND 765kV TRANSMISSION LINES

A review was made by the Protection Task force of the setting criteria for 220kV, 400kV and 765kV transmission lines (both uncompensated and series compensated) and the recommendations on the settings to be adopted are given below. The recommendations are based on guidelines given in following documents.

- CBIP Publication no 274: Manual on Protection of Generators, Generator Transformers and 220kV and 400kV Networks
- CBIP Publication no 296: Manual on Reliable Fault Clearance and Back-Up Protection of EHV and UHV Transmission Networks
- CIGRE WG B5.10, 411: Protection, Control and Monitoring Of Series Compensated Networks
- CIGRE WG 34.04 ; Application Guide on Protection Of Complex Transmission Network Configurations

A. UNCOMPENSATED TRANSMISSION LINES

1. ZONE-1 REACH SETTING:

Zone-1: To be set to cover 80% of protected line length. Set zero sequence compensation factor K_N as $(Z_0 - Z_1) / 3Z_1$.

Where:

Z_1= Positive sequence impedance of the protected line

Z_0 = Zero sequence impedance of the protected line

Note: With this setting, the relay may overreach when parallel circuit is open and grounded at both ends. This risk is considered acceptable.

2. ZONE-2 REACH SETTING:

Zone-2: To be set to cover minimum 120% of length of principle line section. However, in case of double circuit lines 150% coverage must be provided to take care of under reaching due to mutual coupling effect. Set K_N as $(Z_0 - Z_1) / 3Z_1$.

The 150% setting is arrived at considering an expected under reach of about 30% when both lines are in parallel and a margin of 20%. The degree of under reach can

be calculated using equation $K_{0M} / 1+K_0$ Where $K_{0M} = Z_{0M}/ 3Z_1$ and $K_0 = (Z_0 - Z_1) / 3Z_1$. It is recommended to check the degree of under reach due to mutual coupling effect to be sure that setting of 150% is adequate.

Sometimes impedance so selected might enter the next voltage level. However, un-selectivity in the Zone-2 grading is generally not to be expected when in-feeds exist at the remote sub-station as they reduce the overreach considerably.

This holds good for majority of the cases, however, for certain cases, where in-feed from other feeder at the local bus is not significant, Zone-2 of remote end relay may see the fault at lower voltage level. Care has to be taken for all such cases by suitable time delay.

3. ZONE-3 REACH SETTING:

Zone-3 distance protection can offer time-delayed remote back-up protection for an adjacent transmission circuit. To achieve this, Zone-3 distance elements must be set according to the following criteria where possible.

Zone-3 should overreach the remote terminal of the longest adjacent line by an acceptable margin (typically 20% of highest impedance seen) for all fault conditions.

Set K_N as $(Z_0 - Z_1) / 3Z_1$.

However, in such case where Zone-3 reach is set to enter into next lower voltage level, Zone-3 timing shall be coordinated with the back-up protection (Directional over current and earth fault relay) of power transformer. Where such coordination cannot be realised, other means like application of back up distance protection for power transformer or special protection scheme logic may have to be considered to achieve protection coordination.

4. RESISTIVE REACH SETTING

For phase to ground faults, resistive reach should be set to give maximum coverage considering fault resistance, arc resistance & tower footing resistance. It has been considered that ground fault would not be responsive to line loading.

For Zone-1 resistive reach, attention has to be given to any limitations indicated by manufacturer in respect of resistive setting vis-a-vis reactance setting to avoid overreach due to remote in-feed. *It is recommended to study the impact of remote end infeed for expected power flow & fault resistance on the extent of overreach. This is particularly important for short lines.*

In case of phase to phase fault, resistive reach should be set to provide coverage against all types of anticipated phase to phase faults subject to check of possibility against load point encroachment considering minimum expected voltage and maximum load expected during short time emergency system condition.

It is recommended that all the distance relays should have quadrilateral / polygon characteristic. For relays having Mho characteristic, it is desirable to have load encroachment prevention characteristic or a blinder.

In the absence of credible data regarding minimum voltage and maximum load expected for a line during emergency system condition, following criteria may be considered for deciding load point encroachment:

- Maximum load current (Imax) may be considered as 1.5 times the thermal rating of the line or 1.5 times the associated bay equipment current rating (the minimum of the bay equipment individual rating) whichever is lower. (Caution: The rating considered is approximately 15minutes rating of the transmission facility).
- Minimum voltage (Vmin) to be considered as 0.85pu (85%).

Due to in-feeds, the apparent fault resistance seen by relay is several times the actual value. This should be kept in mind while arriving at resistive reach setting for Zone-2 and Zone-3.

5. ZONE-2 TIMER SETTING:

A Zone-2 timing of 0.35 seconds (considering LBB time of 200mSec, CB open time of 60ms, resetting time of 30ms and safety margin of 60ms) is recommended. However,

if a long line is followed by a short line, then a higher setting (typically 0.6second) may be adopted on long line to avoid indiscriminate tripping through Zone-2 operation on both lines.

For special cases, following shall be the guiding philosophy:

Since Zone-2 distance protection is set to overreach the circuit it is intended to protect, it will also be responsive to faults within adjacent power system circuit. For this reason the time delay for Zone–2 back-up protection must be set to coordinate with clearance of adjacent circuit faults, within reach, by the intended main protection or by breaker fail protection.

The following formula would be the basis for determining the minimum acceptable Zone-2 time setting:

$$t_{z2} > t_{MA} + t_{CB} + t_{z2reset} + t_s$$

Where:

t_{Z2} = Required Zone-2 time delay

t_{MA} = Operating time of slowest adjacent circuit main protection or Circuit Local back-up for faults within Zone-2 reach

t_{CB} = Associated adjacent circuit breaker clearance time

$t_{Z2reset}$ = Resetting time of Zone-2 impedance element with load current present

t_S = Safety margin for tolerance (e.g. 50 to 100ms)

Unequal lengths of transmission circuit can make it difficult to meet the Zone-2 secondary reach setting criterion. In such cases it will be necessary to co-ordinate Zone-2 with longer time delay. The time t_{MA} in equation must be the adjacent circuit Zone-2 protection operating time.

6. ZONE-3 TIMER SETTING

Zone-3 timer should be set so as to provide discrimination with the operating time of relays provided in subsequent sections with which Zone-3 reach of relay being set, overlaps. Typical recommended Zone-3 time is 0.8 to 1.0 second.

For Special cases, where co-ordination between long and short lines is required, following formula would be the basis for determining the minimum acceptable Zone-3 time setting:

$$t_{z3} > t_{MA} + t_{CB} + t_{z3reset} + t_s$$

Where:

t_{Z3} = Required Zone-3 time delay

t_{MA} = Operating time of slowest adjacent circuit local back-up protection

t_{CB} = Associated adjacent circuit breaker clearance time

$t_{Z3reset}$ = Resetting time of Zone-3 impedance element with load current present

t_S = Safety margin for tolerance (e.g. 50 to 100milliseconds)

7. LOAD IMPEDANCE ENCROACHMENT

With the extended Zone-3 reach settings, that may be required to address the many under reaching factors already considered, load impedance encroachment is a significant risk to long lines of an interconnected power system. Not only the minimum load impedance under expected modes of system operation be considered in risk assessment, but also the minimum impedance that might be sustained for seconds or minutes during abnormal or emergency system conditions. Failure to do so could jeopardize power system security.

Ideal solution to tackle load encroachment may be based on the use of blinders or by suitably setting the resistive reach of specially shaped impedance elements or by use of polygon type impedance elements.

It is recommended that all the distance relays should have quadrilateral / polygon characteristic. For relays having Mho characteristics, it is desirable to have load encroachment prevention characteristics or a blinder.

In the absence of credible data regarding minimum voltage and maximum load expected for a feeder during emergency system condition, following criteria may be considered for deciding resistive reach / blinder setting to prevent load point encroachment:

- Maximum load current (Imax) may be considered as 1.5 times the thermal rating of the line or 1.5 times the associated bay equipment current rating (the minimum of the bay equipment individual rating) whichever is lower. (Caution: The rating considered is approximately 15 minutes rating of the transmission facility).
- Minimum voltage (Vmin) to be considered as 0.85pu (85%).
- For setting angle for load blinder, a value of 30 degree may be adequate in most cases.

For high resistive earth fault where impedance locus lies in the Blinder zone, fault clearance shall be provided by the back-up directional earth fault relay.

8. ZONE-4 SUBSTATION LOCAL BACKUP PROTECTION SETTINGS

Zone-3 distance protection is usually targeted to provide only remote back-up protection. In such a case, the distance relay may be provided with an additional zone of reverse-looking protection (e.g. Zone-4) to offer substation-local back-up protection. The criterion for setting Zone-4 reverse reach would be as under.

- The Zone-4 reverse reach must adequately cover expected levels of apparent bus bar fault resistance, when allowing for multiple in feeds from other circuits. For this reason, its resistive reach setting is to be kept identical to Zone-3 resistive reach setting.

With a reverse reach setting of less than the Zone-1 reach of distance protection for the shortest line connected to the local bus bar, the Zone-4 time delay would only need to co-ordinate with bus bar main protection fault clearance and with Zone-1 fault clearance for lines out of the same substation. For this reason this can be set according to the Zone-2 time setting guidelines.

9. USE OF SYSTEM STUDIES TO ANALYSE DISTANCE RELAY BEHAVIOUR

Often during system disturbance conditions, due to tripping of one or more trunk lines, some lines get overloaded and the system voltage drops. During such conditions the back-up distance elements may become susceptible to operation due to encroachment of impedance locus in to the distance relay characteristic.

While the ohmic characteristic of a distance relay is independent of voltage, the load is not generally constant-impedance. The apparent impedance presented to a distance relay, as the load voltage varies, will depend on the voltage characteristic of the load. If the low voltage situation resulted from the loss of one or more transmission lines or generating units, there may be a substantial change in the real and reactive power flow through the line in question. The combination of low voltage and worsened phase angle may cause a long set relay to operate undesirably either on steady state basis, or in response to recoverable swings related to the initiating event.

The apparent impedance seen by the relay is affected by in-feeds, mutual coupling and therefore the behaviour of distance relay during various system condition needs to be studied wherever necessary to achieve proper relay coordination.

It is desirable and hence recommended that system studies are conducted using computer-aided tools to assess the security of protection by finding out trajectory of impedance in various zones of distance relay under abnormal or emergency system condition on case-to-case basis particularly for critical lines / corridors.

In addition, the settings must be fine-tuned, simulating faults using Real Time Digital Simulator on case-to-case basis particularly for critical lines / corridors.

Such facilities available at CPRI, POWERGRID or elsewhere in the country should be used for protection related studies.

10. DIRECTIONAL PHASE OVER CURRENT PROTECTION

Directional phase over current relays are still being used as back-up protection for 220kV transmission lines by many utilities. In view of time coordination issues and increased fault clearance time in the event of failure of main distance protection, *it is recommended that for all 220kV lines also main-1 and main-2 protections similar to 400kV lines be provided.*

11. DIRECTIONAL GROUND OVER CURRENT PROTECTION (DEF) SETTINGS

Normally this protection is applied as a supplement to main protection when ground fault currents may be lower than the threshold of phase over current protection. It might also be applied as main protection for high resistance faults.

The ground over current threshold should be set to ensure detection of all ground faults, but above any continuous residual current under normal system operation. Continuous residual current may arise because of following:

- Unbalanced series impedances of untransposed transmission circuits
- Unbalanced shunt capacitance of transmission circuits.
- Third harmonic current circulation.

Various types of directional elements may be employed to control operation of ground over current (zero sequence over current) protection response. The most common approach is to employ Phase angle difference between Zero sequence voltage and current, since the relaying signals can easily be derived by summing phase current signals and by summing phase voltage signals from a suitable voltage transformer.

However this method is not suitable for some applications where transmission lines terminated at different substations, run partially in parallel. In such cases following

type of directional control is recommended to be used for the directional earth fault relay.

- Relative phase of negative sequence voltage and current

To ensure proper coordination, operating time must be set according to following criteria:

The DEF protection should not operate when the circuit local backup protection of remote end clears a fault in an adjacent circuit i.e DEF should be coordinated with the remote end LBB.

12. POWER SWING BLOCKING FUNCTION

While the power-swing protection philosophy is simple, it is often difficult to implement it in a large power system because of the complexity of the system and the different operating conditions that must be studied. There are a number of options one can select in implementing power-swing protection in their system. Designing the power system protection to avoid or preclude cascade tripping is a requirement of modern day power system. Below we list two possible options:

12.1. Block all Zones except Zone-I

This application applies a blocking signal to the higher impedance zones of distance relay and allows Zone 1 to trip if the swing enters its operating characteristic. Breaker application is also a consideration when tripping during a power swing. A subset of this application is to block the Zone 2 and higher impedance zones for a preset time (Unblock time delay) and allow a trip if the detection relays do not reset.

In this application, if the swing enters Zone 1, a trip is issued, assuming that the swing impedance entering the Zone-1 characteristic is indicative of loss of synchronism. However, a major disadvantage associated with this philosophy is that indiscriminate line tripping can take place, even for recoverable power swings and risk of damage to breaker.

12.2. Block All Zones and Trip with Out of Step (OOS) Function

This application applies a blocking signal to all distance relay zones and order tripping if the power swing is unstable using the OOS function (function built in modern distance relays or as a standalone relay). This application is the recommended approach since a controlled separation of the power system can be achieved at preselected network locations. Tripping after the swing is well past the 180 degree position is the recommended option from CB operation point of view.

Normally all relay are having Power swing Un-block timer which unblocks on very slow power swing condition (when impedance locus stays within a zone for a long duration). Typically the Power swing un-blocking time setting is 2sec.

However, on detection of a line fault, the relay has to be de-blocked.

12.3. Placement of OOS trip Systems

Out of step tripping protection (Standalone relay or built-in function of Main relay) shall be provided on all the selected lines. The locations where it is desired to split the system on out of step condition shall be decided based on system studies.

The selection of network locations for placement of OOS systems can best be obtained through transient stability studies covering many possible operating conditions.

Till such studies are carried out and Out-of-Step protection is enabled on all identified lines, it is recommended to continue with the existing practice of Non-Blocking of Zone-I on Power Swing as mentioned under Option-12.1 above. However it should be remembered that with this practice the line might trip for a recoverable swing and it is not good to breakers.

Committee strongly recommends that required studies must be carried out at the earliest possible time (within a timeframe of one year) to exercise the option-12.2 & 12.3 above.

13. LINE OVERVOLTAGE PROTECTION

FOR 400kV LINES: Low set stage (Stage-I) may be set in the range of 110% - 112% (typically 110%) with a time delay of 5 seconds. High set stage (Stage-II) may be set in the range 140% - 150% with a time delay of 100milliseconds.

FOR 765kV LINES: Low set stage (Stage-I) may be set in the range of 106% - 109% (typically 108%) with a time delay of 5 seconds. High set stage (Stage-II) may be set in the range 140% - 150% with a time delay of 100milliseconds.

However, for over voltage Stage-I protection, a time grading of 1 to 3 seconds may be provided between overvoltage relays of double circuit lines. Grading on overvoltage tripping for various lines emanating from a station may be considered and same can be achieved using voltage as well as time grading. Longest timed delay should be checked with expected operating time of Over-fluxing relay of the transformer to ensure disconnection of line before tripping of transformer.

It is desirable to have Drop-off to pick-up ratio of overvoltage relay better than 97% (Considering limitation of various manufacturers relay on this aspect).

14. LINE DIFFERENTIAL PROTECTION

Many transmission lines are now having OPGW or separate optic fibre laid for the communication. Where ever such facilities are available, it is recommended to have the line differential protection as Main-I protection with distance protection as backup (built-in Main relay or standalone). Main-II protection shall continue to be distance protection. For cables and composite lines, line differential protection with built in distance back up shall be applied as Main-I protection and distance relay as Main-II protection. Auto-recloser shall be blocked for faults in the cables.

15. MAINTAINING OPERATION OF POWER STATION AUXILIARY SYSTEM OF NUCLEAR POWER PLANTS:

Depression of power supply voltages for auxiliary plant in some generating stations may reduce the station output. Maintenance of full generation output may be a

critical power system security factor. In the case of nuclear plant, auxiliary power supplies are also a major factor in providing full nuclear plant safety and security.

The potential loss of system generation or the potential challenges to nuclear plant safety systems may be factors which will dictate the longest acceptable clearance times for transmission circuit faults in the vicinity of a power station. This should be further taken up with utilities of nuclear plants and this and any other requirements should be understood and addressed.

16. **COORDINATION BETWEEN SYSTEM STUDY GROUP AND PROTECTION ENGINEERS**

For quite a few cases where system behaviour issues are involved it is recommended that power system study group is associated with the protection engineers. For example power swing locus, out of step tripping locations, faults withstands capability, zone2 and zone3 overlap reach settings calculations are areas where system study group role is critical/essential.

B. SERIES COMPENSATED TRANSMISSION LINES:

Following phenomenon associated with the protection of Series compensated lines require special attention:

1) VOLTAGE AND CURRENT INVERSION

1.1. Voltage inversion on Series Compensated line:

In this case the voltage at the relay point reverses its direction. This phenomenon is commonly called as voltage inversion. Voltage inversion causes false decision in conventional directional relays. Special measures must be taken in the distance relays to guard against this phenomenon.

1.2. Current inversion on Series Compensated line:

Fault current will lead source voltage by 90 degrees if $X_C > X_S + X_{L1}$ Current inversion causes a false directional decision of distance relays (voltage

memories do not help in this case). [Here X_C is reactance of series capacitor, X_S is source reactance and X_{L1} is reactance of the line]

Current inversion influences operation of distance relays and therefore they cannot be applied without additional logic for the protection of series compensated lines when possibility of current inversion exists. Performance of directional comparison protections, based on residual (zero sequence) and negative sequence currents are also affected by current inversion. *It is therefore, recommended to check the possibility of current inversion through system studies at the planning stage itself.*

2) LOW FREQUENCY TRANSIENTS

Series capacitors introduce oscillations in currents and voltages in the power systems, which are not common in non-compensated systems. These oscillations have frequencies lower than the rated system frequency and may cause delayed increase of fault currents, delayed operation of spark gaps as well as delayed operation of protective relays.

Low frequency transients have in general no significant influence on operation of line current differential protection as well as on phase comparison protection. However they may significantly influence the correct operation of distance protection in two ways:

-They increase the operating time of distance protection, which may in turn influence negatively the system stability

-They may cause overreaching of instantaneous distance protection zones and this way result in unnecessary tripping on series compensated lines.

It is recommended to reduce the reach setting by a safety factor (Ks) to take care of possible overreach due to low frequency oscillations.

3) MOV INFLUENCE AND APPARENT IMPEDANCE

Metal oxide varistors (MOV) are used for capacitor over-voltage protection. In contrast to spark gaps, MOVs carry current when the instantaneous voltage drop

across the capacitor becomes higher than the protective voltage level in each half-cycle. Extensive studies have been done by Bonneville Power Administration in USA to arrive at a non-linear equivalent circuit for a series connected capacitor using an MOV. The composite impedance depends on total fault current and protection factor k_p.

The later is defined by equation.

$$k_p = \frac{U_{MOV}}{U_{NC}}$$

Where U_{MOV} is voltage at which MOV starts to conduct theoretically and U_{NC} is voltage across the series capacitor when carrying its rated nominal current

This should be considered while relay setting.

4) IMPACT OF SC ON PROTECTIVE RELAYS OF ADJACENT LINES

Voltage inversion is not limited only to the buses and to the relay points close to the series compensated line. It can spread deep into the network and this way influence the selection of protection devices (mostly distance relays) at remote ends of the lines adjacent to the series compensated circuit, and sometimes even deeper in the network. Estimation of their influence on performances of existing distance relays of adjacent lines must be studied. In the study, it is necessary to consider cases with higher fault resistances, for which spark gaps or MOVs on series capacitors will not conduct at all.

If voltage inversion is found to occur, it may be necessary to replace the existing distance relays in those lines with distance relays that are designed to guard against this phenomenon.

5) MULTI CIRCUIT LINES

Two parallel power lines both series compensated running close to each other and ending at the same busbar at both ends) can cause some additional challenges for distance protection due to the zero sequence mutual impedance. The current

reversal phenomenon can also raise problems from the protection point of view, particularly when the power lines are relatively short and when permissive overreach schemes are used.

Influence of zero sequence mutual impedance

Zero sequence mutual impedance Z_{M0} will not significantly influence the operation of distance protection as long as both circuits are operating in parallel and all precautions related to settings of distance protection on series compensated line have been considered. Influence of parallel line switched off & earthed at both ends, on the operation of distance protection on single operating circuit is well known.

The presence of series capacitor additionally exaggerates the effect of zero sequence mutual impedance between two circuits. The effect of zero sequence mutual impedance on possible overreaching of distance relays is increased further compared to case of non-compensated lines. This is because while the series capacitor will compensate self-impedance of the zero sequence network the mutual impedance will be same as in the case of non-compensated double circuit lines. The reach of under reaching distance protection zone 1 for phase to earth measuring loops must further be reduced for such operating conditions.

Zero sequence mutual impedance may also disturb the correct operation of distance protection for external evolving faults during auto reclosing, when one circuit is disconnected in one phase and runs in parallel during dead time of single pole auto reclosing cycle. *It is recommended to study all such operating conditions by dynamic simulations in order to fine tune settings of distance relays.*

6) DIRECTIONAL RESIDUAL OVERCURRENT PROTECTION

All basic application considerations, characteristic for directional residual over-current protection on normal power lines apply also to series compensated lines with following additions. Low fault currents are characteristic of high resistive faults. This means that the fault currents may not be enough to cause voltage drops on series capacitors that would be sufficient to start their over-voltage protection.

Spark gaps may not flash over in most cases, and metal oxide varistors (MOVs) may not conduct any significant current. Series capacitors may remain fully inserted during high resistive earth faults.

Local end directional residual OC protection:

The directional relay operates always correctly for reverse faults. VT located between bus and capacitor generally does not influence directional measurement. But in case VT is located between line and capacitor it may influence correct operation: While reverse faults are detected correctly the forward operation is dependent on system conditions. Additional zero sequence source impedance can be added into relay circuits to secure correct directional measurement.

Remote end directional residual OC protection:

In this case the current can be reduced to extremely low values due to low zero sequence impedance at capacitor end. Further the measured residual voltage can be reduced to very low value due to low zero sequence source impedance and/or low zero sequence current. Zero sequence current inversion may occur at the capacitor end (dependent on fault position). Directional negative sequence OC protection too may face very similar conditions.

Adaptive application of both the above OC protection principles can be considered wherever required to get the desired result.

7) DISTANCE PROTECTION SETTINGS GUIDELINES

- Basic criteria applied for Z1 & Z2 reach settings are :
  - Zone-1 should never overreach for the fault at remote bus
  - Zone-2 should never under reach for fault on protected line
  - Permissive overreach (POR) schemes are usually applied

Distance protection Zone 1 shall be set to

Zone-1 is set usually at 80% of Ks x $X_{Z1} = K_S \cdot (X_{11} + X_{12} - X_C)$ Where X_{11} is reactance between CT and capacitor and X_{12} is reactance between capacitor and remote end Bus, X_c is reactance of capacitor and K_S is safety factor to prevent possible overreaching due to low frequency (sub-harmonic) oscillations. These setting guidelines are applicable when VT is installed on the bus side of the capacitor . It is possible to remove X_C from the above equation in case VT is installed on line side , but it is still necessary to consider the safety factor.

- Alternatively, Zone-1 is set at 80% of line impedance with a time delay of 100millisecond. POR Communication scheme logic is modified such that relay trips instantaneously in Zone-1 on carrier receive. (For remote end relay of the line looking into series capacitor)
- Zone-2 is set to 120 % of uncompensated line impedance for single circuit line. For double circuit lines, special considerations are mentioned at Section B-5 above.
- Phase locked voltage memory is used to cope with the voltage inversion. Alternatively, an intentional time delay may be applied to overcome directionality problems related to voltage inversion.
- Special consideration may be required in over voltage stage-I (low set) trip setting for series compensated double circuit lines. It has been experienced that in case of tripping of a heavily loaded circuit, other circuit experience sudden voltage rise due to load transfer. To prevent tripping of other circuit on such cases, over-voltage stage-I setting for series compensated double circuit lines may be kept higher at 113%.

8) SIMULATION STUDIES

System studies, Use of real Time digital simulators, Tests using EMTP files are very important when applying protections for series compensated lines. *It is recommended to carry out such studies specific to each line.*

PROTECTION SYSTEM MANAGEMENT

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RECOMMENDATIONS FOR PROTECTION SYSTEM MANAGEMENT:

During the discussions and interactions with the various stake holders of the protection system, it was strongly felt by the protection sub-committee members that in addition to technical issues related to protection, the management issues related to protection system need to be addressed. A questionnaire related to applicable protection setting & coordination philosophy was sent to all utilities through RPC. Responses were received only from few utilities. These responses show that there is no uniformity in the protection philosophy followed by different utilities throughout the country. Further, lack of response from most of the utilities also indicates the lack of resources on their part to handle the protection system. In order to comprehensively address the protection issues in the utilities, following are the recommendations.

1. ESTABLISHING PROTECTION APPLICATION DEPARTMENT:

1.1. It is recommended that each utility establishes a protection application department with adequate manpower and skill set.

1.2. The protection system skill set is gained with experience, resolving various practical problems, case studies, close interaction with the relay manufactures and field engineers. Therefore it is proposed that such people should be nurtured to have a long standing career growth in the protection application department.

2. RELAY SETTING CALCULATIONS

2.1. The protection group should do periodic relay setting calculations as and when necessitated by system configuration changes. A relay setting approval system should be in place.

2.2. Relay setting calculations also need to be revisited whenever the minor configuration or loading changes in the system due to operational constraints. Feedback from the field/substations on the performance of

the relay settings should be collected and settings should be reviewed and corrected if required.

3. COORDINATION WITH SYSTEM STUDY GROUP, SYSTEM PLANNING GROUP AND OTHER STAKEHOLDERS

3.1. It is recommended that each utility has a strong system study group with adequate manpower and skill set that can carry out various system studies required for arriving at system related settings in protection system in addition to others studies.

3.2. The protection application department should closely work in co-ordination with the utility system study group, system planning group, the system operation group.

3.3. Wherever applicable, it should also co-ordinate and work with all power utilities to arrive at the proper relay setting calculations taking the system as a whole.

3.4. The interface point relay setting calculations at CTU-STU, STU-DISCOMS, STU-GEN Companies, CTU-GEN Companies and also generator backup relay setting calculations related to system performance should be periodically reviewed and jointly concurrence should be arrived. The approved relay settings should be properly document.

3.5. Any un-resolved issues among the stakeholders should be taken up with the RPC and resolved.

4. SIMULATION TESTING FOR CHECKING DEPENDABILITY AND SECURITY OF PROTECTION SYSTEM FOR CRITICAL LINES AND SERIES COMPENSATED LINES

4.1. Committee felt that even though Real Time Digital Simulation (RTDS) and other simulation facilities are available in the country, use of the same by the protection group is very minimum or nil.

4.2. It is recommended that protection system for critical lines, all series compensated lines along with interconnected lines should be simulated for intended operation under normal and abnormal system conditions

and tested for the dependability and security of protection system. The RTDS facilities available in the country like at CPRI, POWERGRID and other places should be made use of for this purpose.

4.3. The network model should be periodically updated with the system parameters, as and when network changes are incorporated.

5. ADOPTION OF RELAY SETTING AND FUNCTIONAL VERIFICATION OF SETTING AT SITE

5.1. Protection application department shall ensure through field testing group that the final relay settings are exactly adopted in the relays at field.

5.2. There should be clear template for the setting adoption duly authorized and approved by the field testing in charge.

5.3. No relay setting in the field shall be changed without proper documentation and approval by the protection application department.

5.4. Protection application department shall periodically verify the implemented setting at site through an audit process.

6. STORAGE AND MANAGEMENT OF RELAY SETTINGS

6.1. The committee felt that with the application of numerical relays, increased system size & volume of relay setting, associated data to be handled is enormous. It is recommended that utilities shall evolve proper storage and management mechanism (version control) for relay settings.

6.2. Along with the relay setting data, IED configuration file should also be stored and managed.

7. ROOT CAUSE ANALYSIS OF MAJOR PROTECTION TRIPPING (MULTIPLE ELEMENT OUTAGE) ALONGWITH CORRECTIVE & IMPROVEMENT MEASURES

7.1. The routine trippings are generally analysed by the field protection personnel. For every tripping, a trip report along with associated DR and event logger file shall be generated. However, for major tripping in the system, it is recommended that the protection application department shall perform the root cause analysis of the event.

7.2. The root cause analysis shall address the cause of fault, any mal-operation or non-operation of relays, protection scheme etc.

7.3. The root cause analysis shall identify corrective and improvement measures required in the relay setting, protection scheme or any other changes to ensure the system security, reliability and dependability of the protection system.

7.4. Protection application group shall keep proper records of corrective and improvement actions taken.

8. PERFORMANCE INDICES: DEPENDABILITY & SECURITY OF PROTECTION SYSTEM

8.1. The committee felt that key performance indices should be calculated on yearly basis on the dependability and security of protection system as brought out in CBIP manual.

9. PERIODIC PROTECTION AUDIT

9.1. Periodic audit of the protection system shall be ensured by the protection application team.

9.2. The audit shall broadly cover the three important aspect of protection system, namely the philosophy, the setting, the healthiness of Fault Clearing System.

10. REGULAR TRAINING AND CERTIFICATION

10.1. The members of the protection application team shall undergo regular training to enhance & update their skill sets.

10.2. The training modules shall consist of system studies, relaying applications, testing & commissioning

10.3. Certification of protection system field engineer for the testing & commissioning of relay, protection scheme is strongly recommended.

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR 765kV, 400kV & 220kV SUBSTATIONS

Introduction:

This check list is prepared by the Protection sub-committee under task force to enable audit of practices followed in protection application & criteria used for setting calculations in 220kV, 400kV & 765kV substations. It aims to cover the entire fault clearance system used for overhead lines & cables, power transformers, shunt reactors and bus bars in a substation. The objective is to check if the fault clearance system provided gives reliable fault clearance.

The check list is generally based on the guidelines given in the following documents:

- CBIP Publication no 274: Manual on Protection of Generators, Generator Transformers and 220kV and 400kV Networks
- CBIP Publication no 296: Manual on Reliable Fault Clearance and Back-Up Protection of EHV and UHV Transmission Networks
- CIGRE WG B5.10, 411: Protection, Control and Monitoring Of Series Compensated Networks

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR

765kV, 400kV & 220kV SUBSTATIONS

CHECK-LIST:

Check list for different protected objects & elements in fault clearance system are as under:

(put √ mark in the appropriate box)

A. Transmission Lines (OHL and Cables)

1.	Independent Main-I and Main-II protection (of different make OR different type) is provided with carrier aided scheme	☐ YES ☐ NO
2.	Are the Main-I & Main-II relays connected to two separate DC sources (Group-A and Group-B)	☐ YES ☐ NO
3.	Is the Distance protection (Non-switched type, suitable for 1-ph & 3-ph tripping) as Main1 and Main2 provided to ensure selectivity & reliability for all faults in the shortest possible time	☐ YES ☐ NO
4.	Is both main-I & Main-II distance relay are numerical design having Quadrilateral or Polygon operating characteristic	☐ YES ☐ NO
5.	In the Main-I / Main-II Distance protection, Zone-I is set cover 80% of the protected line section	☐ YES ☐ NO
6.	In the Main-I / Main-II distance protection, Zone-2 is set cover 120% of the protected line section in case of Single circuit line and 150% in case of Double circuit line	☐ YES ☐ NO
7.	In the Main-I / Main-II distance protection, Zone-3 is set cover 120% of the total of protected line section plus longest line at remote end as a minimum.	☐ YES ☐ NO

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR

765kV, 400kV & 220kV SUBSTATIONS

8.	Resistive reach for Ground fault element set to give maximum coverage considering fault resistance, arc resistance & tower footing resistance. (In case, It is not possible to set the ground fault and phase fault reaches separately, load point encroachment condition imposed on Phase fault resistive reach shall be applied)	☐ YES ☐ NO
9.	Resistive reach for Phase fault element set to give maximum coverage subject to check of possibility against load point encroachment considering minimum expected voltage and maximum load.	☐ YES ☐ NO
10.	In case of short lines, is manufacturers recommendation considered in respect of resistive setting vis a vis reactance setting to avoid overreach.	☐ YES ☐ NO
11	Is Zone-2 time delay of Main-I / Main-II distance relay set to 0.350 seconds ? In case any other value has been set for Zone-II timer, kindly specify the value and justification thereof.	☐ YES ☐ NO
12	Is Zone-3 timer is set to provide discrimination with the operating time of relays at adjacent sections with which Zone-3 reach of relay is set to overlap. Please specify the Zone-3 time set.	☐ YES ☐ NO
13.	Is Zone-4 reach set in reverse direction to cover expected levels of apparent bus bar fault resistance, when allowing for multiple in feeds from other circuits?	☐ YES ☐ NO
14.	Is reverse looking Zone-4 time delay set as Zone-2 time delay?	☐ YES ☐ NO
15.	Is Switch on to fault (SOTF) function provided in distance relay to take care of line energisation on fault? Whether SOTF initiation has been implemented using hardwire logic	☐ YES ☐ NO ☐ YES ☐ NO

	In case of Breaker and half switching scheme, whether initiation of line SOTF from CB closing has been interlocked with the other CB	☐ YES ☐ NO
16.	Whether VT fuse fail detection function has been correctly set to block the distance function operation on VT fuse failure	☐ YES ☐ NO
17.	Is the sensitive IDMT directional E/F relay (either separate relay or built-in function of Main relay) for protection against high resistive earth faults?	☐ YES ☐ NO
18.	Is additional element (Back-up distance) for remote back-up protection function provided in case of unit protection is used as Main relay for lines?	☐ YES ☐ NO
19.	In case of Cables, is unit protection provided as Main-I & Main-II protection with distance as back-up.	☐ YES ☐ NO
20.	Are the line parameters used for setting the relay verified by field testing	☐ YES ☐ NO
21.	Is Two stages Over-Voltage protection provided for 765 & 400kV Lines? Do you apply grading in over-voltage setting for lines at one station. Please specify the setting values adopted for: Stage-I : (typical value - 106 to 112 % , delay : 4-7 Sec) Stage-II: (typical value - 140 to 150%, delay: 0 to 100msec.)	☐ YES ☐ NO ☐ YES ☐ NO
22.	Is 1-ph Auto –reclosing provided on 765, 400 & 220kV lines? Please specify the set value: Dead time: (typical 1 Sec) Reclaim time: (typical 25 Sec)	☐ YES ☐ NO

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR

765kV, 400kV & 220kV SUBSTATIONS

23.	Is the Distance communication. Scheme Permissive Over Reach (POR) applied for short lines and Permissive Under Reach (PUR) applied for long lines? If any other communication scheme has been applied, please provide the detail with justification thereof.	☐ YES ☐ NO
24.	Is the Current reversal guard logic for POR scheme provided on Double circuit lines?	☐ YES ☐ NO
25.	In case the protected line is getting terminated at a station having very low fault level i.e. HVDC terminal, whether week end-infeed feature has been enabled in respective distance relay or not	☐ YES ☐ NO
26.	In case of protected line is originating from nuclear power station, are the special requirement (stability of nuclear plant auxiliaries) as required by them has been met	☐ YES ☐ NO
27.	What line current , Voltage and Load angle have been considered for Load encroachment blinder setting and what is the resultant MVA that the line can carry without load encroachment. (In the absence of Load encroachment blinder function, this limit shall be applied to Zone-3 phase fault resistive reach.)	I= V= Angle: S=
28.	a) What are the Zones blocked on Power swing block function: b) Setting for Unblock timer: (typical 02 second) c) Out of Step trip enabled	Z1 / Z2 / Z3 / Z4 Time: ☐ YES ☐ NO
29.	Whether the location of Out of step relay has been identified on the basis of power system simulation studies	☐ YES ☐ NO
30.	a) Is the Disturbance recorder and Fault locator provided on all line feeder ? b) Whether standalone or built in Main relay c) Whether DR is having automatic fault record download facility to a central PC d) Whether DR is time synchronised with the GPS based time	☐ YES ☐ NO Standalone / built-in ☐ YES ☐ NO

	synchronising equipment	☐ YES ☐ NO
	e) Whether DR analog channels contain line phase & neutral current and line phase & neutral voltage.	☐ YES ☐ NO
	f) Whether DR digital channel as a minimum contain the CB status, Main-I & II trip status, LBB trip status, Over-voltage trip status, Stub protn trip status, Permissive and direct carrier receive status, Line reactor trip status.	☐ YES ☐ NO

B. Power Transformers

1.	Do you use Group A and Group B protections connected to separate DC sources for power transformers	☐ YES ☐ NO
2.	Do you follow CBIP guideline (274 & 296) for protection setting of transformer	☐ YES ☐ NO
3.	Do you use duplicated PRD and Bucholtz initiating contact for power transformers at 765kV and 400kV levels	☐ YES ☐ NO
4.	Do you classify transformer protections as below in groups: Group A — Group B • Biased differential relay — Restricted earth fault (REF) relay • PRD , WTI — Buchholz Protection, OTI • Back up Protection(HV) — Back up Protection(MV) • Overfluxing protection(HV) — Overfluxing protection(MV)	☐ YES ☐ NO
5.	In case of Breaker & half switching scheme, whether CT associated with Main & Tie Breakers are connected to separate bias winding of the low impedance Biased differential protection in order to avoid false operation due to dissimilar CT response.	☐ YES ☐ NO
6.	Is Restricted earth fault (REF) protection used a high impedance type	☐ YES ☐ NO

7.	Are Main protection relays provided for transformer are of numerical design.	☐ YES ☐ NO
8.	a) Are directional over current & earth fault relays provided as back-up protection of Transformer are of numerical design. b) Do the back-up earth fault relays have harmonic restrain feature	☐ YES ☐ NO ☐ YES ☐ NO
9.	Is Fire protection system (HVW type) provided for power transformer and functioning	☐ YES ☐ NO
10.	a) Is the Disturbance recorder provided for Transformer feeder b) Whether standalone or built in Main relay c) Whether DR is having automatic fault record download facility to a central PC d) Whether DR is time synchronised with the GPS time synchronising equipment	☐ YES ☐ NO Standalone/built-in ☐ YES ☐ NO ☐ YES ☐ NO

C. Shunt Reactors

1.	Do you use Group A and Group B protections connected to separate DC sources for reactors	☐ YES ☐ NO
2.	Do you follow CBIP guideline (274 and 296) for protection setting of reactors	☐ YES ☐ NO
3.	Do you use duplicated PRD and Bucholtz initiating contact for Reactors at 765kV and 400kV levels	☐ YES ☐ NO
4.	Do you classify Reactor protections as below in groups: Group A — Group B • Biased differential relay — R.E.F Protection	☐ YES ☐ NO

	• PRD , WTI Buchholz Protection, OTI • Back up impedance Protection Or Direction O/C & E/F relay	
5	In case of Breaker & half switching scheme, whether CT associated with Main & Tie Breakers are connected to separate bias winding of the low impedance Biased differential protection in order to avoid false operation due to dissimilar CT response.	☐ YES ☐ NO
6	Is Restricted earth fault (REF) protection used a high impedance type	☐ YES ☐ NO
7	Are Main & back-up protection relays provided for Reactor are of numerical design.	☐ YES ☐ NO
8	Is Fire protection system (HVW type) provided for Reactor and functioning	☐ YES ☐ NO
9	a) Is the Disturbance recorder and Fault locator provided on all the Shunt Reactors used in 765 kV, 400 kV substations? b) Whether standalone or built in Main relay c) Whether DR is having automatic fault record download facility to a central PC	☐ YES ☐ NO Standalone/built-in ☐ YES ☐ NO

D. Bus bars

1.	Bus Bar protection for 765, 400 & 220kV buses is provided	☐ YES ☐ NO
2.	Duplicated Bus bar protection is provided for 765kV and 400kV buses	☐ YES ☐ NO
3.	CBIP guideline for Protection (274 and 296) settings is followed	☐ YES ☐ NO

4	In an existing substation if CTs are of different ratios, is biased type bus protection provided.	☐ YES ☐ NO
5	In stations where single bus bar protection is provided, is backup provided by reverse looking elements of distance relays or by second zone elements of remote end distance relays?	☐ YES ☐ NO
6	In case of GIS where burn through time of SF6 is shorter than remote back up protection is the bus bar protection duplicated irrespective of voltage level?	☐ YES ☐ NO
7	Since it is difficult to get shutdowns to allow periodic testing of bus protection, numerical bus protections with self-supervision feature is an answer. Is this followed?	☐ YES ☐ NO

E. Disturbance Recorder (DR) and Event Logger (EL)

1	a) Is the Disturbance recorder and Fault locator provided on all line feeder of 765, 400 & 220kV substations?	☐ YES ☐ NO
	b) Whether standalone or built in Main relay	Standalone / built-in
	c) Whether DR is having automatic fault record download facility to a central PC	☐ YES ☐ NO
	d) Whether Central PC for DR , EL are powered by Inverter (fed from station DC)	☐ YES ☐ NO
2.	Whether DR is having the following main signals for lines: <u>Analogue signals</u>: • From CT: IA, IB, IC, IN • From VT: VAN, VBN, VCN • From Aux. VT: V0 <u>Digital Signals</u> • Main 1 Carrier receive	☐ YES ☐ NO

	• Main 1 Trip • Line O/V Stage I / Stage II • Reactor Fault Trip • Stub Protection Operated. • Main II Trip • Main II Carrier Receive • Direct Trip CH I / II • CB I Status (PH-R, Y & B) • CB II Status (PH R, Y & B) • Bus bar trip • Main / Tie CB LBB Operated • Main / Tie Auto-reclose operated. DR for Transformer / Reactor feeder should contain analog channel like input currents & voltage. Binary signal include all protection trip input, Main & Tie CB status, LBB trip	
3.	Whether substation (765, 400 , 220kV) is having Event logger facility (standalone or built-in-SAS)	☐ YES ☐ NO
4.	Whether GPS based time synchronizing equipment is provided at the substation for time synchronizing of Main relays / DR/ Event logger / SAS/ PMU / Line Current Differential Relays	☐ YES ☐ NO

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR

765kV, 400kV & 220kV SUBSTATIONS

F. Circuit Breakers

1.	Is breaker fail protection (LBB / BFR) provided for all the Circuit Breakers at 220kV , 400kV & 765kV rating	☐ YES ☐ NO
3.	For Circuit Breaker connected to line feeder / transformer feeder, whether operation of LBB / BFR sends direct trip signal to trip remote end breaker ?	☐ YES ☐ NO
4.	For lines employing single phase auto reclosing, Is start signal from protection trip to LBB / BFR relay is given on single phase basis?	☐ YES ☐ NO
5.	Is separate relay provided for each breaker and the relay has to be connected from the secondary circuit of the CTs associated with that particular breaker?	☐ YES ☐ NO
6.	Is LBB relay provided with separate DC circuit independent from Group-A and Group-B Protections?	☐ YES ☐ NO
7.	Is the LBB initiation provided with initiating contact independent of CB trip relay contact?	☐ YES ☐ NO
8.	Is Separation maintained between protective relay and CB trip coil DC circuit so that short circuit or blown fuse in the CB circuit will not prevent the protective relay from energizing the LBB scheme?	☐ YES ☐ NO
9.	Is LBB relay initiated by Bus bar protection in addition to other fault sensing relays, since failure of CB to clear a bus fault would result in the loss of entire station if BFP relay is not initiated?	☐ YES ☐ NO
10.	Is tripping logic of the bus bar protection scheme used for LBB protection also?	☐ YES ☐ NO
11.	Are the special considerations provided to ensure proper scheme operation by using Circuit Breaker contact logic in addition to current detectors in cases breaker-fail relaying for low energy faults like buchholz operation?	☐ YES ☐ NO

12.	Are the Current level detectors set as sensitive as the main protection? (Generally setting of 0.2 A is commonly practiced for lines and transformers)	☐ YES ☐ NO
13.	Is timer set considering breaker interrupting time, current detector reset time and a margin? (Generally a timer setting of 200ms has been found to be adequate)	☐ YES ☐ NO
14.	Is the back-up fault clearance time is shorter than the operating time of the remote protections (distance relay Zone-2) ?	☐ YES ☐ NO
15.	Is the breaker failure protection provided with two steps (First stage – retrip own CB, Second stage- Trip all associated CBs) . This mitigates unwanted operation of breaker failure protection during maintenance and fault tracing.	☐ YES ☐ NO
16.	Is the breaker failure protection hardware provided is separate from line /transformer feeder protection?	☐ YES ☐ NO

G. Communication systems

1.	a) Do you use PLCC for tele-protection of distance relays at 765, 400 & 220kV feeders b) Specify type of coupling c) Whether redundant PLCC channels provided for 400 & 765kV lines d) Specify number of PLCC channels per circuit : e) Whether dependability & security of each tele-protection channel measured & record kept ?	☐ YES ☐ NO (Ph-Ph / Ph-G/ Inter-circuit) ☐ YES ☐ NO (One / two) ☐ YES ☐ NO
2.	a) In case you use OPGW for tele-protection, are they on geographically diversified route for Main-I and Main-II relay? b) Whether dedicated fibre is being used for Main-I / Main-II relay or multiplexed channel are being used.	☐ YES ☐ NO Dedicated / multiplexed

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR

765kV, 400kV & 220kV SUBSTATIONS

H. Station DC supply systems

1.	Do you have two separate independent DC system (220V or 110V) (Source-A and Source-B)	☐ YES ☐ NO
2.	Do you have two independent DC system (48V) for PLCC (source-A and source-B)	☐ YES ☐ NO
3.	There is no mixing of supplies from DC source-A and DC source-B	☐ YES ☐ NO
4.	Whether the protection relays and trip circuits are segregated into two independent system fed through fuses from two different DC source	☐ YES ☐ NO
5.	Whether Bay wise distribution of DC supply done in the following way: a) Protection b) CB functions c) Isolator / earth switch functions d) Annunciation / Indications e) Monitoring functions	☐ YES ☐ NO
6	Whether following has been ensured in the cabling: a) Separate cables are used for AC & DC circuits b) Separate cables are used for DC-I & DC-II circuits c) Separate cables are used for different cores of CT and CVT outputs to enhance reliability & security	☐ YES ☐ NO
7	Is guidelines prescribed in CBIP manual 274 & 296 followed in general	☐ YES ☐ NO

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR

765kV, 400kV & 220kV SUBSTATIONS

E. PERFORMANCE INDICES

1.	Is there a system of periodically measuring Dependability & Security of Protection system (as given in CBIP manual 296) and recorded	☐ YES ☐ NO
2.	Is there a system of periodically measuring Dependability of switchgear associated with Protection system and recorded	☐ YES ☐ NO
3.	Is there a process of Root cause analysis of unwanted tripping events	☐ YES ☐ NO
4.	Are improvement action like revision of relay setting, better maintenance practices, modernising & retrofitting of switching & protection system taken based on above data.	☐ YES ☐ NO
5.	Is attention also given to DC supply system, tele-protection signalling, healthiness of tripping cables, terminations etc. in order to improve the performance of fault clearance system	☐ YES ☐ NO

CHECK LIST FOR AUDIT OF FAULT CLEARANCE SYSTEM FOR

765kV, 400kV & 220kV SUBSTATIONS

F. ADDITIONAL CHECKS FOR SERIES COMPENSATED LINES

1.	What is the operating principle of Main protection employed	☐ Distance ☐ Line Current differential
2.	Are both main-I & Main-II distance relay are numerical design	☐ YES ☐ NO
3.	Are both main-I & Main-II distance relay suitable for Series compensated lines	☐ YES ☐ NO
4.	Are POR tele-protection scheme employed for distance relays	☐ YES ☐ NO
5.	Position of Line VT provided on series compensated line	☐ Between Capacitor and line ☐ Between Capacitor and Bus
6.	What is the under reaching (Zone 1) setting used in teleprotection schemes (Local & Remote end)	% of line length Rationale:
7.	What is the overreaching (Zone 2) setting in used teleprotection schemes	% of line length Rationale:
8.	What kinds of measurement techniques are used to cope with voltage inversion?	☐ Phase locked voltage memory ☐ Intentional time delay Other, specify:
9.	Whether system studies carried out to check the possibility of current inversion due to series compensation	☐ YES ☐ NO
10.	Whether any system studies conducted to find the impact of	☐ YES ☐ NO

	series compensation on the performance of protections installed on adjacent lines? If yes, how many lines were found to be affected. Pl. specify _____	
11	If YES, are the affected protections on adjacent lines changed / setting revised after the introduction of series compensation?	☐ YES ☐ NO
12.	Is dynamic simulation done to fine tune settings of distance relay installed on series compensated double circuit lines?	☐ YES ☐ NO
13.	Whether performance of directional earth fault relay verifies by simulation studies	☐ YES ☐ NO
14.	When is flashover of spark gaps expected?	☐ For protected line Faults up to ohms ☐ For external faults an adjacent lines
15.	Whether measures taken for under/overreach problems at sub-harmonic oscillations?	☐ YES ☐ NO
16.	Whether MOV influence considered while setting the distance relay reach	☐ YES ☐ NO
17.	Have you experienced any security problems (Relay mal-operation) with high frequency transients caused by ☐ Flashover of spark gaps ☐ Line energisation Other, specify:	☐ YES ☐ NO
18.	If YES, how the above problem has been addressed?	_____

DETAILS OF PROTECTION AUDIT

A. **General Information:**

1 Name of Sub-station

2 Date of first commissioning

3 Type of Bus Switching Scheme:

4 Whether SLD collected or Not:

5 Audit Team:

1.

2.

3.

1) Instrument Transformer (To be filled for each one of them)

A Current transformer (C T)

1 Location of CT

a Date of CT ratio Test Testing

b

		Core I	Core II	Core III	Core IV	Core V	Core VI
i	Ratio Adopted						
ii	Ratio measured						
iii	error calculated						
	Knee point voltage						

B Capacitive voltage transformer (C V T)

1	Location of CVT			
a	Date of Testing			
b	CVT ratio Test			
		Core I	Core II	Core III
i	Ratio Adopted			
ii	Ratio measured			
iii	error calculated			
2	Location of CVT			
a	Date of Testing			
b	CVT ratio Test			
		Core I	Core II	Core III
i	Ratio Adopted			

ii	Ratio measured			
iii	error calculated			

2) Availability of Protection System

A) **Bus Bar relay**

		765kV	400kV	220kV
i)	Make and Model of Bus Bar relay			
ii)	Whether stability checks done or not			
iii)	Date of testing			
iv)	Remarks (if any)			

C) **Sub-station protection and monitoring Equipments**

	System	LBB (Make & Model)	Functional (Yes / No)	Date of last testing	Event Logger (Make & Model)	Functional (Yes / No)	Synchonising Facility Available or not	Synchro Check Relay (Make and Model)	Setting of Synhrocheck Relay
i)	765kV System								
II)	400kV System								
III)	220kV System								

D. **Transmission Line Protection**

	Name of Line	Main-I Protection (Make and Model)	Functional (Yes / No)	Date of testing	Main-II Protection (Make and Model)	Functional (Yes / No)	Date of testing	LBB Protection (Make and Model)	Functional (Yes / No)	Date of testing	PLCC/Protection coupler (Make and Model)	Functional (Yes / No)	DR (Make & Model)	Functional (Yes / No)	Time Synch. Unit (Make & Model)	OK / No OK
i)	Line-1															
ii)	Line-2															
iii)	Line-3															
iv)	Line-4															
v)	Line-5															
vi)	Line-6															

E) **Transformer Protection**

	Name of ICT	Differential Protection (Make & Model)	REF Protection (Make & Model)	Back-up Over Current Protection (Make & Model)	Over Flux Protection (Make & Model)	OTI/WTI Indication working or not	Bucholtz / PRD	Other protection	Date of last testing	LA Rating HV Side	LA Rating IV Side
i)	ICT-1										
ii)	ICT-2										
iii)	ICT-3										
iv)	ICT-4										

F) Reactor Protection

	Name of Reactor	Differential Protection (Make & Model)	REF Protection (Make & Model)	Back-up Impedance Protection (Make & Model)	OTI/WTI Indication working or not	Bucholtz / PRD	Other prot'n	Date of testing	LA Rating HV Side
i)	Line -1 Reactor								
ii)	Line -2 Reactor								
iii)	Bus Reactor-1								
iv)	Bus Reactor-2								

3) Line Parameter

		Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
i)	Name of Line						
ii)	Line Length						
iii)	Line Parameters (In Ohms/Per KM/Per Phase Primary value)						
	R1						
	X1						
	Ro						
	Xo						
	RoM						
	XoM						

iv) Present Relay setting

a Adopted Relay setting — Enclosed as Annexure -I (Please enclose the settings for all lines, transformers, Reactors and Bus Bars)

b Recommended — Enclosed as Annexure -II (Please enclose the settings for all lines, transformers, Reactors and

relay setting Bus Bars)

4) DC supply

		220 /110 V DC-I	220 /110 V DC-II	48 V DC-I	48 V DC-II
a	Measured voltage (to be measured at furthereset Panel				
i)	Positive to Earth			NA	NA
ii)	Negative to Earth				
b	No.of Cells Per Bank				
c	Availability of Battery Charger	Yes/No	Yes/No	Yes/No	Yes/No

5) Circuit Breaker

		Make and Model	Status of Breaker Available or Not	No.of trip/close coil & healthiness	PIR (Available or Not)	Date of Last Timing taken	Remarks (If any)
A.	**765kV System**						
i).	765kV Bay-1						
ii).	765kV Bay-2						
iii).	765kV Bay-3						
iv).	765kV Bay-4						
v).	765kV Bay-5						
vi).	765kV Bay-6						
B.	**400kV System**						
i).	400 KV Bay-1						
ii).	400 Kv Bay-2						
iii).	400 Kv Bay-3						
iv).	400 Kv Bay-4						
v).	400 Kv Bay-5						
vi).	400 Kv Bay-6						
vii).	400 Kv Bay-7						
viii).	400 Kv Bay-8						
ix).	400 Kv Bay-9						
x).	400 Kv Bay-10						
B	**220kV System**						
i).	220kV Bay-1						
ii).	220kV Bay-2						
iii).	220kV Bay-3						
iv).	220kV Bay-4						
v).	220kV Bay-5						

vi).	220kV Bay-6						
vii).	220kV Bay-7						
viii).	220kV Bay-8						

Note: rows to be added / deleted as required for no. of bays

6) **Availability of auxiliary System**

i)	**Auxiliary Supply**	Source of Supply	Reliability of Supply	Average tripping per month
	Supply-I			
	Supply-II			

ii) **DG Set**
Make
Rating
Whether Dg set on
Auto or manual
Fuel level

7) **Availability of UFR relay**
Make
Setting

8) **Availability of df/dt relay**
Make
Setting

9) **Special Protection Scheme (SPS)**
Available (Yes/No)
Verification

10) **Status of Corrective action based on Tripping analysis**

11) **Any Other Observation/ Comments**