

# EASTERN REGIONAL POWER COMMITTEE

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## MINUTES OF 30<sup>th</sup> PROTECTION SUB-COMMITTEE MEETING HELD AT ERPC, KOLKATA ON 16.04.2015 (THURSDAY) AT 11:00 HOURS

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List of participants is enclosed at **Annexure-A**

Member Secretary, ERPC chaired the meeting and welcomed all the participants to the 30<sup>th</sup> PCC meeting. He informed that in view of CERC directives on repeated tripping in Jharkhand system, a team from ERPC was sent to JUSNL substations (e.g. 220kV Chandil, Ranchi and 132kV Hatia S/s) to review the implementation of recommendations of earlier ERPC teams and any other protection deficiencies. The report will be placed in next PCC meeting. Thereafter, he requested SE (PS), ERPC to take up the agenda points in seriatim.

### **PART – A**

#### **ITEM NO. A.1: Confirmation of minutes of 29<sup>th</sup> Protection sub-Committee Meeting held on 20<sup>th</sup> March, 2015 at ERPC, Kolkata.**

The minutes of 29<sup>th</sup> Protection Sub-Committee meeting held on 20.03.15 circulated vide letter dated 06.04.15.

No comments have been received from any constituent.

The minutes of the above meetings may be confirmed.

#### **Deliberation in the meeting**

*Members confirmed the above minutes.*

### **PART – B**

#### **ANALYSIS & DISCUSSION ON GRID INCIDENCES WHICH OCCURRED IN CTU/STU SYSTEMS DURING MARCH, 2015.**

#### **ITEM NO. B.1: Disturbance at 220kV Dehri (BSPTCL) S/s on 05/03/15 at 19:08hrs.**

As reported by BSPTCL, at 19:10 hrs, total power failed at Dehri GSS due to breaking of R phase drop jumper of 220KV Gaya-Dehri ckt II. All 220 KV ckts from Dehri i.e. Gaya (PG)-Dehri ckt I & II and Pusauli(PG)-Dehri were made OFF.

BSPTCL may explain.

#### **Deliberation in the meeting**

*BSPTCL explained that R-phase drop jumper of 220KV Gaya-Dehri line- II was broken and hanging at 220kV Dehri S/s and heavy sparking was observed. To control the situation the operator hand tripped all the 220kV lines at Dehri s/s, thus creating total power failure. However, no relay indication was observed at 220kV Dehri S/s and there was no bus bar differential relay available at there.*

*It was felt that manual/hand tripping of all 220kV lines in a substation during such incidence is not correct practice and advised to isolate if possible only the faulty line if possible so that the total power failure of the substation could be avoided.*

BSPTCL agreed to take care in future.

ERLDC showed PMU plot and explained that at around 19:05:56:880hrs there was 4kV and 3KV voltage dip in Y-Ø and B-Ø respectively & 36A rise in Y-Ø and marginal rise in B-Ø line current of 400 kV Sasaram-Biharsariff-II line was observed at the time of fault. PMU data also showed that the fault was cleared in about 400ms.

Since no report has been received from Powergrid ER-I on the above observation and their representative was also not present in the meeting, PCC could not correlate the two incidences and arrive at any conclusion. PCC decided to discuss the issue in next PCC meeting after getting the details from Powergrid ER-I. **Powergrid ER-I shall submit the event details for further analysis.**

#### **ITEM NO. B.2: Disturbance at 220kV Bodhgaya S/s (BSPTCL) on 10/03/15 at 23:02 hrs.**

As informed by ERLDC, due to busting of R-phase CT of 220kV Gaya-Bodhgaya-I at Bodhgaya end multiple trippings occurred and Bodhgaya substation became completely dark.

BSPTCL may explain.

#### **Deliberation in the meeting**

Details of the line tripping at 220/132kV Bodhgaya S/s were placed in the meeting as follows:

<b>Sl. No.</b>	<b>Details of tripping from Bodhgaya end</b>	<b>Relay at local end</b>	<b>Relay at remote end</b>
1.	220KV PGCIL Gaya ckt-1	Dir. O/C, 86	Zone-3, Dir. E/F
2.	220KV PGCIL Gaya ckt-2	Dir. O/C, Dist. R-phase, backup, 86	Did not tripped hanging from Gaya side later hand tripped.
3.	220KV Biharsharif ckt-1	Dir. E/F, 86	
4.	220KV Biharsharif ckt-2	Dir.E/F, Dist R-phase, Backup, 86	
5.	220/132KV 150 MVA T1&2	Dir. E/F, 86	
6.	220/132KV 150 MVA T3	Ref trip, 86	
7.	220/132KV 150 MVA T4	86	
8.	Chandauti ckt-3&4	Dir. E/F, 86	

It was understood that the fault was occurred in 220kV Gaya (PG)-Bodhgaya line-I due to busting of R-phase CT at Bodhgaya end. The fault got cleared from Bodhgaya end on over current but the same was isolated in zone 3 distance protection from Gaya (PG) end, instead of zone 2. Due to delayed fault clearance from Gaya (PG) end, the fault persisted and got feed from Bodhgaya end through 220kV Gaya-Bodhgaya line-II and resulted in tripping of 220kV Gaya-Bodhgaya line-II from Bodhgaya end.

The reports of BSPTCL indicated that the fault was in zone 3 from Gaya (PG) end instead of zone 2. Since Powergrid ER-I representative was not present in the meeting, PCC decided to obtain the reports from PGCIL ER-I and discuss the issue in next PCC meeting. Powergrid was requested to submit the details urgently.

**ITEM NO. B.3: Disturbance at 400/220 kV Meramundali S/s on 12/03/15 at 17:19 hrs.**

As reported by OPTCL, at 17:19 hrs, the following elements tripped at Meramundali S/s due to operation of LBB and 400 kV Bus-I became dead:

- 400 kV Meramundali- Angul ckt-II,
- 400 kV Meramundali- IbTPS ckt-II,
- 400 kV Meramundali- Mendhasal ckt,
- 400/220 kV ICT-I,
- 400 kV Meramundali- JSPL-I (main breaker only)

OPTCL may explain.

**Deliberation in the meeting**

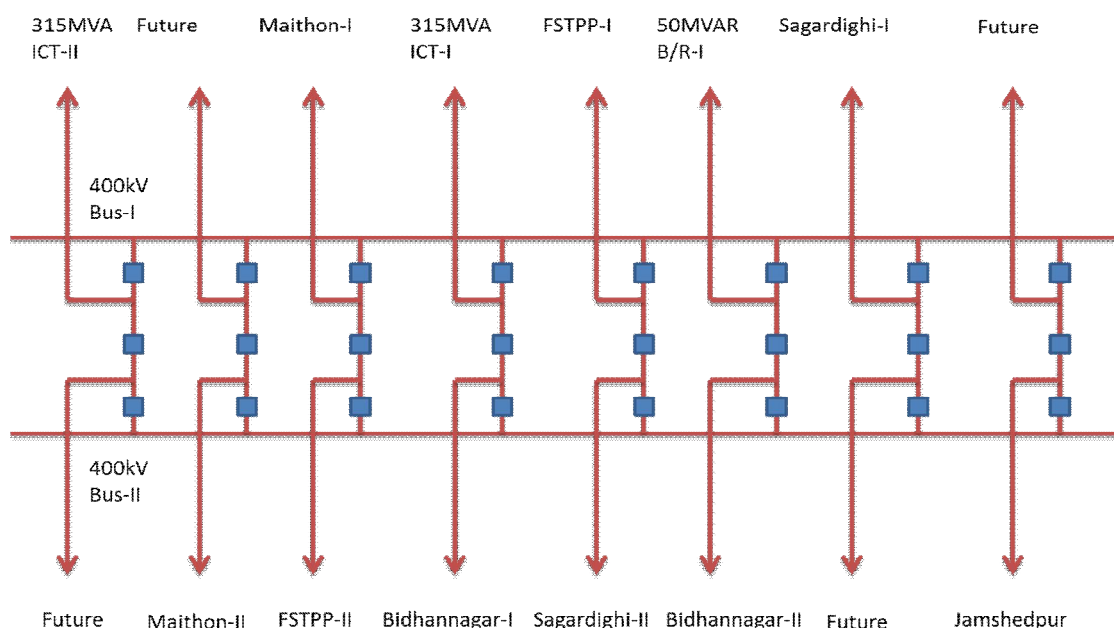
*OPTCL informed that all the lines connected to 400kV Bus-I of 400/220 kV Meramundali S/s got tripped on initiation of LBB protection caused reported by some spurious signal. No fault and relay indication was detected during the inspection at Meramundali S/s.*

**ITEM NO. B.4: Disturbance at 400kV Durgapur S/s on 03/03/15 at 18:54hrs**

As reported by ERLDC, Y-phase CT of main bay of 400kV Durgapur-Sagardighi-I burst due to which Bus bar protection i.r.to 400kV Bus-I operated and various feeders and ICTs tripped.

Powergrid may explain.

**Deliberation in the meeting**



*Powergrid informed that two simultaneous faults were occurred at 400kV Durgapur s/s, one at 18:54:10:520hrs, where Y-phase to earth fault on 400kV Durgapur-Bidhannagar-II and the fault was got isolated by distance protection (FL-126m, 27KA, Main-1 REL670, Main-2 MICOMP442) from Durgapur end. Then at 18:54:22:480hrs, there was failure of Y-phase CT which led to fault in Bus-I. Bus bar protection operated at 400kV Durgapur S/s (ABB RADHA HIGH IMPEDANCE) and tripped all lines connected to Bus-I.*

*However, 400kV Durgapur-Bidhannagar-I line got tripped due to reactor back-up impedance protection operation and 400kV Durgapur-Farakka-1 line tripped (18:54:22:528Hrs) due to STUB/SOTF(SIEMENS 7SA52) protection which may be considered as mal-operation.*

Powergrid informed that after investigation it was found that the voltage selection of the line reactor of 400kV Durgapur-Bidhannagar-I was from bus-I which caused unwanted operation of backup impedance protection of the reactor. Regarding tripping of 400kV Durgapur-Farakka line-I, investigation revealed that stub protection initiation was given from isolator and breaker parallelly instead of series or only from isolator. Powergrid informed that both had been corrected and working now satisfactorily.

#### **ITEM NO. B.5: Disturbance at 400kV Malda S/s on 15/03/15 at 02:59 hrs**

As reported by ERLDC, at 02:59 hrs fault occurred at 400kV Bus Coupler Y-ph CT secondary terminal at Malda due to fire leading to tripping of following elements:

- 400 kV Malda- Purnea- I & II
- 400 kV Malda- Farakka- I & II
- 400 kV ICT- III & V

Powergrid may explain.

#### **Deliberation in the meeting**

Powergrid explained that the fault was at 400kV Bus Coupler, Y-ph, CT secondary terminal at Malda S/s (2 Main & 1 Transfer bus scheme) and the bus-coupler O/C relay did not operate which led to Bus fault. The bus differential protection which supposed clear the fault, also failed to operate due to malfunction. Hence the above mentioned transmission lines got tripped from remote end on zone 2 distance protection.

Powergrid reported that bus differential protection relay had been changed and the order for new numerical bus differential protection for Malda S/s has also been placed.

ERLDC shown the PMU plot and informed that the fault got isolated in 450 ms and approximately matching with zone 2 timing.

#### **ITEM NO. B.6: Repeated tripping of 765 kV Angul-Jharsuguda-II on attempting to charge on 29.03.15 & 31.03.15.**

ERLDC vide letter dated 02.04.2015 reported that 765 kV Angul- Jharsuguda-II line was tripped several times since it was charged for the first time on 29/03/2015. Further, it was observed that the fault was repetitive in nature and it hampers the grid security as well.

Powergrid may explain/update.

#### **Deliberation in the meeting**

Powergrid informed that there was some tree infringements in the middle somewhere in the line section for which the line was getting tripped. The auto-reclosure feature although was in service but not operated during above incidences possibly due to improper settings.

Powergrid informed that auto-reclosure feature has been reconfigured and put into service.

#### **ITEM NO. B.7: Disturbance at Teesta-V on 21/03/15 at 11:17 Hrs**

At 11:17:03 Hrs 400 kV Teesta- Rangpo –II was tripped on distance protection at zone-1, B-phase and line was restored at 11:17:05 Hrs due to successful operation of auto-reclose. After that at 11:17:08 Hrs unit #2 tripped on Generator Protection trip 86-1 by over frequency protection. Thereafter both lines Teesta-Rangpo- I & II protection system was blocked due to the operation of VT fail (VTF) protection due to unavailability of voltage at voltage transformer.

Powergrid may explain.

### **Deliberation in the meeting**

*Powergrid informed that at 400kV Rangpo S/s end auto-reclosure was operated but not reclosed because of carrier problem. Since 400kV Teesta V-Rangpo line section is a short line (having length of only 11km), so the zone-2 reach of distance protection at 400 kV Rangpo is being overlapped with zone-2 of 400kV Binaguri-Rangpo (line length of 167 km) at Binaguri end. Hence, for a fault close to 400kV Teesta-V HPS both the distance relays at 400kV Rangpo and Binaguri ends identifying the fault in zone 2 and start racing for tripping simultaneously.*

*On the above incident one ckt of 400 kV Binaguri-Rangpo was under shutdown and the second ckt tripped on zone-2 successively which led to dead bus of 400 kV Rangpo S/s.*

*It was felt that this condition could be avoided if carrier protection was healthy. Hence, PCC advised Powergrid to take special care for maintaining the carrier protection healthy for this line. PCC also suggested Powergrid for considering time grading of zone 2 time settings of both the lines (400 kV Binaguri-Rangpo and 400 kV Rangpo-Teesta) to avoid such uncoordinated tripping even during carrier failure of the line.*

*Powergrid agreed.*

### **ITEM NO. B.8: Tripping of 400 KV Kahalgaon - Barh#1 on 13/03/15 at 22:43 hrs**

As reported by NTPC, auto reclosure operation occurred in 400KV Kh-Barh#2. At the same time Zone#2 start appeared in 400KV Kh-Barh#1. Spurious three phase tripping (SOTF) through ABB Make relay REL 521 generated & 400KV Kh-Barh#1 line tripped. NTPC is in consultation with OEM of this relay in this regard.

NTPC may update.

### **Deliberation in the meeting**

*NTPC informed that they are in process of rectification in consultation with OEM and it will be taken up during ensuing overhaul i.e. in May, 2015.*

### **ITEM NO. B.9: Tripping of 400 KV Kahalgaon - Barh#2 on 13/03/15 at 16:22 hrs, 14/03/15 at 10:07 & 10:52 Hrs. and 27/03/15 at 16:38 hrs.**

As reported by NTPC, 400 KV Kh-Barh #2 tripped on zone-1 distance protection, Auto reclose was in OFF position as per ERLDC msg, so Auto reclose failed as per scheme.

NTPC may explain.

### **Deliberation in the meeting**

*NTPC informed that OPGW work was going on hence the auto reclosure feature was kept disable.*

### **ITEM NO. B.10: Tripping of 400 kV Kahalgaon-Farakka#1 on 30/03/15 at 15:24 hrs**

As reported by NTPC, distance protection started due to 1Ø fault (Y-E) at distance 14.2 KM. Auto reclose started as per scheme but line tripped instantly due to Overvoltage protection (Stage II-140%, Inst). Y phase LA with its counter was found in damaged condition during site inspection.

NTPC may update.

### **Deliberation in the meeting**

*NTPC informed that the LA along with its counter was subsequently replaced.*

### **ITEM NO. B.11: Tripping incidences in the month of March, 2015**

Other tripping incidences occurred in the month of March, 2015 which needs explanation from constituents of either of the end. Details are enclosed in **Annexure-B.11**.

Members may discuss.

### **Deliberation in the meeting**

*Concerned members explained each of the tripping incidences. Details are updated in Annexure-B.11.*

## **PART- C**

### **FOLLOW-UP OF DECISIONS OF THE PREVIOUS PROTECTION SUB-COMMITTEE MEETING(S)**

**(The status on the follow up actions is to be furnished by respective constituents)**

### **ITEM NO. C.1: Disturbance in OPTCL system on 10/02/15 at 16:11hrs & 16:24hrs.**

At 16:11hrs, as reported by ER-II, 400kV Rengali-Indrāvati (PG) tripped from Rengali end on spurious tripping during NTAMC work. Consequently, HVDC power was being ramped down from around 800MW to 600MW (with 300MW per pole) on request of ERLDC. Just before achieving 600MW power order, at 16:24hrs, 400kV Jeypore-Bolangir line tripped on O/V Stg-1 operation at Jeypore end only. The system was remaining stably integrated upto this point. Subsequently a fault was initiated in 220kV OPTCL Grid due to snapping of pipe connecting R-Ø isolator of 220kV Meeramundali-Bhanjanagar line-II at Meramundali end which led to tripping of

220kV Meramundali-Bhanjanagar D/C,  
220kV Theruvali-Bhanjanagar D/C,  
220kv Theruvali-Laxmipur-Jeynagar D/C section,  
200kv Theruvali-Narendrapur(one ckt) ,  
220kV Narendrapur-Mendhasal and several other 220/132kV lines in Odisha Grid.

Due to the above trippings, South Odisha got isolated along with Balimela/Indravati HEP units and there was a heavy dip in voltage at Jeypore 400kV Bus. Consequently, HVDC Pole-2 tripped immediately on 'DC voltage low'. Heavy fluctuations in voltage and frequency were observed at Jeypore bus. Subsequently, HVDC Pole-1 tripped due to low voltage at Gazuwaka followed by tripping of 400 Jeypore-Gazuwaka-D/C on O/V Stage-2 and 400 Jeypore-Indrāvati on O/V Stage-1 operation. Subsequently the above island disintegrated further into two separate islands comprising of Balimela and Indravati HEPs and both the island ultimately collapsed leading to total collapse of South Odisha system.

Specifically, the following lines tripped:

- 400kV Jeypore- Indrāvati (PG)
- 400kV Indrāvati (PG)- Indrāvati(GR)
- 220kV Jeypore- Jaynagar-D/C
- 220kV Jaynagar-Balimela-D/C

- 220kV Jaynagar-Upper Kolab-D/C
- 220kV Jaynagar-Laxmipur-Theruvalli-D/C
- 220kV Theruvalli- Indrāvati (GR)-I,II,IV
- 220kV Theruvalli- Narendrapur D/C
- 220kV Bhanjanagar-Meramundali-D/C
- 220kV Bhanjanagar-Mendhasal
- 220kV Narendrapur-Mendhasal-I

During 29<sup>th</sup> PCC deliberation it was understood that, after tripping of 400kV Rengali-Indravati S/C and subsequent ramping down of HVDC power to 600 MW, the system remained stably connected and was feeding power to HVDC Gazuwaka. It was observed that, even after tripping of 400kV Jeypore-Bolangir, the voltage at Jeypore dropped to the range of 380kV to 390kV and power to South Odisha as well as to SR (through HVDC Gazuwaka) continued to be fed through OPTCL system. As observed from the relay data presented by OPTCL during the meeting, the current through both the 220kV Meramundali-Bhanjanagar circuit rose to more than 800A. This led to snapping of pipe connecting R-Ø isolator of 220kV Meramundali-Bhanjanagar-II at Meramundali end. However, 220kV Mendhasal-Bhanjanagar continued to remain in service and cater Bhanjanagar load. It appears that due to delayed clearance of the fault, 220kV Meramundali-Bhanjanagar D/C, 220 kV Bhanjanagar-Theruvalli D/C, also got tripped. In the absence of DR plots of the concerned lines, it was not possible to analyze further. At the same time, tripping of 220kV Theruvalli-Narendrapur, 220kV Narendrapur-Mendhasal and 220kV Theruvalli-Laxmipur-Jeynagar D/C also seen. Thus, due to the above un-coordinated trippings, an island was formed comprising Indrāvati HEP and Balimela generation, with reduced adjoining loads and HVDC Gazuwaka with power order of 50/60MW. The above island further disintegrated into two separate islands and both the islands collapsed on hand-tripping of Balimela/Indravati units(after) leading to total power outage in the areas south to Bhanjanagar and Mendhasal.

After detailed discussion, PCC suggested the following:

- No code was issued in respect of NTAMC work being carried out at Rengali (due to which spurious tripping occurred from Rengali end). Expediting closing of Rengali-Indravati 400kV S/C could have avoided the subsequent tripping of the lines. Powergrid is advised to ensure that, such incidents should not reoccur in future.
- O/V tripping of 400kV Jeypore-Bolangir from Jeypore end only needs to be analyzed considering that O/V was not shown in the DR channels and that no DT was sent to Bolangir (as the line remained charged from Bolangir end).
- Un-coordinated trippings of lines from Bhanjanagar, Theruvalli, Mendhasal, Meramundali, Jaynagar and Narendrapur were also observed on occurrence of fault at Meramundali. A thorough audit of protection systems at the above substations of OPTCL needs to be carried out.
- From DR obtained from Jeypore and report from GRIDCO, it can be observed that, there was a voltage unbalance. Reasons for the same needs to be investigated.
- Installation of 125MVAR Bus reactor at Jeypore needs to be expedited.
- As already discussed earlier, the conditions for run-back of HVDC Gazuwaka power order need reviewing.

### **Deliberation in the meeting**

*OPTCL informed that protection audit of OPTCL substations by CPRI will be started from last week of April, 2015.*

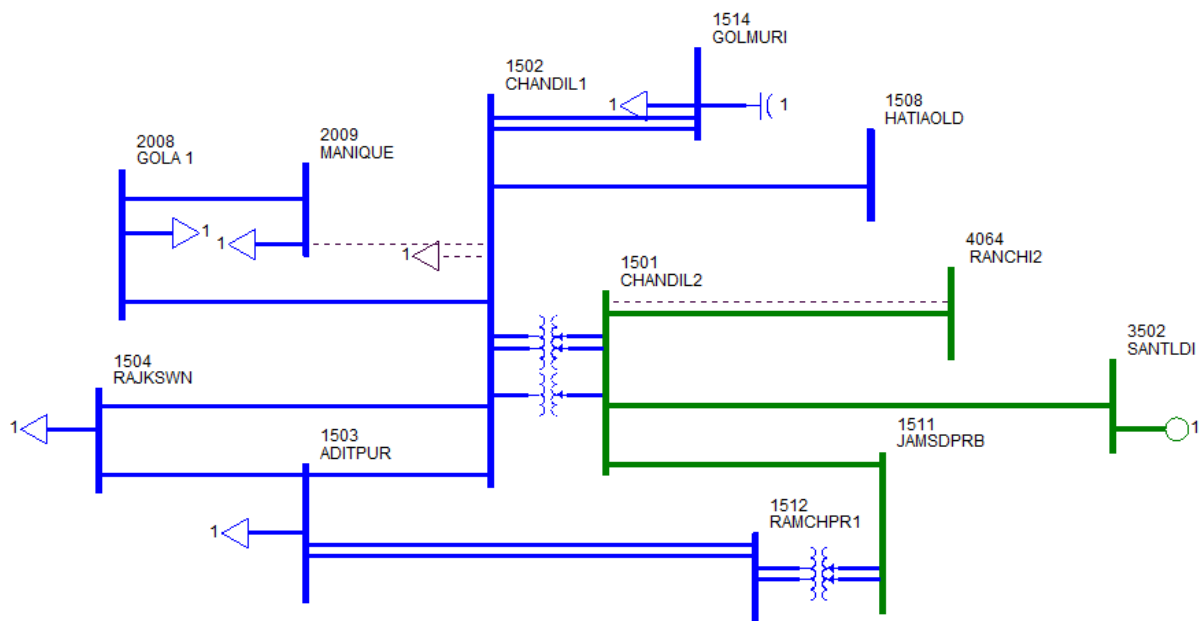
**ITEM NO. C.2: Total power failure at 220kV Chandil S/s (JUSNL system) on 15/02/15 at 13:25 hrs, 17/02/15 at 20:13 hrs and 18/02/15 at 12:26 hrs .**

JUSNL informed that following remedial actions have been taken,

- 1) C.T. polarity of STPS feeder was found wrong and the same has been corrected.

- 2) Zone II time settings have been changed to 150ms from 300ms on carrier trip is not available.
- 3) Earthing system has been checked
- 4) Concerned GM cum CE of Transmission Zone-III, has been requested to complete the following works on priority basis:
  - (a) Replacement of damaged/defective J.B. of C.T. &P.T.
  - (b) Replacement/proper routing of cables.
  - (c) Proper Sealing of gaps/holes of junctions Box and control panels .
  - (d) Maintenance of equipments of GSS religiously and Tan Delta of CT/PT to avoid failure of equipments in GSS.
  - (e) Again rechecking of all cables and wiring, CT polarity. etc. to avoid malfunction of relays.
  - (f) Checking of Earth resistance of structure, Panels and installed equipments.
  - (g) Provision of PLCC carrier trip and two group protection (Main I &II) of different make relay.

Above matters have already been discussed in special meeting in office Chamber of MD/JUSNL held on 05/02/2015 with all Zone's GMs and MD has directed all concerned GM of all Zone of JUSNL for immediate compliance.



In 29th PCC, JUSNL explained that due to reverse CT polarity in B-ph at Chandil end the 220 KV Chandil-STPS line got tripped from Chandil end and the same has been rectified. JUSNL reported that the CT polarity has been changed.

Regarding tripping of 220kV Chandil-Ramchandrapur S/C from Ramchandrapur end JUSNL informed that it is a mal-operation of old EM relays and the relays will be replaced with numerical relays.

PCC advised JUSNL to analyze the tripping of 220kV Chandil-Ranchi S/C line from Chandil end on 15/02/15 and report within a week.

JUSNL may update.

### **Deliberation in the meeting**

*JUSNL clarified that the flag of O/C relay of 220 kV Chandil-Ranchi S/C line was got stuck on 15/02/15 and the O/C relay had been replaced thereafter.*



### **ITEM NO. C.3: Repeated tripping of lines from Meramundali end on over-voltage**

In 27<sup>th</sup> PCC, OPTCL was advised to explore the possibilities of charging idle charged lines from other end instead of charging from Meramundali end or at suitable voltage level so that the over voltage tripping problem at 400kV Meramundali S/s could be minimized.

In case the above action fails to yield results, OPTCL was advised to consider the grading in over voltage settings, so that idle charged lines will trip first and provide relief for over voltage.

Thereafter, ERLDC informed that on 2<sup>nd</sup> January, 2015 sudden rise in voltage (440kV) had been observed at 400kV Meramundali S/s and it was remained for about 30 min.

PCC advised OPTCL to examine the reason behind such high voltage, and check the output of bus CVT in particular and report. OPTCL may also consider to employ numerical relay for over voltage protection which has pickup to drop off ratio above 95%.

In 28<sup>th</sup> PCC, OPTCL updated that bus CVT at 400kV Meramundali S/s had been checked and the results were found satisfactory. OPTCL confirmed that the idle charged 400kV Meramundali-IbTPS D/C lines are now charged at 220kV.

With the help of SCADA output of 400kV Meramundali bus voltage on 2.1.2015 at 05:40hrs and 6:01 hrs ERLDC explained, that there was sudden rise of voltage at Meramundali S/s. Moreover, at 06:01hrs the voltage shot up from 425kV to 440kV and sustained at that level up to 06:34 Hrs.

After detailed deliberation, it was concluded that over voltage at Meramundali S/s was due to more MVAR injection by the associated 400kV lines (both operational/idle charged) and only 400kV Meramundali-Angul line-I&II is the only sink of reactive power.

PCC advised OPTCL to take the following actions to minimize the impact of over voltage:

- Investigate the reason for such sudden rise in voltage and also to carry out MVAR flow study at 400kV Meramundali S/s during over voltage scenario/condition.
- Shift the idle charged 400 kV Meramundali-New Dubri line from Meramundali end to other source or lower voltage level for overvoltage relief.
- Set the pickup to drop up ratio of overvoltage relay setting at more than 98%.
- Voltage grading should be done for over voltage settings for all the lines of Meramundali S/s.
- The 80 MVAR line reactor of 400kV Meramundali-Jeypore line (Presently with Meramundali-Angul line-I of Powergrid) which was out of service for long due to non-availability of 400kV LA and other problems, should be charged immediately.
- The 50MVAR line reactor of 400kV Meramundali-IbTPS line-II shall be connected as a bus reactor.
- The 50MVAR line reactor of 400kV Meramundali-IbTPS line-I shall also be connected as bus reactor after necessary rectification of LA & PT selection switch.
- Main CB of 400kV Meramundali-Mendasal line shall be commissioned expeditiously.

In case of continuous overvoltage condition at Meramundali S/s reported by SLDC, OPTCL, ERLDC will explore to resort to S/C operation of 400kV D/C lines around neighboring Sub-stations if line loading is within safe limits particularly during lean hours of the day.

In 29<sup>th</sup> PCC, OPTCL informed that LA has been arranged *and the 80 MVAR bus reactor at Meramundali S/s will be charged within 2 days.*

OPTCL may update.

## **Deliberation in the meeting**

*OPTCL informed that the idle charged 400 kV Meramundali-New Duburi line from Meramundali end has been shifted to lower voltage level. The 80 MVAR Reactor was charged but the reactor was hand tripped on 10/04/2015 at 09:14 hrs as the WTI temperature reached more than 90°C. Prior to that alarm annunciation had come before one hour @ 85° C.*

*PCC advised OPTCL and Powergrid to rectify the problem and charge the above reactor immediately. PCC also advised OPTCL to comply the other recommendations in order to overcome high voltage condition at 400kV Meramundali S/s.*

### **ITEM NO. C.4: Oscillations observed in CESC system at early hours of 06/01/15**

In 27<sup>th</sup> PCC, CESC informed that from 1<sup>st</sup> January, 2015 mostly during lean hours they have observed significant active power flow fluctuations in MW (but not in MVAR). On 6<sup>th</sup> January, 2015 the oscillations were so severe fluctuations of power flow remained in the ranges of about 130 MW to 150 MW. Finding no other alternatives, they had changed the grid synchronizing point from 132kV Kasba S/s to Howrah S/s and thereafter the situation got stabilized. At present, they are not observing any oscillations.

CESC also informed that they had already engaged PRDC to investigate the problem and PRDC agreed to give the report within one month.

CESC, SLDC was advised to continue their grid synchronizing point at Howrah S/s until they get report from PRDC.

ERLDC informed that they observed sudden spikes in MVAR flow of CHMKR-I & II lines on 6<sup>th</sup> January, 2015 at around 00:01 hrs and shown the SCADA output.

PCC advised CESC to look into it. CESC agreed.

In 29<sup>th</sup> PCC, CESC informed that PRDC had advised for PSS tuning of all Budge-Budge units to minimize the oscillations during light load periods. CESC informed that the grid synchronization point has been shifted to Kasba from 4<sup>th</sup> March 2015 and no oscillations were observed in the system with the increase in summer load.

PCC agreed to convene a separate meeting on April, 2015 to discuss the PSS tuning issue of Budge-Budge units.

Subsequently, a special meeting for PSS tuning of Budge Budge units was convened on 09.04.15, the minutes is available at ERPC website.

In the special meeting held on 10.04.2015, it was decided that on the issue advice from Prof. Kulkarni, IIT, Mumbai will be sought and as per his guidance PSS tuning of CESC units as proposed by OCC/PCC will be carried out. Towards this a small group comprising members from ERPC, ERLDC, WBSETCL and CESC was formed.

Members of the group will write up a brief snapshot paper elucidating the happening of oscillations recently observed in CESC system mainly on 06/01/2015 and 14/03/2015, with all requisite data. The technical documents prepared by the group will be forwarded to Prof. A. M. Kulkarni for his initial observation and advice.

Members may note.

## **Deliberation in the meeting**

*Members noted the above developments.*

#### **ITEM NO. C.5: Disturbance in FSTPP, NTPC and JSEB system on 06.11.2014**

In 27<sup>th</sup> PCC, NTPC Farakka confirmed from PLCC counter reading that DT signal was sent to Kahalgaon end. However, they will test the PLCC system during opportunity shutdown.

In 29<sup>th</sup> PCC, FSTPP, NTPC informed the status of remaining 400kV CBs at 400kV FSTPP S/s as follows:

- a) Main bay of FSTPP-Sagardighi at FSTPP end : Completed
- b) Bay connecting FSTPP-Malda-II to Bus-II which is under outage since disturbance at FSTPP on 28/08/14 (Bay connecting to Bus-I in service): Work has been completed but not charged. NTPC informed that the CB will be charged by tomorrow.
- a) FSTPP-KhSTPP-IV Tie bay : Work has been completed but not charged. NTPC informed that they required shutdown for charging the Tie bay. OCC advised NTPC to charge the Tie bay in coordination with ERLDC.

NTPC may update.

#### **Deliberation in the meeting**

*FSTPP, NTPC informed the status of remaining 400kV CBs at 400kV FSTPP S/s as follows:*

- a) Main bay of FSTPP-Sagardighi at FSTPP end : *Completed*
- b) Bay connecting FSTPP-Malda-II to Bus-II which is under outage since disturbance at FSTPP on 28/08/14 (Bay connecting to Bus-I in service): *Completed.*
- c) FSTPP-KhSTPP-IV Tie bay : *Work has been completed and it will be charged by end of April, 2015.*

#### **ITEM NO. C.6: Disturbance at OPTCL on 26th August 2014**

*In 29<sup>th</sup> PCC, members updated the status as follows:*

1. Testing of CVTs of 400kV Indravati(PG) – Indravati(OHPC) S/C line installed at both ends, for proper output and satisfactory performance. If required, erroneous CVT to be replaced with a new one -----OHPC informed that new CVT has been arranged and it will be installed by end of March, 2015.
2. Making numerical over-voltage protection to ensure desired drop-off to pick-up ratio (above 0.95) be available at PGCIL and OHPC 400kV S/Stns, in place of existing VTU-31 (EE make) electromechanical relay and reviewing their setting based on observed CVT outputs ----- OHPC informed that after replacement of defective CVT, they will implement the O/V settings in numerical relay (Micom-P442 relay) and they will keep the existing EM O/V relay as alarm.
3. Ensuring that DR is triggered whenever any protection operates and corresponding event log is telemetered to ERLDC with GPS synchronized time stamping. PCC felt Disturbance Recorder is essential for 400kV system and advised concern utilities (OHPC & Powergrid) to implement the same. --- OHPC informed that EL is in service, for time synchronization of DR they are in the process of tendering of GPS and it may take 3-4 months to complete the work. However, they informed that presently the numerical relays are being time synchronized with the help of local time stamping. PGCIL informed that EL has been received at site and they will implement soon.
4. Exploring possibility of incorporating Transient Fault Recorders for the FSCs at Jeypur, for analysis of incidents. ----- PGCIL agreed to implement in numerical relays and EL.
5. The two 400/220kV ICTs at UIHEP are owned and maintained by different utilities viz. OHPC and PGCIL. For proper maintenance coordination and ease of access it is suggested that O&M of both the ICTs should be done by a single utility. PCC advised OHPC and Powergrid to resolve the issue bilaterally.----- OHPC and Powergrid agreed to resolve the issue bilaterally.

6. Reviewing over-current protection settings in 220kV lines of OPTCL—ERPC and ERLDC confirmed that the settings provided are in order.

*PCC advised to complete the above action plans at the earliest.*

OPTCL, OHPC & Powergrid may update.

#### **Deliberation in the meeting**

*PCC advised to complete the above action plans at the earliest.*

### **ITEM NO. C.7: Members may update the following:**

1. In 28<sup>th</sup> PCC, WBSETCL informed that 6 nos CTs are required for bus coupler for bus bar protection. However, the 220 kV two main bus system will be made operational at Bidhannagar S/s within March, 2015.

WBSETCL may update the present status.

#### **Deliberation in the meeting**

*WBSETCL informed that the 220 kV two main bus system will be made operational at Bidhannagar S/s by April, 2015*

2. In 29<sup>th</sup> TCC Meeting, BSPTCL informed that the main protection relay at 132kV Kahalgaon S/s (BSPTCL) will be installed by February, 2015.

In 29<sup>th</sup> PCC, BSPTCL informed that the reconductoring work is near completion and main protection relay will be installed by end of March, 2015.

BSPTCL may update.

#### **Deliberation in the meeting**

*BSPTCL informed that the reconductoring work is near completion and main protection relay will be installed by end of April, 2015.*

3. In 29<sup>th</sup> PCC, JSEB informed that,
  - For replacement of old EM relays with Micom P442 in 132kV Chandil-Hatia-I line, the relay is available at site and it will be installed by April, 2015.
  - JUSNL informed that work has been awarded to M/S Areva for supply, retrofitting, testing and commissioning of Micom relays in 33kV feeders at Jamshedpur. New relays have been installed in 8 feeders and the material yet to be received for installation of relays at rest of the 8 feeders.

JSEB may update.

#### **Deliberation in the meeting**

*JUSNL updated as follows:*

- *For replacement of old EM relays with Micom P442 in 132kV Chandil-Hatia-I line, the relay is available at site and it will be installed by May, 2015.*
- *JUSNL informed that work has been awarded to M/S Areva for supply, retrofitting, testing*

*and commissioning of Micom relays in 33kV feeders at Jamshedpur. New relays have been installed in 8 feeders and the material received for installation of relays at rest of the 8 feeders of Jamshedpur. Work will be completed by May, 2015.*

4. OPTCL may please update the latest status on following substations:

**a) 220 kV Theruvali S/s**

- Seven Nos. electromagnetic Over Current & Earth fault relays at 220 kV Theruvali S/s have been replaced. All electromagnetic Over Current & Earth fault relays at 220 kV Theruvali S/s have been replaced except two relays of Autotransformer-I & II, which are expected to be completed by March, 2015.
- The new 220 kV bus bar protection has been installed at Theruvali but the same could not put in service because of some defective components. Replacement of defective components is in progress by M/s Siemens. The scheme will be put in service by end of March, 2015.

**Deliberation in the meeting**

- *Seven Nos. electromagnetic Over Current & Earth fault relays at 220 kV Theruvali S/s have been replaced. All electromagnetic Over Current & Earth fault relays at 220 kV Theruvali S/s have been replaced except two relays of Autotransformer-I & II, which are expected to be completed by April, 2015.*
- *The new 220 kV bus bar protection has been installed at Theruvali but the same could not put in service because of some defective components. Replacement of defective components is in progress by M/s Siemens. The scheme will be put in service by end of April, 2015.*

**b) 220kV Budhipadar S/s**

- The new 220 kV bus bar protection at Budhipadar S/s has been completed, but due to some relays found defective afterwards, the commissioning could not be completed. M/s. Siemens is replacing the defective relays. The scheme will be put in service by end of April, 2015.

**Deliberation in the meeting**

- *The new 220 kV bus bar protection at Budhipadar S/s has been completed, but due to some relays found defective afterwards, the commissioning could not be completed. M/s. Siemens is replacing the defective relays. The scheme will be put in service by end of April, 2015.*

**c) 400/220 kV Mendhasal S/s**

- In line with advice from 24th PCC carrying out testing of all the relays at Mendhasal S/s and reviewing the resistive reach settings are in progress and would be completed by March, 2015.
- 26th PCC advised OPTCL to install the PLCC system to enable inter tripping.: OPTCL informed that intertripping scheme will be implemented after installation of fiber optic cable (OPGW work).

**Deliberation in the meeting**

- *In line with advice from 24th PCC carrying out testing of all the relays at Mendhasal S/s and reviewing the resistive reach settings are in progress and would be completed by April, 2015.*
- *26th PCC advised OPTCL to install the PLCC system to enable inter tripping.: OPTCL informed that intertripping scheme will be implemented after installation of fiber optic*

*cable (OPGW work).*

**d) 220kV Rengali and Barkote S/s**

- Replacement of Electromagnetic O/C & E/F relays with numerical relays at 220kV Barkote S/s had been completed.
- Four feeders at Rengali S/s are replaced with numerical relays and the installation of other 2 feeders would be completed by March, 2015.

**Deliberation in the meeting**

- *Four feeders at Rengali S/s are replaced with numerical relays and the installation of other 2 feeders would be completed by April, 2015.*

**e) 400kV Meramundali S/s**

- Replacement of BUS-I CB of 401 diameter (IbTPS-II) has been completed.
- Replacement of 220kV CB Auto-II is in progress and expected to be commissioned by March'2015.
- Installation and testing of 220kV Bus bar protection for Meramundali has been completed, expected to be in service by March' 2015.
- 26<sup>th</sup> PCC advised to check the healthiness of CT and enable CT supervision for all CTs: OPTCL informed that work is in progress and expected by end of March, 2015.

**Deliberation in the meeting**

- *Replacement of 220kV CB Auto-II is in progress and expected to be commissioned by April'2015.*
- *Installation and testing of 220kV Bus bar protection for Meramundali has been completed, expected to be in service by April' 2015.*
- *26<sup>th</sup> PCC advised to check the healthiness of CT and enable CT supervision for all CTs: OPTCL informed that work is in progress and expected by end of April, 2015.*

**ITEM NO. C.8: ERPC recommendations on repeated trippings at 132 kV Purnea (BSPTCL) S/S**

In 28<sup>th</sup> TCC, Audit team has presented their observations and recommendations of 132kV Purnea and Forbesgunj (BSPTCL). During presentation three types of recommendations (short term, medium term and long term) were given.

TCC advised BSPTCL to implement the short term and medium term recommendations within 2/3 months time and to place the roadmap for implementation of all the recommendations to ERPC Secretariat at the earliest.

In 25<sup>th</sup> PCC, PCC advised BSPTCL to submit the latest implementation status on ERPC recommendations on monthly basis. BSPTCL agreed.

BSPTCL may update.

**Deliberation in the meeting**

*BSPTCL updated the latest status. The latest status is enclosed at **Annexure-C.8**.*

**ITEM NO. C.9: PROTECTION PHILOSOPHY OF EASTERN REGION**

A special meeting was held on 30.12.2014 to review the zone settings based on CEA recommendations at ERPC, Kolkata. After detailed deliberation, members decided the zone

settings of distance protection as follows:

Sl. No.	Zone	Direction	Protected Line Reach Settings	Time Settings (in Seconds)	Remarks
1	Zone-1	Forward	80%	Instantaneous (0)	As per CEA
2a	Zone-2 (for 400 kV and above)	Forward	For single ckt- 120 % of the protected line	0.35	As per CEA
			For double ckt- 150 % of the protected line	0.5 to 0.6 - if Z2 reach overreaches the 50% of the shortest line ; 0.35- otherwise	As per CEA
2b	Zone-2 (for 220 kV and below)	Forward	120 % of the protected line or 100% of the protected line + 50% of the adjacent shortest line	0.35	As per CEA with minor changes
3	Zone-3	Forward	120 % of the (Protected line + Next longest line)	0.8 - 1.0	As per CEA
4	Zone-4	Reverse	10%- for long lines (for line length of 100 km and above) 20%- for shot lines (for line length of less than 100 km)	0.5- if Z4 reach overreaches the 50 % of reverse shortest line; 0.35- otherwise	As per CEA

In 27<sup>th</sup> PCC, Members raised the issue regarding finalizing settings of the Directional Earth Fault (DEF) and Back up O/C.

In 28<sup>th</sup> PCC, Powergrid informed that the revised settings will be discussed at their Engineering Wing in a separate meeting scheduled to be held in March, 2015. Powergrid informed that they will communicate their views.

It was decided that a Special meeting for finalization of Zone settings as per the revised protection philosophy will be held in the month of April, 2015.

Accordingly, the meeting is scheduled to be held on 10<sup>th</sup> April, 2015. All constituents are requested to submit the zone settings as per revised by 30<sup>th</sup> March, 2015.

*29<sup>th</sup> PCC advised all the constituents to submit the zone settings as per revised settings by 30<sup>th</sup> March 2015.*

*Powergrid informed that the revised settings will be discussed at their Engineering Wing in a separate meeting scheduled to be held in March, 2015. Powergrid informed that they will communicate their views.*

A Special meeting for finalization of Zone settings as per the revised protection philosophy was convened on 10<sup>th</sup> April, 2015; the minutes is available at ERPC website.

Members may note.

### **Deliberation in the meeting**

*PCC requested all the constituents to submit the revised settings within a month.*

*Constituents agreed.*

Minutes of 30<sup>th</sup> PCC meeting

### **ITEM NO. C.10: Third Party Protection Audit Format**

The format for data collection as per the recommendations of Task Force to initiate 2<sup>nd</sup> Third Party Protection Audit was made available in ERPC website and also circulated to constituents by letter vide dated 20.02.2015. All constituents are requested to send the requisite information by 16<sup>th</sup> March, 2015. The further course of action for 2<sup>nd</sup> Third Party Protection Audit will be initiated after receiving the data.

In 28<sup>th</sup> PCC, members advised all constituents to send the data as per format available in ERPC website by 16<sup>th</sup> March, 2015.

In 29<sup>th</sup> PCC, constituents opined that collecting data from sub-station would take time and mean while the Protection Audit may be started.

PCC decided to start the Protection Audit from May, 2015 as per the check list. The check list will be available at ERPC website.

The audit plan is attached at **Annexure- C.10** for finalization and further action.

Members may note.

#### **Deliberation in the meeting**

*Powergrid informed that the new protection settings are under review by their Corporate Protection wing and those settings will be implemented within a month. Powergrid requested to start the 2nd Third Party Protection Audit from June, 2015 onwards.*

*PCC agreed and informed that all constituents should nominate the committee member for the audit in next PCC meeting.*

### **ITEM NO. C.11: Proposal for review of PDO conditions for HVDC Gajuwaka Poles, in view of repeated tripping of lines in S. Odisha**

In 28<sup>th</sup> PCC, In view of repeated trippings of EHV lines causing major disturbance in South Odisha for the past six months, ERLDC proposed to review the PDO conditions for Gazuwaka HVDC back to back poles to meet the eventualities arising out of the consequences. The existing & proposed PDO conditions were presented by ERLDC. While appreciating the consideration of various contingencies over the years experience of major disturbances in South Odisha, PCC felt that power flow limits suggested are purely operational matters. If the power flow limits are approved in OCC meeting, the PDO conditions will be reviewed in next PCC meeting. The constituent members requested to provide the proposals in the MoM to study and offer opinions/feedback in next PCC meeting. ERLDC agreed to the suggestion.

In 29<sup>th</sup> PCC, OPTCL agreed to the proposal.

OCC decided that the issue is to be discussed with Powergrid HVDC engineers for implementation of the proposal.

Powergrid/ERLDC may update.

#### **Deliberation in the meeting**

*PCC advised Powergrid to pursue with their HVDC Corporate wing/SR for implementation of the proposal.*



## ITEM NO. C.12: ANY OTHER ITEM.

### 1. Delayed fault clearance of 400kV Bongaigaon-New Siliguri-III in the month of January, 2015 ----NLDC

NLDC vide letter dated 21.02.2015 informed that, the fault in above said line was not cleared within specified time as per section 3.e of Grid Standards Regulation of CEA, 2010, twice in the month of January, 2015.

#### Deliberation in the meeting

*PCC advised Powergrid to investigate and submit the report and remedial actions taken. Powergrid agreed.*

### 2. Disturbance in South Odisha system on 12<sup>th</sup> April, 2015

At 10:53hrs of 12/04/15, due to a disturbance South Odisha including ISTS system around 150MW load loss occurred at Bhanjanagar/Nayagarh. Prior to the disturbance, 315MVA ICT-I at Mendhasal was taken under shutdown for repair works of the bus side isolator. To avoid over loading of ICT-II, radialization of Mendhasal loads was done by opening of 220kV Mendhasal-Narendrapur, 220kV Mendhasal-Bhanjanagar and 220kV Mendhasal-Nayagarh ckt. Due to this power flow in 220kV Meramundali-Bhanjanagar-D/c increased to around 150MW/ckt. HVDC Gazuwaka flow was 700MW at the time of the incident. At 10:53hrs, 400kV Angul-Bolangir tripped on R-N fault (If=1kA) 94km from Angul end. This led to increase in power flow through both 400kV Rengali-Indrāvati-Jeypore and 220kV Meramundali-Bhanjanagar D/C. Coincidentally, 220kV Meeramundali-Bhanjanagar-II tripped on R-N fault from Bhanjanagar end at that time, leading to tripping of 220kV Meeramundali-Bhanjanagar-I on O/C protection at 10:55hrs (Pre-tripping flow observed to be around 230MW as per SCADA data). The above trippings led to isolation of South Odisha system from the rest of Odisha grid. As only 400kV Rengali-Indrāvati-Jeypore remained in service feeding HVDC Gazuwaka and South Odisha loads, heavy dip in 400kV Bus voltage at Jeypore occurred to around 350kV with similar dip in Gazuwaka (east Bus voltage) (reported to be as low as 260kV). It is suspected that due to above low voltage at Gazuwaka (EB), PDO operated to ramp down HVDC Gazuwaka to 500MW. However, even after ramp down to 500MW low voltage at Gazuwaka (EB) continued due to which HVDC Gazuwaka flow was further reduced to 300MW. The above led to over voltage situation at Jeypore bus and at 11:10hrs, 400kV Jeypore-Bolangir (which was in floating condition) tripped on over voltage which was confirmed by DT signal received at Bolangir end. At the same time 400kV Jeypore-Gazuwaka-I also tripped on over voltage at Jeypore. At 11:11hrs, both 160MVA Auto transformers at Bhanjanagar tripped due to over flux relay operation. 400kV Angul-Bolangir and 400kV Jeypore-Bolangir was taken into service at 11:43hrs and 11:50hrs respectively. 220kV Meeramundali-Bhanjanagar-I charged at 12:12hrs and ckt-II was declared faulty as the ckt again tripped on R-N fault.

#### Discrepancies

- Radialization of Mendhasal ICT and loads by opening of outgoing/incoming feeders without availing code and intimation to ERLDC needs to be addressed.
- It is observed that Powergrid took significant time to collect and furnish relay indications to ERLDC and further to charge Jeypore-Bolangir-Angul sections. Such delay in furnishing of information/taking action needs to be minimized.
- As per PMU data there was no Auto reclose operation i.r.to 400kV Angul-Bolangir line even though the fault was a single phase to ground fault.
- OPTCL/GRIDCO is also significant time to furnish the relay indications and inform details of events due to which there was a delay in taking action/restoration.

### **Deliberation in the meeting**

*ERLDC explained the details of the incidence.*

*PCC advised OPTCL and Powergrid to furnish the detailed report with DR/EL data related to the above tripping so that it can be discussed in next PCC meeting.*

### **3. Presentation on Superconducting Fault Current Limiters by Applied Materials**

#### **Deliberation in the meeting**

*A brief presentation was delivered by M/S Applied Materials engineers on Superconducting Fault Current Limiters. They explained the technology behind the superconductor FCL and how it is beneficial to limit the fault current and its uses in transmission system. Also, the various roles of Superconducting Fault Current Limiters by which it can be used such as limiting the fault current of transmission line, limiting the fault level at substation and hence enhancing the existing substation capacity without splitting the bus etc. . The presentation is enclosed at **Annexure-C.12.3**.*

Meeting ended with vote of thanks to the chair.

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Participants in the 30<sup>th</sup> PCC Meeting of ERPC

Venue: ERPC Conference Room, Kolkata

Time: 11:00 hrs

Date: 16.04.2015 (Thursday)

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"Coming together is a beginning, staying together is progress, and working together is success." –Henry Ford

### Participants in the 30<sup>th</sup> PCC Meeting of ERPC

Venue: ERPC Conference Room, Kolkata

Time: 11:00 hrs

Date: 16.04.2015 (Thursday)

Sl No	Name	Designation/ Organization	Contact Number	Email	Signature
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37					
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## List of intra regional transmission lines (220 kV &amp; above) in ER which tripped in Mar'15

LINE NAME	TRIP DATE	TRIP TIME	Fault Clearance time in msec	Relay Indication LOCAL END	Relay Indication REMOTE END	Auto Recloser Operated for L-G Fault	DR/EL received	DR/EL received within 24 Hrs	Remarks/Brief Reasons
400 KV KODARMA-GAYA-I	03.03.15	16:49	<100	R-N	R-N Zone I 48.1 km from Gaya f/c 4.8 kA	unsuccessful autoreclose operation found in pmu	Yes	No	R-N fault (Three consecutive voltage dips found in pmu). PG (ER-1) not available for discussion.
400 KV BARIPADA-JAMSHEDPUR	04.03.15	23:40	<100	Y-N	Y-N E/F z-1 4.11 km from Jmsdpur If = 18.29 kA	successful but tripped again within 3 sec	Yes	No	line is tried to restore on 00:31 hrs on 05.03.15 but tripped again on same fault indication. Tripping was in order
400 KV ARAMBAG - BAKRESWAR	10.03.15	12:28	Not found in pmu	Y-N	Y-N	Not found in pmu	No	No	Y-N fault. It was informed that Auto reclosure was out of service due to carrier problem.
400 KV MERAMANDLI - MENDASAL	12.03.15	17:18	Not found in pmu	BUS -1 FAULT AT MERAMANDLI	Information not available	Not found in pmu	No	No	BUS -1 FAULT AT MERAMANDLI. No fault, spurious signal was generated.
400 KV MERAMANDLI - ANGUL - 2									
400 KV DURGAPUR-JAMSHEDPUR	13.03.15	12:36	<100	R-N 59.3 km from DGP F/C 4 kA	R-N	unsuccessful autoreclose operation found in pmu	No	No	R-N fault (Three consecutive voltage dips found in pmu). Autoreclosure is healthy. The line was charged after line patrolling.
400 KV KHSTPP-BARH-II	13.03.15	16:26	<100	DISTANCE PROTECTION(Z 1 TRIP-39.5%,R-PHASE,5.2 KA, 85 km from KhSTPP)	R-N	A/R under s/d	No	No	R-N fault, Discussed in Item n. B.9
400 KV KAHALGAON - BARH - 1	13.03.15	22:43	<100	Z-II, 3 Phase trip	B-N	Not found in pmu	Yes	No	B-N fault (from PMU), The incidence was happend during OPGW work.
400 KV KHSTPP-BARH-II	14.03.15	10:07	<100	Z-I, R-Y, 87 km from KhSTPP	Information not available	A/R under s/d	No	No	Y-N fault from pmu but from KhSTPP report R-Y phase, The incidence was happend during OPGW
400 KV KHSTPP-BARH-II	14.03.15	10:52	<100	Z-I, R-N, 89 km from KhSTPP	Information not available	A/R under s/d	No	No	Y-N fault from pmu but from KhSTPP report R-N phase, The incidence was happend during OPGW work.
400 KV GAYA KODERMA II	14.03.15	13:32	<100	B-N 6.52 kA. 31.3 km from Gaya	B-N, Z-I, 3.15 f/c, 116.5 km from Koderma	unsuccessful autoreclose operation found in pmu	No	No	B-N fault
400 KV DSTPS-RAGHUNATHPUR-II	15.03.15	12:10	88.38	B-N, z-II, 2.988 kA f/c, 78.77 km from DSTPS	Information not available	unsuccessful autoreclose operation found in pmu	No	No	B-N FAULT
400 KV GAYA-KODARMA-II	15.03.15	13:15	400	Information not available	B-N Z-II Fault Current-3.39KA, Direct Trip send, 86.1 & 86.2operated, dist-119.4KM	At 13:17:06 A/R successful at koderma end. At 13:17:33 A/R not successful at Koderma end	Yes	No	B-N FAULT, No report recieved from Gaya end.
400 KV GAYA-KODARMA-I	15.03.15	12:55	<100	Information not available	R-N, Z-I, 5.12 kA, 98.7 km from koderma	unsuccessful autoreclose operation found in pmu	Yes	No	There were 3 consecutive trippings: 12:55:08 A/R successful, 12:55:41 A/R successful, 12::55:52 A/R unsuccessful, No report recieved from Gaya end.
400 KV GAYA-KODARMA-I	15.03.15	14:11	<100	Information not available	R-N, Z-I, 3.94 kA f/c, 101.3 km from koderma	A/R successful at koderma end but unsuccessful at Gaya end. Line was hanging from Koderma end till 16:24 hrs	Yes	No	R-N FAULT. No report recieved from Gaya end.

LINE NAME	TRIP DATE	TRIP TIME	Fault Clearance time in msec	Relay Indication LOCAL END	Relay Indication REMOTE END	Auto Recloser Operated for L-G Fault	DR/EL received	DR/EL received within 24 Hrs	Remarks/Brief Reasons
400 KV KHARAGPUR-KTPP -I	20.03.15	10:10	<100	No information found	B-N, Z-I, 1.8 km from ktp, 13.8 kA f/c	Not found in pmu	No	No	B-N fault. Autoreclosure is in service at Kharagpur end.
400 KV BINAGURI-RANGPO-2	21.03.15	11:17	<360	Z-2, Y-N	No information found	unsuccessful autoreclose operation found in pmu	No	No	Unsuccessful A/R operation found in pmu after 4 sec of the tripping. Discussed in item no. B7.
400 KV TEESTA RANGPO DC	21.03.15	11:17	<360	VTF	No information found	A/R Successful at Teesta end for ckt II but then line tripped on VTF	Yes	Yes	VT fail protection (VTF). Discussed in item no. B7.
400 KV JEERAT-BAKRESWAR	22.03.15	10:45	pmu data was down	Information not available	Information not available	pmu data was down	No	No	DISC INSULATOR FAILED IN TL 102 , B PHASE . INSULATOR REPLACED
400 KV MEERAMUNDALI-MENDASHAL	22.03.15	15:06	<100	Information not available	Information not available	Not found in pmu	No	No	B-N fault. Autoreclosure was not initiated OPTCL was advised to give a report.
400 KV ARAMBAG-BAKRESWAR	23.03.15	12:01	<100	C-N , ZONE 1 , FAULT LOOP L3N, DISTANCE =29.2 KM, FAULT CURRENT=8.8A KA	C-N , ZONE 2 , FAULT LOOP L3N, DISTANCE =102.5KM,	Not found in pmu	No	No	B-N fault. Autoreclosure was not operated due to carrier problem, the same has been rectified.
400 KV BARIPADA-MENDASAL-1	25.03.15	15:56	<100	Information not available	Information not available	Not found in pmu	No	No	R-N FAULT. Powergrid was advised to give a report.
400 KV RANCHI-ROURKELA-I	26.03.15	19:02	>300	Not tripped	Y-N, Z-II, 167 km from RKL, F/C 2.3 kA	Not found in pmu	No	No	Y-N fault. PG ER-I not available for discussion.
400 KV KAHALGAON - BARH - II	27.03.15	16:38	<100	Z-1, 6.6 kA, B-N 64 km from KhSTPP, distance 30 %	Z-1, 2.9 kA, B-N, 116 km from Barh	A/R shutdown	No	No	B-N fault
400 KV GAYA - KODARMA -2	27.03.15	18:29	<100	B-N, 52.2 KM from Gaya end F/C 5.53 KA	B phase Z1 85 KM from Koderma F/C 5.72 KA	unsuccessful autoreclose operation found in pmu	Yes	Yes	(In case of auto reclose operation more than one voltage dips observed. These types of voltage dips observed in previous tripping of Gaya - Koderma also). No report received from Gaya end.
400 KV JAMSHEDPUR-BARIPADA LINE	27.03.15	23:06	<100	Y-B PHASE FAULT, 21.8 KM FROM JSR. F.C-IY-12.7KA, IB-12.46. KA	Y-B, 114.3 km from Baripada, IY = 2.84 kA, IB = 3.08 kA	L-L fault	Yes	No	The rope related to opgw work during severe storm to fall causing ph to ph fault (Though L-L fault but rise in zero sequence voltage observed in pmu suspecting L-L-G fault)
400 KV RENGALI-KEONJHAR	28.03.15	13:27	<100	Z2, B-N 92.7km from Rengali F/C 3.966 kA	Zone - 1, 6.6 kM from Keonjhar Fault current - 2.91 kA,	Not found in pmu	Yes	No	B-N fault. Powergrid was advised to check.
400 KV BIHARSHARIFF-SASARAM II	30.03.15	13:17	<100	R-phase LA blast at Biharsharif end. Fault current = 28 KA, Distance = 0.07 KM	No information found	unsuccessful autoreclose operation found in pmu	Yes	Yes	R-PH LA BURST AT BIHARSHARIFF
400 KV GAYA-KODERMA-II	30.03.15	13:28	<100	B-N FAULT, 31.4 KV FROM GAYA	No information found	unsuccessful autoreclose operation found in pmu	No	No	B-N fault
400 KV PURNEA-BIHARSHARIFF-II	30.03.15	13:47	<100	Information not available	B-N fault. Fault current = 11.22 KA, 13.46 KM from Biharsharif end	A/R successful. But line tripped due to fault in reclaim time	Yes	Yes	B-N FAULT
400 KV MAITHON-MEJIA-I	30.03.15	14:34	93.93	Information not available	Z-I, B-N, f/c= 1.045 kA at Mejia end	A/R successful at Maithon end	No	No	TRIPPED ON B-N , A/R SUCCESSFUL AT MAITHON END

LINE NAME	TRIP DATE	TRIP TIME	Fault Clearance time in msec	Relay Indication LOCAL END	Relay Indication REMOTE END	Auto Recloser Operated for L-G Fault	DR/EL received	DR/EL received within 24 Hrs	Remarks/Brief Reasons
400 KV FARAKKA - KAHALGAON - 1	30.03.15	15:24	<100	Z-I, Y -N, 5.4 kA fc, 71 km (68.4%) from Farakka end	Overvoltage protection (inst.) then Y-N, Z-I, 14.1 km from Kahalgaon	unsuccessful autoreclose operation found in pmu (line tripped instantly at Kahalgaon due to overvoltage relay action)	Yes	No	PROBLEM AT Y-PHASE LA AT KAHALGAON END. <i>Discussed in Item no. B.10.</i>
400 KV JEERAT-SUBHASGRAM	30.03.15	19:18	<100	Information not available	Information not available	A/R SUCCESSFUL AT SUBHASGRAM END	No	No	TRIPPED ON B-N , A/R SUCCESSFUL AT SUBHASGRAM END. <i>Tripping incidence was occurred during OPGW work.</i>
765 kV Angul Sundargarh II	31.03.15	09:48	<100	Y-N, Z-I, FC 2.78 kA, 202 km from Angul	Y-N, FC 3.66 kA, 161.8 km from Sundargarh	Not found in pmu	No	No	Y-N fault
400 KV MERAMANDALI-MENDHASAL	31.03.15	16:36	Not found in pmu	Information not available	Information not available	Not found in pmu	No	No	TRIPPED FROM MENDHASAL END ONLY. <i>No fault spurious signal was generated.</i>
220 KV TARKERA-ROURKELA D/C	12.03.15	11:50	>600	B-N	B-N	Not found in pmu	No	No	B-N Fault. <i>Autoreclosure was not in service.</i>
220 KV DHANBAD - MAITHON - 2	27.03.15	17:17	<160	B phase Z1 at Dhanbad end (Fault location 25.52 KM)	B phase Z1 at Maithon end (Fault location 34.3 KM)	Two voltage dips observed within 5 sec	No	No	B-N Fault. <i>Autoreclosure did not operated successfully.</i>
220 KV MUZAFFARPUR-HAZIPUR-II	31.03.15	09:46	<100	Information not available	Information not available	Not found in pmu	No	No	B-N FAULT. <i>Autoreclosure was not in service.</i>
220 KV PURNEA-MADHEPURA-I	31.03.15	12:29	<100	Information not available	Information not available	Not found in pmu	No	No	R-PHASE JUMPER SNAPPED AT LOC 65/0. <i>Autoreclosure was not in service.</i>

## ERPC recommendations:

S.No.	Recommendations:	Latest status
i	CT Secondary cables of all the 132KV Bays are to be replaced by 2.5 sq mm 4 core Multi-stranded Armoured cables with proper terminations at CT Base Terminal Box, CTJB and Panel end.	Work will be completed by March, 2015
ii	The CTJB of all the 132KV Bays are to be replaced by proper CTJB having approved specifications. The terminal Blocks of the CTJB should be stud type which comes along with the CTJB. The Cables should be brought inside the CTJB with proper GLANDS and dressing. The CTJB should be EARHTED through 4mm Flat Earthing strips duly connected to the earthing mesh in the switchyard .  The same is also applicable for 132KV Bus PTJB	Completed.
iii	Earth Resistance of all the structures of the 132KV Switchyard ( i.e. CT Structure, Breaker Structure, Isolator Structure, Gantry, Bus Support Structures, PT structures, etc.) should be measured and it should be brought down within 1(one) ohms wherever applicable.	completed (earth resistance bellow 0.5 ohm)
iv	TAN DELTA Measurements of all the 132KV CT's are to be carried out. The TAN DELTA value should be within <b>2%</b> (C.P.R.I recommended limit for 132 kV C.T, whereas some utilities prefers 1% also) and if any value exceeds this, or an increasing pattern is observed on subsequent measurements, and if any value exceeds this, then the particular CT has to be replaced by a healthy CT.	Completed, Out of 8 CTs two CTs in Saharsa bay have been replaced with new CTs. 3 CTs in PGCIL-I bay have been replaced.
v	132KV CT Specifications are to be standardised for 132KV Lines and transformers for the whole BSPTCL system in order to reduce human error during Installation and Commissioning. This type of varied CT's having different Core Classifications is not advisable to be used in the Protection System. This will in turn reduce the margin of error during commissioning process as well as reduce the INVENTORY for Spares.	In process
vi	Presently the CT Ratio of all the 132KV CT's are to be checked for its ratio and Polarity. Thereafter, the Protection and the Metering Cores are to be identified which will be used for Distance, Backup and Metering Purpose for all the Three Phases. Accordingly, the Connections in the CTJB and thereafter the terminations to the Panel end are to be completed. For a Guideline, the PS class Cores having a saturation of around 1400Volts may be used for Distance Protection, another PS class core or 5P cores can be used for Back-Up Directional Protection (using one PS core for one Phase and 5P core for the other 2 phases having different magnetising characteristics should always be discouraged for High impedance type protections mainly for transformer/ feeders), and the 0.2 or 1.0 Class core should be used for metering.	Completed
vii	Retrofitting of Protection Relays were carried out in different 132KV Lines. There are no approved drawings available for the retrofitted panels and the Installation of some of the New Relay with the individual panel wiring along with the terminations were not done in a proper fashion. From the quality of dressing and terminations, it clearly signifies that there was absolutely no supervision by any BSPTCL authority when the VENDOR was carrying out the work of installation and commissioning. The dressings of the wires along with the terminations are to be completed for all the panels where New Relays have been installed.	Completed
viii	The committee also felt that the drawing and documentation was very poor on the Substation Side as well as the MRT side of BSPTCL. Not a single Control and Protection Drawing for 132KV bays were available at the S/Stn end by which a person can work and rectify faults in different circuits.	As the panel are of very old and obsolete, their drawings may not be available. Drawings of newly retrofitted relays of 132kV lines have been maintained and copy has been submitted to ERPC.
ix	The work specified in item 3 and 4 under ANALYSIS part are to be completed immediately. Till completion, the existing setting at 132 kV Purnea (PGCIL) end should continue.	work completed



## Annexure-C.10

### Third Party Protection Schedule

Itinerary of audit	Group-I			Group-II		
	Date of Audit	Substations	Lodging and Boarding	Date of Audit	Substations	Lodging and Boarding
Cluster-I		Bidhannagar (WBSETCL) & Durgapur (PG)	Stay at DVC guest house		Subhasgram (PG)	Transportation will be arranged by Powergrid
		DSTPS(DVC) & Mejia (DVC)	Transportation will be arranged by Powergrid		Kolaghat (WBPDCL) & Kharagpur (WBSETCL)	
					Jeerat (WBSETCL)	
	Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities		Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities	
Cluster-II		Mendhasal (OPTCL)	Stay at Talcher, NTPC guest house  Transportation from Kolkata to Bhubaneswar & back will be arranged individual by organizations and rest of the transportations arrangement will be done by Powergrid		Bakreswar (WBPDCL) & Sagardighi (WBPDCL)	Stay at Sagardighi Guest House on 27 <sup>th</sup> Dec'12, Transportation will be arranged by Powergrid
		Talcher STPS (NTPC)			Farakka (NTPC) & Malda (PG)	Stay at NTPC, Farakka Guest House on 28 <sup>th</sup> and 29 <sup>th</sup> Dec'12, Transportation will be arranged by Powergrid
		Angul & GMR				
	Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities		Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities	

## Annexure-C.10

<b>Group-I</b>			
Date of Audit	Substations	Lodging and Boarding	Transport
	PPSP (WBSETCL) & Maithon (PG)	Stay at Maithon PGCIL guest house	Transportation will be arranged by Powergrid
	Maithon RB (MPL) & Raghunathpur (DVC) (Audit only up to the commercially installed elements)	Stay at Santladihi(WBPDCL) guest house	
	Santladihi(WBPDCL) & Arambagh (WBSETCL)	If required, stay at Santladihi(WBPDCL) guest house	
	Tisco(DVC)	Stay at Jamshedpur, PGCIL guest house	Audit team will reach Jamshedpur on their own transportation arrangement and rest of the transportation arrangement will be done by Powergrid
	Jamshedpur (PG) & Ramchandrapur (JSEB)	Stay at Jamshedpur, PGCIL guest house	Transportation will be arranged by Powergrid
	Chandil(JSEB) & Ranchi(PG)	Stay at Ranchi, PGCIL guest house	Transportation will be arranged by Powergrid
	Koderma (DVC) PTPS		Audit team will return back from Koderma on their own transportation arrangement
Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities		

<b>Group-II</b>			
Date of Audit	Substations	Lodging and Boarding	Transport
	Rourkela (PG) & Tarkera (OPTCL)	Stay at Rourkela PGCIL guest house	Audit team will reach Rourkela on their own transportation arrangement and rest of the transportation arrangement will be done by Powergrid
	Joda(OPTCL)	Stay at Baripada PGCIL guest house	Transportation will be arranged by Powergrid
	Baripada (PG)	If required, stay at Baripada PGCIL guest house	Audit team will return back from Baripada on their own transportation arrangement
	Jaypore(PG)	Stay at Jaypore, PGCIL Guest House	Audit team will reach Jaypore on their own transportation arrangement and rest of the transportation arrangement will be done by Powergrid

## Annexure-C.10

	Indravati (PG), & Indravati (OHPC)	Stay at Indravati, PGCIL Guest House	Transportation will be arranged by Powergrid
	Jharsuguda	Stay at PGCIL Guest House	Transportation will be arranged by Powergrid
	Bolangir (PG) & Rengali (PG)	If required, stay at Rengali, PGCIL Guest House	Audit team will return back from Rengali on their own transportation arrangement
Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities		
	Barh(NTPC) (Audit only up to the commercially installed elements)	Stay at Kahalgaon, NTPC Guest House	Audit team will reach Barh(NTPC) on their own transportation arrangement and rest of the transportation arrangement will be done by Powergrid
	Kahalgaon (NTPC)	Stay at Kahalgaon, NTPC Guest House	Transportation will be arranged by Powergrid
	Banka (PG) & Purnea (PG)	Stay at Purnea, PGCIL Guest House	Transportation will be arranged by Powergrid
	Dalkhola(PG)		Audit team will return back from Dalkhola on their own transportation arrangement
Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities		

Date of Audit	Substations	Lodging and Boarding	Transport
	Parulia (DVC)	Stay at Durgapur, PG guest house.  Stay at Mejia, DVC guest house	Audit team will reach Durgapur on their own transportation arrangement and rest of the transportation arrangement will be done by Powergrid
	Mejia (DVC) & Kalyaneswari (DVC)	Stay at Maithon, PGCIL guest house.	Transportation will be arranged by Powergrid
	Bokaro (DVC)	Stay at TVNL guest house.	Transportation will be arranged by Powergrid
	TVNL	Stay at TVNL guest house.	Audit team will return back from Bokaro on their own transportation arrangement
Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities		

## Annexure-C.10

Group-II			
Date of Audit	Substations	Lodging and Boarding	Transport
	Jamshedpur (DVC)	Stay at Jamshedpur PGCIL guest house.	Audit team will reach Jamshedpur on their own transportation arrangement and rest of the transportation arrangement will be done by Powergrid
	Budipadar(OPTCL)	Guest house will be arranged by OPTCL/OPGC.	Transportation will be arranged by Powergrid
	IB TPS (OPGC)	If required, stay at OPGC guest house.	Audit team will return back from IB TPS on their own transportation arrangement
Team member	One representative from ERPC One representative from ERLDC One representative from PGCIL One representative from auditee utilities		



# Superconducting Fault Current Limiters

Eastern Region Protection Group



Vikas Dabeer  
Shankar Kodle

<http://www.appliedmaterials.com/technologies/fault-current-limiters>

16<sup>th</sup> April 2015

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## WHAT WE DO

We make the **equipment** that makes the components that change the world.




We lead the nanomanufacturing technology revolution with **products, solutions** and **services** that transform markets, create opportunities, and offer a cleaner, brighter future to people around the world.

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# Applied Materials Profile

<http://www.appliedmaterials.com/technologies/fault-current-limiters>



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## Applied Materials Global Strength



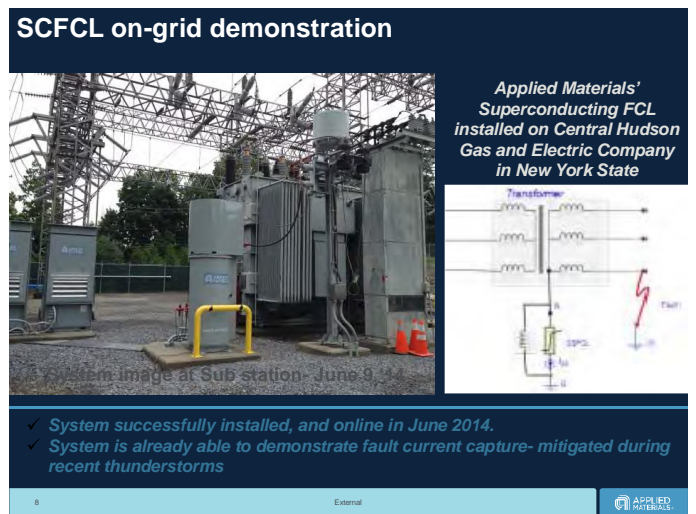
APPLIED MATERIALS INC	
Market Cap:	\$29.16 billion
Fiscal 2014 Revenue:	\$9.1 billion
Fiscal 2014 R&D:	\$1.4 billion
Founded:	November 10, 1967
Headquarters:	Santa Clara, California
Global Presence:	84 locations in 18 countries
Fortune 500 Ranking:	302
RD&E and/or Manufacturing Centers:	China, Germany, India, Israel, Italy, Singapore, Taiwan, United States
Employees:	~13,700 worldwide
Patents:	~10,400 issued

APPLIED MATERIALS INDIA PVT LTD	
Founded:	June, 2002
Headquarters:	Bangalore
India Presence:	Chennai, Delhi, Mumbai
Lab Space:	> 25,600 sq. ft.
University Spend:	> INR 75 CR
Employees:	~ 2300

\*including RFTs, contractors & associates

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## SSFCL – Installed in Melbourne, Australia

### Normal Operation

- ▶ Voltage = 22 kV class
- ▶ Load current = minimal (N-G)

### Installation

- ▶ Brushfire mitigation proof and quantification

### Performance

- ▶ Fully tested at KEMA and at AMAT labs
- ▶ Commission testing performed and passed onsite.
- ▶ Regulator testing to be performed in Spring 2015

#### Utility Design Focused

- Environmental enclosure
- Ingress protection sensitive
- Thermal Management



22kV SSFCL N-G System Commissioned – October 2014

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## Fault Currents are Destructive

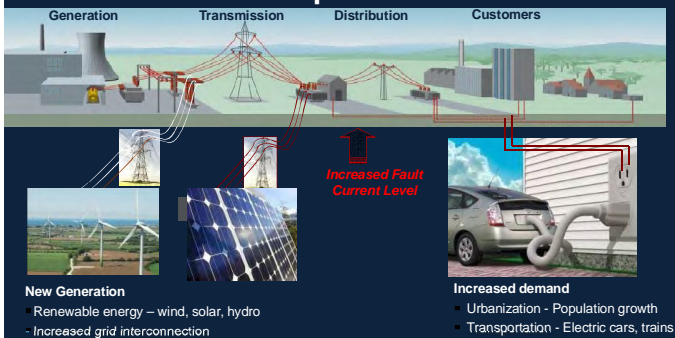
- ▶ Large fault currents can cause the grid to fail catastrophically
- ▶ Even small fault currents can damage the grid's capital infrastructure
  - ▶ Age equipment
  - ▶ Premature failures
  - ▶ Performance degradation



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## Drivers of the Fault problems



### New Generation

- Renewable energy – wind, solar, hydro
- Increased grid interconnection

### Increased demand

- Urbanization - Population growth
- Transportation - Electric cars, trains

**Economic Growth and Large Investments in Distributed Generation are driving new Grid Architectures. Fault currents are rising**

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## Scenarios for use of FCLs

Driver	SCFCL Role	Benefit to customer
Increase Substation Capacity	Limit FC on system and allow more generators to be connected	Defer capital expenditures on new substation or Equipment
Interconnect new generation	Limit FC created by new generators	Higher utilization of assets Increase efficiency
Protect Key Assets	Protect transformers or circuit breakers from FC and extend key asset life	Reduce Repair and Maintenance cost and downtime
Interconnect Distributed Generators	Limit FC on transformers Allow more power flow in parallel	Facilitate integration of distributed/ localized generation ( solar, wind micro-hydel etc.)
A More Reliable and Resilient Grid	Enable closing of Bus Ties, interconnect Substations Tightly Meshed Grid for increased Power Reliability and resiliency	More reliable and strong grid increasing options to deliver high quality power

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External



## Current options to mitigate Fault Currents

- ✓ Utility over-engineer system
- ✓ Introduce mitigations with detrimental impact

Mitigations	Impact
Bus Splitting (\$\$)	<b>Reduces</b> flexibility and reliability
High impedance transformers (\$\$\$)	<b>Increases</b> transformer cost and losses
Current Limiting Reactors (\$\$)	<b>Increases</b> active and reactive power loss, voltage drops causing voltage stability issues
Breaker & Busbar Upgrades (\$\$)	<b>High</b> sub-station down-time and cost
New Substations (\$\$\$\$)	<b>High</b> cost of land & new cable lines

Current Solutions are non-optimum and may require **additional mitigation**

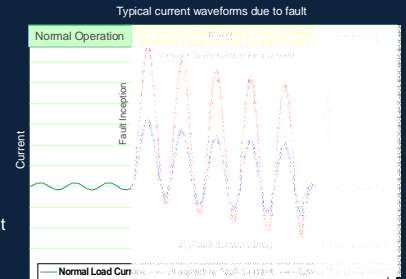
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## Desired Characteristics of an Ideal FCL

- An Ideal Fault Current Limiter would

- In normal operation, it is virtually "**transparent**" (no power or voltage loss) to the network
- **Increase the impedance** on the line well before the first fault peak (when the most damage occurs)
- Diminish the fault current by at least a **factor of 2** for its duration
- Return the source impedance to its **original value**



Fault Current Limiters reduce Fault Currents **Without the Need for Mitigation**

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## Fault Current Limiters – Doing More with Less

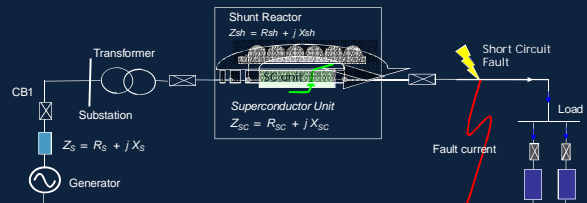
- ✓ **Enhance** reliability and quality of power
- ✓ **Protect** key assets
- ✓ **Increase productivity** of current grid assets
- ✓ **Mitigate** the damaging consequences of fault currents
- ✓ **Enable** efficient and higher reliability grid architectures like Ring systems



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## How an SCFCL works



### Normal operation

- Load current flows through superconducting unit
- SCFCL introduces nearly zero impedance and zero voltage drop

### Fault Condition

- Superconductor inherently senses fault current, quenches, **inserts high resistance in ~ 1 ms**
- Current transfers to shunt and limits fault current

### Recovery

- Superconducting unit recovers superconducting state quickly (seconds)

Fault detection and current limiting is done with passive inherent superconductor properties – **laws of physics rather than electronics**

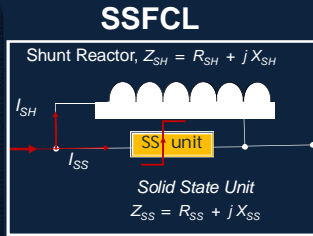
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## How a SSFCL works

- Uses Solid state power electronics (IGBT's) instead of Superconducting tape
- Does not require liquid nitrogen cooling
- Uses proprietary design concepts for Current, Voltage and Thermal management
- In normal operation  $Z_{SS} \ll Z_{SH}$
- During fault  $jX_{SS}$  increases and the current flows through the shunt reactor



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## SCFCL - Validation



## Fault Current Limiter – Product Line

### Transmission System FCL

- ▶ Superconducting Fault Current Limiter
- ▶ 11 kV to 230 kV transmission voltage levels
- ▶ > 1000 A load current
- ▶ Up to 50 % or higher fault current reduction
- ▶ Fault detection (response time) < 1 ms
- ▶ Recovery time - < 3 secs
- ▶ Single Platform for the entire Grid 11 KV to 230+ KV



SCFCL

### Distribution System FCL

- ▶ Solid State Fault Current Limiter
- ▶ Up to 45 kV distribution voltage levels
- ▶ > 1000 A load current
- ▶ Up to 50 % or higher fault current reduction
- ▶ Proprietary design concepts for Current, Voltage and Thermal management



SSFCL

### Fast Switch FCL (FSFCL)

- ▶ Fast Electromagnetic switch that interrupts current with 1 cycle
- ▶ Shunt reactor or mutual inductor
- ▶ Current limiting where 1st peak limitation is not critical
- ▶ Arc energy reduction – arc flash control
- ▶ Arc flash control – fire hazard reduction
- ▶ Speed up breaker interruption time – by reducing current zero time using low X/R ratio shunt reactor
- ▶ Electromagnetic force reduction –  $F = k|I|^2 dt$



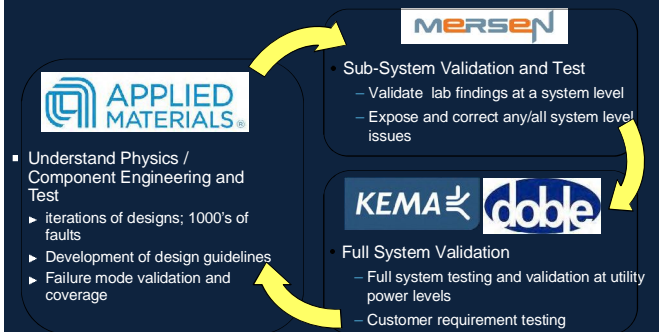
FSFCL

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## Testing Methodology



Multiple Labs Enable Fast, Efficient Development and Learning

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## Fault Current Limiter Testing Performance

✓ Tested and qualified at 230 KV.

✓ 5 Weeks of KEMA Testing

✓ Lifetime Tested for 200 Bus Faults (>40 Years)

**KEMA 1** – Architecture Validation – The FCL works as designed (Performance envelope to 125KV, 56 kA and 60 % Reduction)

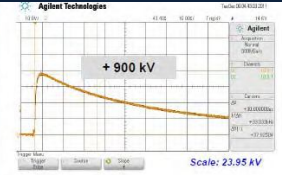
**KEMA 2** – System Performance – Controls, User Interface and refrigeration integration validated

**KEMA 3** – Life testing and Customer Validation (>200 Fault Test)

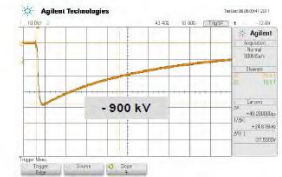
**KEMA 4** – Component Characterization

**KEMA 5** – Product Platform Validation and System Optimization

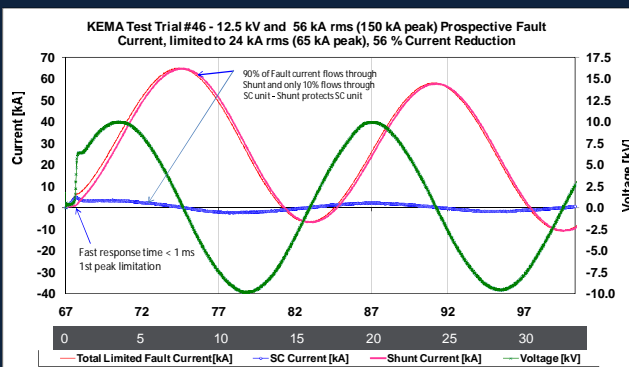
## Transmission Impulse test results



- Impulse test at 900 kV BIL
  - 15 Impulses at +900 kV – Pass
  - 15 Impulses at -900 kV – Pass
- AC withstand Voltage
  - 266 kV Single Phase (460 kV 3-phase)
  - 1 minute test at 266 kV – Pass



## Actual KEMA Test Results



1st peak response within ~ 1 ms response time.

## Customer Inputs for FCL System

Selected Site Name / Location			
Requirement	Values	Comments	
<b>Power System</b>			
System Voltage (3 phase Line-to-Line)		kVrms	
Load Current – Continuous / Maximum	/	Arms	
System MVA – Continuous / Maximum	/	MVA	
Prospective Fault Current - Symmetric		kArms	
Ratio of Fault current to Max load current (Fault C/Max Load)		Calculated by Applied	
<b>Fault &amp; Recovery</b>			
Fault Duration Before Protection System Acts		Cycles	
Required Fault Current Reduction – 1 <sup>st</sup> peak		%	
Required Limited Fault Current - Symmetric		kArms	
Impulse Voltage (BIL) Rating Requirement		kV	
Switching Re-closure Sequence and Timing			
<b>Site Selection and Logistics</b>			
Maintenance cycle at existing facility			

## Data/ Documents from Customer

Requirement	Values	Comments
Technical Details		
Load currents and fault current by feeder		A rms
Breaker Ratings :		A kA
1. Continuous Current		
2. Fault Current		
Thermal rating of the lines.		kV
What are your targeted goals for Fault Current Reduction?		%
Transformer ratings, fault contribution and Y or delta config.		
Single Line Diagram with Normal Currents and Fault Contributions (peak and symmetrical). Please indicate the lines which are paralleled for redundancy.		Need Electronic copy
Layout Drawing of Sub-station		Need Electronic copy
System Study report for existing system		

External

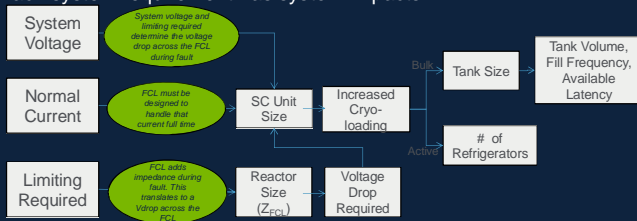


## FCL Design Tradeoffs / Sensitivities

Major Items Influencing System Design are:

1. System Voltage
2. System Normal Current
3. Current Limiting Required

Each system requirement has system impacts:



External

