REPORT

ON THE

GRID DISTURBANCE ON 30TH JULY 2012

AND

GRID DISTURBANCE ON 31ST JULY 2012

Submitted in Compliance to

CERC Order in Petition No. 167/Suo-Motu/2012 dated 1st Aug2012

8th August 2012

CHAPTER – 1

EXECUTIVE SUMMARY

The All India demand met is of the order of 110,000 MW currently. The synchronously connected NEW Grid comprising of the Northern, Western, Eastern and North-Eastern Grids is meeting a demand of about 75,000 to 80,000 MW. The Southern Grid which is connected to NEW Grid asynchronously, is the meeting a demand of about 30,000 MW. The generation resources, primarily coal, are located in the Eastern part of the country, hydro in the north and north-east and the major load centers are located in the North, West and South parts of the country. The backbone of the transmission grid is formed by the 400 kV transmission system and the upcoming 765 kV lines.

There have been major grid disturbances on the 30th and the 31st July 2012 which have affected large parts of the Indian Electricity Grids. Due to high load and failure of monsoon, Northern Region was drawing a large quantum of power from neighboring Western and Eastern Grids whereas due to rains in Western Region demand was less and it was under-drawing. This situation led to a much skewed load generation balance among the regions. A large quantum of power was flowing from the Western Grid to the Northern Grid directly as well as through the Eastern Grid and the system was under stress. .Briefly, the details of the grid disturbances on the two days are given below.

1.1 Grid Disturbance on 30th July 2012

A disturbance occurred in the Northern India electricity grid at 0233 hours of 30th July 2012 leading to a blackout in nearly the entire Northern region covering all the 8 States i.e., the States of Delhi, Uttar Pradesh, Uttarakhand, Rajasthan, Punjab, Haryana, Himachal Pradesh and Jammu and Kashmir as well as the Union Territoryof Chandigarh. The frequency just before the incident was 49.68 Hz. The All India Demand Met prior to the incident was about 99700 MW and the demand being met in the Northern Region was about 38000 MW.

Small pockets of generation and loads in the Northern Region survived the blackout which comprised of 3 generating units at Badarpur thermal power station with approximately 250 MW load in Delhi, Narora Atomic Power Station in UP on house load some parts of Rajasthan system (around Bhinmal) that remained connected to the Western Grid with a load of about 100 MW and some parts of Uttar Pradesh system (around Sahupuri) that remained connected with Eastern region. Some load of Western Region (around Gwalior area) remained connected to NR via 400 kV Gwalior-Agra-I.

Immediately after the disturbance, restoration of the affected areas was taken up. Startup supply was extended to the thermal power stations and essential loads by taking assistance

from the neighboring Eastern and the Western Grids. Hydro generation was self started at Uri and Salal in J & K; Chamera-1, Nathpa Jhakri ,Karcham Wangtoo, Bhakra and Pong in Himachal Pradesh; and Chibro/Khodri HEP in Uttarakhand.

Supply was extended to all emergency loads such as Railways, Metros and airport mostly by about 0800 hours. By 1000 hours of 30th July 2012, nearly 40% of the antecedent load (more than 15000MW) had been restored covering most of the towns and all thermal power stations were extended start up supply. The Northern Regional System was fully restored by 1600 Hrs.

1.2 Grid Disturbance on 31st July 2012

Another disturbance that occurred at 1300 hours of 31st July 2012 affected the Northern, Eastern and North-Eastern electricity grids. The frequency before the incident was 49.84 Hz. The All India Demand Met just prior to the incident was about 100,500 MW and the demand being met in the NEW Grid was 73000 MW approximately.

Approximately 48000MW of consumer load across 21 States and 1 Union Territory was affected by the grid disturbance. The areas which survived included Western Region, generating units at Narora Atomic Power Station, Anta GPS, Dadri GPS and Faridabad GPS as well as part of Delhi system in NR and system comprising of Sterlite/IB TPS, Bokaro Steel and CESC Kolkata systems in ER.

Immediate steps were initiated for restoration of the areas affected in the incident. Start up supply was extended from the Western Region and the Southern Region which were intact. Several hydro units in the Northern Region, Eastern Region and North-Eastern Region were self started. Supply was extended to emergency loads such as Railways, Metro, Mines and Airports, etc. All emergency loads such as Railways, Metros and airport were provided with power supply mostly by about 1530 hours approximately. The system was restored fully by about 2130 hrs of 31st July 2012.

1.3 Direction of the Hon'ble Commission Vide Petition No. 167/Suo Moto/2012

Central Electricity Regulatory Commission (CERC) vide Petition No. 167/Suo Moto/2012 dated 1st August 2012 (copy enclosed as Exhibit – 1) has given a direction to investigate into the incidences of grid failure on 30th July 2012 and 31st July 2012 and submit a report within a week from the date of issue of the order. The Hon'ble Commission has directed that the report shall include the following:-

a) Antecedent conditions of frequency
b) Inter-regional/inter-State line flow
c) Voltages at inter-State/inter- regional point
d) Conditions of outage at inter-regional/inter-State lines prior to disturbance
e) Report of the Sequence of Event recorder maintained by RLDCs

f) Disturbance recorder reports and any other associated reports.

1.4 Preliminary Report on the Grid Disturbances on 30th July 2012 and 31st July 2012 to the Hon'ble Commission

This preliminary report is being submitted in compliance to the Hon'ble Commission's directive in Petition No. 167/Suo Moto/2012 dated 1st August 2012 as mentioned above. The organization of the Report is briefly given below.

Chapter – 2 describes the antecedent conditions prevailing in the grid on the 30th July 2012 which includes the frequency profile, important line flows including inter-regional/inter-state line flows, voltages at important nodes and line outages just prior to the grid disturbance. This section also speaks of the messages issued by NLDC/RLDCs in the context of the prevailing conditions.

Chapter – 3 gives the preliminary analysis of the grid disturbance on the 30th July 2012 and includes the analysis of the contingency situations, Sequence of Events, outputs of the disturbance recorders and other reports received from the substations.

Chapter – 4 describes the restoration process undertaken on the 30th July 2012 after the grid disturbance. Startup supply was availed from the Western Region and the Eastern Region which were intact. It mentions the extension of supply to essential loads such Railways, Metro, etc., extension of supply to thermal power stations, self – start by hydro units and the build-up of the NR System.

Chapter – 5 describes the antecedent conditions prevailing in the grid on the 31st July 2012 which includes the frequency profile, important line flows including inter-regional/inter-state line flows, voltages at important nodes and line outages just prior to the grid disturbance. This section also speaks of the messages issued by NLDC/RLDCs in the context of the prevailing conditions.

Chapter – 6 gives the preliminary analysis of the grid disturbance on the 31st July 2012 and includes the analysis of the contingency situations, Sequence of Events, outputs of the disturbance recorders and other reports received from the substations.

Chapter – 7 describes the restoration process undertaken on the 31stJuly 2012 after the grid disturbance. Startup supply was availed from the Western Region and the Southern Region which were intact. It mentions the extension of supply to essential loads such Railways, Metro, Mines, etc., extension of supply to thermal power stations, self – start by hydro units and the build-up of the Northern, Eastern and the North-Eastern Grids.

Chapter – 8 discusses the status of communication and telemetry facilities available at the RLDCs/NLDC including data availability before and after the grid disturbance. It mentions the impact of the non-availability of the data and deliberates on the urgent need for coordinated planning and implementation of communication infrastructure in the power sector.

Chapter – 9 analyzes the disturbances from various view points and in different perspectives. The underlying causes and the suggested measures to reduce the probability of re-occurrence of such grid disturbances are discussed. A number of issues have been thrown up by the recent grid disturbances and these include the following:

a) Skewed load generation balance across Regional grids
b) Grid indiscipline including overdrawals and under drawals
c) Depleted reliability margins
d) Failure of defense mechanisms
e) Absence of primary response from generators
f) Insufficient visibility and situational awareness at Load Despatch Centers
g) Inadequate appreciation of transfer capability vis-à-vis transmission capacity
h) Inadequate dynamic reactive reserves
i) Performance of the Protection Systems
j) Impediments to the speedy restoration of the systems
k) Distortions arising from the existing Regulations on grant of connectivity
l) Excessive reliance on unscheduled interchange rather than organized electricity markets
m) Tightening of the stipulated range for grid frequency
n) Institutional issues

The chapter also deliberates on the actions taken after the occurrence of the disturbances. These are critical issues which have come to the fore and which need attention in the context of grid disturbances on 30th and 31st July 2012. Course correction is required in all time horizons right from long term measures, medium term measures and immediate actions to be taken.

1.5 Enquiry Committee Constituted by Ministry of Power, Govt. of India

Ministry of Power, Government of India vide OM No. 17/1/2012-OM dated 3rd August 2012 has constituted a Committee under the Chairmanship of Chairperson CEA having independent members to enquire into the Grid Disturbances on the 30th and 31st July 2012. Further, POWERGRID and POSOCO have been directed to assist the Committee.

In view of above, a copy of this preliminary report is also being made available to the Committee set up by the Ministry of Power, Government of India in compliance to the directions given by the Government.

CHAPTER-2

ANTECEDENT CONDITIONS FOR 30-JULY-2012

2.1 Power supply position and inter regional flows

The power supply position prior to the grid disturbance at 0200 Hrs, in terms of generation, demand met and import from other regions for all Regions, is indicated diagrammatically below in Figure 2.1. Import from Bhutan was about 1127 MW and 1900 MW power was being transmitted to SR from the NEW Grid. Frequency trend of Ballabhgarh sub-station in Northern Region on 30th July 2012 is shown in Figure 2.2. Frequency recorded through PMUs at different locations in NEW grid before and after the incident is shown in Figure 2.3. A demand of 38322 MW was being met by the Northern Grid at 0200 hrs prior to the disturbance.

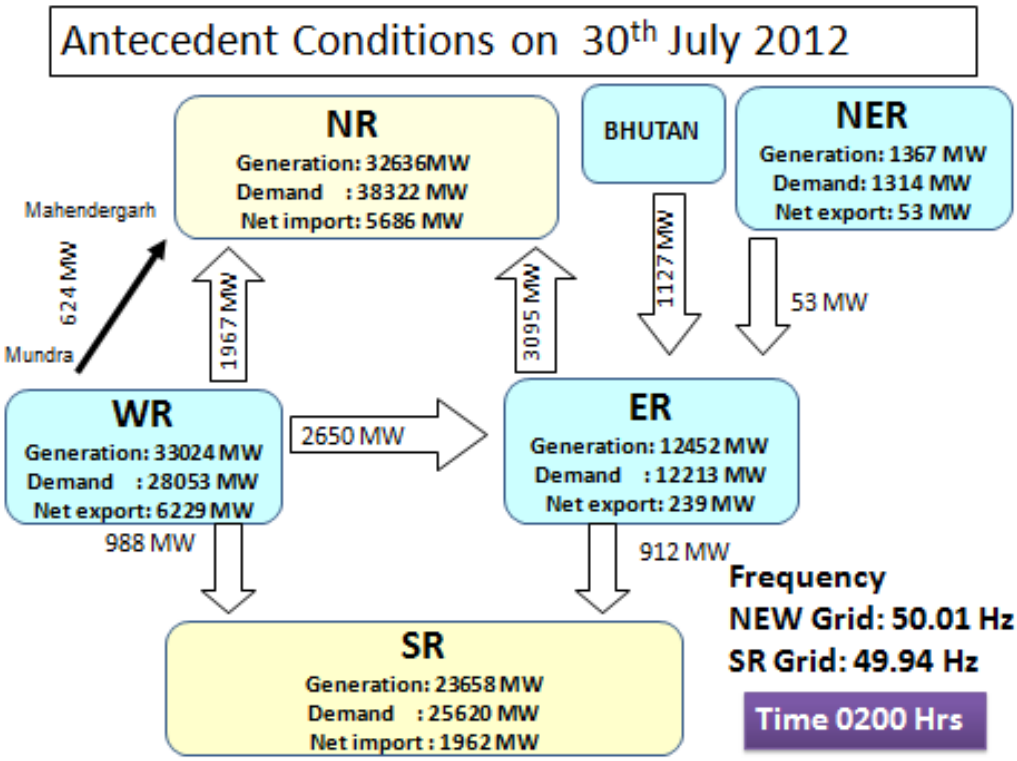


Figure 2.1

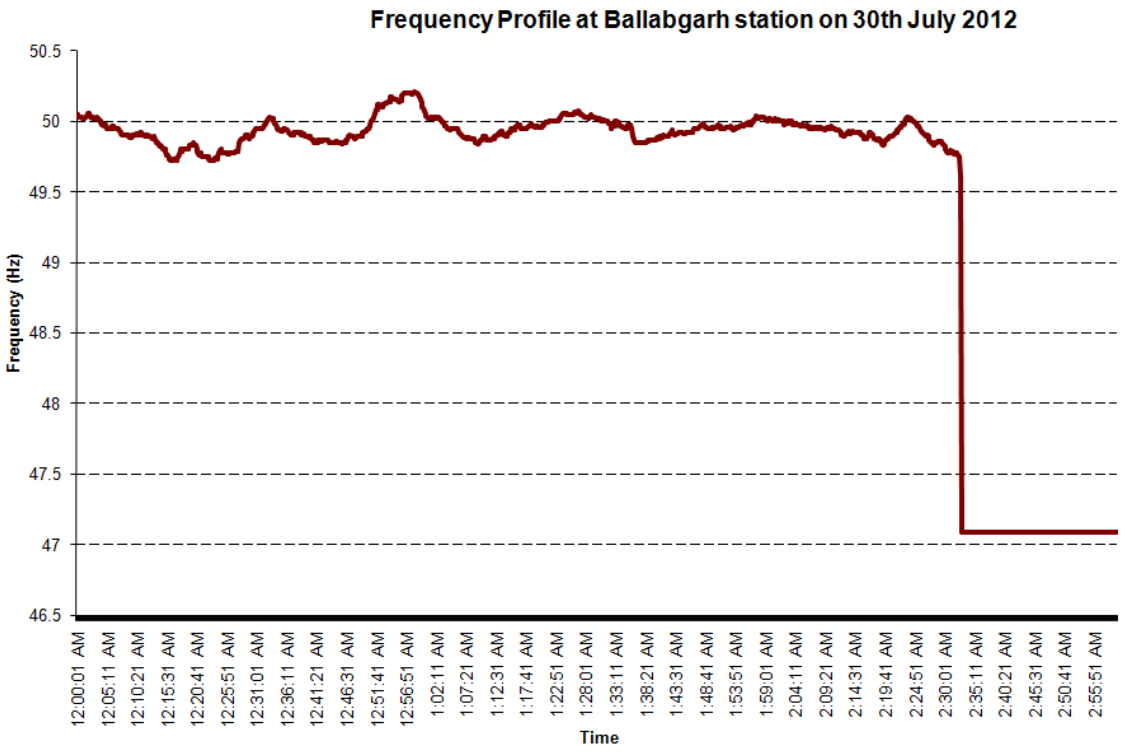


Figure 2.2

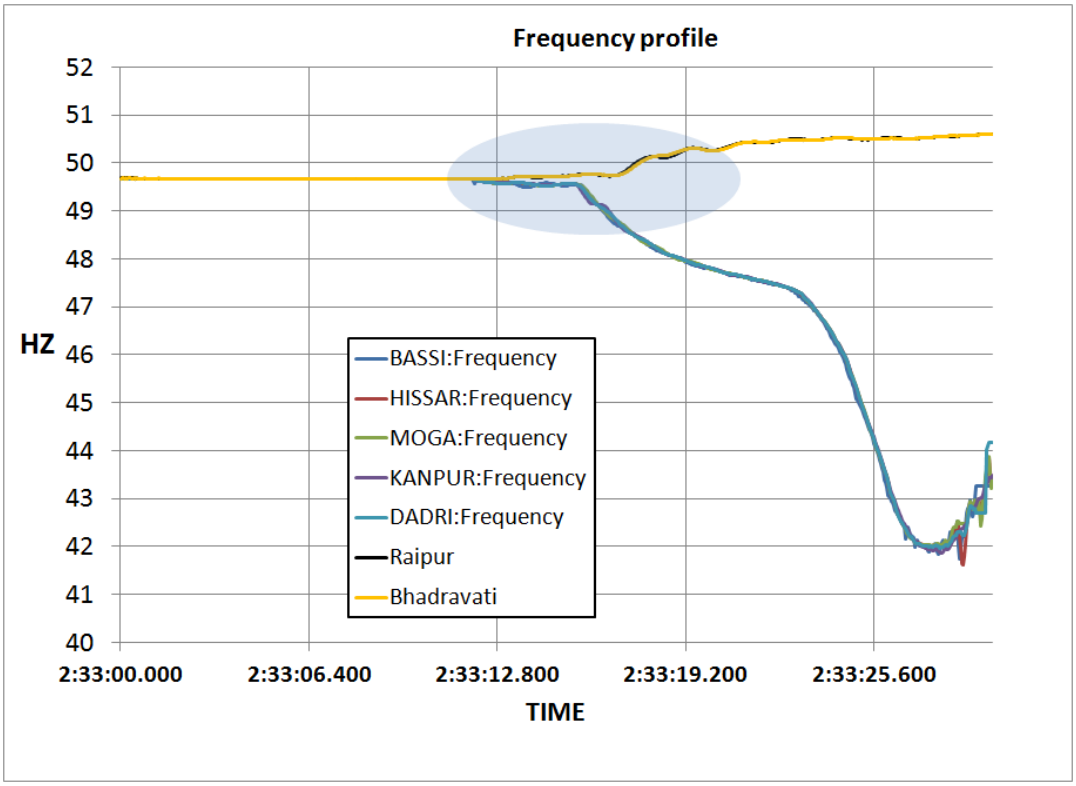


Figure 2.3

The power supply position prior to the grid disturbance at 0230 Hrs, in terms of import/ export from other regions for all Regions, is indicated diagrammatically below in Figure 2.4

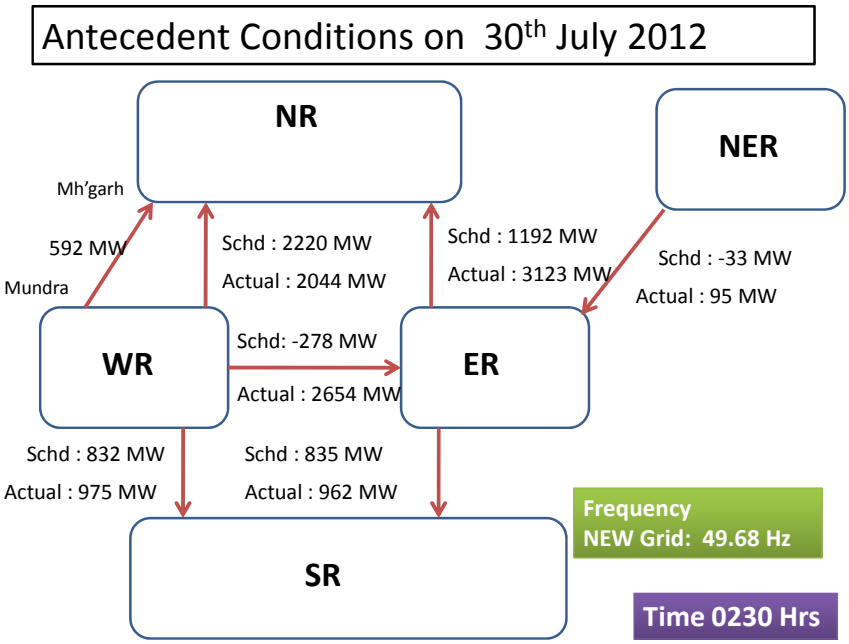


Figure 2.4

2.2 Outage Status and Power flow on Inter regional links between WR, NR and ER

As can be seen from details shown at Fig 2.1, at 0200 hrs NR was importing 1967 MW from WR, 624 MW through dedicated Mundra-Mahendergarh HVDC and 3095 MW from ER thereby importing a total quantum of 5686 MW. As can be seen from Fig 2.4, the total import by NR at 0230 hrs is 5759 MW. The element wise power flow on the WR – NR corridor is given below in Table – 2.1. The element wise power flow on the WR – NR corridor is given below in Table – 2.2. The element wise power flow on the WR – ER corridor is given below in Table – 2.3.

Table – 2.1: WR-NR inter regional links

S No.	Inter-regional link	Voltage	Powerflow (MW) at 0200 hrs	Powerflow (MW) at 0230 hrs	Remark
1	Gwalior-Agra-I	400 kV	1009	1055	-
2	Gwalior-Agra-II	400 kV	-	-	Planned outage since 11:47 hrs of 28-07-2012 for up gradation of 400 kV to 765 kV at

S No.	Inter-regional link	Voltage	Powerflow (MW) at 0200 hrs	Powerflow (MW) at 0230 hrs	Remark
					Bina and Gwalior end
3	Zerda-Kankroli	400 kV	-	-	Forced outage since 22:18 hrs of 29-Jul-2012 to take out one T&P which got stuck with polymer insulator
4	Zerda-Bhinmal	400 kV	346	369	-
5	Badod-Kota	220 kV	-	-	Forced outage (overload and later breaker problem at Kota end) since 15:15 hrs of 29-Jul-2012
6	Badod-Morak	220 kV	-	-	Forced outage (overload) since 00:12 hrs of 30-Jul-2012
7	Malanpur-Auraiya	220 kV	69	49	-
8	Mehgaon-Auraiya	220 kV	43	60	-
9	Vindhyachal back to back	-	500	511	-
10	**Total WR to NR**		**1967**	**2044**	
11	Import through dedicated HVDC Mundra Mahendergarh	500 kV	624	592	

Table – 2.2: ER-NR inter regional links

S No.	Inter-regional link	Voltage	Powerflow (MW) at 0200 hrs	Powerflow (MW) at 0230 hrs	Remark
1	Muzaffarpur-Gorakhpur-I	400 kV	550	555	-
2	Muzaffarpur-Gorakhpur-II	400 kV	561	562	-
3	Barh-Balia-I	400 kV	-	-	Tripped on over voltage at 17:51 hrs of 29-July-2012
4	Barh- Balia-II	400 kV	-	-	Manually opened on

S No.	Inter-regional link	Voltage	Powerflow (MW) at 0200 hrs	Powerflow (MW) at 0230 hrs	Remark
					high voltage since 05:45 hrs of 28-July-2012
5	Patna-Balia-I	400 kV	390	398	-
6	Patna-Balia-II	400 kV	390	398	-
7	Biharshariff-Balia-I	400 kV	320	324	-
8	Biharshariff-Balia-II	400 kV	342	337	-
9	Pusauli-Allahabad	400 kV	115	116	Pusauli back-to-back in HVDC mode at 300 MW
10	Pusauli-Sarnath	400 kV	175	179	
11	Pusauli-Sahupuri	220 kV	172	172	Operating in radial mode
12	Pusauli-Balia	400 kV	80	82	-
13	Gaya-Fatehpur	765 kV	-		Charging attempt taken at 22:37 hrs of 27-July-2012. Line did not hold and kept open on high voltage
14	**Total ER to NR**		**3095**	**3123**	

Table – 2.3: WR-ER inter regional links

S No.	Inter-regional link	Voltage	Powerflow (MW) at 0200 hrs	Powerflow (MW) at 0230 hrs	Remark
1	Raigarh-Sterlite-I	400 kV	277	286	-
2	Raigarh-Sterlite-II	400 kV	294	269	-
3	Raigarh-Rourkela-I	400 kV	581	572	-
4	Raigarh-Rourkela-II	400 kV	561	560	-
5	Sipat-Ranchi-I	400 kV	-	-	Forced outage (Isolator sparking at Sipat) since 01:35 hrs of 29-July-2012
6	Sipat-Ranchi-II	400 kV	654	641	-
7	Raigarh-Budhipadar	220 kV	-77	-80	-
8	Korba-Budhipadar-I	220 kV	171	209	-
9	Korba-Budhipadar-II	220 kV	161	197	-
10	**Total WR-ER**		**2650**	**2654**	

2.3 Transmission Element outage within the Regional grids

Some transmission lines were under outage prior to the occurrence of the grid disturbance. The reasons of outage of the transmission lines are classified as planned outage, forced outage and lines opened to control high voltages in the system.

A region wise list of the transmission lines under outage at 0230 hrs on 30th July 2012 is given in Table 2.4 below.

Table – 2.4: Antecedent Transmission Line Outages on 30.07.2012 before Grid disturbance at 02:30 Hrs

Sl. No.	Name of the Line	Voltage Level (kV)	Owner	Outage date	Time (hrs)	Reason
NORTHERN REGION						
Planned Outage						
1	Agra-Bassi line-3	400	PGCIL	28.07.12	8:10	S/D for LILO work of Agra-Bassi-II
2	Bassi-Jaipur line-1	400	PGCIL	28.07.12	8:10	LILO work of line of Agra-Bassi-2 at Jaipur (S)
3	Agra-Bassi line-2	400	PGCIL	28.07.12	8:19	LILO work of line at Jaipur (S)
4	Agra-Fatehpur	765	PGCIL	26.07.12	14:24	For balance construction work
Forced outage						
1	Bhinmal-Kankroli	400	PGCIL	29.07.12	21:45	Due to decaping.
2	Hissar-Hissar(IA) line-1&2	220	PGCIL	24.07.12	14:28	CB problem at Hissar (HVPN) end
3	Badod-Sakatpura	220	RRVPNL	29.07.12	15:15	Phase to earth fault, line faulty
4	Bhinmal-Sirohi	220	RRVPNL	29.07.12	15:40	Phase to earth fault.
Opened on High Voltage						
1	Bhiwadi-Neemrana	400	PGCIL	23.07.12	19:00	Tripped on High voltage.
2	Akal-Barmer	400	RRVPNL	28.07.12	10:30	Opened Manually due to high Voltage
3	Jodhpur-Rajwest line-2	400	RRVPNL	30.07.12	22:30	Opened Manually due to high Voltage
4	Manesar-Neemrana	400	PGCIL	15.07.12	17:00	Opened Manually due to high Voltage
5	Neemrana-Sikar line-1	400	PGCIL	23.07.12	19:00	Opened Manually due to high Voltage

Sl. No.	Name of the Line	Voltage Level (kV)	Owner	Outage date	Time (hrs)	Reason
6	Bhilwara-Chabra	400	RRVPNL	20.07.12	7:46	Opened Manually due to high Voltage
WESTERN REGION						
Planned Outage						
1	Bina-Gwalior 2	400	PGCIL	27.07.12	10:26	Construction Work
Forced outage						
1	Nagda-Shujalpur 1	400	PGCIL	07.07.12	12:24	Oil Leakage in B-Ph Bushing of the reactor at Nagda
2	Parli-Parli 2	400	PGCIL	19.07.12	21:15	Clearance Problem

Sl. No.	Name of the Line	Voltage Level (kV)	Owner	Outage date	Time (hrs)	Reason
Opened on High Voltage						
1	Satna-Bina 2	400	PGCIL	26.07.12	18:52	High Voltage
2	Damoh-Birsinghpur 2	400	PGCIL	13.07.12	8:20	High Voltage
3	Nagda-Rajgarh 1	400	MPSEB	20.07.12	11:18	High Voltage
4	765 kV Seoni-Bina 1	765	PGCIL	03.07.12	18:59	High Voltage
5	765 kV Seoni-Wardha 2	765	PGCIL	23.07.12	11:52	High Voltage
6	Bina –Indore	400	PGCIL	21.07.12	7:47	High Voltage
7	Korba-Birsinghpur	400	PGCIL	05.07.12	12:25	High Voltage
8	Birsinghpur-BALCO	400	PGCIL	22.06.12	12:43	High Voltage
9	Raigarh-Raipur 1	400	PGCIL	20.07.12	11:05	High Voltage
10	Raigarh-Raipur 2	400	PGCIL	21.07.12	3:18	High Voltage
11	Jabalpur-Itarsi 2	400	PGCIL	20.07.12	1:34	High Voltage
12	Itarsi-Khandwa 2	400	PGCIL	20.07.12	18:38	High Voltage
13	Nagda-Dehgam 1	400	PGCIL	28.07.12	15:51	High Voltage
14	Wardha-Akola 1	400	PGCIL	20.07.12	12:51	High Voltage
15	Parli (PG)-Sholapur (PG) 1	400	PGCIL	23.07.12	17:44	High Voltage
16	Bhadrawati-Parli 1	400	PGCIL	21.07.12	10:43	High Voltage
17	Aurangabad-Bhusawal	400	MSEB	27.06.12	17:05	High Voltage
18	Aurangabad-Deepnagar	400	MSEB	03.07.12	15:29	High Voltage

19	Karad-Kolhapur 2	400	MSEB	28.07.12	16:18	High Voltage
20	Birsinghpur-Katni S/C	400	MPSEB	14.06.12	10:00	High Voltage
21	SSP-Rajgarh 2	400	MPSEB	25.07.12	11:31	Tripped on Over voltage
22	ISP-Nagda	400	MPSEB	24.07.12	23:42	High Voltage
23	Itarsi-Bhopal	400	MPSEB	29.07.12	17:27	High Voltage
EASTERN REGION						
Planned Outage						
1	Ranchi-MPL D/C	400	PGCIL	27.07.12	9:11	Shutdown up to 18:00 Hrs of 04.08.12
2	Binaguri – Purnea-I	400	PGCIL	18.07.12	7:27	S/D up to 14.08.12
Forced outage						
1	Sagardighi-Durgapur S/C	400	WBSETCL	25.04.12	17:06	3 nos. Tower Collapsed
2	Maithon-Durgapur I	400	PGCIL	28.07.12	23:38	Tripped on B-ph to earth fault
Opened on High Voltage						
1	Baripada-Mendhasal -I	400	PGCIL	14.07.12	22:18	High Voltage

2.4 Antecedent generation outage in NEW Grid

Some generating units were under outage for different reasons, some under forced outage and some under planned outage. The outages in the Western Region, Eastern Region and Northern Region are given below in Table – 2.5.

Table – 2.5: Antecedent Generating Unit Outages on 30-Jul-2012 at 0230 hrs

Sl. No.	Plant name	Unit No.	Capacity (MW)	Reason for outage
Western Region				
1	Vindhyachal	9	500	BTL
2	Adani, Mundra	4	330	MFT
3	Adani, Mundra	6	660	PA fan problem
4	Dhabol	3A,2A,2B	960	Gas Shortage
5	Chandrapur	6	500	Annual Overhauling
6	Sipat 1	1	660	Loss of Fuel since 22.07.12
Eastern Region				
1	Farakka	1	200	Unit#5 out on Coal Shortage
2	Farakka	5	500	over hauling
3	Bokaro B	1	210	over hauling
4	Bakreshwar	3	210	over hauling

Sl. No.	Plant name	Unit No.	Capacity (MW)	Reason for outage
5	Mejia	3	210	Boiler license Renewal
Northern Region				
1	RAPS-A	1	100	Subject to regulatory clearance.
2	Bhakra (L)	2	108	Up gradation work.
3	Bhakra (L)	5	108	Up gradation work.
4	Dehar	4	165	Annual maintenance.
5	Tanda	2	110	Annual maintenance.
6	Auriaya GPS	3	111	Closed by plant due to less requisition / Taken under S/D for AMP w.e.f. 00:00hrs dt 10.07.2012 by NTPC.
7	Auriaya GPS	6	109	Closed by plant due to less requisition / Taken under S/D for AMP w.e.f. 00:00hrs dt 10.07.2012 by NTPC.
8	Rihand Stage-1	1	500	Annual maintenance.
9	Dadri Gas	4	130	Equivalent operating hour inspection work
10	GNDTPS (Bhatinda)	3	110	Up gradation work.
11	GNDTPS (Bhatinda)	4	110	Renovation and modernization work
12	Parichha TPS	1	110	Unit#1 under forced outage
13	Parichha TPS	2	110	Renovation and modernization work
14	Obra TPS	10	210	Renovation and modernization work
15	Obra TPS	11	210	Renovation and modernization work
16	Rosa TPS	1	300	Manually closed by plant due to commercial dispute with UPPCL
17	Rajwest LTPS	2	135	Annual maintenance.
18	Suratgarh TPS	3	250	Annual maintenance.
19	Barsingsar LTPS	2	125	Boiler tube leakage.
20	Chamera-1 HEP	1	180	Shaft seal leakage.
21	ISGTPP, Jhajjar	2	500	Electro static precipitator problem
22	DCRTPP, Yamunanagar	1	300	Turbine damaged.
23	DCRTPP, Yamunanagar	2	300	Turbine vibration high
24	Harduaganj TPS	8	250	Generator earth fault.
25	Harduaganj TPS	9	250	Boiler tube leakage.
26	Anpara-C TPS	1	600	Generator earth fault
27	Anpara-C TPS	2	600	Coal Shortage
28	Jhajjar-CLP(IPP) TPS	2	660	Taken out by plant due to coal mill problem.
29	RGTPP, Khedar	1	600	Vibration in Rotor.
30	Giral TPS	2	125	Leakage in shaft seal problem
31	Vishnuprayag HEP	1	100	High silt level.
32	Vishnuprayag HEP	2	100	High silt level.
33	Vishnuprayag HEP	3	100	High silt level.

Sl. No.	Plant name	Unit No.	Capacity (MW)	Reason for outage
34	Vishnuprayag HEP	4	100	High silt level.
35	Kota TPS	4	210	water feed pump problem
36	Dadri TPS	1	210	Closed On request of DTL

2.5 Antecedent generation availability in NEW Grid at 0200 hrs

The total antecedent generation in the NEW Grid was 79479 MW. The generating station-wise 'Declared Capacity', 'Schedule', 'Actual Generation' and the 'UI' is shown in Table – 2.6 for Northern Region. Similarly, Table – 2.7, Table – 2.8 and Table – 2.9 show the generating station-wise position for Eastern, Western and North-Eastern Regions.

Table – 2.6: Antecedent Generating Station Details for NR at 0200 hrs

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
Northern Region					
1	Singrauli	1500	1500	1545	45
2	Rihand I & II	1390	1390	1403	12
3	Unchahar	850	850	844	-6
4	Dadri Thermal - I	550	550	563	13
5	Dadri Thermal- II	830	830	900	70
6	Jhajjar	415	415	415	0
7	Shree Cement	0	267	197	-70
8	Dadri Gas	580	538	548	10
9	Auraiya Gas	405	302	306	4
10	Anta Gas	393	349	354	5
11	Narora	258	258	236	-22
12	RAPP B	507	507	411	-96
13	RAPP C	400	400	432	32
14	Nathpa Jhakri	1605	1605	1600	-4
15	Bhakra	656	656	637	-19
16	Tehri	785	760	753	-7
17	Dehar	600	600	573	-27
18	Chamera I	356	356	365	9

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
19	Salal I & II	661	660	601	-59
20	Uri	425	430	432	2
21	Pong	108	108	108	0
22	Dulhasti	386	390	390	0
23	Dhauliganga	277	284	282	-2
24	Chamera II	300	302	302	0
25	Bairasiul	182	182	120	-62
26	Tanakpur	94	93	95	1

Table – 2.7: Antecedent Generating Station Details for ER at 0200 hrs

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
1	Farakka	1360	912	953	41
2	Tala	982	982	1102	120
3	Kahalgaon I	402	402	426	24
4	Kahalgaon II	350	350	362	12
5	Talcher-I	850	850	856	6
6	Talcher-II	1750	1750	1589	-161
7	Teesta	510	510	497	-13
8	Chukha	385	385	281	-104
9	Rangeet	62	62	61	0

Table – 2.8: Antecedent Generating Station Details for WR at 0200 hrs

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
1	KSTPS	2460	2460	2540	80
2	TAPS I	147	147	133	-14
3	TAPS II	901	901	912	11
4	Gandhar (Gas + RLNG)	625	559	552	-7
5	Kawas (Gas +Liquid+ RLNG)	639	271	299	28
6	Kakrapar	405	405	390	-15

7	Pench	0	0	0	0
8	SardarSarovar	50	50	46	-4
9	Sipat	1420	1420	1814	394
10	VSTPS	2545	2545	2550	5

Table – 2.9: Antecedent Generating Station Details for NER at 0200 hrs

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
1	Ranganadi	330	401	400	-1
2	Kathalguri	145	145	157	12
3	Kopili	99	99	95	-4
4	RC Nagar	78	78	82	4
5	Doyang	55	56	57	1
6	Khandong	45	44	45	1
7	Kopili Stage II	21	21	21	0
8	Loktak	105	98	99	1

2.6 Antecedent State power supply position at 0200 hrs

A total demand of 79902 MW was being met by the NEW Grid prior to the disturbance. The state wise power supply position including 'Schedule', 'Actual', 'UI', 'State's own generaiton' and 'Demand Met' is shown below. Tables 2.10, 2.11, 2.12 and 2.13 show the State wise power supply position for Northern Region, Eastern Region, Western Region and the North-Eastern Regions respectively.

Table – 2.10: Antecedent State wise details for NR at 0200 hrs

S No.	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	Punjab	4850	5426	576	2776	8201
2	Haryana	2648	3205	557	2142	5347
3	Rajasthan	1861	1474	-387	4569	6042
4	Delhi	3088	2805	-283	976	3781
5	Uttar Pradesh	5587	6310	723	4178	10488

6	Uttarakhand	512	593	81	400	993
7	Chandigarh	295	230	-65	0	230
8	Himachal Pradesh	43	-88	-131	552	464
9	Jammu & Kashmir	694	-15	-709	457	443

Table – 2.11: Antecedent State wise details for ER at 0200 hrs

Sno.	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	West Bengal	1587	1571	-16	3423	4993
2	Bihar	1429	1619	190	1	1620
3	Orissa	800	753	-47	1510	2263
4	Jharkhand	480	409	-71	65	474
5	DVC	-702	-728	-26	2695	1967
6	Sikkim	36	25	-11		25

Table – 2.12: Antecedent State wise details for WR at 0200 hrs

	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	Maharashtra	3765	3293	-472	6168	9462
2	Gujarat	1465	751	-714	9003	9753
3	Madhya Pradesh	1629	821	-808	2311	3124
4	Chhattisgarh	496	265	-232	2202	2467
5	Dadra & Nagar Haveli	589	579	-10		578
6	Daman & Diu	236	237	1		237
7	Goa	228	211	-17		211

Table – 2.13: Antecedent State wise details for NER at 0200 hrs

S No.	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	Assam	498	600	102	253	853
2	Meghalaya	100	104	4	86	190
3	Tripura	65	43	-22	81	124
4	Manipur	103	52	-51		52

5	Mizoram	39	17	-22		17
6	Nagaland	42	37	-5		37
7	Arunachal Pradesh	103	76	-27		76

2.7 Antecedent voltage at important EHV substations at 0200 hrs

The antecedent voltage profile at important EHV substations is shown below in Table – 2.14.

Table – 2.14: Antecedent Voltage Profile at important stations at 0200 hrs

S. No.	Station Name	Region	Voltage (kV)	S. No.	Station Name	Region	Voltage (kV)
1	Uri	NR	388	11	Kahalgaon	ER	403
2	Kishenpur	NR	411	12	Baripada	ER	421
3	Nathpa Jhakri	NR	402	13	Ranchi	ER	415
4	Amritsar	NR	389	14	Jamshedpur	ER	422
5	Mandaula	NR	406	15	Bhopal	WR	414
6	Ballabgarh	NR	407	16	Khandwa	WR	427
7	Agra	NR	396	17	Padghe	WR	421
8	Gorakhpur	NR	397	18	Bhusawal	WR	439
9	Kanpur	NR	399	19	Gwalior	WR	388
10	Suratgarh	NR	399	20	Bongaigaon	NER	389
				21	Balipara	NER	403
				22	Misa	NER	412

2.8 Power Supply position just prior to the disturbance at 0230 hrs

Power supply position of NR constituents at 0230 hrs, 30th July 2012

Table-2.15: Power supply position of NR constituents at 0230 hrs

State	Schedule (MW)	Actual (MW)	OD (+) / UD (-) (MW)
Punjab	4769	5092	325
Haryana	2586	3103	518
Rajasthan	1717	1379	-335
Delhi	2987	2715	-123
UP	5475	6331	861
Uttarakhand	475	636	161
HP	88	-93	-181
JK	683	-1	-683
Chandigarh	295	234	-61

Power supply position of WR constituents at 0230 hrs, 30th July 2012

Table 2.16: Power supply position of WR constituents at 0230 hrs

State	Schedule (MW)	Actual (MW)	OD (+) / UD (-) (MW)
Gujarat	1450	651	-799
Maharashtra	3755	3238	-517
Chattisgarh	496	392	-104
Madhya Pradesh	1633	757	-876
Goa	228	205	-23
Daman and Diu	236	230	-6
Dadra and Nagar Haveli	589	579	-10

Generator	Schedule (MW)	Actual (MW)	OI (+) / UI (-) (MW)
Vindhyachal	2545	2205	-340
Korba	1990	2156	166
Sipat	1420	1818	398
Kawas	250	304	54
Gandhar	540	541	1
Tarapur	1048	1137	89
Kakrapar	405	442	37
Sardar Sarovar	50	29	-21

2.9 Messages issued from the control room

Several messages were issued from the control rooms of RLDCs/NLDC. These are collectively enclosed as Exhibit 2.86.

2.10 Observations from the antecedent conditions

It may be seen from the data in the table and the enclosed exhibits that

- The frequency and voltage in the entire NEW grid were within the standards prescribed in the Indian Electricity Grid Code.
- The state of EHV transmission elements in different regions is shown in Table2.4.
- Hydro generation in the NEW grid was significantly high except the forced outage of few generating units in Northern Region due to high silt.

- There was extremely heavy over-drawal by the constituents of NR grid and heavy under-drawal/ over-injection by the constituents of WR.
- Some thermal/gas generating units in the Northern Region were under forced outage either due to technical reasons or due to coal.
- Unit 3 of Sipat Stage I (660 MW) was undergoing trial operation as it was expected to be in commercial operation w.e.f 1st August 2012. As evident from table 2.16, this infirm power was getting injected into the system as Unscheduled Interchange.

  Before the disturbance, despite requests from WRLDC to Sipat for reducing generation and thereby relieve high loading in the transmission corridor, the generating plant refused to do the same on account of imminent commercial declaration (Ref: Messages exchanged between WRLDC and Sipat, NTPC in Exhibit 2.86)
- The power to Northern Region was flowing via the available WR-NR Inter regional links as well as via the WR-ER-NR route.
- The inter-regional links between the Western and Northern Region were constrained due to forced/planned outage of certain transmission elements.
- Efforts were being made to reduce the heavy import by Northern Region as well as to reduce the heavy export by Western Region.

Note:

- *The figures shown in this section are based on data from SCADA system and are indicative of the scenario as visible to the operator in the control room*
- *The trends are enclosed as Exhibit 2.1-2.85.*

CHAPTER 3

ANALYSIS OF THE DISTURBANCE ON 30TH JULY 2012

3.0 Introduction:

Analysis of this disturbance required collection of data from three RLDCs, NLDC as well as all the power stations and sub-stations in Northern Region, Western Region and Eastern Region through the Regional Load Despatch Centres (RLDCs). This process took considerable time and till the time of writing the report data from many power stations has still not been received. This is notwithstanding the explicit provisions in the CEA Grid Standards and the Indian Electricity Grid Code (IEGC).

The analysis[1] presented in this report is based on the inputs received so far at NLDC. Behavior of TCSC and SVC has not been analyzed and needs to be studied separately. The records referred to in this analysis are enclosed at Exhibit 3.

3.1 Sequence Of Events (SOE) on 30th July 2012:

The antecedent conditions on 30th July 2012 have already been described in Chapter 2. The sequence is outlined in Table 3.1 below and has been co-related from the record obtained at NLDC so far. It contains mainly the lines which are relevant to understanding the tripping. These can also be referred to in Exhibit 3. Further Figure 3.1 may be referred to for ease of understanding of the network. The phase convention RYB is used throughout for the sake of uniformity. The Sequence of Events recorded at RLDCs is enclosed as per details below.

Exhibit 3.1: Western Regional Load Despatch Centre (WRLDC)

Exhibit 3.2: Eastern Regional Load Despatch Centre (ERLDC)

Exhibit 3.3: Northern Regional Load Despatch Centre (NRLDC)

Table 3.1 Sequence Of Events on 30th July 2012

S. No	Time hh:mm:ss:msec	Event	Remarks
1	00:10 hours of 30th Jul 2012	220 kV Badod-Modak	As per SLDC MP's report (Exhibit 3.4), the line tripped at 0000 hours on overload. Loading reported at 300 MW.
2	01:35 hours of 30th July 2012	220 kV Gwalior(PG)-	As per SLDC MP's report, the line tripped on overload with the antecedent flow being

[1] The analysis presented here is preliminary based on the information received at NLDC by 09-Aug-2012.

S. No	Time hh:mm:ss:msec	Event	Remarks
		Gwalior(MP)-2	of the order of 270 MW from Gwalior MP to Gwalior PG. As per this report, two 220 kV outlets from Gwalior (PG), Ckt 1 to Gwalior(MP) and Ckt 2 to Malanpur were under planned shutdown since 29th July 2012. Thus with this tripping, the 220 kV connection between Gwalior (MP) and Gwalior(PG) was lost. The 220 kV Bina-Gwalior D/C lines were effectively no longer in parallel to the 400 kV Bina-Gwalior section after this tripping.
3	02:33 hours of 30th July 2012	220 kV Gwalior(PG)-Malanpur-1	As per SLDC MP's report, this tripped on overload with antecedent load of 280 MW. SLDC MP's report states a time of around 0234 hours; however considering the power flows and the network topology it is more likely that this circuit has gone around the same time as S no. 4. With this tripping, the approx. 180 MW load of 220 kV Malanpur and 220 kV Mehgaon substations in MP came totally on 220 kV Auraiya viz. Northern Region.
4	02:33:11:976 (as per WRLDC SOE)	400 kV Bina-Gwalior –1	The 400 kV Bina-Gwalior-Agra ckt 2 was under planned outage for upgradation to 765 kV level. Circuit 1 tripped on operation of Main-2 protection at Bina end. As per the DR of this line at Bina end (Exhibit 3.5), the voltage at the time of tripping is of the order of 220 kV phase to neutral or approximately 374 kV with phase current of the order of 2.23 kA (this corresponds to approximately 1450

S. No	Time hh:mm:ss:msec	Event	Remarks
			MVA). Timings match with WRLDC SOE. The line has remained hanging from Gwalior end due to which over-voltage protection operated later. The event list at Bina(Exhibit 3.6) indicates that Zone-3 of Main-2 protection (SIPRO) has operated. There is no evidence of a fault in the system and therefore it appears to be a case of load encroachment. As per the Gwalior end DR of REL670 numerical relay installed on Agra-1 line (Exhibit 3.7), the voltage at Gwalior end just before tripping of400 kV Bina-Gwalior-1 line (conclusion from reduction in flow on Gwalior-Agra), is of the order of 210 kV phase to neutral (approx. 362 kV phase to phase) while current is of the order of 1.8 kA (this corresponds to approx. 1130 MVA).
5	02:33:13:474 (Bhinmal Main 2 DR timings)	220 kV Bhinmal (PG)-Sanchore and 220 kV Bhinmal-Dhaurimanna	Main 2 REL 670 operated in Zone-1 on three phase Zone-1 indications apparently due to load encroachment of the distance relays. DR shows all the three phase to neutral voltages touching 103 kV (approx. 175 kV phase to phase) and current touching 800 amps. (Exhibit 3.8) As per SLDC Rajasthan's report (Exhibit 3.9), the Dhaurimanna circuit tripped on distance protection Zone-1 on three phase indications. With these trippings, 400 kV Zerda-Bhinmal inter-regional line would have become purely radial to Western region catering to

S. No	Time hh:mm:ss:msec	Event	Remarks
			the load of Bhinmal (Rajasthan).
6	02:33:13:927 (as per Rourkela DR time) Rourkela RTU reporting to ERLDC shows time of 02:33:15:025 but the RTU is not time synchronised)	400 kV Jamshedpur-Rourkela-2	Main-2-> MICOM P442 has operated. As per the DR phasors, the phase to neutral voltage in RYB phases to neutral are 216 kV, 214 kV and 210 kV respectively with phase currents being 1.10 kA, 1.17 kA and 1.14 kA respectively (Exhibit 3.10). This corresponds to 726 MVA approximately and 362 kV phase to phase voltage. DR values are at Exhibit 3.11. The tripping appears to be a load encroachment. Results of Rourkela end DR also consistent with Jamshedpur end DR (Exhibit 3.12). This DR needs verification w.r.t time synchronized. The line remained hanging from Jamshedpur end but tripped subsequently on over-voltage.
7	02:33:13:996	400 kV Rourkela-Jamshedpur-1	Main-2 distance protection operated at Rourkela end. As per the DR phasors, the phase to neutral voltage in RYB phases to neutral are 218 kV, 213 kV and 220 kV respectively with phase currents being 1.29 kA, 1.34 kA and 1.31 kA respectively. This corresponds to 850 MVA approximately and 362 kV phase to phase voltage. (Exhibit 3.13). DR values at Exhibit 3.14. The operation of the relay appears to be due to load encroachment.

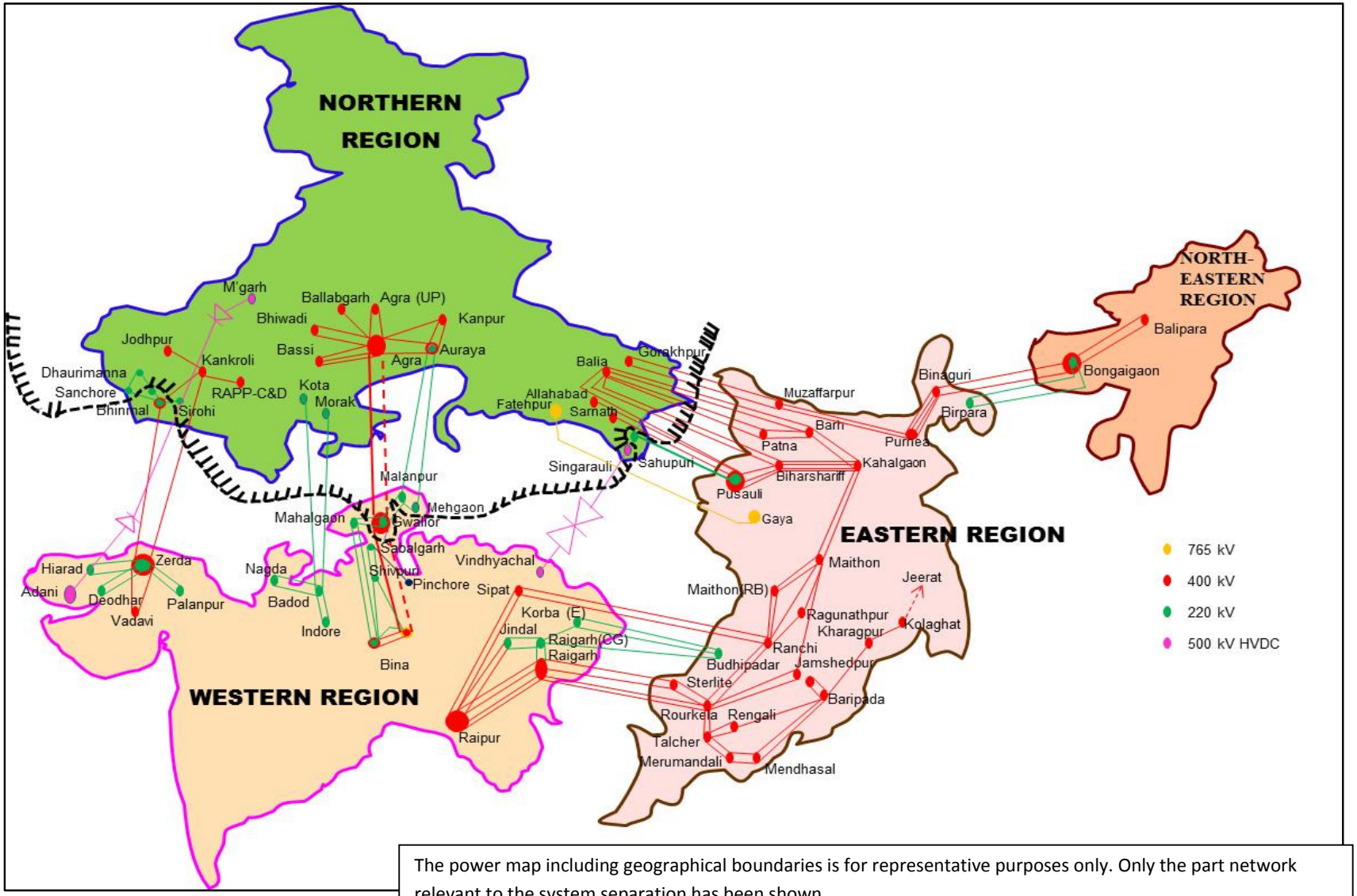
S. No	Time hh:mm:ss:msec	Event	Remarks
			Results of Rourkela end DR also consistent with Jamshedpur end DR. This DR needs verification w.r.t. time synchronization. (Exhibit 3.15) The line remained hanging from Jamshedpur end but subsequently tripped due to over-voltage protection.
8	02:33:15:181 (ERLDC SOE time; Muzaffarpur RTU not synchronized) 02:32:16:521 (Muzaffarpur end DR time) 02:33:15:400 (Gorakhpur end EL time appears to be closer to actual at Exhibit 3.17)	400 KV Gorakhpur-Muzaffarpur -2	Tripped from Gorakhpur end on operation of Main-1 protection. The Muzaffarpur end DR (Exhibit 3.16) indicates swing conditions with the RYB phase to neutral voltages at 123 kV, 116 kV and 115 kV respectively while the phase currents are 2.42 kA, 2.48 kA and 2.45 kA respectively. PSB operated at Muzaffarpur end and Main-1/2 didn't trip. The relay at Gorakhpur end tripped as impedance locus passed through second quadrant of zone-1. Immediately direct trip was received from remote end causing tripping at Muzaffarpur sub-station. 400 kV Muzaffarpur-Gorakhpur D/C line is a Quad Moose line with Fixed Series Capacitor (FSC) and Thyristor Controlled Series Capacitor (TCSC) at Gorakhpur end.
9	02:33:15:400 (Gorakhpur EL time as NRLDC SOE not available)	400 kV Muzaffarpur-Gorakhpur-1	Tripped from Gorakhpur end due to operation of Main-1 protection apparently due to power swing/load encroachment. The line was in charged condition from Muzaffarpur end, subsequently direct trip received at Muzaffarpur end on 03:03 hrs and line tripped from Muzaffarpur end also. DR at Muzaffarpur end (Exhibit 3.18) shows

S. No	Time hh:mm:ss:msec	Event	Remarks
			116-125 kV phase-neutral voltage & 2.42 kA phase current. 400 kV Muzaffarpur-Gorakhpur D/C line is a Quad Moose line with Fixed Series Capacitor (FSC) and Thyristor Controlled Series Capacitor (TCSC) at Gorakhpur end.
10	02:33:15:491 (Biharshariff DR time which is consistent with EL timings also)	400kV Biharshariff-Balia-1	Both Main-1 (MICOM P442) and Main-2 (SIPROTEC) distance protection operated at Biharsharif end due to power swing (Exhibit 3.19). DR shows that the phase to neutral voltage is of the order of 126 kV and phase current of the order of 2.56 kA (Exhibit 3.20).
11	02:33:15:491 (Biharshariff DR time which is consistent with EL time; exhibit 3.22)	400kV Biharshariff-Balia-2	Both Main-1 (MICOM P442) and Main-2 (SIPROTEC) distance protection operated at Biharsharif end due to power swing. (Exhibit 3.19). DR shows that the phase to neutral voltage is of the order of 131 kV and phase current of the order of 2.50 kA (Exhibit 3.21).
12	02:33:15:576 (as per Patna Main-1 DR and matches with EL(Exhibit 3.25) and Main-2 DR)	400 KV Patna-Balia-1	Tripped at Patna end on operation of Main-2 protection due to power swing. The DR of Main-1 and Main-2 protection (Exhibit 3.23 and 3.24) shows that the voltage has dipped to as low as 36-41 kV phase to neutral with the current as high as 2.75 kA.
13	02:33:15:576 (timing as per Patna Main-1 and Main 2 DRs as well as Event Logger (Exhibit	400 kV Patna-Balia -2	Tripped at Patna end on operation of Main-2 protection due to power swing. The DR of Main-1 and Main-2 protection (Exhibit 3.26 and 3.27) shows that the voltage has dipped to as low as 37.5 kV phase to neutral with the current as high as 2.97 kA, 3.58 kA and

S. No	Time hh:mm:ss:msec	Event	Remarks
	3.25) all of which are consistent.)		3.06 kA in RYB phases respectively.
14	02:33 to 02:34 (anytime between S no 13 to 17)	400 kV Sasaram (Pusauli)-Balia	The DR at Sasaram (Pusauli) end (Exhibit 3.28) does not appear to be time synchronised as the timing of REL670 relay is 03:31:24:367. The line has tripped on operation of Main-2 protection; however the current is of the order of 0.7 kA and voltage 176 kV phase to neutral.
15	With the above tripping, the Northern Region got disconnected on AC from the Western and Eastern Region. The timings as derived from the Disturbance Recorders and Event Loggers matches well with the frequency profile available from the Phasor Measurement Units (PMUs) installed in Northern region and Western Region as well as the Wide Area Frequency Measurement System (WAFMS) from IIT Bombay available on the public domain. These plots are indicated in Fig 3.2 and Fig 3.3 below. The PMU data in Western Region and Northern Region is transmitted to the respective RLDCs and the angular difference has been plotted in Fig 3.2 while analysing the data after the disturbance. The frequency of the Northern region system declined sharply and by 02:33:22 (6.5 seconds) it had already gone below 47.5 Hz and collapsed as units started pulling out apparently due to under-frequency protection of generators. The Northern Region was importing approximately 5767 MW from the neighbouring regions out of which 1400 MW was being imported on three HVDC links as under: 1) HVDC Mundra-Mohindergarh : 600 MW 2) HVDC back to back Vindhyachal: : 500 MW 3) HVDC back to back Pusauli : 300 MW Thus in the first instance when Northern Region separated out on AC from the Western Region and Eastern Region, it would have lost a maximum of 4367 MW (5767 MW-1400 MW). Considering that Northern Region has close to 10000 MW load-shedding envisaged through Under Frequency Relays (UFRs) out of which 4000 MW is flat frequency and 6000 MW through df/dt relays. The rapid frequency decline shows that the adequate relief by way of operation of flat frequency and df/dt wasnot there, which		

S. No	Time hh:mm:ss:msec	Event	Remarks
	is a matter of serious concern and needs to be examined separately.		
16	In rest of the NEW grid (minus Northern region), the frequency increased to 50.92 Hz by 02:35 hours. A few generating units tripped. Some 400 kV lines tripped on high voltage. The details are as under: Eastern Region: 1. Mejia – B Unit # 2 (Loss of Generation 400MW) 2. DSTPS Unit #1 (loss of Generation 250MW) 3. MPL Unit # 1 (Loss of Generation 450MW) **400 kV circuits** 1. Kahalagaon – Biharshariff-I 2. Kahalagaon – Biharshariff-III 3. Kahalagaon – Biharshariff-IV 4. Kahalgaon-Barh-I 5. Kahalgaon-Barh-II 6. Barh-Patna-I 7. Barh-Patna-II 8. Biharshariff-Gaya S/C 9. Rourkella-Ranchi-I 10. Purnea-Binaguri-II In Western Region, the following generating units and transmission lines tripped at the time of disturbance. 1) K(E) EXTN Unit II (250 MW) 2) K(E) EXTN Unit I (250) 3) APL Mundra unit-9 (660 MW) 4) APL Mundra unit-7 (660 MW) 5) Parli-5 (210 MW) 6) Nasik-4 (210 MW) 1) 400 kV Satna-Bina-3 2) 400 kV Bableshwar-Padghe-2 3) 400 kV Bhusawal-Deepnagar-2 4) 400 kV Bableshwar-Aurangabad S/C 5) 400 kV Satna-Bina-4 6) 400 kV Seoni-Khandwa-1		

S. No	Time hh:mm:ss:msec	Event	Remarks
	7) 400 kV Jejuri-Koyna Stage 4 At 0339 hours there was a disturbance at Vindhyachal STPS and the following generating units and transmission lines tripped. This needs to be examined separately as the details are not available so far. 1) Units 3,4,5,7,8 and 10 (first three 210 MW units and the latter 500 MW units). 2) 400 kV Jabalpur-1,2 and 4 lines at Vindhyachal 3) 400 kV Satna-2,3 and 4 at Vindhyachal 4) Vindhyachal HVDC Block-2 5) 400 kV Itarsi-Jabalpur-1 This tripping led to a delay in extension of start up supply to Northern Region through the AC bypass which was finally extended at 04:52 hours.		



The power map including geographical boundaries is for representative purposes only. Only the part network relevant to the system separation has been shown.

Figure 3.1:Sketch showing the axis of separation on 30th July 2012

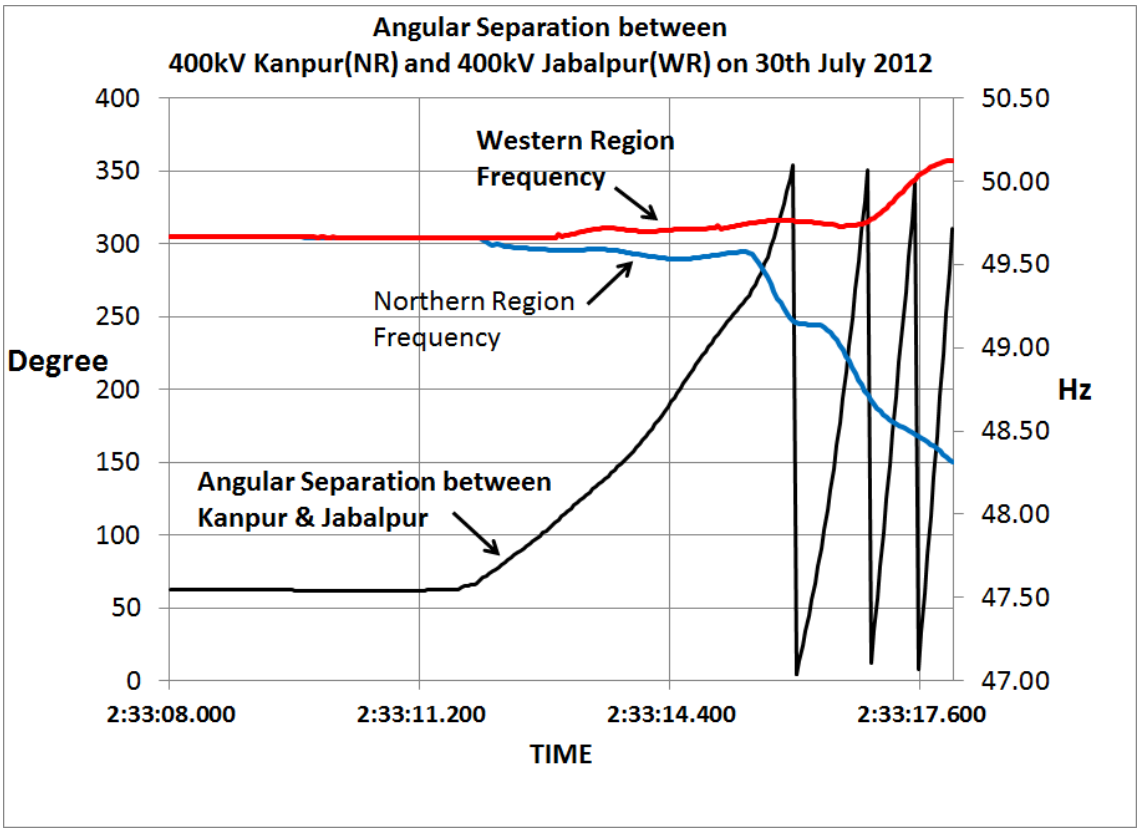


Fig 3.2: Frequency profile from the Phasor Measurement Units (PMUs) data at RLDCs

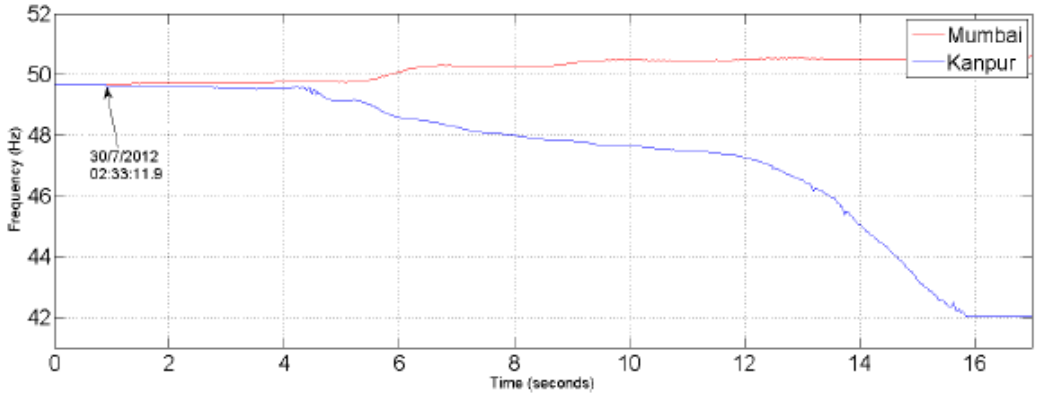


Fig 3.3: Frequency profile as captured by IIT Bombay's Wide Area Frequency Measurement System

3.3 Observations on the above sequence:

From Chapter 2 it would be seen that there is the large quantum of unscheduled exports from Western region (of the order of 3000 MW) and unscheduled import by Northern Region (of the order of 2000 MW). This skewed despatch scenario arose due to heavy demand in Northern Region following failure of the South-West monsoon and surplus in Western region. For scheduled transfers between regions, RLDCs/NLDC work out the transfer capability and approve the schedules only if the transfer capability is not violated. However in respect of unscheduled transfers, the frequency linked Unscheduled Interchange (UI) mechanism does not help in mitigating network congestion.

There is a mechanism to kick in congestion charges in the upstream and downstream system. However, it was difficult for NLDC to kick in congestion charges as per the existing approved procedure as the same arose due to outage of the network. The 400 kV Bina-Gwalior-Agra-2 was under plannedshutdown since 28th July 2012 for up-gradation work to 765 kV. Thereafter outages started from the afternoon of 29th July 2012 as under:

Table 3.2: Outages of the transmission network in the West to North direction

S no	Time	Transmission element	Reason
1	15:15	220 kV Kota-Badod	Tripped due to operation of distance protection three phase Zone-1 indications at Badod end. The line was idly charged from Badod end and could not be closed at Kota end due to a reported breaker problem.
2	15:40	220 kV Binmal(PG)-Sirohi	Phase to earth fault. The two 220 kV outlets to Bhinmal(RVPNL) and one to Sanchore were in service from Bhinmal (PG).
3	21:45	400 kV Bhinmal-Kankroli	Tripped due to insulator de-capping.
4	22:18	400 kV Zerda-Kankroli	Emergency outage for a period of two hours to take out one Tool & Plant (T & P) which got stuck with one polymer insulator.

As would be observed from the Table 3.1 and 3.2 above, the 400 kV network between Western Region and Northern Region got depleted progressively over the night starting with a planned outage on a high capacity corridor followed by two forced outages in quick succession.

The tripping of 220 kV Badod-Modak at 0010 hours and 220 kV Gwalior (MP)-Gwalior (PG)- 2 at 0135 hours would have resulted in increase on flow on 400 kV Gwalior-Bina as well as dip in voltage at Bina/Gwalior. Under normal circumstances when all the 400 kV links between Western region and Northern Region are in service, the 220 kV underlying parallel network carries less power and is generally monitored at the SLDC level. The RLDCs and NLDC monitor the 220 kV network only if it is inter-state and inter-regional or the same is included in the list of important elements as specified in the Operating Procedures issued by the RLDCs.

Thus the 220 kV underlying network assumed importance once the 400 kV network got depleted.However as seen from the above there were outages in the 220 kV Rajasthan system at Bhinmal and Madhya Pradesh at Gwalior.While the analysis above shows that the power flow on the 400 kV Bina-Gwalior-1 line was of the order of 1450 MVA just before tripping, the operators at WRLDC and NLDC were observing a constant value of 1000 MW as the data appears to have frozen.

The operators at NRLDC, WRLDC and NLDC were making continuous efforts through verbal messages and written messages which are enclosed in Exhibit 2.86. Sipat TPS whose unit 3 came under Commercial operation wef 1st August 2012 continued to generate about 400 MW under UI despite persuasion by WRLDC to reduce generation. A list of messages issued is tabulated below.

Important messages issued on 29.07.12 & 30.07.12				
Date	**Time**	**From**	**Message summary**	**Issued To**
29.07.12	2110	NRLDC	400 kV Agra-Gwalior is 896 MW; 2nd ckt is out Reduce drawal within schedule: Punjab: 994 MW, Haryana: 493 MW, UP: 366 MW; All the States will be responsible in case of untoward tripping	Punjab, Haryana, Rajasthan, Delhi, UP, Uttarakhand
29.07.12	2137	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	NLDC
29.07.12	2147	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	GETCO, MPPTCL

Important messages issued on 29.07.12 & 30.07.12				
Date	**Time**	**From**	**Message summary**	**Issued To**
29.07.12	2150	RRVPNL Jaipur	Opening of 220 kV Modak- Badod line	NRLDC
29.07.12	2220	WRLDC	Overloading of lines 400 kV Kahalgaon-Maithon-D/C, 400 kV Maithon-Durgapur-II, 400 kV Rourkela-Talcher-D/C.	NLDC, NRLDC
29.07.12	2227	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors	GETCO, MPPTCL, MSETCL
29.07.12	2246	NLDC	Reducing O/D by NR constituents.	NRLDC
29.07.12	2248	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors. Low voltage at Gwalior and high angular in WR-NR	NLDC
29.07.12	2250	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	GETCO, MPPTCL, MSETCL
29.07.12	2258	NRLDC	Request for Unrequisitioned power within NR GPS to reduce loading of 400 kV Gwalior-Agra-II and OD from other regions	Punjab, Haryana, Uttar Pradesh
29.07.12	2330	NRLDC	400 kV Agra-Gwalior is 975 MW; Agra-Gwalior ckt-II, Zerda-Kankroli and Kota-Badod under shut down Reduce drawal within schedule: Punjab: 544 MW, Haryana: 315 MW, UP: 1000 MW; All the States will be responsible in case of untoward tripping	Punjab, Haryana, Uttar Pradesh

Important messages issued on 29.07.12 & 30.07.12				
Date	**Time**	**From**	**Message summary**	**Issued To**
29.07.12	2331	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	GETCO, MPPTCL, CSPTCL, GOA
29.07.12	2335	WRLDC	Regarding Bina-Gwalior-Agra-Ckt-2 status	CPCC,JBP
29.07.12	2342	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	NLDC
29.07.12	2343	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	GETCO, MPPTCL
29.07.12	2345	WRLDC	Reduce generation at Sipat-III	NTPC
29.07.12	2348	NLDC	Reducing the O/D by NR constituents	NRLDC
30.07.12	0008	WRLDC	Line Loading of 220 kV KEB-Budhipadar-Ckt-II & III	CSPTCL, Raipur
30.07.12	0010	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	GETCO, MSETCL, MPPTCL
30.07.12	0018	WRLDC	Tripping of Badod-Modak line	SLDC,MPPTCL, NRLDC, NLDC
30.07.12	0021	NLDC	Reduce the U/D by constituents	WRLDC
30.07.12	0053	NRLDC	URS in Anta and Dadri GPS scheduled to Hanyana due to overloading of IR lines	Haryana
30.07.12	0057	NLDC	Reduce the O/D of NR	NRLDC

Important messages issued on 29.07.12 & 30.07.12				
Date	**Time**	**From**	**Message summary**	**Issued To**
30.07.12	0058	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	GETCO,MPPTCL, MSETCL
30.07.12	0121	NRLDC	400 kV Agra-Gwalior > 1050 MW; Punjab OD 641 MW; Violation of Punjab ATC of 5100 MW; Requested to reduce drawal	PUNJAB
30.07.12	0125	WRLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.	GETCO, MPPTCL, MSETCL

It has to be appreciated that in an integrated and meshed system, a 10 MW reduction on 220 kV Badod-Kota line would require at least 100 MW load shedding in Northern Region and similar backing down of generation in Western region. This calls for a fast response time from all the SLDCs and power stations.

As seen from the above sequence, this tripping is essentially a Zone-3 tripping on load encroachment. These settings need to be examined separately. In the past such relay surprises when the system was stressed have led to blackouts on 12th October 2007 in Northern Grid, 2nd January 2010 in Northern Grid (twice) and on 18th November 2010 in Mumbai system.

After the tripping of 400 kV Bina-Gwalior-1, the system has collapsed within seconds and beyond the control of the operator.After this line has tripped a number of lines have tripped on distance protection either due to load encroachment or power swing. In many cases only one out of the two distance protection scheme has sensed the load encroachment and tripped the line. For a heavily stressed or loaded system, dynamic reactive power consumption at both ends of the line is essential to compensate the additional reactive power consumed by the line. This was possibly not adequate. A clear picture can emerge only after observing the Data Acquisition System (DAS) outputs from the different power plants and whether the generators reached their over-excitation limit during this event.

The East to North ties tripped leading to separation of Northern region. Six East to North ties which were in service were high capacity Quad Moose conductors, two of which had FSC and TCSC also. Separation on such a high capacity multiple circuit corridor due to load encroachment/power swing is again an issue which needs to be examined.

The Northern Region after separation of the NEW grid should ideally have survived due to Under Frequency Relay (UFR) and df/dt relay load-shedding. That the frequency could not stabilize is a matter of concern needs a detailed investigation separately.

In rest of the NEW grid also, the frequency rose to 50.92 Hz and tripping of seventeen 400 kV lines on high voltage and nine generating units due to various reasons is also a matter of concern as secondary disturbances could have taken place in this system also. It again illustrates the absence of primary response from the generating units and lack of dynamic reactive resources.

CHAPTER 4

RESTORATION SEQUENCE AFTER GRID DISTURBANCE ON 30TH JULY 2012

4.1 Restoration Process in Northern Region

4.1.1 Extension of Power Supply to Subsystems:

I. Extension of Power from Western Region

a. **From 400 kV Zerda-Bhinmal** : Supply to Rajwest TPS & Giral TPS within Rajasthan was restored from Western Region through 400kV Zerda-Bhinmal, 220kV Bhinmal-Dhaurimana-Rajwest, 220kV Rajwest – Barmer-Giral TPS. Power supply further extended to Wind farm at Akal (Jaisalmer)

b. **From 220 kV Badod-Morak**: Power supply was extended to Kota TPS & Suratgarh TPS in Rajasthan system through Western Region interconnection at 220kV Badod-Morak. Power supply further extended to 220kV Morak-KTPS, 220kV KTPS-Heerapura-Khetri-Junjhunu-Ratangarh-SuratgarhTPS. Power extended from Kota (Rajasthan) to Traction .

c. **From 220kV Mehgaon-Auraiya** : Western region supply from 220kV Mehgaon-Auraiya was extended to Auraiya GPS. It was further extended to 220kV Auraiya-to Traction, 220kV Auraiya- Sikandra (UP) to Traction , 400kV Auraiya-Agra & 400kV Auraiya-Kanpur.

d. **From 400 kV Gwalior- Agra** : Power supply from 400kV Bina-Gwalior-Agra was extended to 400kV Ballabgarh to Bamnauli. From Bamnaulli supply was extended to Mundka. Supply for start up was extended from Mundka to Jhajjar-APCPL TPS.

e. **From HVDC Vindhyachal AC Bypass** : At 0339 hours there was a disturbance at Vindhyachal STPS and the generating units at VSTPS and transmission lines tripped. This tripping led to a delay in extension of start up supply to Northern Region through the AC bypass which was extended at 04:53 hrs. However, 400 kV NTPC/VSTPS – HVDC feeder 2 tripped at 06:07 hrs from VSTPP end. At 08:16 hrs 400 kV NTPC/VSTPS – HVDC feeder 1 was finally charged from NTPC Vindhyachal end.

II. Extension of Power from Eastern Region

a. Power Supply was extended from ER through Sasaram to Sarnath & Allahabad. Power supply from Sarnath was extended to 400kV Sarnath-Anpara TPS, 400kV AnparaTPS-Singrauli TPS & Singrauli TPS – Rihand

TPS. 400kV Allahabad supply extended to 220kV Allahabad (Rewa Road) to Traction (Railway)in Uttar Pradesh and 220kV Allahabad subsystem.

b. Power Supply was extended from ER through Balia/Gorakhpur to 400kV Gorakhpur(UP) & 400kV Lucknow. Power supply from 400kV Gorakhpur (UP) was extended to 220kV Gorakhpur (UP) to Tanda TPS. 400kV Lucknow power was extended to RosaTPS. 400kV Lucknow power was extended to 400/220kV Lucknow(UP), 220kV Sarojini Nagar-Traction, 220kV Sarojini Nagar-Raibareilly-Unchahar TPS.

III. Dadri Gas self started and lighted up 220kV Dadri Thermal & 400kV Dadri Thermal. Traction supply was extended from Dadri Gas

4.1.2 Extension of startup supply to Generating Stations

I. Start up supply was extended to **Rajwest TPS** in Rajasthan through 220kV Bhinmal-Dhaurimanna-Rajwest at 03:20 hrs.

II. Startup supply to **Kota TPS** was extended from Western Region through 220kV Badod-Morak at 03:35 hrs and then Morak-KTPS at 03:39hrs.

III. Start up power to **Giral TPS** was extended from 220 kV Bhinmal-Dhaurimanna-Barmer-Giral TPS at 3:40 hrs. Power was extended to wind farm in Rajasthan.

IV. **DMRC** supply was restored from BTPS-Mehrauli-DMRC at 03:48 hrs.

V. Western region supply was extended to **Auraiya GPS** from 220kV Mehgaon-Auraiya at 04:07 hrs. Auraiya start up GT#1 at 05:23 hrs.

VI. Start up power extended to **Tanda TPS** (UP) from 220kV Gorakhpur-Tanda at 04:21 hrs. Tanda TPS Unit#4 come up at 06:36 hrs.

VII. Power supply was extended from Kota TPS to Heerapura S/S at 04:23 hrs, Heerapura-Khetri at 05:14 hrs, Khetri-Jhunjhunu at 05:26 hrs and Jhunjhunu-Ratangarh at 05:25 hrs and further extended to **Suratgarh TPS**.

VIII. **Dadri Gas** self started at 04:25 hrs and then extended supply to 220kV Dadri Thermal through interconnector. 220kV Dadri thermal start up at 04:28hrs.

IX. Power supply was extended from Dadri Gas to **Dadri Thermal** through 400/220 kV ICT at 04:25 hrs. First machine of Dadri Thermal synchronized at 11:49 hrs.

X. Power Supply was extended from Sasaram in ER to 400kV Sarnath – **AnparaTPS**-1 at 04:53 hrs. Anpara Units start up at 06:47hrs.

XI. **Anta GPS** survived on house load and synchronized to grid at 04:50 Hrs (220kV Anta-Kota charged at 03:56 hrs and 220kV Anta-Dausa charged at 5:19 hrs as per SoE)

XII. Power supply was extended to **ROSA TPS** at 05:12 hrs from 400kV Lucknow (PG), Unit#4 (At 400kV) start up at 11:07 hrs.

XIII. **ShreeCement** Unit#1 & 2 started up at 05:35 hrs, Power Supply was extended through Kota (PG) at 05:21 hrs.

XIV. Startup power to **Ropar TPS** was extended from 220kV Bhakra-220/132kVGanguwal-Kotla-Ropar at 05:30 hrs. Ropar TPS Units start up at 12:00 hrs.

XV. Traction supply from **Sarojini Nagar** (Uttar Pradesh) was restored at 05:48 hrs.

XVI. Power supply was extended from Sarojini Nagar-Raibareilly to **Unchahar TPS** at 06:00hrs, Unchahar units started up at 10:42 hrs.

XVII. Attempt was made to extend power from Vindhyachal AC Bypass to Singrauli-Rihand Complex at 4:53 hrs. But VSTPP-HVDC feeder 1 tripped from NTPC – VSTPP end.

XVIII. Second attempt to extend the start up power to **Singrauli STPS** through 400kV Singrauli-Anpara suceeded at 06:25 hrs. Singrauli Unit#3 lighted up at 08:00hrs and synchronized at 10:08 hrs.

XIX. Power Supply was extended to **Rihand STPS** through 400kV Singrauli-Rihand-2 at 06:35 hrs. Rihand Unit#2 lighted up at 09:20 hrs and synchronized at 11:20 hrs.

XX. Start up power to **Obra TPS** was extended from Pipri (Rihand-Hydro) hydro station (Blackstarted) at 06:45 hrs. Obra TPS unit#9 revived at 08:43 hrs and synchronized at 10:26 hrs.

XXI. **Badarpur TPS** survived and operated in Island mode with Unit#1, 3 & 5 and this island collapsed at 06:48 hrs. BTPS supply was extended through 220kV Sarita Vihar at 07:10 hrs. BTPS unit#3 was synchronized at 10:25 hrs.

XXII. Startup power to **Jhajjar TPS** was extended from Mundka (Bawana-Mundka-Bamnoli) at 07:30 hrs. Jhajjar TPS unit#1 was synchronized at 18:56 hrs.

XXIII. Start up supply to **Parichha TPS** was extended from 220kV Orai-1 at 07:35 hrs. Parichha TPS unit#4 synchronized at 15:24 hrs.

XXIV. Start up power to **Panipat Stage-2** was extended from Rohtak (Bahadurgarh-Luna Mazra-Sampla-Rohtak) at 08:30 hrs. Panipat unit#6 synchronized at 11:30 hrs.

XXV. Start up power to **LehraMohabbat TPS** (Punjab) was extended from Barnala at 09:32 hrs. LehraMohabbat unit#1 revived at 14:16 hrs and synchronized at 15:30 hrs.

XXVI. **Narora Atomic Power Station** survived on house load.

XXVII. Start up supply to **Khedar TPS** was extended from 400kV Fatehabad (PG) at 10:23 hrs. Unit-2 at Khedar TPS lighted up at 18:26 hrs & synchronized on 31-July-2012, 01:20hrs.

XXVIII. 220kV Faridabad GPP-Samapur line charged at 08:00 hrs. **Faridabad GT#1** started and synchronized at 08:44 hrs. GT#2 started and synchronized at 10:00 hrs and STG synchronized at 12:28 hrs.

4.1.3 Black start by Hydro stations:

I. Bhakra(L)

a. Bhakra(L) blackstarted at 03:40 hrs and ran in island upto 03:57 hrs, again blackstart at 05:15 hrs and collapse at 06:29 hrs. Bhakra again blackstart at 07:05 hrs and extended Power Ganguwal-Dhulkote- Panipat TPS.

II. Salal HEP

a. Unit#2 of Salal blackstarted and ran in island with Jammu & Kishenpur load from 04:00-04:20 hrs,04:40-08:30hrs,09:40-10:38 hrs, 10:42-11:15 hrs & 11:38-12:21 hrs

b. Unit#1 of Salal blackstarted and ran in island with Jammu & Kishenpur load from 05:45-08:30 hrs,11:26-11:30hrs & synchronized at 12:30 hrs

III. Pong

a. Pong U#1 blackstarted at 04:26 hrs and ran in island with Jallandhar (Punjab) load till 04:33 hrs. Again blackstarted at 04:50 hrs and ran in island with Dasuya(Punjab) load till 05:03 hrs. Pong U#1 finally started at 09:19 hrs and synchronized.

IV. Uri HEP

a. Uri HEP black started at 04:31hrs & power extended to Wagoora and then to Zainkote.

V. Nathpa-Jhakri

a. Nathpa-Jhakri black started at 05:09Hrs. 400kv Jhakri-Nallagarh charged at 05:16Hrs.

VI. Chamera-2 and Chamera-1

a. Chamera-I U#3 black-started at 05:38 hrs and power extended to 400kV Jallandar. & load at 220kV Jallandar (Punjab) of 160MW. Island collapse at 06:20Hrs. At 09:59Hrs power extended to Chamera-1 from Jallandhar through 400kV Chamera-1-Jallandhar Ckt-1. At 10:01 Hrs U#3 synchronized and loaded upto 180MW. At 10:17Hrs U#2 synchronized and loaded upto 180MW. 400kV Chamera-1-Jallandhar Ckt-2 charged at 10:47Hrs.

b. Power supply extended to Chamera-2 from Chamera-1 at 10:50Hrs

VII. Tanakpur HEP

a. Tanakpur U#1 started at 06:41Hrs, U#2 at 06:47Hrs and U#3 at 07:00Hrs by extending power through 220kV CB ganj (Bareli-UP)

VIII. Dhauliganga HEP

a. Dhauliganga U#2 started at 07:03Hrs after extending power through 400/220kv Bareilly (UP). Dhauliganga. U#1 started at 07:11Hrs and U#3 started at 07:54Hrs.

A comparison of the time taken in extension of startup power and time taken for synchronization by major thermal generating station is depicted in the chart below:

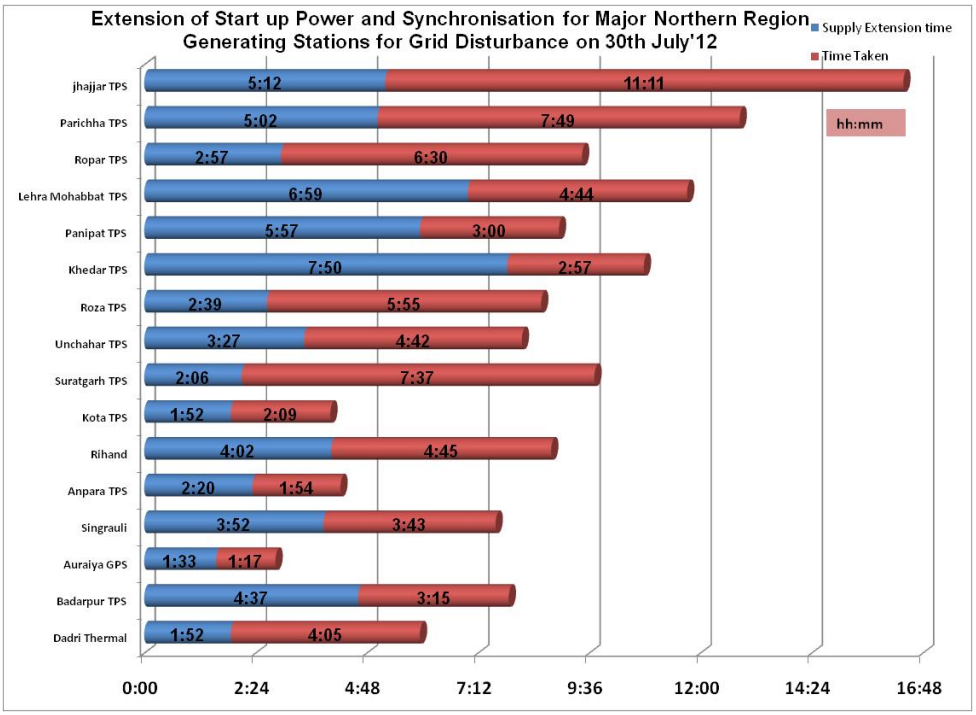


Chart: 4.1

The detailed sequence of events is attached as Exhibit 4.1

4.1.4 Restoration of Traction Supply

Priority was given to restore traction supply as soon as possible. The details of restoration of traction is given below:

I. Traction supply from Kota restored at 03:55 hrs.
II. Traction power at Sarojini Nagar was restored at 05:48 hrs
III. Traction supply from Auraiya extended to Phuphund and further to traction sub-station at Shikhobad, Etwah,Rura at 05:55hrs.
IV. Power supply was extended from DadriGas to Dhankaur, then Dhankaur to traction sub-stations shahibabad, Dankaur,Khurja, Hathras & Mitwali at 06:08 hrs
V. Traction power at 66kV Ballabhgarh(BBMB) was restored at 06:22 hrs from Ballabhgarh PG.
VI. Power supply to traction at Narela-NDPL(66kV) was extended from 220kV Mandola-Narela at 06:55 hrs.
VII. Traction supply from Agra was restored at 07:18 hrs.
VIII. Traction supply from Abdullapur to traction substation Kurali, Jagadhari,AnandpurShahib, Rajpura & Ghagar restored at 07:25 hrs, 07:50hrs, 08:06 hrs, 09:44 hrs & 09:53 hrs respectively.
IX. Traction supply from Kanpur-Naubasta to Malwan restored at 07:33 hrs

X. Traction power at Diwana from Panipat restored at 08:12 hrs

XI. Traction power at Chankyapuri was restored at 08:57 hrs from 220kV Bamnoli-Dial-Mehrauli-Ridge Valley.

XII. Power supply from Pong HEP (BBMB) extended to 220kV Jallandhar-Butari and then extended to traction substation Butari, Chiharu & Sahnewal at 10:28 hrs

XIII. Power supply of traction substation at Kanth, Fazalpur, Roorkee & Ummartali restored at 16:55hrs, 16:55hrs, 15:55 hrs & 16:36 hrs respectively.

XIV. Restoration of power supply at Delhi Metro Mehrauli was done 03:48 hrs, Rohini at 06:48 hrs, KashmiriGate at 07:10 hrs, Kanjhawala at 07:48 hrs, Mundka at 07:51 hrs, Pappankalan-1 at 08:08 hrs, Pappankalan-2 at 08:08 hrs, DIAL at 08:18 hrs & Parkstreet at 09:38hrs.

The station wise details of restoration of traction supply is tabulated below:

Restoration of Traction Supply after Grid Disturbance at 02:33hrs of 30th July 2012				
SL. NO	**Feeding point from Grid to Railway Traction**	**Time**	**Supply extended to Railway Traction**	**Time**
1	Kota	03:40	Kota traction	03:55
2	Lucknow	05:12	Sarojininagar	05:48
3	Ballabgarh-BBMB	05:20	Ballabgarh tarction	06:22
4	Auriya Gas	05:23	Phaphund	05:55
5	Auraiya Gas	05:23	Agra	07:18
6	Muzaffarnagar	06:05	Roorkee	07:20
7	Dadri Gas	06:08	Dhankaur	06:08
8	Moradabad	06:15	a)Fazalpur	06:25
9	Moradabad	06:15	b)Kanth	06:25
10	Luckhnow	05:20	c)Ummartali	06:55
11	Kanpur	06:34	a)Malawan	07:33
12	Bawana	06:40	Narela	06:54
13	Abdullapur	07:27	a)Jagadhri	07:50
14	Abdullapur	07:28	b)Anandpur Sahib	08:06
15	Abdullapur	07:29	c) Rajpura	09:44
16	Abdullapur	07:30	d)Ghaggar	09:53
17	Bamnauli	08:01	Chankyapuri traction	08:57
18	Panipat	08:02	Diwana	08:12
19	Ludhiana	09:07	c)Sahnewal	10:28
20	Jallandhar	09:18	a)Butari	10:28
21	Jallandhar	09:19	b)Chiharu	10:28

Table : 4.1

The time taken for restoration of power supply at traction sub station is depicted in chart below:

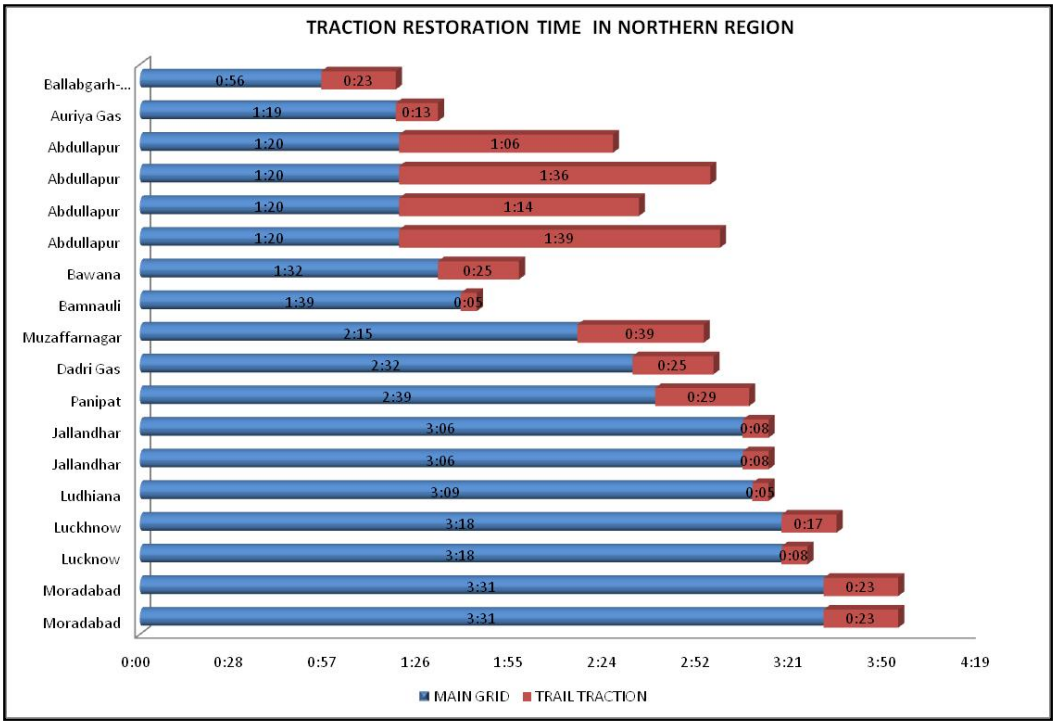
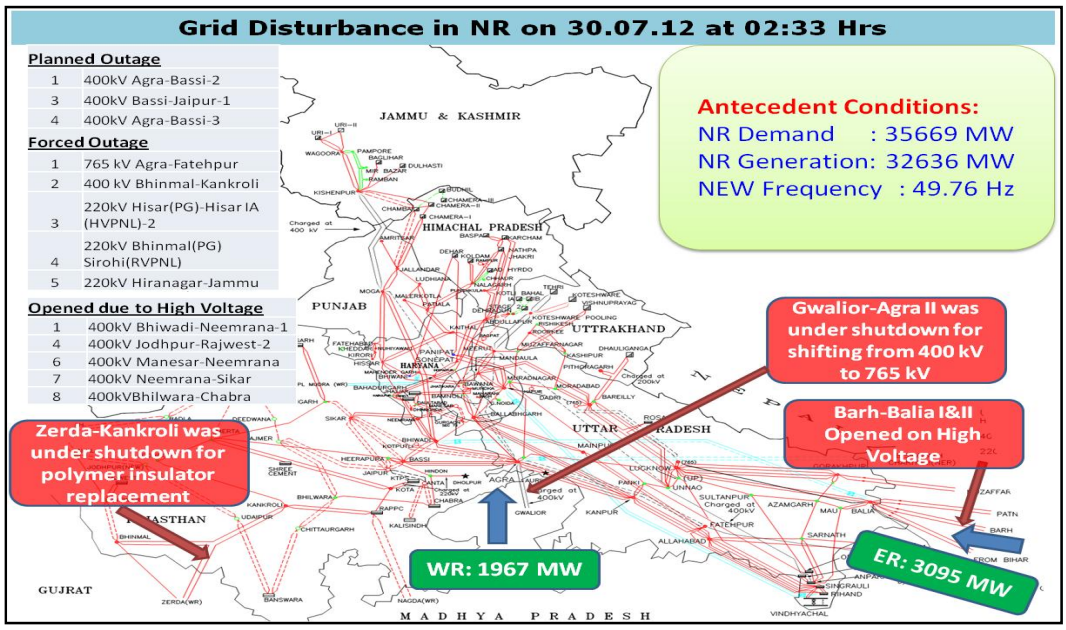
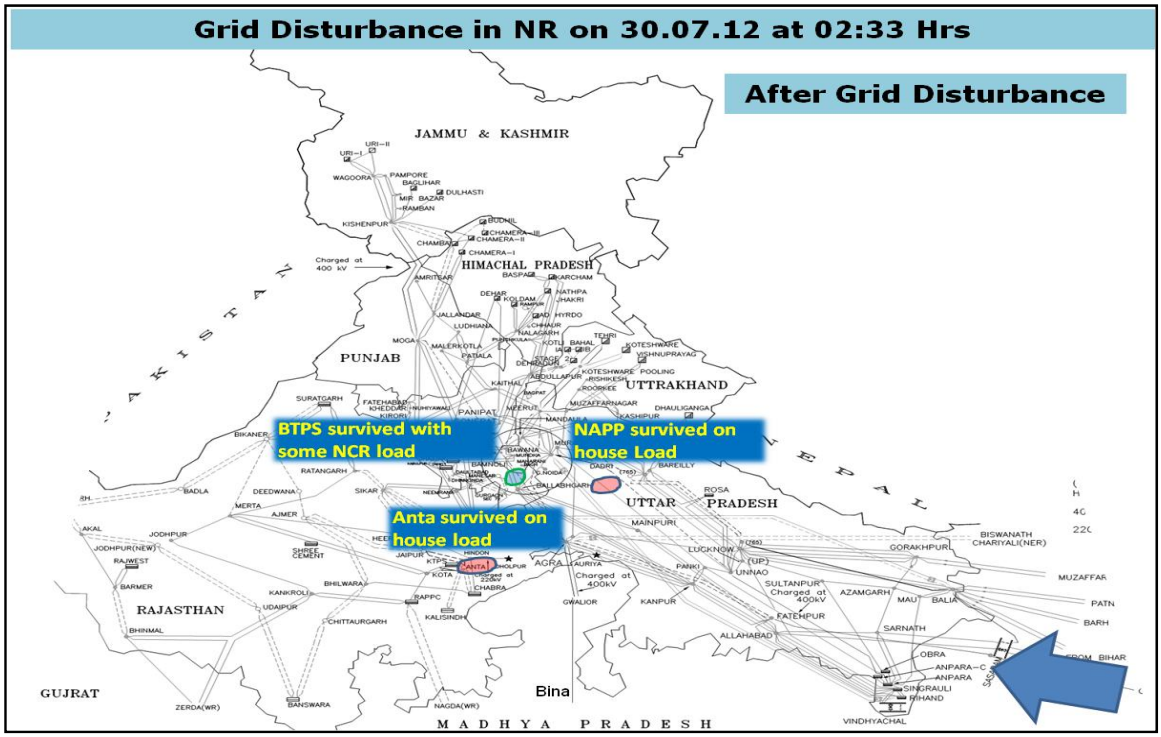
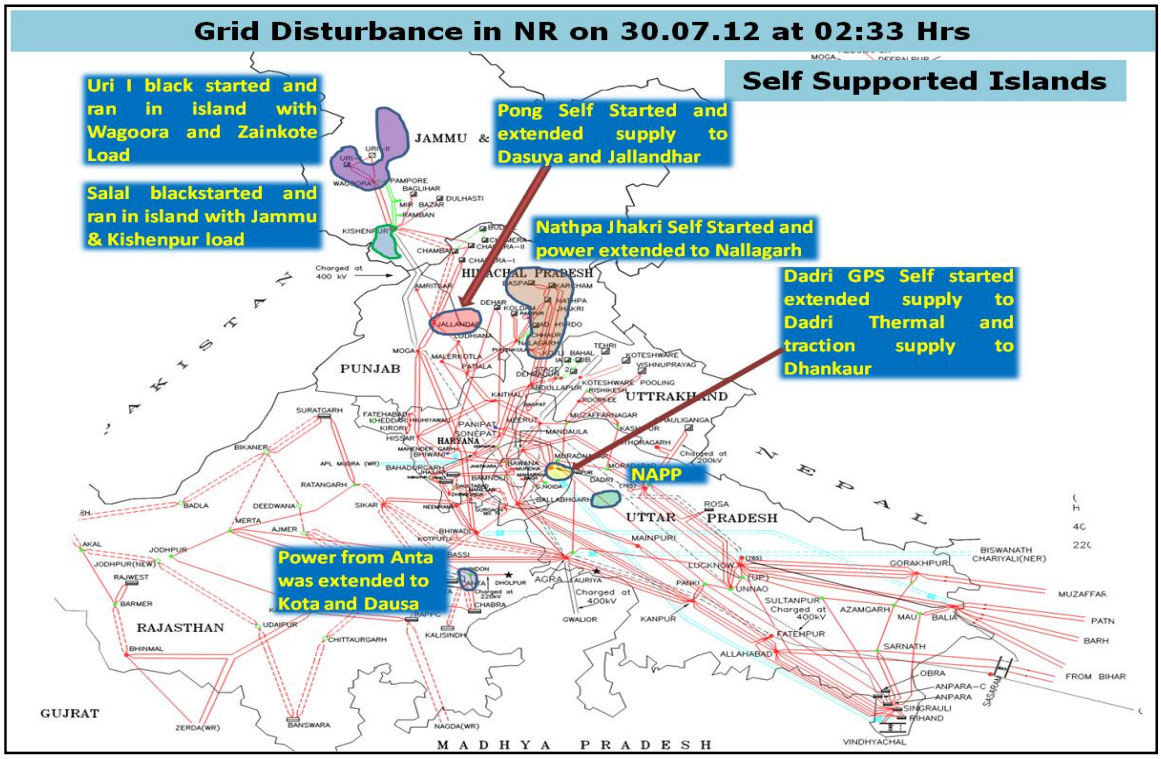


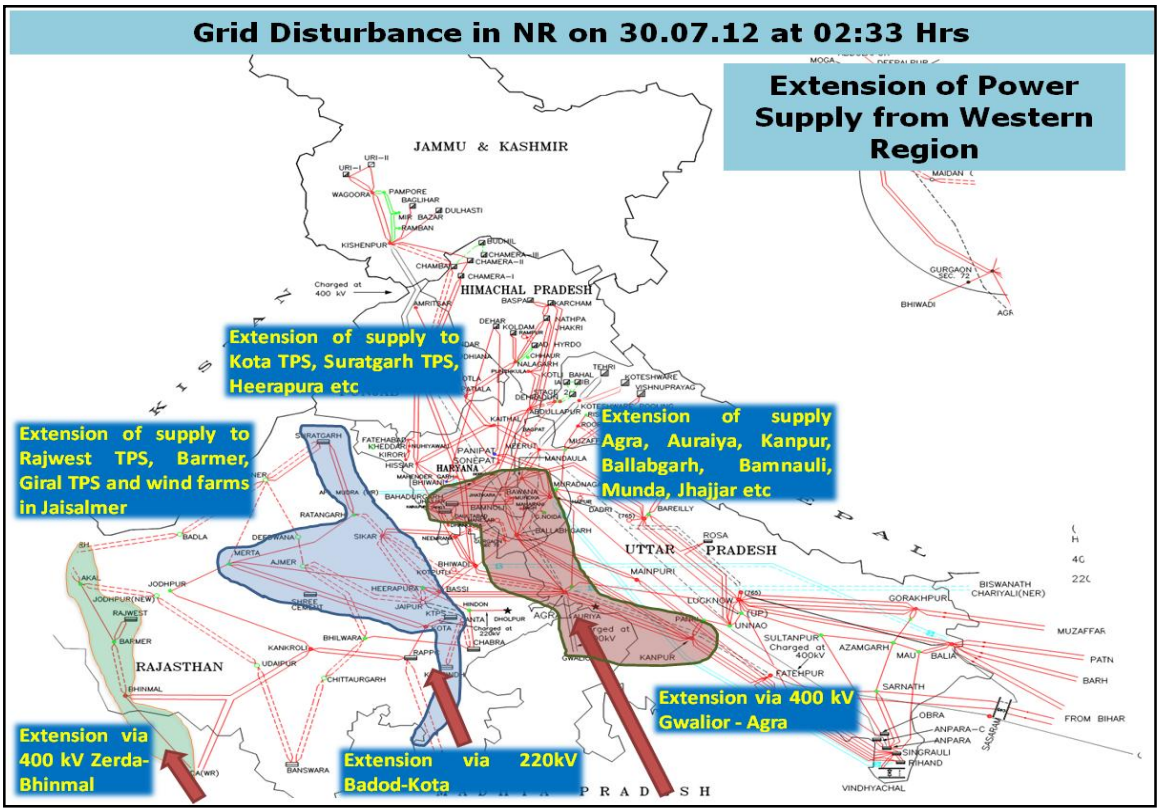
Chart: 4.2

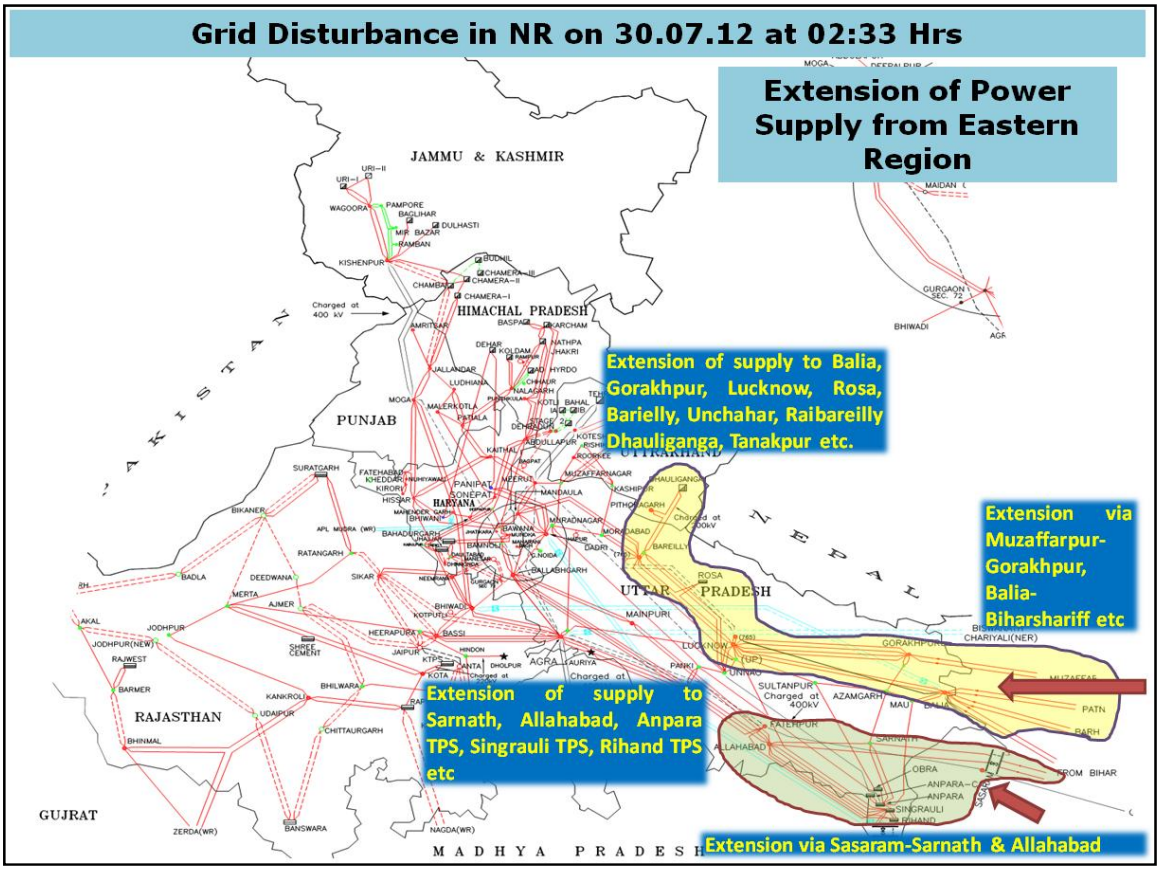
4.1.5 : Pictorial Representation of Restoration




Grid Disturbance in NR on 30.07.12 at 02:33 Hrs
After Grid Disturbance
BTPS survived with some NCR load
NAPP survived on house Load
Anta survived on house load
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
UTTRAKHAND
UTTAR PRADESH
RAJASTHAN
GUJRAT
MADHYA PRADESH
Bina


Grid Disturbance in NR on 30.07.12 at 02:33 Hrs
Self Supported Islands
Uri I black started and ran in island with Wagoora and Zainkote Load
Salal blackstarted and ran in island with Jammu & Kishenpur load
Pong Self Started and extended supply to Dasuya and Jallandhar
Nathpa Jhakri Self Started and power extended to Nallagarh
Dadri GPS Self started extended supply to Dadri Thermal and traction supply to Dhankaur
NAPP
Power from Anta was extended to Kota and Dausa
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
UTTRAKHAND
UTTAR PRADESH
RAJASTHAN
GUJRAT
MADHYA PRADESH


Grid Disturbance in NR on 30.07.12 at 02:33 Hrs
Extension of Power Supply from Western Region
Extension of supply to Kota TPS, Suratgarh TPS, Heerapura etc
Extension of supply to Rajwest TPS, Barmer, Giral TPS and wind farms in Jaisalmer
Extension of supply Agra, Auraiya, Kanpur, Ballabgarh, Bamnauli, Munda, Jhajjar etc
Extension via 400 kV Zerda-Bhinmal
Extension via 220kV Badod-Kota
Extension via 400 kV Gwalior - Agra
JAMMU & KASHMIR
HIMACHAL PRADESH
HARYANA
RAJASTHAN
UTTAR PRADESH
MADHYA PRADESH
NEPAL


Grid Disturbance in NR on 30.07.12 at 02:33 Hrs
Extension of Power Supply from Eastern Region
Extension of supply to Balia, Gorakhpur, Lucknow, Rosa, Barielly, Unchahar, Raibareilly Dhauliganga, Tanakpur etc.
Extension via Muzaffarpur-Gorakhpur, Balia-Biharshariff etc
Extension of supply to Sarnath, Allahabad, Anpara TPS, Singrauli TPS, Rihand TPS etc
Extension via Sasaram-Sarnath & Allahabad
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
HARYANA
RAJASTHAN
UTTAR PRADESH
GUJRAT
MADHYA PRADESH
NEPAL

4.2 Revival of Interconnection with Eastern Region

The event led to tripping of lines in ER connecting to Northern Region grid along with other lines and tripping of generating units viz Mejia-B Unit #2, DSTPS Unit #1, and MPL Unit #2 in DVC system. The sequence of restoration was as follows:

Date	Time	Activity	Remarks
30-07-2012	2:50	Rourkela-Jamshedpur - I	
30-07-2012	2:54	Biharsharif-Kahalgaon - I	Hand Tripped at 3:36 HRs
30-07-2012	3:04	Biharsharif-Gaya	
30-07-2012	3:11	Biharsharif-Kahalgaon - III	
30-07-2012	3:14	Binaguri-Purnea-II	
30-07-2012	3:23	Biharsharif-Balia-I	
30-07-2012	3:33	Biharsarif-Kahalgaon - IV	
30-07-2012	3:51	By Pass HVDC Sasaram B/B	
30-07-2012	4:11	Kahalgaon-Barh- I	
30-07-2012	4:14	Pusauli-Allahabad	Over Voltage Tripping at 4:22 Hrs
30-07-2012	4:19	MPL-Maithon -II	
30-07-2012	4:22	Patna-Barh - I	
30-07-2012	4:39	Pusauli-Sarnath	
30-07-2012	5:27	Muzaffarpur-Gorakhpur-II	
30-07-2012	5:27	Muzaffarpur-Gorakhpur-I	
30-07-2012	5:27	Patna-Balia-I	
30-07-2012	5:43	Biharsharif-Balia-II	
30-07-2012	5:51	**Synchronisation of Mejia-B Unit# 2**	
30-07-2012	5:57	Biharsharif-Kahalgaon - I	
30-07-2012	6:17	Pusauli-Allahabad	
30-07-2012	6:54	Rourkela-Jamshedpur - II	
30-07-2012	7:01	Ranchi-Rourkela -II	
30-07-2012	7:26	Maithon-Ranchi-I	
30-07-2012	11:36	**Synchronisation of DSTPS Unit # 1**	
30-07-2012	14:54	**Synchronisation of MPL Unit # 2**	

Table : 4.2

4.3 Revival of Transmission Lines and Generating Units in Western Region

Date	Time	Activity	Remarks
30-07-2012	4:20	K(E) EXTN Unit II	
30-07-2012	4:38	K(E) EXTN Unit I	
30-07-2012	5:24	APL HVDC POLE I	
30-07-2012	5:24	APL Unit 9 Synchronised	
30-07-2012	5:32	220 kV Gwalior -Malanpur I	
	5:43	Bableshwar-Aurangabad S/C	
30-07-2012	5:46	400 kV Babhleshwar-Padghe II	
30-07-2012	6:48	400 kV VSTPS -Essar Mahan	
30-07-2012	6:51	VSTPS Unit 10 Synchronised	Tripped on Gen Differential Protection at 3:39 hrs
30-07-2012	7:11	VSTPS-Satna II	
30-07-2012	7:34	Vin"chal HVDC Pole I	
30-07-2012	7:35	Satna-Bina III	
30-07-2012	7:38	VSTPS Unit 5 Synchronised	Tripped on Loss of Excitation at 3:39 hrs
30-07-2012	7:41	VSTPS Unit 8 Synchronised	Tripped on Loss of Excitation at 3:39 hrs
30-07-2012	8:02	VSTPS-Jabalpur I	
30-07-2012	8:03	VSTPS Unit 4 Synchronised	
30-07-2012	8:16	Vin"chal HVDC Pole II	
30-07-2012	8:18	400KV Jejuri-Koyna Stage-IV	
30-07-2012	8:42	VSTPS Unit 7 Synchronised	Tripped on Gen Differential Protection at 3:39 hrs
30-07-2012	9:41	400 kV Bhuswal-Deepnagar II	
30-07-2012	9:44	VSTPS-Satna III	

Table : 4.3

CHAPTER- 5

ANTECEDENT CONDITIONS FOR 31-JULY-2012

5.1 Power supply position and inter regional flows

The power supply position prior to the grid disturbance at 1230 Hrs, in terms of generation, demand met and import from other regions for all Regions, is indicated diagrammatically below in Figure 5.1. Import from Bhutan was about 1114 MW and 1745 MW power was being transmitted to SR from the NEW Grid. Frequency trend of Ballabhgarh sub-station in Northern Region on 31st July 2012 is shown in Figure 5.2. Frequency recorded through PMUs at different locations in NR grid before and after the incident is shown in Figure 5.3. A total demand of 76403 MW was being met by the NEW Grid (North-East-West and North-East Grids) prior to the disturbance. The demand met by the Northern Region was 33945 MW, Western Region was 28053 MW, Eastern Region was 13179 MW and the North-Eastern Region was 1226 MW.

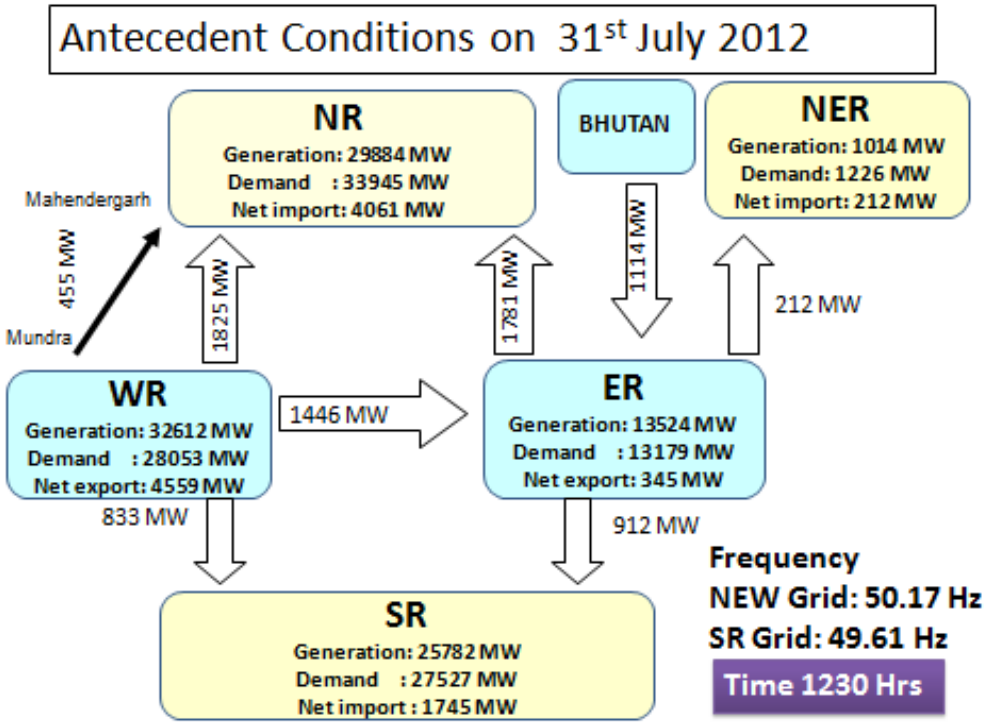


Figure 5.1

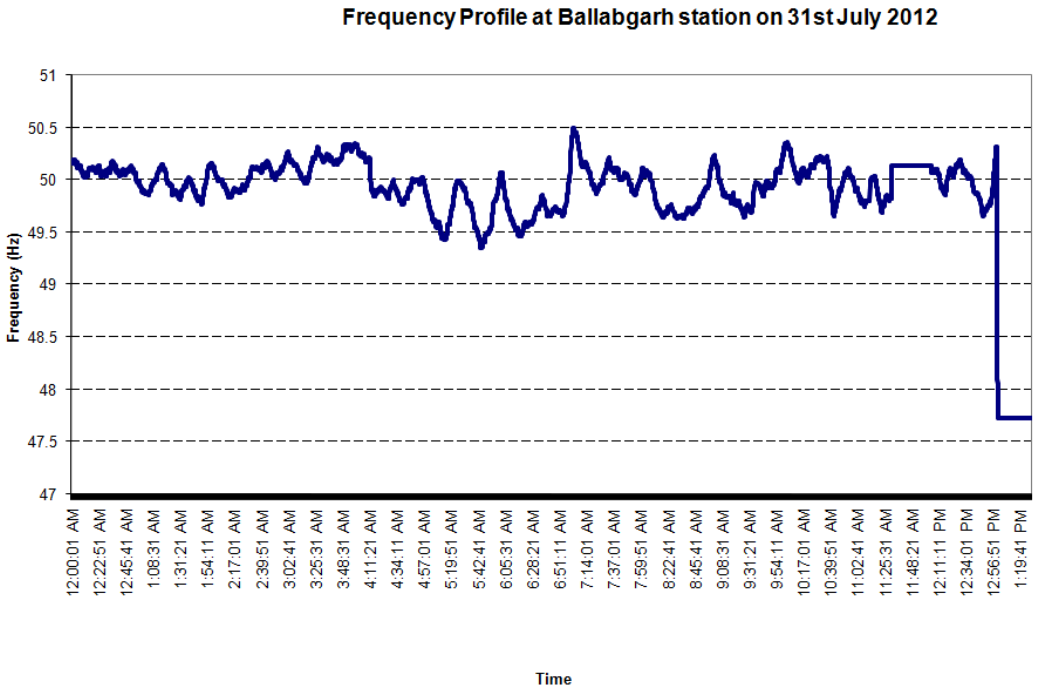


Figure 5.2

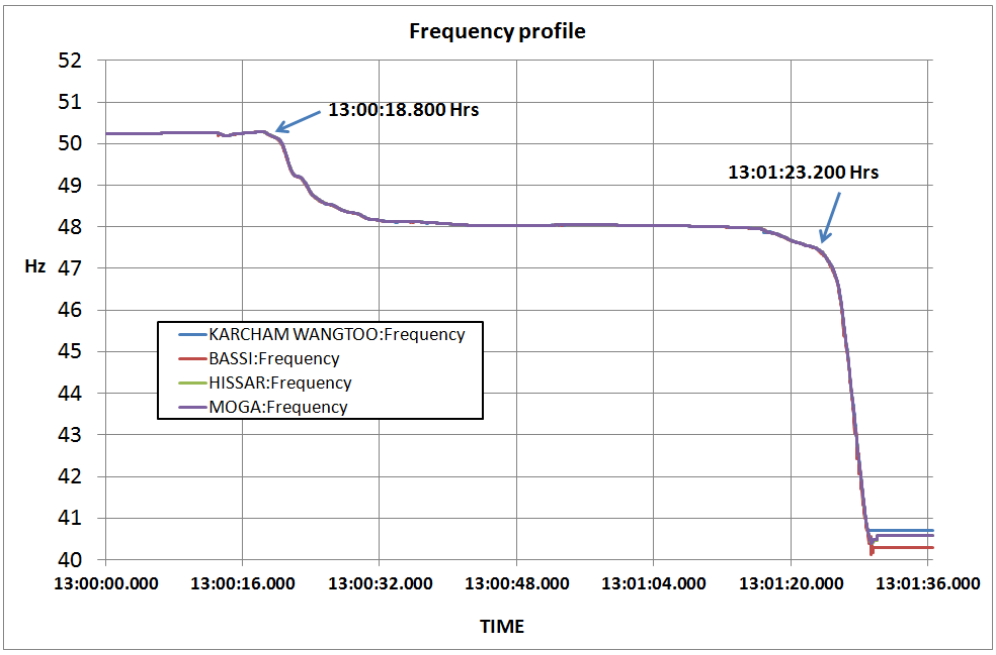


Figure 5.3

The power supply position prior to the grid disturbance at 1257 Hrs, in terms of import/ export from other regions for all Regions, is indicated diagrammatically below in Figure 5.4.

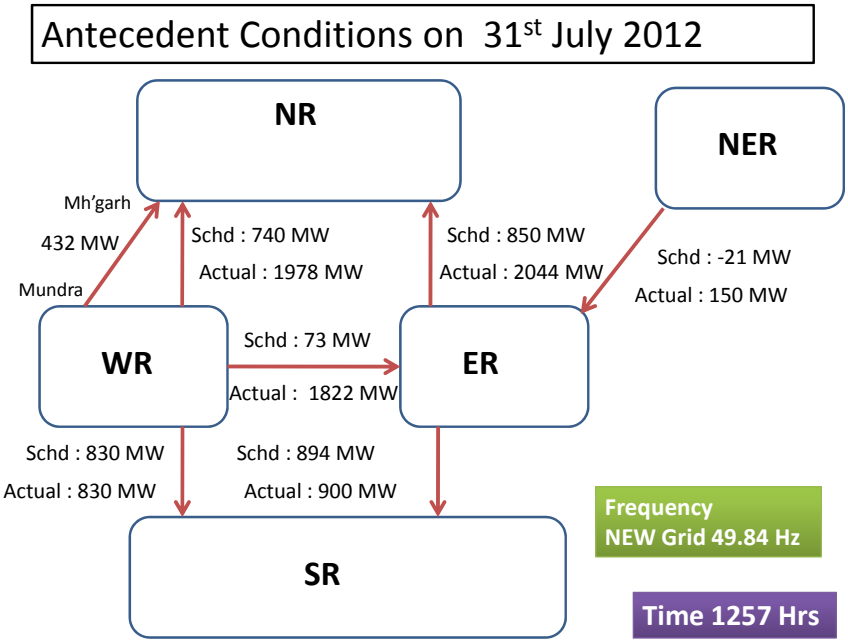


Figure 5.4

5.2 Outage Status and Power flow on Inter regional links between WR, NR and ER

As can be seen from details shown at fig 5.1, at 1230 hrs Northern Region was importing was importing 1825 MW from WR, 455 MW through dedicated Mundra-Mahendergarh HVDC and 1781 MW from ER thereby importing a total quantum of 4061 MW. Further, as can be seen from fig 5.4, the total import by NR at 1257 hrs is 4454 MW. The element wise power flow on the WR – NR corridor is given below in Table – 5.1. The element wise power flow on the WR – NR corridor is given below in Table – 5.2. The element wise power flow on the WR – ER corridor is given below in Table – 5.3.

Table – 5.1: WR-NR inter regional links

S No.	Inter-regional link	Voltage	Powerflow MW at 1230 hrs	Powerflow (MW) at 1257 hrs	Remarks
1	Gwalior-Agra-I	400 kV	801	1076	-
2	Gwalior-Agra-II	400 kV	-	-	Planned outage since 11:47 hrs of 28-07-2012 for up gradation of 400 kV to 765 kV at Bina and Gwalior end
3	Zerda-Kankroli	400 kV	-	-	Forced outage (Phase to earth fault) since 06:59 hrs of 31-July-2012. Earlier tripped at 02:22 hrs, 03:10 hrs and 04:51hrs of 31-July-12 also
4	Zerda-Bhinmal	400 kV	-	-	Forced outage (Phase to earth fault) since 07:59 hrs of 31-July-2012
5	Badod-Kota	220 kV	227	290	
6	Badod-Morak	220 kV	238	Forced Shutdown	Tripped on overload
7	Malanpur-Auraiya	220 kV	34	49	-
8	Mehgaon-Auraiya	220 kV	24	66	-
9	Vindhyachal back to back	-	500	497	-
10	**Total WR to NR**		**1825**	**1978**	
11	Import through dedicated HVDC Mundra Mahendergarh	500 kV	455	432	

Table – 5.2: ER-NR inter regional links

S No.	Inter-regional link	Voltage	Powerflow MW at 1230 hrs	Powerflow (MW) at 1257 hrs	Remark
1	Muzaffarpur-Gorakhpur-I	400 kV	484	476	-
2	Muzaffarpur-Gorakhpur-II	400 kV	435	487	-
3	Barh-Balia-I	400 kV	-	-	Manually opened on over voltage since 18:00 hrs of 30-July-2012
4	Barh- Balia-II	400 kV	-	-	Manually opened over voltage since 05:45 hrs of 28-July-2012
5	Patna-Balia-I	400 kV	-	-	Manually opened on over voltage since 07:09 hrs of 31-Jul-2012
6	Patna-Balia-II	400 kV	310	361	-
7	Biharshariff-Balia-I	400 kV	-	-	Manually opened on over voltage since 07:11 hrs of 31-July-2012
8	Biharshariff-Balia-II	400 kV	305	342	-
9	Pusauli-Allahabad	400 kV	92	139	HVDC Pusauli back-to-back in AC bypass mode
10	Pusauli-Sarnath	400 kV	30	114	
11	Pusauli-Sahupuri	220 kV	125	125	Operating in radial mode
12	Pusauli-Balia	400 kV	-	-	Tripped due to grid disturbance at 02:33 hrs of 30-July-2012 and kept open on over voltage.
13	Gaya-Fatehpur	765 kV	-	-	Charging attempt taken at 22:37 hrs of 27-July-2012. Line did not hold and kept open on high voltage
14	**Total ER to NR**		**1781**	**2044**	

Table – 5.3: WR-ER inter regional links

S No.	Inter-regional link	Voltage	Powerflow MW at 1230 hrs	Powerflow (MW) at 1257 hrs	Remark
1	Raigarh-Sterlite-I	400 kV	125	162	
2	Raigarh-Sterlite-II	400 kV	116	149	
3	Raigarh-Rourkela-I	400 kV	382	434	
4	Raigarh-Rourkela-II	400 kV	370	419	
5	Sipat-Ranchi-I	400 kV	-	-	Forced outage (isolator sparking at Sipat) since 01:35 hrs of 29-July-2012
6	Sipat-Ranchi-II	400 kV	343	516	
7	Raigarh-Budhipadar	220 kV	-23	-37	
8	Korba-Budhipadar-I	220 kV	66	88	
9	Korba-Budhipadar-II	220 kV	67	91	
10	**Total WR-ER**		**1446**	**1822**	

5.3 Transmission Element under outage at 1257 hrs

Some transmission lines were under outage prior to the occurrence of the grid disturbance. The reasons of outage of the transmission lines are classified as planned outage, forced outage and lines opened to control high voltages in the system.

A region wise list of the transmission lines under outage at1257 hrs on 31st July 2012 is given in Table 5.4 below.

Table – 5.4: Antecedent Transmission Line Outages on 31.07.2012 before Grid disturbance at 1257 Hrs

Sl. No.	Name of the Line	Voltage Level (kV)	Owner	Outage date	Time (Hrs)	Reason
NORTHERN REGION						
Planned Outage						
1	Bassi-Jaipur-1	400	PGCIL	28.07.12	8:10	LILO work of line of Agra-Bassi-2 at Jaipur (S)
2	Agra-Bassi-2	400	PGCIL	28.07.12	8:19	LILO work of line at Jaipur (S)
3	Agra-Fatehpur	765	PGCIL	26.07.12	14:24	For balance construction work
Forced Outage						
1	Bhiwadi-Neemrana-2	400	PGCIL	23.07.12	19:00	Tripped on High voltage.
2	Bhinmal-Kankroli	400	PGCIL	29.07.12	21:45	Due to decaping.
3	Gorakhpur(PG)-Lucknow-2	400	PLINK	30.07.12	2:33	Tripped during grid disturbance &Kept open on high voltage
4	Kota-Merta-1	400	PGCIL	30.07.12	2:33	Grid disturbance
5	Heerapura-Hindaun-2	400	RRVPNL	30.07.12	2:34	Grid disturbance
6	Hissar(PG)-Hissar IA (HVPNL)-2	220	PGCIL	24.07.12	14:28	CB problem at Hissar (HVPN) end
7	Bhinmal(PG)-Sirohi(RVPNL)	220	RRVPNL	29.07.12	15:40	Phase to earth fault.
8	Hiranagar-Jammu	220	PGCIL	30.07.12	22:22	Overloading of Salal-Jammu.
Opened due to High Voltage						
1	Manesar-Neemrana-1	400	PGCIL	15.07.12	17:00	HIGH VOLTAGE
2	Chhabra-Hindaun-2	400	RRVPNL	30.07.12	2:34	HIGH VOLTAGE
3	Jodhpur-Rajwest-2	400	RRVPNL	30.07.12	22:03	HIGH VOLTAGE
4	Barmer-Rajwest-1	400	RRVPNL	31.07.12	3:45	HIGH VOLTAGE

Sl. No.	Name of the Line	Voltage Level (kV)	Owner	Outage date	Time (Hrs)	Reason
5	Akal-Barmer-1	400	RRVPNL	31.07.12	3:57	HIGH VOLTAGE

WESTERN REGION						
Planned Outage						
1	Bina-Gwalior 2	400	PGCIL	27.07.12	10:26	Construction Work
Forced Outage						
1	CGPL-Chorania 1	400	PGCIL	30.07.12	5:26	Tripped due to pollution
2	CGPL-Chorania 2	400	PGCIL	31.07.12	1:28	Distance protection operated
3	Parli-Parli 2	400	PGCIL	19.07.12	2115	Clearance Problem
4	Karad-Jaigad 2	400	MSEB	30.07.12	-	Distance protection operated
Opened due to High Voltage						
1	Damoh-Birsinghpur 2	400	PGCIL	13.07.12	8:20	High Voltage
2	Nagda-Rajgarh 1	400	MPSEB	20.07.12	11:18	High Voltage
3	Seoni-Bina 1	765	PGCIL	03.07.12	18:59	High Voltage
4	Seoni-Wardha 2	765	PGCIL	23.07.12	11:52	High Voltage
5	Bina –Indore	400	PGCIL	21.07.12	7:47	High Voltage
6	Korba-Birsinghpur	400	PGCIL	05.07.12	12:25	High Voltage
7	Birsinghpur-BALCO	400	PGCIL	22.06.12	12:43	High Voltage
8	Raigarh-Raipur 1	400	PGCIL	20.07.12	11:05	High Voltage
9	Itarsi-Khandwa 2	400	PGCIL	20.07.12	18:38	High Voltage
10	Wardha-Akola 1	400	PGCIL	20.07.12	12:51	High Voltage
11	Bachao-Ranchodpura 2	400	PGCIL	31.07.12	08:37	Tripped on high voltage
12	Aurangabad-Bhusawal	400	MSEB	27.06.12	17:05	High Voltage
13	Aurangabad-Deepnagar 2	400	MSEB	03.07.12	15:29	High Voltage
14	Karad-Kolhapur 2	400	MSEB	28.07.12	16:18	High Voltage
15	Birsinghpur-Katni S/C	400	MPSEB	14.06.12	10:00	High Voltage
16	SSP-Rajgarh 2	400	MPSEB	25.07.12	11:31	Tripped on Over voltage
17	ISP-Nagda	400	MPSEB	24.07.12	23:42	High Voltage
18	Itarsi-Bhopal 1	400	MPSEB	29.07.12	17:27	High Voltage
19	Parli-Sholapur 1	400	PGCIL	23.07.12	17:44	High Voltage
20	Kolhapur-Mapusa 2	400	PGCIL	26.07.12	23:50	High Voltage
21	Adani-Sami 1	400	GEB	31.07.12	05:34	Tripped on O/V
22	Amreli-Jetpur	400	GEB	31.07.12	00:05	High Voltage
23	Asoj-Chorania 1	400	GEB	31.07.12	00:35	High Voltage

Sl. No.	Name of the Line	Voltage Level (kV)	Owner	Outage date	Time (Hrs)	Reason
EASTERN REGION						
Planned Outage						
1	Ranchi – MPL – II	400	PGCIL	27.07.12	9:11	Shutdown up to 18:00 Hrs of 04.08.12
2	Binaguri – Purnea-I	400	PGCIL	18.07.12	7:27	S/D up to 14.08.12
Forced Outage						
1	Sagardighi – Durgapur S/C	400	WBSETCL	25.04.12	17:06	3 nos. Tower Collapsed
Opened due to High Voltage						
1	Baripada-Mendhasal I	400	PGCIL	14.07.12	22:18	High Voltage
2	Ranchi – MPL – I	400	PGCIL	27.07.12	9:11	Line available but not taken back in service due to high voltage

5.4 Antecedent generation outage in NEW grid on 31st July 2012 at 1257 hrs

Some generating units were under outage for different reasons, some under forced outage and some under planned outage. The outages in the Western Region, Eastern Region and Northern Region are given below in Table – 5.5.

Table – 5.5: Antecedent Generating Unit Outages on 31-Jul-2012 at 1257 hrs

Sl. No.	Plant name	Unit No.	Capacity (MW)	Reason for outage
Western Region				
1	Dhabol	3A,2A,2B	960	Gas Shortage
2	CGPL	1	830	Emitting line tripped
3	CGPL	2	830	-
4	Sipat 1	1	660	Loss of Fuel since 22.07.12
5	Vindhyachal	9	500	BTL
6	Chandrapur	6	500	Annual Over Haul
7	Adani, Mundra	2	330	-
8	Adani, Mundra	3	330	Gen. Protection Operated
9	Adani, Mundra	4	330	Master Fuel Trip
10	Adani, Mundra	6	660	PA Fan Problem
11	Adani, Mundra	8	660	SPS Operated

Sl. No.	Plant name	Unit No.	Capacity (MW)	Reason for outage
12	Adani, Mundra	9	660	SPS Operated
Eastern Region				
1	Santaldih	6	250	Turbine Speed High
2	Mejia	1	210	Coal Shortage
3	Farakka	1&5	200&500	Unit#5 out on Coal Shortage
4	Bokaro B	1	210	Overhauling
5	Mejia	3	210	Boiler license Renewal
6	Sterlite	2	600	Tripped on 220 kV GRIDCO line fault
7	Kahalgaon STPS	5&6	2*500	Coal Shortage
8	MPL	1	525	Coal Shortage
9	DPL	7	300	High Furnace Pressure
10	Kahalgaon STPS	3	210	Out Since 26.07.12
Northern Region				
1	Auraiya	3	111	Closed by plant due to less requisition / Taken under S/D for AMP w.e.f. 00:00hrs dt 10.07.2012 by NTPC.
2	Auraiya	6	109	Closed by plant due to less requisition / Taken under S/D for AMP w.e.f. 00:00hrs dt 10.07.2012 by NTPC.
3	Bhakra (L)	2	108	Up gradation work.
4	Bhakra (L)	5	108	Up gradation work.
5	Bhatinda	3	110	Up gradation work.
6	Bhatinda	4	110	Renovation and modernization work
7	Dehar	4	135	Annual Maintenance
8	Obra	10	210	Renovation and modernization work
9	Obra	11	210	Renovation and modernization work
10	Paricha	2	110	Renovation and modernization work
11	Rajwest	2	135	Annual maintenance.
12	RAPS-A	1	100	Subject to regulatory clearance.
13	Rihand-1	2	500	Boiler tube leakage.
14	ROSA-TPS	1	300	Manually closed by plant due to commercial dispute with UPPCL.
15	Suratgarh	3	250	Annual maintenance.
16	Tanda	2	110	Annual maintenance.
17	AnparaC	1	600	Generator earth fault
18	AnparaC	2	600	Coal Shortage

Sl. No.	Plant name	Unit No.	Capacity (MW)	Reason for outage
19	Barsinghsar	1	125	Grid disturbance
20	Barsinghsar	2	125	Boiler tube leakage.
21	Chamera-1	1	180	Shaft seal leakage.
22	Chhabra	1	250	Grid disturbance
23	CLP Jhajjar	2	500	Taken out by plant due to coal mill problem.
24	Dadri TPS	4	210	Tripped/bearing gear problem
25	DCRTP	1	300	Turbine vibration high.
26	DCRTP	2	300	Turbine damaged.
27	Giral	2	125	Leakage in shaft seal problem
28	Harduaganj	8	250	Generator earth fault.
29	Harduaganj	9	250	Boiler tube leakage.
30	Jhajjar	2	500	Electro static precipitator problem
31	Khedar	1	600	Vibration in Rotor.
32	Panipat	1	117	LTSH Tube leakage.
33	Panipat	5	210	Grid disturbance.
34	Paricha	1	110	Boiler tube leakage.
35	RAPS-B	1	220	Grid disturbance
36	RAPS-B	2	220	Grid disturbance
37	RAPS-C	1	220	Grid disturbance
38	RAPS-C	2	220	Grid disturbance
39	Rihand-1	2	500	Boiler tube leakage.
40	Suratgarh TPS	4	250	Grid disturbance
41	Tanda	4	110	Grid disturbance
42	VishnuPrayag	1	100	High silt level.
43	VishnuPrayag	2	100	High silt level.
44	VishnuPrayag	3	100	High silt level.
45	VishnuPrayag	4	100	High silt level.

5.5 Antecedent generation availability in NEW Grid on 31st July 2012 at 1230 hrs

The total antecedent generation in the NEW Grid was 77034 MW. Generation in NR was 29884 MW, in WR was 32612 MW, in ER was 13524 and in NER was 1014 MW. The generating station-wise 'Declared Capacity', 'Schedule', 'Actual Generation' and the 'UI' is shown in Table – 5.6 for Northern Region. Similarly, Table – 5.7, Table – 5.8 and Table – 5.9 shows the generating station-wise position for Eastern, Western and North-Eastern Regions.

Table – 5.6: Antecedent Generating Station Details for NR at 1230 hrs

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
1	Singrauli	1855	1855	1874	19
2	Rihand I & II	940	940	945	5
3	Unchahar	825	825	821	-4
4	Dadri Thermal Stage I	580	428	433	5
5	Dadri Thermal Stage II	650	650	650	0
6	Jhajjar	400	307	307	0
7	Shree Cement	0	265	271	6
8	Dadri Gas	770	704	718	15
9	Auraiya Gas	381	317	297	-20
10	Anta Gas	385	342	343	1
11	Narora	260	260	236	-24
12	RAPP B	400	400	415	15
13	RAPP C	0	0	0	0
14	Nathpa Jhakri	1605	1605	1610	5
15	Bhakra	754	754	776	22
16	Tehri	800	140	359	219
17	Dehar	600	600	585	-15
18	Chamera I	356	356	356	0
19	Salal I & II	660	665	616	-51
20	Uri	360	370	419	50
21	Pong	218	218	219	1
22	Dulhasti	386	386	390	4
23	Dhauliganga	277	278	278	1
24	Chamera II	300	301	302	1
25	Bairasiul	182	178	178	0
26	Tanakpur	94	93	95	1

Table – 5.7: Antecedent Generating Station Details for ER at 1230 hrs

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
1	Farakka	1360	912	699	-213
2	Tala	1050	1050	1093	43
3	Kahalgaon I	402	402	412	10

4	Kahalgaon II	400	380	376	-5
5	Talcher-I	580	580	684	104
6	Talcher-II	1070	1070	1265	195
7	Teesta	504	502	491	-11
8	Chukha	264	264	314	49
9	Rangeet	62	62	61	0

Table – 5.8: Antecedent Generating Station Details for WR at 1230 hrs

S No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
1	KSTPS	2360	2360	2460	100
2	TAPS I	147	147	129	-18
3	TAPS II	901	901	912	11
4	Gandhar (Gas + RLNG)	610	469	536	67
5	Kawas (Gas +Liquid+ RLNG)	615	221	274	53
6	Kakrapar	405	405	387	-18
7	Pench	0	0	0	0
8	SardarSarovar	1134	1134	1122	-12
9	Sipat	1420	1420	1849	429
10	VSTPS	2520	2520	2540	20

Table – 5.9: Antecedent Generating Station Details for NER at 1230 hrs

S. No.	Generating Station	Declared Capacity (MW)	Schedule (MW)	Actual (MW)	UI (MW)
1	Ranganadi	0	0	0	0
2	Kathalguri	180	180	210	30
3	Kopili	99	99	94	-5
4	RC Nagar	76	76	77	1
5	Doyang	58	59	58	-1
6	Khandong	45	45	45	0
7	Kopili Stage II	21	22	21	-1
8	Loktak	105	105	106	1

5.6 Antecedent State power supply position on 31st July 2012 at 1230 hrs

A total demand of 76403 MW was being met by the NEW Grid prior to the disturbance. The state wise power supply position including 'Schedule', 'Actual', 'UI', 'State's own generation' and 'Demand Met' is shown below. Tables 5.10, 5.11, 5.12 and 5.13 show the State wise power supply position for Northern Region, Eastern Region, Western Region and the North-Eastern Regions respectively.

Table – 5.10: Antecedent State wise details for NR at 1230 hrs

S No.	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	Punjab	4662	4698	36	2570	7268
2	Haryana	2291	2869	578	1491	4361
3	Rajasthan	1644	2209	565	3740	5949
4	Delhi	2821	2693	-128	1247	3938
5	Uttar Pradesh	3341	3441	101	4442	7882
6	Uttarakhand	449	607	158	400	1007
7	Chandigarh	295	247	-48	0	247
8	Himachal Pradesh	195	80	-116	584	664
9	Jammu & Kashmir	689	603	-86	456	1058

Table – 5.11: Antecedent State wise details for ER at 1230 hrs

	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	West Bengal	1311	1495	182	3456	4950
2	Bihar	1275	1293	19	1	1295
3	Orissa	594	455	-137	1842	2298
4	Jharkhand	431	350	-79	445	797
5	DVC	-464	-511	-46	2389	1879
6	Sikkim	26	40	14		40

Table – 5.12: Antecedent State wise details for WR at 1230 hrs

S No.	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	Maharashtra	4268	3821	-447	7434	11255
2	Gujarat	2094	1639	-455	8454	10093
3	Madhya Pradesh	1515	1487	-28	1931	3418
4	Chhattisgarh	488	50	-438	2129	2179
5	Dadra & Nagar Haveli	572	574	2		574
6	Daman & Diu	255	244	-11		244
7	Goa	279	262	-17	25	287

Table – 5.13: Antecedent State wise details for NER at 1230 hrs

S No.	State	Schedule (MW)	Actual (MW)	UI (MW)	State Gen (MW)	Demand Met (MW)
1	Assam	341	533	192	173	706
2	Meghalaya	48	69	21	68	137
3	Tripura	30	33	3	81	114
4	Manipur	76	66	-10		66
5	Mizoram	32	37	5		37
6	Nagaland	26	32	7		32
7	Arunachal Pradesh	36	53	17		53

5.7 Antecedent voltage at important stations at 1230 hrs

The antecedent voltage profile at important EHV substations is shown below in Table – 5.14.

Table – 5.14: Antecedent Voltage Profile at important stations at 1230 hrs

S. No.	Sub station	Region	Voltage (kV)		S. No.	Sub station	Region	Voltage (kV)
1	Uri	NR	381		11	Kahalgaon	ER	411
2	Kishenpur	NR	403		12	Baripada	ER	421
3	Nathpa Jhakri	NR	396		13	Ranchi	ER	425
4	Amritsar	NR	387		14	Jamshedpur	ER	424
5	Mandaula	NR	405		15	Bhopal	WR	410
6	Ballabgarh	NR	404		16	Padghe	WR	414
7	Agra	NR	391		17	Gwalior	WR	393
8	Gorakhpur	NR	414		18	Khandwa	WR	424
9	Kanpur	NR	398		19	Bhusawal	WR	437
10	Suratgarh	NR	407		20	Bongaigaon	NER	397
					21	Balipara	NER	411
					22	Misa	NER	417

5.8 Power Supply position just prior to the disturbance

Power supply position of NR constituents at 1257 hrs, 31st July 2012

Table-5.15: Power supply position of NR constituents at 1257 hrs

State	Schedule (MW)	Actual (MW)	OD (+) / UD (-) (MW)
Punjab	4661	4582	-79
Haryana	2292	3562	1270
Rajasthan	1635	2397	762
Delhi	2820	2650	-171
UP	3339	3438	99
Uttarakhand	448	627	179
HP	197	70	-128
JK	686	628	-58
Chandigarh	295	242	-53

Table-5.16: Power supply position of WR constituents at 1257 hrs

State	Schedule (MW)	Actual (MW)	OD (+) / UD (-) (MW)
Gujarat	2089	1026	-1063
Maharashtra	4260	3562	-698
Chattisgarh	488	115	-373
Madhya Pradesh	1523	1572	49
Goa	279	265	-14
Daman and Diu	255	225	-30
Dadra and Nagar Haveli	572	566	-6

Generator	Schedule (MW)	Actual (MW)	OI (+) / UI (-) (MW)
Vindhyachal	2520	2181	-339
Korba	1890	2077	187
Sipat	1420	1849	429
Kawas	152	304	152
Gandhar	444	548	104
Tarapur	1048	1125	77
Kakrapar	405	416	11
Sardar Sarovar	1134	991	-143

5.9 Messages issued from the control room

Several messages were issued from the control rooms of RLDCs/NLDC. These are collectively enclosed at Exhibit 5.104.

5.10 Observations from the antecedent conditions

It may be seen from the data in the table and exhibits that

- The frequency and voltage in the entire NEW grid were within the limits prescribed in the Indian Electricity Grid Code.
- The inter-regional links between WR and NR were constrained due to forced/ planned outage of certain transmission elements.
- The state of important EHV transmission elements in different regions is shown under table 5.4.
- Hydro generation in the NEW grid was significantly high except the forced outage of few generating units in Northern Region due to high silt.

- There was extremely heavy overdrawal by the constituents of NR grid and heavy under-drawal/ over-injection by the constituents of WR grid.
- Some thermal/gas generating units in the Northern Region were under forced outage either due to technical reasons or due to coal shortage or due to under-requisition by the respective beneficiaries. Few of the thermal generating units in Northern Region were yet to attain generation after the grid disturbance on 30-July-2012.
- Unit 3 of Sipat Stage I (660 MW) was undergoing trial operation as it was expected to be in commercial operation wef 1st August 2012. As evident from table 5.16, this infirm power was getting injected into the system as Unscheduled Interchange.
- Before the disturbance, despite requests from WRLDC to Sipat for reducing generation and thereby relieve high loading in the transmission corridor, the generating plant refused to do the same on account of imminent commercial declaration The power to Northern Region was flowing via the available WR-NR Inter regional links as well as via the WR-ER-NR route.
- Efforts were being made to reduce the heavy import by Northern Region as well as to reduce the heavy export by Western Region.

Note:

- *The figures shown in this section are based on data from SCADA system and are indicative of the scenario as visible to the operator in the control room*
- *The trends are enclosed as Exhibit 5.1-5.103.*

CHAPTER 6

ANALYSIS OF THE DISTURBANCE ON 31ST JULY 2012

6.0 Introduction:

Analysis of this disturbance required collection of data from all RLDCs, NLDC as well as all the power stations and sub-stations in Northern Region, Western Region, North-Eastern and Eastern Regions through the Regional Load Despatch Centres (RLDCs). This process took considerable time and till the time of writing the report data from many power stations has still not been received. This is notwithstanding the explicit provisions in the CEA Grid Standards and the Indian Electricity Grid Code (IEGC).

The analysis[2] presented in this report is based on the inputs received so far at NLDC. Behavior of TCSC and SVC has not been analyzed and needs to be studied separately. The records referred to in this analysis are enclosed at Exhibit 6.

6.1 Sequence Of Events (SOE) on 31st July 2012:

The antecedent conditions on 31st July 2012 have already been described in Chapter 5. The sequence is outlined in Table 6.1 below and has been co-related from the record obtained at NLDC so far. It contains mainly the lines which are relevant to understanding the tripping. These can also be referred to in Exhibit 6. Further Figure 6.1 may be referred to for ease of understanding of the network. The phase convention RYB is used throughout for the sake of uniformity. The Sequence Of Events recorded at RLDCs is enclosed as per details below.

Exhibit 6.1 : Western Regional Load Despatch Centre (WRLDC)

Exhibit 6.2: Eastern Regional Load Despatch Centre (ERLDC)

Exhibit 6.3: Northern Regional Load Despatch Centre (NRLDC)

Exhibit 6.4: North Eastern Regional Load Despatch Centre (NERLDC)

Table 6.1: Sequence Of Events on 31st July 2012

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
1	07:59	400 kV Zerda-Bhinmal	Tripped on B-phase to earth fault and taken under shutdown subsequently. It had earlier tripped at 0335, 0556,0729 and 0759 hours.

[2] The analysis presented here is preliminary based on the information received at NLDC by 09-Aug-2012.

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
2	06:59	400 kV Zerda-Kankroli	Tripped on fault at 02:22, 03:10 and 06:59 hours on fault and taken under shutdown subsequently.
3	12:56:55:097 (as per WRLDC SOE)	220 kV Badod-Modak	Tripped on overload from Badod end as per SLDC MP's report (Exhibit 6.5). As per SLDC Rajasthan report (Exhibit 6.6), Suratgarh unit 1 of 250 MW capacity tripped at 1250 hours on drum level low. This has led to increase in flow on 220 kV Badod-Kota and Badod-Modak after 1250 hours.
4	12:58:48:727 (as per WRLDC SOE)	220 kV Badod-Kota	Tripped on overload from Badod end. As per SLDC Rajasthan report, Suratgarh unit 1 of 250 MW capacity tripped at 1250 hours on drum level low. This has led to increase in flow on 220 kV Badod-Kota and Badod-Modak after 1250 hours.
5	13:00:13:045 (as per WRLDC SOE protection operation)	400 kV Bina-Gwalior 1	Tripped at Bina end on Main 2 Zone-3 protection operation. Timing as per Bina EL 13:00:13:037 (Exhibit 6.7). From the DR output of Main 2 it is evident that there is no fault on the line and it appears to be a case of load encroachment. As per the DR output (Exhibit 6.8) from Main 1 (REL670), the phase to ground voltage is of the order of 209 kV i.e.362 kV phase to phase and current is of the order of 2 kA. Timing as per this DR is 13:00:13:102. The loading corresponds to 1254 MVA. 400 kV Gwalior sub-station records (Exhibit 6.9) indicate low voltage of the

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
			order of 330 kV at Gwalior from 1257 hours onwards as well as at 220 kV buses.
6	13:00:15:022 (as per WRLDC SOE)	220 kV Bina(MP)-Gwalior (MP)-2	As per SLDC MP's report, the line tripped at Gwalior end on R and B phase overcurrent. No DR was available from MP.
7	13:00:15:068 (as per WRLDC SOE)	220 kV Bina(MP)-Gwalior (MP)-1	As per SLDC MP's report, the line tripped at Gwalior end on R and B phase overcurrent. No DR available. 220 kV Shivpuri-Sabalgarh section and 132 kV Pichore-Shivpuri also tripped. With this tripping, the Gwalior part of Western Region got electrically disconnected from Western Region but remained connected with Northern Region via 400 kV Agra (PG)-Gwalior (PG), thus at this moment Gwalior MP load, Malanpur and Mehgaon areas are fed from Agra end.
8	13:00:15:548 (as per ERLDC SOE)	220 kV bus coupler at Tarkera.	Details not available from Odisha SLDC.
9	13:00:17:600 (as per Jamshedpur EL at Exhibit 6.10) 13:00:18:545 (as per ERLDC SOE but Jamshedpur RTU is not time synchronized)	400 kV Jamshedpur-Rourkela-1	400 kV Jamshedpur-Rourkela-2 could not be restored after the tripping on 30th July 2012 due to bursting of a Lightning Arrestor (LA) at Rourkela and the same was under replacement. The circuit 1 tripped at Jamshedpur end on Main-1 (RAZFE) protection. As per the DR at Exhibit 6.11 (timing 13:00:13:207), the antecedent conditions

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
			before tripping are 209 kV phase to ground voltage (corresponding to 362 kV phase to phase) while the current is of the order of 1.98 kA. No evidence of any fault on the line from this DR. So it appears to be a case of load encroachment. The loading is of the order of 1241 MVA.
10	13:00:17:948 (as per ERLDC SOE and matches with Ranchi EL at Exhibit 6.12)	400 kV Ranchi-Maithon	400 kV Ranchi-Maithon Right Bank D/C line was out due to damaged tower initially; however ckt 1 was available since 30th July 2012 but kept off to control high voltage. The line tripped at Ranchi end on Main-2 protection (REL670), Zone-4. DR not available for this instant of time. A case of reverse reach under power swing conditions.
11	13:00:19:645 (as per Rourkela end DR)	400 kV Rourkela-Sterlite-2	Tripped from Rourkela end on operation of Group A and Group B trip. The DR at Rourkela end at Exhibit 6.13 shows that the voltage has dipped to 38,kV, 115 kV and 122 kV phase to ground in R, Y and B phases respectively with the respective currents going up to 1.97 kA 2.3 kA and 2.6 kA. The line was hanging from Sterlite end and tripped later on over-voltage. Load encroachment/power swing is the likely cause of tripping at Rourkela end.
12	13:00:19:945 (as per Ranchi PG EL).	400 kV Ranchi-Sipat-2	400 kV Ranchi-Sipat-1 was not in service at this instance due to a problem in isolator at Sipat end.

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
	ERLDC SOE shows 13:00:20:017		Circuit2 tripped at Ranchi end on Main-1 (7SA522) protection operation apparently on power swing/load encroachment. Has not tripped at Sipat end at this instance. The DR at Ranchi end at Exhibit 6.14 shows that the current has increased to 1A secondary value corresponding to 2 kA (assuming a CT Ratio of 2000:1) while the voltage has dipped to approx. 10 volts secondary side (corresponding to approx..63 kV phase to phase). The Sipat end DR at Exhibit 6.15 at this instant also shows current of approx. 2 kA but the voltage at Sipat end corresponds to 210 kV phase to ground (approx. 362 kV phase to phase). The line has not tripped at Sipat end at this instant but 4 seconds later on high voltage. The voltage difference between Sipat and Ranchi clearly shows the swing conditions in the system.
13	13:00:19:948 (as per DR at Rourkela end)	400 kV Raigarh-Rourkela-3	The DR at Rourkela end at Exhibit 6.16 shows the voltage dipping to 23 kV phase to ground viz. 40 kV phase to phase and a current of 2.2 kA.The line tripping could be due to power swing/load encroachment. Thereafter the current is disappearing but the voltage rose high. In fact the maximum RMS voltage recorded is 310 kV phase to ground viz. 527 kV phase to phase and subsequently leading to over-voltage trip.
14	13:00:19:974 (Rourkela timing as	400 kV Ranchi-Rourkela-1	400 kV Ranchi-Rourkela-1 tripped at Rourkela end on operation of Main-1

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
	per DR) 13:00:20:013 (as per ERLDC SOE)		protection. DR at Rourkela end at Exhibit 6.17 shows voltage dip in all three phases to 40-47 kV level phase to ground (viz 68-79 kV phase to phase). Current has also gone up to a maximum of 2.4 kA in R-phase and 1.8 kA in Y and B phases. The line appears to have tripped due to power swing/load encroachment. Line remained hanging from Ranchi end and finally tripped at Ranchi end on overvoltage at 13:00:25:180.
15	13:00:19:981 (Rourkela end DR)	400 kV Talcher-Rourkela-2	Tripped at Rourkela end on operation of Main-1 and Main-2 distance protection. DR at Rourkela end at Exhibit 6.18 shows that the voltage in all three phases have gone to as low as 16 to 22 kV in the three phases with respect to ground and current in the three phases are in the range of 3.2-3.5 kA. The line appears to have tripped due to power swing. The line remained hanging from Talcher end and tripped later on over-voltage.
16	13:00:19:986 (Rourkela end DR)	400 kV Talcher-Rourkela-1	Tripped at Rourkela end on operation of Main-1 and Main-2 distance protection. DR at Rourkela end at Exhibit 6.19 shows the voltage in all three phases have gone to as low as 210 kV, 165 kV, 223 kV respectively in R, Y and B phases to ground. Current has gone to as high as 4.2 kA in all the three phases. The tripping is apparently on power swing. Line remained hanging from Talcher end

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
			and tripped subsequently on overvoltage.
17	13:00:20:017 (as per ERLDC SOE which matches closely with Ranchi EL timings also)	400 kV Ranchi-Raghunathpur	Tripped on Main-1 protection (7SA22) at Ranchi end. DR at Exhibit 6.20 shows that voltage has dipped to 10 volt secondary on all three phases (corresponding to approx. 65 kV phase to phase) and current 2.8 A secondary (approx. 2.8 kA assuming a CT Ratio of 1000/1). The tripping appears to be on power swing.
18	With these trippings, the East/North/North East system separated from the Western grid at 13:00:20:017 hours. Please refer to Fig 6.1 showing the sketch indicating axis of separation. Here there is a slight inconsistency with respect to PMU data. The PMU data from Northern Region and Western Region (Fig 3.2) suggests that the system separation has taken place at approx. 13:00:18:400 (also consistent with the frequency plots uploaded by IITB at Fig 3.3 below); a clear 1.60 seconds difference with respect to the DR/EL/RLDC SOE timing. This needs to be examined in detail as the DR/EL/RLDC SOE timing is consistent across ERLDC, WRLDC, Ranchi EL and Rourkela DR/numerical relays for all the above tripping. (Only Rourkela timing drifted slightly approx. 100 msec slower). Even the last element which tripped above is showing swing like conditions/voltage collapse before the tripping. The PMU data in Western Region and Northern Region go to the respective RLDCs and the angular difference has been plotted in Fig 6.2 while analysing the data after the disturbance. The 400 kV Rourkela and Ranchi buses remained with Western Region at the above instance of separation. However the 400 kV Ranchi-Rourkela -2 tripped on overvoltage a few seconds later isolating Ranchi bus also. Similarly 400 kV Rourkela bus remained connected to Sterlite on Ckt 1; however Sterlite reports a manual opening of this line from their end leading to 400 kV Rourkela bus also becoming dead. Sterlite and Ib TPS in Odisha remained connected to the Western Region while Talcher and South Odisha remained connected with the NER/ER/NR system through 400 kV Talcher-Rengali-Baripada-Kharagpur-Kolaghat lines.		

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
	The antecedent flow across the axis of separation at 1255 hrs was as under: 1) 220 kV Badod-Kota : 285 MW 2) 220 kV Badod-Modak : 253 MW 3) 400 kV Bina-Gwalior-1 : 923 MW 4) 220 kV Bina-Gwalior(MP)-1 : 165 MW 5) 220 kV Bina-Gwalior (MP)-2 : 165 MW 6) 400 kV Rourkela-Jamshedpur-1 : 524 MW 7) 400 kV Ranchi-Maithon : 324 MW 8) 400 kV Ranchi-Raghunathpur : 293 MW 9) 400 kV Rourkela-Talcher-1 : 490 MW 10) 400 kV Rourkela-Talcher-2 : 490 MW **Total: : 3912 MW**		
19	In the Western Region due to loss of the above export to rest of the NEW grid, the frequency shot up to 51.46 Hz and the following generating units and transmission lines tripped due to process related issues and high voltage respectively. The frequency stabilized at around 51.0 Hz. The rise in frequency only illustrates the poor level of primary response. Lines: 400 kV Seoni-Khandwa-I 400 kV Satpura –ISP S/C (at ISP end Over Voltage stg I, DT received at Satpura end.) 400 kV Raipur –Sipat I & II 220 kV Raigarh(PG)-Raigarh(CSEB) I & II, tripped at PG end only(as reported by Chhattisgarh). 400 Kv Raipur-Raigarh III Units: Sipat Unit 2 (660 MW) DSPM units 1 & 2 (2 x 250 MW) APL unit 7.(660 MW)		
20	The Southern region lost about 2000 MW infeed from the NEW Grid over Talcher-Kolar HVDC bipole and the frequency declined from 50.06 Hz to 48.88 Hz as per		

S no	Time (hh:mm:ss:msec)	Element outage	Remarks
	SCADA. The frequency controller at Bhadrawati HVDC acted and the power flow from Western region to Southern region increased from 880 MW to 1100 MW. System Protection Scheme (SPS) at Kolar end did not operate.		
21	In the rest of the NEW grid, due to loss of the infeed of 3912 MW from Western Region, the frequency dropped sharply and in fifteen (15) seconds stabilized at 48.12 Hz. This low value of frequency is not understandable considering that the ER/NER/NR grid has by design 5600 MW flat frequency Under Frequency Relay (UFR) load shedding and 6020 MW of df/dt relay shedding as 6020 MW. The frequency should not have declined to this extent. Adequate UFR load-shedding could have brought the frequency to a safer level to safeguard tripping of units affected by the frequency transient or any generator trip on under-frequency. All the three stages of UFR and df/dt relays were called upon to operate but the meagre relief did not help in really taking the frequency to safe level and this is a cause of concern and needs to be examined separately.		
22	13:00:35 onwards up to 13:01:29	The frequency started falling sharply after 13:01:12 and the system collapsed by 13:01:29 hours possibly due to tripping of generators or onset of load.	

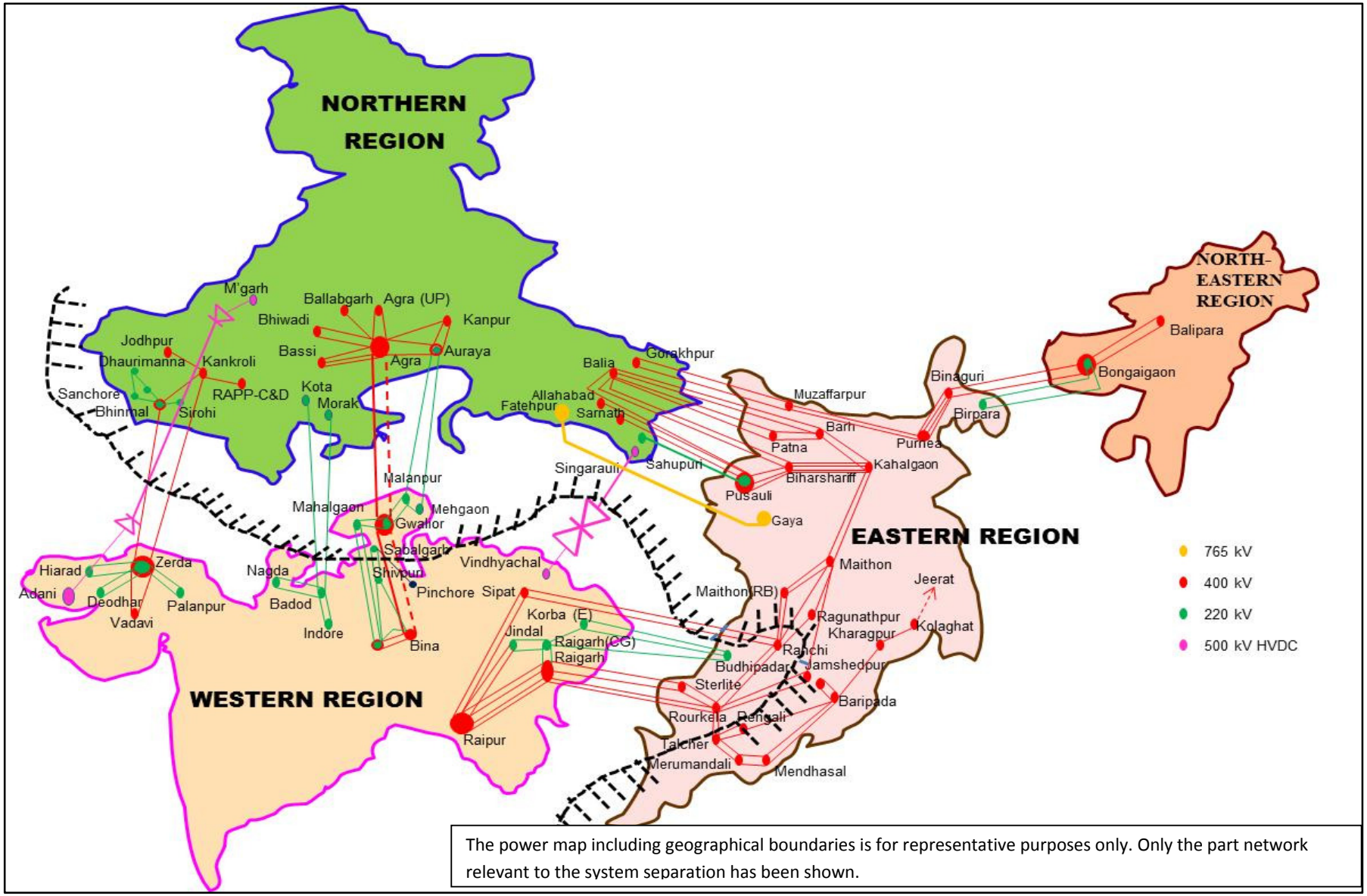


Fig 6.1: Sketch showing the axis of separation on 31st July 2012

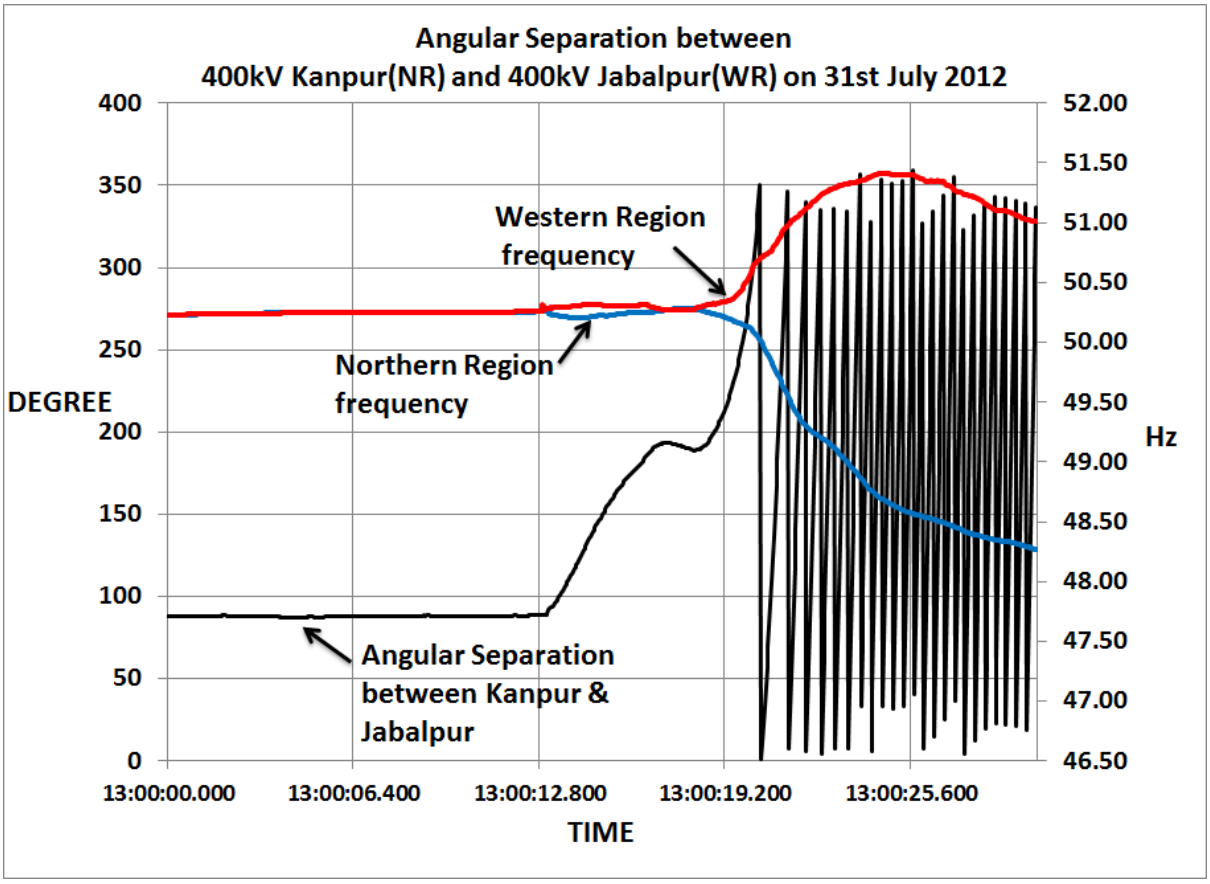


Fig 6.2: Frequency profile and angular separation from the Phasor Measurement Units (PMUs) at NRLDC

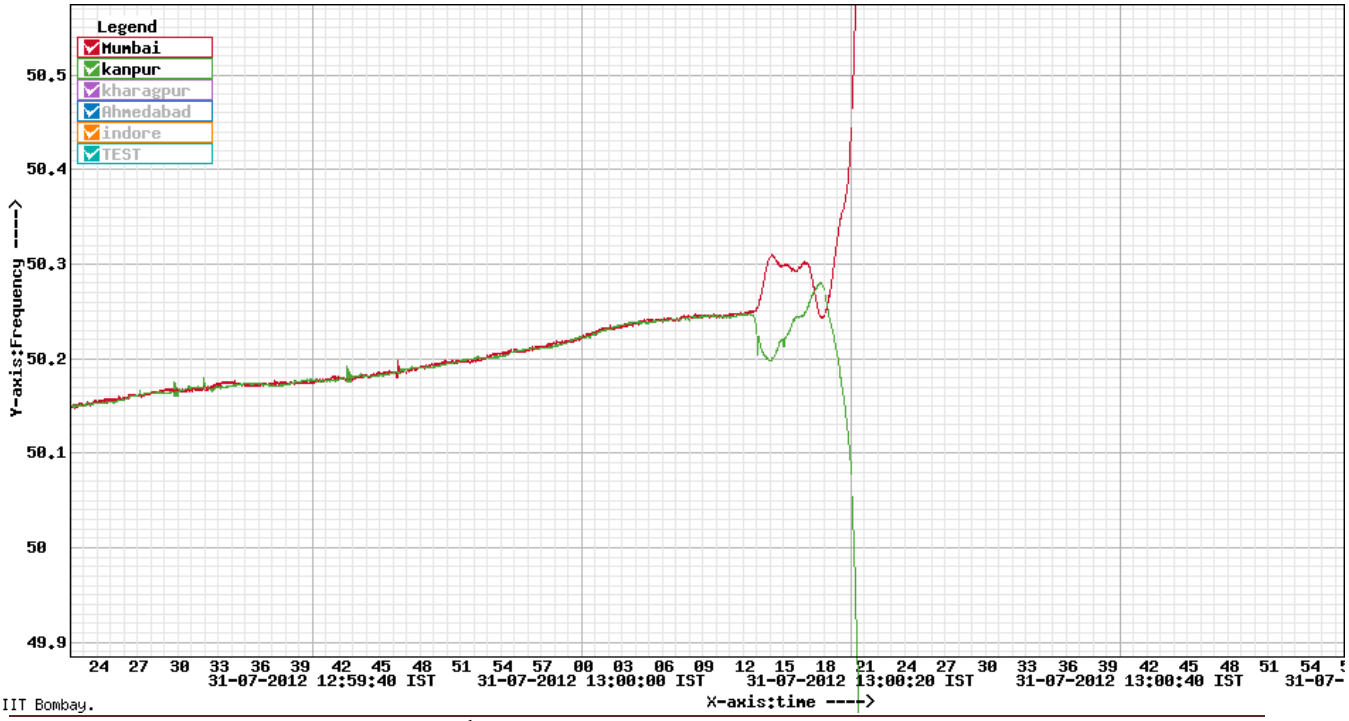


Fig 6.3: Frequency profile from IITB's Wide Area Frequency Measurement System

6.2 Modal analysis based on PMU data at WRLDC:

Based on the modal analysis of the PMU data available at WRLDC for both 30th and 31st July 2012, the following observations are made:

1. 2 Hz mode present on both days with almost zero damping but with significant amplitude.
2. Inter-area modes 0.35 Hz and 0.68 Hz present with negative or close to zero damping.
3. New inter-area modes 0.53 Hz and 0.71 Hz was present with negative damping and amplitude is also significant.
4. Some intra-plant modes can be seen on both the days with negative damping.
5. The presence of these modes with less damping indicates system is in a stressed condition. The mode behaviour before disturbance, during the disturbance and after the disturbance is shown in the plots. Any tripping under such stressed conditions can lead to growing oscillations manifesting in a disturbance.

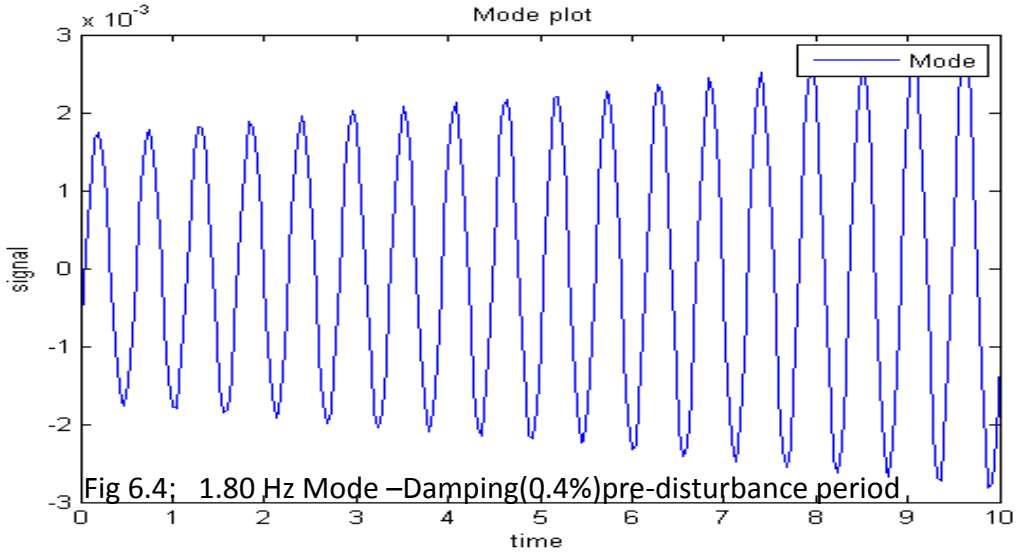


Fig 6.4; 1.80 Hz Mode –Damping(0.4%)pre-disturbance period

Figure 6.4: 30th July 2012-----1.80 Hz mode (damping -0.8%) before disturbance

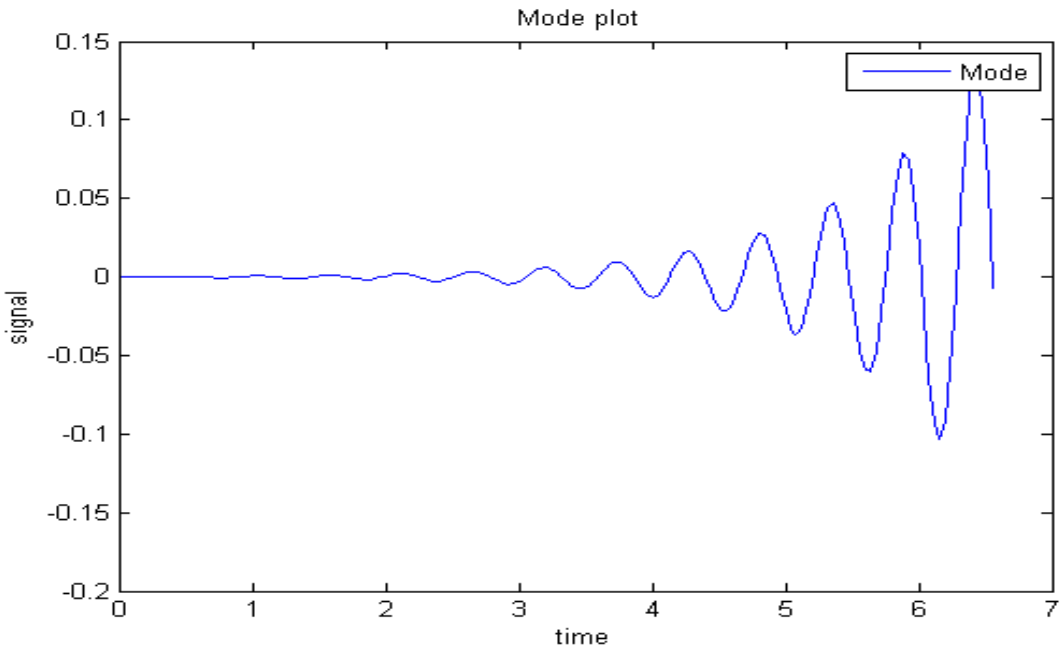


Fig 6.5: 30th July 2012—1.85 Hz mode (damping -8.2%) during disturbance period

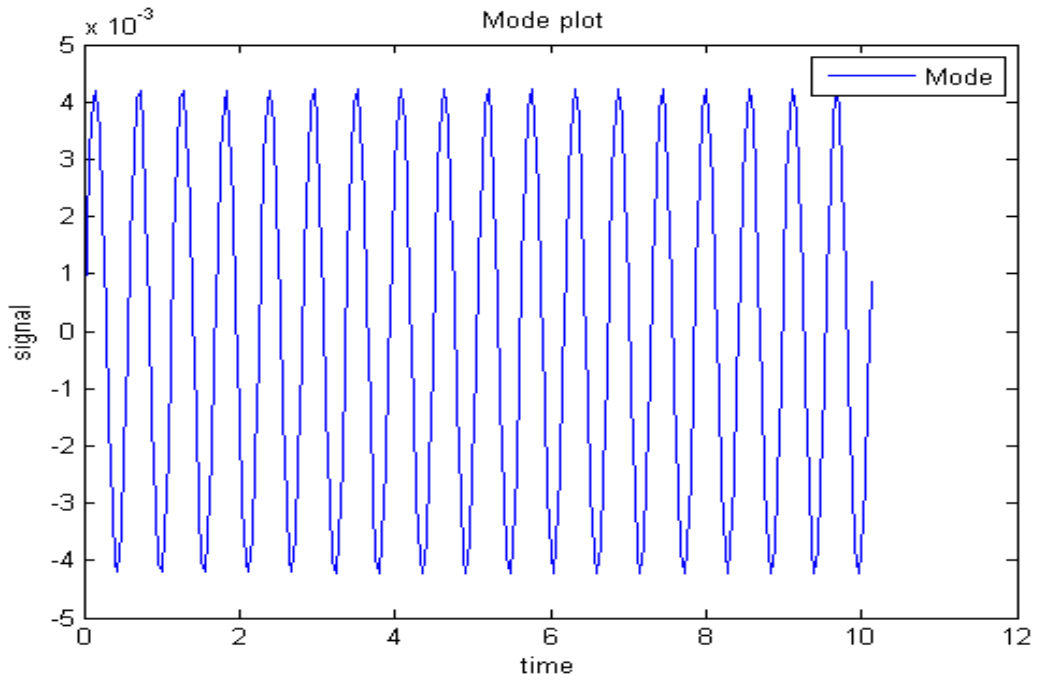


Fig 6.6: 30th July 2012-1.78 Hz mode (damping-0%) post-disturbance phase

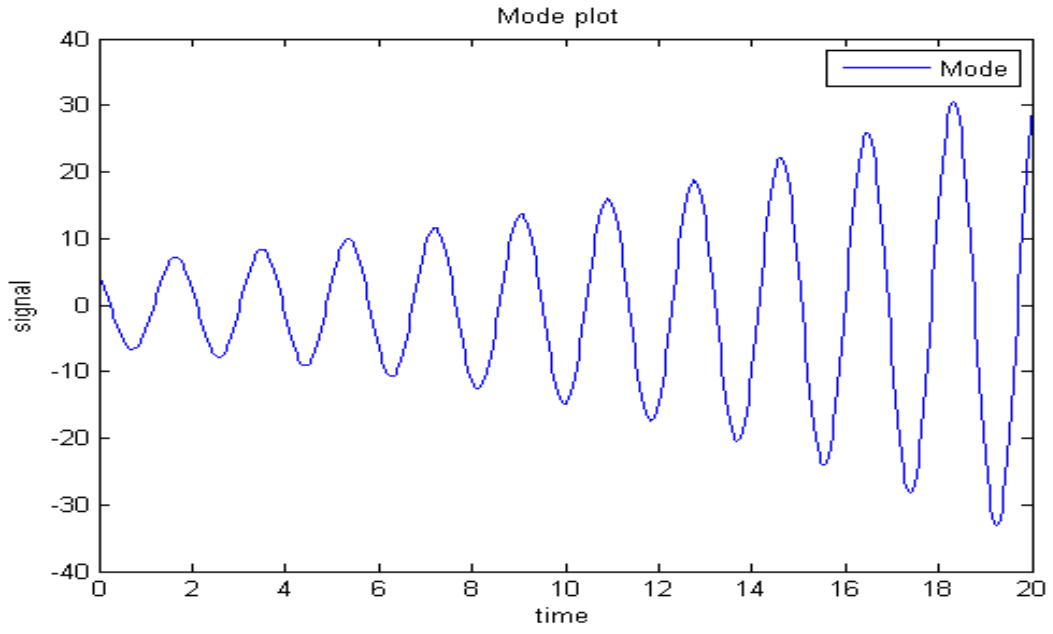


Fig 6.7: 31st July 2012—0.53 Hz (damping:-2%)-pre-disturbance

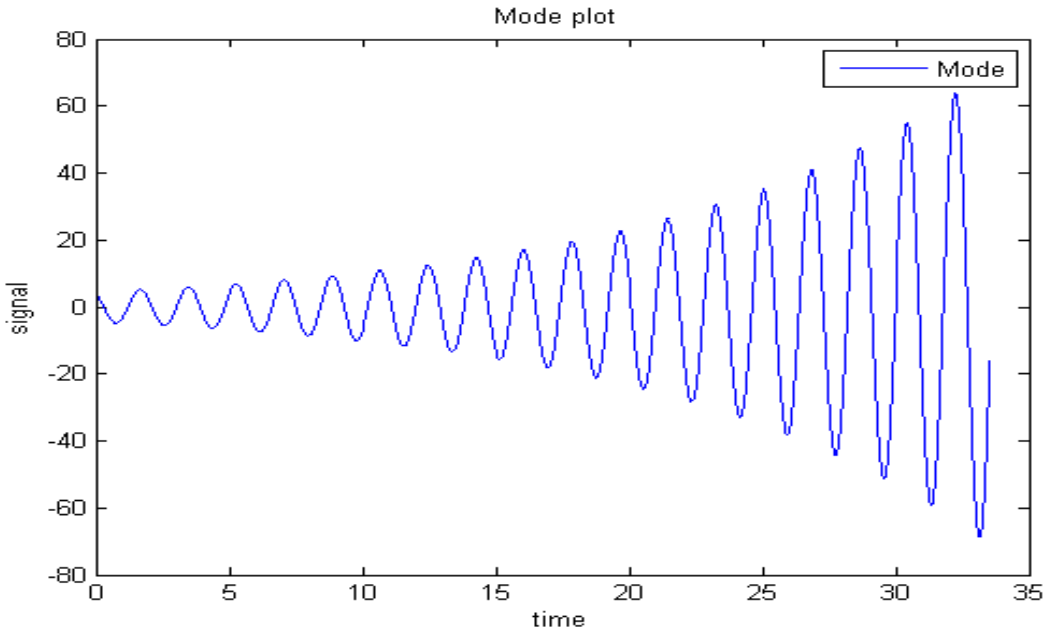
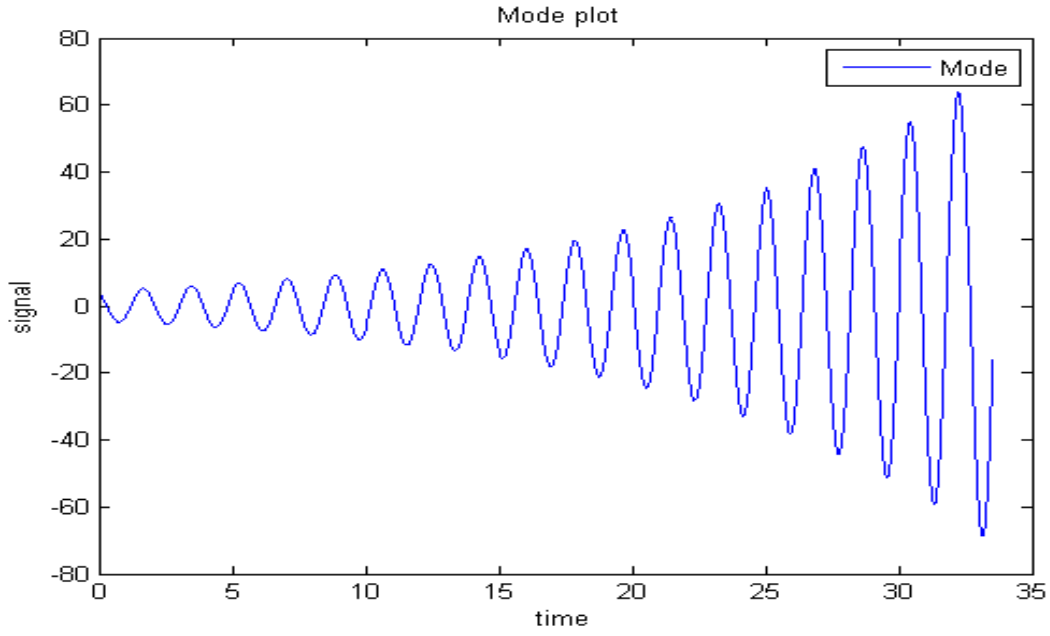


Fig 6.7: 31st July 2012—0.55 Hz (damping:-2.3%)- disturbance



6.

Fig 6.8: 31st July 2012: 0.55 Hz (damping: -0.2%)---post disturbance

6.3 Observations on the sequence above:

From Chapter 5 it would be seen that there is the large quantum of unscheduled exports from Western region (of the order of 3000 MW) and unscheduled import by Northern Region (of the order of 2500 MW). This skewed despatch scenario arose due to heavy demand in Northern Region following failure of the South-West monsoon and surplus in Western region. For scheduled transfers between regions, RLDCs/NLDC work out the transfer capability and approve the schedules only if the transfer capability is not violated. However in respect of unscheduled transfers, the frequency linked Unscheduled Interchange (UI) mechanism does not help in mitigating network congestion.

There is a mechanism to kick in congestion charges in the upstream and downstream system. However, it was difficult for NLDC to kick in congestion charges as per the existing approved procedure as the same arose due to outage of the network. The 400 kV Bina-Gwalior-Agra-2 was under planned shutdown since 28th July 2012 for up-gradation work to 765 kV. As would be observed from the above table, the 400 kV network between Western Region and Northern Region got depleted in the morning hours of 31st July 2012 starting with a planned outage on a high capacity corridor followed by two forced outages.

Under normal circumstances when all the 400 kV links between Western region and Northern Region are in service, the 220 kV underlying parallel network carries less power and is generally monitored at the SLDC level. The RLDCs and NLDC monitor the 220 kV network only if it is inter-state and inter-regional or the same is included in the list of important elements as specified in the Operating Procedures issued by the RLDCs.

Thus the 220 kV underlying network assumed importance once the 400 kV network got depleted. However as seen from the table above there were outages in the 220 kV Madhya Pradesh system at Gwalior. This compounded the problem leading to a somewhat increased loading on the 400 kV Bina-Gwalior line and the 220 kV MP to Rajasthan tie lines.

The operators at NRLDC, WRLDC and NLDC were making continuous efforts through verbal messages and written messages which are enclosed in Exhibit 5.104. Sipat TPS whose unit 3 came under commercial operation wef 1st August 2012 continued to generate 400 MW under UI despite persuasion by WRLDC to reduce generation. A list of messages is tabulated below.

Messages issued on 31st July 2012

Time	From	Issued to	Message Summary
0514	NRLDC	RAJASTHAN	Low frequency 49.41 Hz; Rajasthan OD by 300 MW; Curtail OD (Message type A)

Time	From	Issued to	Message Summary
0516	NRLDC	UTTARAKHAND	Low Freq. Operation & Restriction on Load
0518	NRLDC	HARYANA	Low frequency 49.5 Hz; Haryana OD by 170 MW; Curtail OD (Message type A)
0546	NRLDC	UTTAR PRADESH	Low frequency 49.35 Hz; Uttar Pradesh OD by 370 MW; Curtail OD (Message type A)
0553	NRLDC	UTTAR PRADESH	Overdrawal by utilities causing overloading of lines and low voltage UP overdrawal 391 MW at 49.44 Hz Requested u/s 29 of EA 2003 to maintain drawal within schedule and comply IEGC provisions and directions of NRLDC
0831	CPCC	WRLDC	400KV RANCHI-SIPAT-1 IN OFF CONDITION.
0834	NRLDC	HARYANA	Haryana OD by 321 MW; Curtail OD (Message type A)
0835	NRLDC	PUNJAB	Punjab OD by 320 MW; Curtail OD (Message type A)
0836	NRLDC	UTTARAKHAND	Uttarakhand OD by 309 MW; Curtail OD (Message type A)
0837	NRLDC	RAJASTHAN	Rajasthan OD by 405 MW Curtail OD (Message type A)
1242	WRLDC	NLDC,GETCO,MSETCL	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors.
1245	NRLDC	HARYANA	400 kV Gwalior Agra > 900 MW; Reduce OD to control loading; else grid incidence
1250	WRLDC	NLDC	To keep the Flow gates within the limits of TTC of WR-NR and WR-ER corridors. Badod-Modak :273MW Badod-kota:261MW
1255	NLDC	WRLDC,ERLDC	Reduce Underdrawal& Maintain Schedule

Time	From	Issued to	Message Summary
1300	WRLDC	NLDC	Urgent action to save grid to reduce overdrawal immediately

It has to be appreciated that in an integrated and meshed system, a 10 MW reduction on 220 kV Badod-Kota line would require at least 100 MW load shedding in Northern Region and similar backing down of generation in Western region. This calls for a fast response time from all the SLDCs and power stations.

At 1250 hours, tripping of Suratgarh unit 1 in Rajasthan led to further transfers between Western Region and Northern Region. However even before the flow could be controlled, the 220 kV MP to Rajasthan D/C lines, 400 kV Gwalior-Bina-1 and 220 kV Bina-Gwalior D/C tripped within four minutes span. This was effectively a N-G-3 contingency as far as the system was concerned. It is stated that the transmission system is not planned and operated for a N-G-3 contingency. A part of MP load also got incident on Northern region after these trippings further stressing the network in Eastern Region when the West to North ties snapped.

As seen from the above sequence, the tripping of 400 kV Bina-Gwalior-1 appears to bea case of Zone-3 distance protection acting due to load encroachment. These settings need to be examined separately. In the past such relay surprises when the system was stressed have led to blackouts on 12th October 2007 in Northern Grid, 2nd January 2010 in Northern Grid (twice) and on 18th November 2010 in Mumbai system.

After the tripping of 400 kV Bina-Gwalior-1, the system has collapsed within seconds and beyond the control of the operator. The power flowing from West to North took a longer path via Eastern Region. Here the following circuits were out either due to equipment problem and/or voltage control.

- 400 kV Sipat-Ranchi-1 due to isolator problem at Sipat end
- 400 kV Rourkela-Jamshedpur-2 due to Lightning Arrestor (LA) problem at Rourkela
- 400 kV Ranchi-Maithon RB-2 due to tower damage
- 400 kV Ranchi_Maithon RB-1 due to high voltage.

Many transmission lines tripped on load encroachment/power swing with only one out of the two distance protection scheme detecting the swing and tripping the lines leading to system separation. The relay behaviour under different load conditions needs to be studied separately.Heavy loading on transmission lines necessitates reactive power support from the generators at both ends of the line. This aspect is generally not factored in appropriately. This had led to Eastern Region experiencing a sudden dip in voltage due to wheeling of power to Northern Region even though the antecedent voltages were much above the nominal. . A clear

picture can emerge only after observing the Data Acquisition System (DAS) outputs from the different power plants and whether the generators reached their over-excitation limit during this event.

The Northern-Eastern and North Eastern regions after separation from the NEW grid should ideally have survived due to Under Frequency Relay (UFR) and df/dt relay load-shedding. In fact the frequency stabilized at 48.12 Hz for nearly a minute before it collapsed. The UFR load-shedding was not adequate to bring the frequency back to a safer level of 49.5 Hz and above. Any unit tripping at 48.12 Hz and/or onset of load could have caused the frequency to decline below 47.5 Hz where most of the generators trip out leading to a collapse. This is a matter of concern and needs to be examined separately.

In the Western Region also the frequency rose to 51.4 Hz and four generating units and five 400 kV lines tripped. The frequency rise to this level indicates the absence of primary response from generating units.

CHAPTER 7

RESTORATION SEQUENCE AFTER GRID DISTURBANCE ON 31ST JULY 2012

7.1 Restoration Process in Northern Region

7.1.1 Extension of Power Supply

I. Western Region supply was extended by charging Gwalior-Agra I. This was further extended to Kanpur, Ballabgarh, and Delhi etc.

II. Western Region supply was also extended by 220 kV Morak-Badod. This was further extended to Western Rajasthan System.

III. Western Region supply was also extended from 400kV Vindhyachal TPS to 400kV Vindhyachal Back to Back station through AC bypass mode.

IV. Western Region supply was also extended from 220kV Mehgaon & 220kV Malanpur lines.

7.1.2 Extension of startup supply to Power Stations

V. Singrauli STPS

a. Western Region supply was extended from 400kV Vindhyachal TPS to 400kV Vindhyachal Back to Back station through AC bypass mode.
b. Start up supply was extended to Singrauli STPS through 400kV Vindhyachal-Singrauli line-2 at 13:46 hrs but 400kV Vindhyachal-Singraui line-2 tripped at 15:13 hrs.
c. Second time start up supply was successfully extended at 15:45 hrs.
d. Singrauli STPS Unit#1 was synchronized at 19:00 hrs.

VI. Rihand STPS

a. Start up supply to Rihand STPS was extended from Western Region (Vindhyachal Back to Back station-Singrauli) through 400kV Singrauli-Rihand line at 13:53hrs but it tripped at 15:14 hrs.
b. Second time statup was again extended from Singrauli at 16:21 hrs but this again tripped.
c. Finally startup was extended via 400kV Allahabad-Rihand line at 18:33 hrs. Rihand STPS Unit#3 was synchronized at 23:58 hrs.

VII. Anpara TPS

a. Start up power to Anpara TPS was extended from Singrauli STPS (Vindhyachal Back to Back station-Singrauli-Anpara) at 16:20 hrs.
b. Anpara TPS unit#1 was synchronized at 21:59 hrs.

VIII. Jhajjar TPS

a. 400kV Gwalior-Agra charged at 13:43 hrs. Supply extended to 400kV Ballabgarh(PG) via 400kV Agra-Ballabgarh which was charged at 13:57 hrs.
b. Western region supply (Gwalior-Agra-Ballabgarh) was extended from 400kV Ballabgarh to Bamnauli at 14:09 hrs.
c. Power supply was extended from Bamnaulli supply to Mundka at 14:27 hrs.
d. Startup Power was extended from Mundka to Jhajjar TPS at 14:35 hrs. Jhajjar unit#1 was synchronized at 22:08 hrs.

IX. Unchahar TPS

a. Western region supply (Gwalior-Agra) was extended to 400kV Kanpur via 400kV Agra (PG)-Kanpur line at 14:58 hrs.
b. Startup power to Unchahar TPS was extended from 400kV Kanpur (PG) at 15:01 hrs vide 220kV Kanpur (PG)-Unchahar line.
c. Unchahar TPS unit#1 was synchronized at 18:51 hrs.

X. Tanda TPS

a. Western region supply (Gwalior-Agra-Kanpur) was extended to 400kV Panki at 15:57 hrs.
b. Power Supply from Panki was extended to Unnao at 16:17 hrs. Power supply was extended from Unnao to Lucknow (UP) at 16:19 hrs.
c. Power supply from Lucknow (UP) was extended to Lucknow(PG) at 16:34 hrs. Subsequently Power Supply was extended from Lucknow(P.G) to Sultanpur at 16:50 hrs.
d. Startup supply was extended to Tanda TPS from Sultanpur at 17:20 hrs. Tanda TPS unit#4 synchronized at 19:07 hrs.

XI. Narora Atomic Power Station

a. NAPS survived on house load. NAPS supply was extended to 220kV Simboli(UPPTCL) at 15:53 hrs.
b. This subsystem was synchronized with the subsystem formed with Tehri Hydro and Koteshwar hydro at Meerut (PG) at 16:21 hrs. At 16:40 hrs NAPPS was connected with Moradabad (UPPTCL) through 220kV Sambhal at 16:40 hrs.

XII. Dadri GPS & Dadri Thermal

a. Dadri GPS survived on house load. Dadri Gas unit#1 was sychronized at 16:09 hrs.

b. Start up supply to 400 kV Dadri TPS was extended through 220kV interconnector between Dadri GPS & Dadri Thermal at 14:00 hrs. Dadri TPS unit#3 synchronized with grid at 17:43 hrs.

XIII. **Auriaya GPS** survived on house load. Western Region supply was extended from 220kV Mehgaon & 220kV Malanpur lines to Auriaya GPS at 14:20 hrs. Unit#2 of Auriaya GPS was synchronized with grid at 14:50 hrs.
Western region supply from 400kV Agra(P.G) was extented to Auriaya GPS at 16:10 hrs. Supply from Auriaya GPS to 220kV Sikandra (220kV Agra) was revived at 15:35 hrs.

XIV. Startup supply to **Rosa TPS** was extended from 400kV Bareilley (PG) [Tehri-Koteshwar(PG)-Meerut(PG)-Barellley(PG)-Rosa TPS] at 16:21 hrs through 400kV Bareilley-Rosa line. Rosa TPS unit 2 was synchronized at 19:03 hrs.

XV. Start up supply to **Parichha TPS** was extended from 220kV Orai [400/220 kV Panki-220kV Chibra mau-220kV Mainpuri (UP)-220kV Orai] at 17:06 hrs. Parichha TPS unit#4 synchronized at 21:56 hrs.

XVI. Start up power to **Obra TPS** was extended from Pipri hydro station (Blackstarted) at 16:55 hrs. Obra TPS unit#1 was synchronized at 19:26 hrs.

XVII. Startup power to **Panipat TPS stage-2** was extended from 400kV Abdullapur(PG) [400/220kV Abdullapur-220kV Yamuna Nagar-220kV Nilokheri-220kV Karnal-Panipat(BBMB)] at 15:40 hrs. Unit#6 at Panipat TPS was synchronized at 17:31 hrs.

XVIII. Start up power to **Panipat TPS Stage-1** was extended from 220kV Dhulkote [220kV Ganguwal Dhulkote-Panipat(BBMB)] at 16:00 hrs. Panipat unit#4 synchronized at 18:10 hrs.

XIX. Start up supply to **Khedar TPS** extended from 400kV Fatehabad (PG) [Chamera-2-Kishenpur-Moga-Fatehabad]) at 16:41 hrs. Unit-1 at Khedar TPS was synchronized at 20:58 hrs.

XX. Startup supply to **Badarpur TPS (BTPS)** was extended from 400/220kV Bamnauli via 220kV Bamnauli-Dial-Mehrauli-BTPS at around 14:40 hrs. BTPS unit was synchronized at 16:18 hrs.

XXI. **Faridabad GPS** survived on house load. 2nd Unit started and synchronized at 14:38 hrs. 220kV FGPS-Samapur line charged at 15:14 hrs. At 15:23 hrs with jerk in the system (220KV Samaypur lines-1&2), GT#1Tripped on reverse power protection, prior to which it was supplying 70MW. GT#1 Synchronized again at 15:36 hrs. STG-Synchronized at 17:22 hrs.

XXII. Startup supply to **Kota TPS** was extended from Rana Pratap Sagar Hydro (Black started) at 13:23 hrs. Unit#7 of Kota TPS was synchronized at 16:01 hrs.

XXIII. Startup supply to **Suratgarh TPS** was extended from Ratangarh at 14:35 hrs. Unit#5 of Suratgarh TPS was synchronized at 19:11 hrs.

XXIV. **Anta GPS** survived on house load. Power extended to 220kV Kota Sakatpura at 13:28 hrs and to RAPP-C at 13:41 hrs. Unit#2 of Anta GPS synchronized at 14:22 hrs.

XXV. 400kV Zerda-Bhinmal (PG) charged at 13:30 hrs. Startup Power was extended to **Giral/Rajwest TPS** via 220kV Bhinamal.

XXVI. **Power Supply to Delhi**: Supply to Delhi was restored from Western Region via Gwalior-Agra-Ballabgarh- Bamnauli-Mundka and from subsystem formed with Tehri HEP i.e., Tehri-Meerut-Mandola-Dadri-Maharanibagh.

XXVII. Supply extended to 400kV Maharanibagh via 400kV Ballabgarh-Maharanibgh at 14:02 hrs & supply extended to 400kV Dadri via 400kV Dadri-Maharani bagh line at 16:57 hrs.

XXVIII. 220kV Badod- Morak charged at 13:45 hrs for extending power from Western Region to Rajasthan.

XXIX. **Subsystems formed**

a. **BBMB subsystem** with Bhakra(L) – Ganguwal – Dhulkote.
b. **Uri Subsystem** with 400kV Uri- Wagoora-Zianakote.
c. **Salal subsystem** with 220kV Salal-400kV Kishenpur-400kV Moga.
d. **Chamera subsystem** with Chamera(1)-Jallandhar-Ludhiana.
e. **Jhakri subsystem** with Jhakri-Abdullapur-Karcham.
f. **AD Hydro subsystem** with AD Hydro-Nalagarh-Patiala.
g. **Tehri subsystem** with Tehri-Koteshwar-Meerut-220kV Modipuram-Muzaffarnagar-400kV Vishnuprayag.
h. **Faridabad subsytem** with Faridabad GPS- Samaypur.
i. **Anta GPS** on house load.

7.1.3 Black start by Hydro stations, formation of sub-system & their synchronization

I. Uri HEP

a. Uri HEP was black started at 13:33 hrs & power was extended to Wagoora and operated in islanded mode with load of Kashmir valley.

II. Salal HEP

a. Salal HEP black started at 13:47 Hrs and power was extended to 220kV Jammu & 220kV Kishenpur which later collapsed.
b. Salal–Kishenpur system restored at 14:02 Hrs. Power from Kishenpur (PG) was extended to Sarna at 14:21 hrs, Barn at 14:27 hrs & Udhampur at 14:56 hrs. From Salal HEP power was extended to 220kV Jammu at 14:16 hrs.

III. Chamera-2 & Chamera-3

a. Supply from Kishenpur(PG) was extended to Chamera-2 Hydro station at 15:08 hrs. Chamear-2 HEP unit#2 was synchronized at 15:38 hrs.
b. Supply from Chamera-2 Hydro station was then extended to 400kV Chamba at 16:37 hrs. From Chamba supply was extended to Chamera-3 Hydro station (220kV). Unit#3 of Chamera#3 Hydro was synchronized at 17:39 hrs.

IV. Chamera-I & Pong Hydro Station

a. Chamera-I black-started at 14:05 hrs and power extended to 400kV Jalandhar.
b. The Island collapsed at 15:53 hrs due to load – generation imbalance in subsystem formed.
c. Chamera-1 HEP black started again at 16:17 hrs and power extended to Jallandhar(PG).
d. Power from Jallandhar(PG) was also extended to 220kV Dasuya at 17:54 hrs. From 220kV Dasuya supply was extended to PONG Hydro station.
e. Chamera-1 supply at Jallandhar(PG) was also extended to Ludhiana(PG) at 16:25 hrs and to 400kV Amritsar at 17:16 hrs

V. Jhakri HEP & Karcham Wangtoo HEP

a. Jhakri HEP unit#6 black started at 13:38 hrs and supply extended to Panchkula(PG) at 14:21 hrs.
b. Power was extended from Panchkula(PG) to Abdullapur(PG) at 14:21 hrs. Power was extended from Abdullapur to Karcham wangtoo Hydro station at 15:35 hrs. Karcham Unit#2 was synchronized with Jhakri supply at 15:36 hrs. Supply was then extended to 220kV DCRTPP, Yamuna nagar at 14:58 hrs.

VI. A.D. Hydro

a. **A.D. Hydro** Unit#2 was black started at 14:10 hrs and supply was extended to Nalagarh (PG).
b. 220kV AD hydro – Nalagarh (PG) line tripped at 16:13 hrs.
c. Supply from Nathpa Jhakri HEP was then extended to Nalagarh(PG) at 16:23 hrs which was extended further to AD hydro at 16:24 hrs.
d. Supply from Nalagarh(PG) was also extended to Patiala(PG) at 16:23 hrs.

VII. Synchronisation of Salal Hydro and Chamera-1 Subsystem

a. The subsystems formed with Salal Hydro and Chamera-1 was synchronized at Moga at 15:36 hrs.

VIII. Synchronisarion of Uri HEP and Salal HEP Sub System

a. At 400kV Wagoora (PG) the Supply from 400kV Kishenpur(PG) & Uri HEP was synchronized at 16:22 hrs through 400kV Wagoora-Kishenpur line-2.

IX. Synchronisation of Nathpa Jhakri, AD Hydro Subsystem with the subsystem formed with WR Power Supply

a. The Western Region supply available at 400kV Bawana (DTL) was extended to Bahadurgarh (PG) at 15:41 hrs. Supply from Bahadurgarh was extended to Sonipat (PG) at 16:13 hrs. The supply from Jhakri, AD Hydro subsystem available at Abdullapur was synchronized with Western Region supply available at Sonipat(PG) by closing of 400kV Abdullapur-Sonipat line at 16:24 hrs.

X. Synchronisation of Chamera-1, Uri HEP & Salal subsystem with Nathpa Jhakri, Karcham Wangtoo HEP

a. The integrated subsystem of Chamera-1, Uri & Salal was synchronized with Jhakri & Karcham wangtoo subsystem at Patiala (PG) at 16:28 Hrs through 400kV Ludhiana-Patiala line.

XI. Supply from 400kV Kishenpur (PG) was extended to Moga (PG) at 15:31 hrs. From Moga (PG) supply was extended to 400kV Fatehabad(PG) at 16:38 hrs. From Fatehabad(PG) start up supply was extended to Khedar TPS. Supply from Fatehabad(PG) supply was also extended to Hissar (PG) at 16:40 hrs. From Hissar (PG) supply was extended to Bhiwani (PG) at 17:03hrs.

XII. Synchronisation of Uri, Salal, Chamera-1, Nathpa Jhakri & AD hydro with Western Region Supply

a. The integrated subsystem formed with Uri, Salal, Chamera-1, Nathpa Jhakri & AD hydro was synchronized at Bhiwani (PG) with western region supply available at Bahadurgarh through synchronization of 400kV Bhiwani(PG)-Bahadurgarh line at 17:35 hrs.

XIII. Tehri HEP

a. Tehri HEP Unit#2 was black started at 14:10 hrs. Supply from Tehri Hydro extended to Koteshswar(PG) at 14:29 hrs.

b. Supply from Koteshwar(PG) was extended to Koteshwar Hydro & 400kV Meerut (PG) at 14:32 hrs. Koteshwar Hydro unit#1 was taken into service at 15:48 hrs.

c. From Meerut(PG) supply was extended to Mandola(PG) at 14:58 hrs.Supply was extended to Bareiley (PG) at 16:20 hrs. The supply from Bareilley(PG) was extended to Rosa TPS at 16:21 hrs.

XIV. Synchronisation of Tehri Sub system with Western Region supply at Dadri TPS

a. The Tehri subsystem was synchronized with Western Region supply at Dadri TPS vide 400kV Dadri-Madola line-1 at 16:13 hrs.

b. This extented subsystem was connected with the link Gwalior-Agra-Kanpur-Panki-Unnao-Lucknow(UP)-Lucknow(PG) at Lucknow(PG) at 16:42 hrs by synchronizing of 400kV Lucknow(PG)-Rosa TPS line.

XV. Bhakra(L)

a. Bhakra(L) blackstarted at 14:00 hrs and startup supply extended to Ropar TPS/Panipat TPS via 132kV Bhakra-Ganguwal-Kotla-Ropar

A comparison of the time taken in extension of startup power and time taken for synchronization by major thermal generating station is depicted in the chart below:

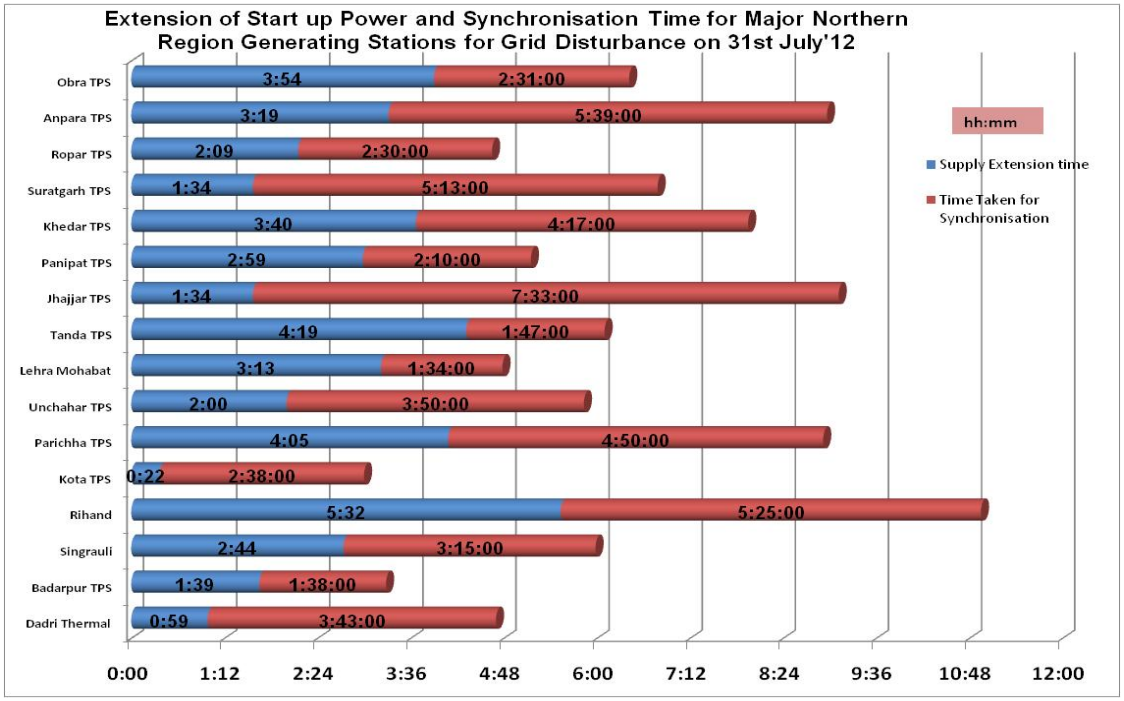


Chart-7.1

Detailed sequence of events are attached as Exhibit 7.1

7.1.4 Restoration of Traction Supply

I. **Delhi Traction Power control area:**

- **i.** 400kV Gwalior-Agra charged at 13:43 hrs. 400kV Agra-Ballabgarh charged at 13:57 hrs.Power supply was further extended from Ballabgarh-PG to Ballabgarh-BBMB.Traction power at Ballabgarh-BBMB(66kV) was restored at 14:20 hrs.
- **ii.** Supply was extended from 400kV Ballabgarh to Bamnauli at 1409 hrs. From Bamnaulli supply was extended to Mundka at 14:27 hrs. Supply from Mundka was extended to Bawana at 14:33 hrs. Power supply was extended from Bawana to Narela(220kV) at 14:57 hrs. Traction power at Narela-NDPL(66kV) was restored at 14:58 hrs.
- **iii.** Start up supply to Auriaya GPS was extended from 220kV Malanpur line to at 14:20 hrs. Power supply was extended to Phaphund at 14:33 hrs. Power supply for traction sub-stations at Shikohabad,Etahwah, Rura were restored at 14:38 hrs.
- **iv.** From 400/220kV Bamnauli start up supply was extended to Mehrauli via 220kV Bamnauli-Dial-Mehrauli at around 14:40 hrs. Traction power at Chankyapuri was restored at 14:45 hrs via Mehrauli-Ridge Valley.
- **v.** Dadri GPS was self started and power supply was extended to Dhankaur at 15:33 hrs.Power supply at traction sub-stations at Shahibabad,Dankaur,Khurja,Hatsras and Mitwali was restored at 15:48 hrs.
- **vi.** Traction power at Diwana(132kV) was restored at 16:09 hrs.

II. **Lucknow Traction Power control area:**

- **i.** Traction power at Sarojininagar was restored at 16:27 hrs.

III. **Ferozpur Traction Power control area:**

- **i.** Power supply fromPong HEP BBMB was extended to Jallandhar. Further power supply for traction sub-stations at Bhutari,Chiharu and Sahnewal were restored at 16:15 hrs.

IV. **Ambala Traction Power control area:**

- **i.** Power supply extebded from NJPC to Abdullhapur-PG. Further power supply for traction sub-stations at Kurali,Ghagar, Anadpur Sahib, Rajpura and Jagdhari were restored at 15:18 hrs, 15:27 hrs,15:35 hrs, 15:57 hrs, 16:00 hrs.

V. **Moradabad Traction Power control area:**

- **i.** Power supply for traction sub-stations at Kanth,Fazalpur,Roorkee and Ummartali were restored at 16:55 hrs,16:55 hrs,15:55 hrs and 16:36 hrs.

VI. Delhi Metro restoration:

Sl. No.	Name of feeding point	Restoration time
1	Pappankala-1	14:13 hrs
2	Pappankala-2	14:14 hrs
3	Dial	14:16 hrs
4	Meherauli	14:20 hrs
5	Mundka	14:27 hrs
6	Sarita Bihar	14:38 hrs
7	Rohini	14:48 hrs
8	Park Street	15:50 hrs
9	Kanjhawala	15:58 hrs

Table: 7.1

The station wise details of restoration of traction supply is tabulated below:

Details of Restoration of Traction Supply in Northern Region				
SL. NO	Feeding point from Grid to Railway Traction	Time	Railway Traction supply exteded	Time
1	Moradabad	16:32	a)Fazalpur	16:55
2	Moradabad	16:32	b)Kanth	16:55
3	Lucknow	16:19	Sarojininagar	16:27
4	Luckhnow	16:19	c)Ummartali	16:36
5	Ludhiana	16:10	a)Sahnewal	16:15
6	Jallandhar	16:07	a)Butari	16:15
7	Jallandhar	16:07	b)Chiharu	16:15
8	Panipat	15:40	Diwana	16:09
9	Dadri Gas	15:33	Dhankaur	15:58
10	Muzaffarnagar	15:16	Roorkee	15:55
11	Bamnauli	14:40	Chankyapuri traction	14:45
12	Bawana	14:33	Narela	14:58
13	Abdullapur	14:21	a)Jagadhri	16:00
14	Abdullapur	14:21	b)Anandpur Sahib	15:35
15	Abdullapur	14:21	c) Rajpura	15:57
16	Abdullapur	14:21	d)Ghaggar	15:27
17	Auriya Gas	14:20	Phaphund	14:33
18	Ballabgarh-BBMB	13:57	Ballabgarh traction	14:20

Table: 2

The time taken for restoration power supply at traction sub station is depicted in chart below:

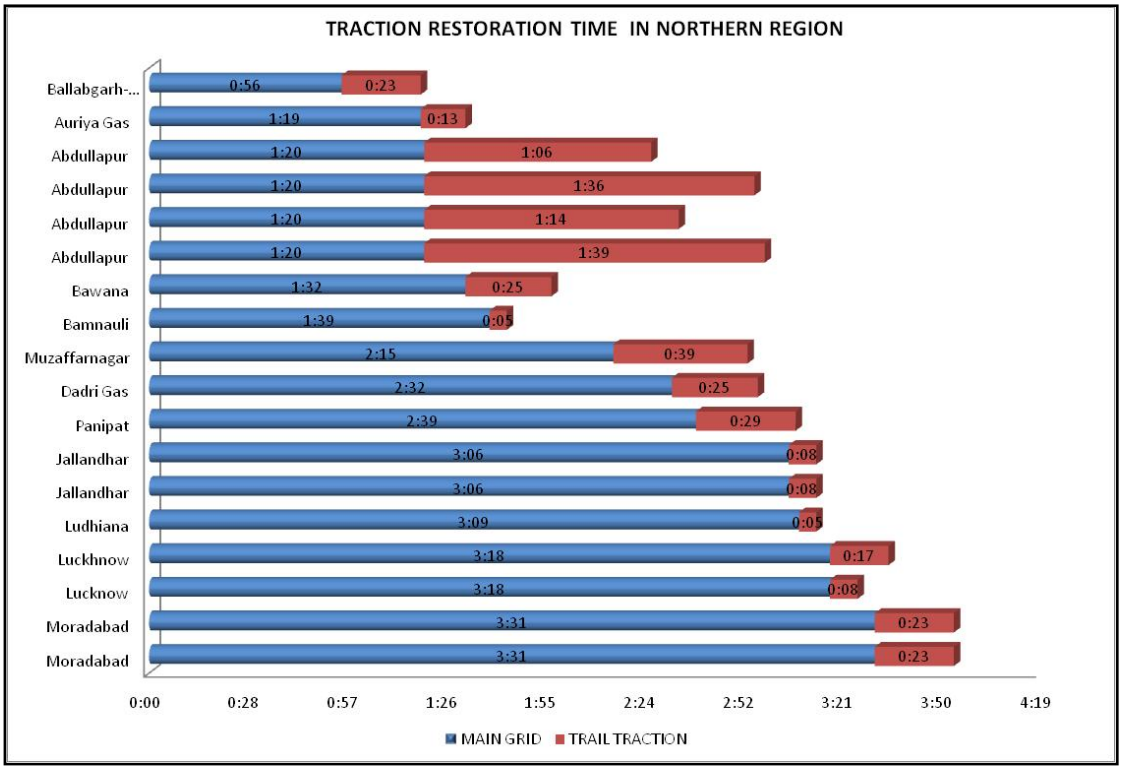
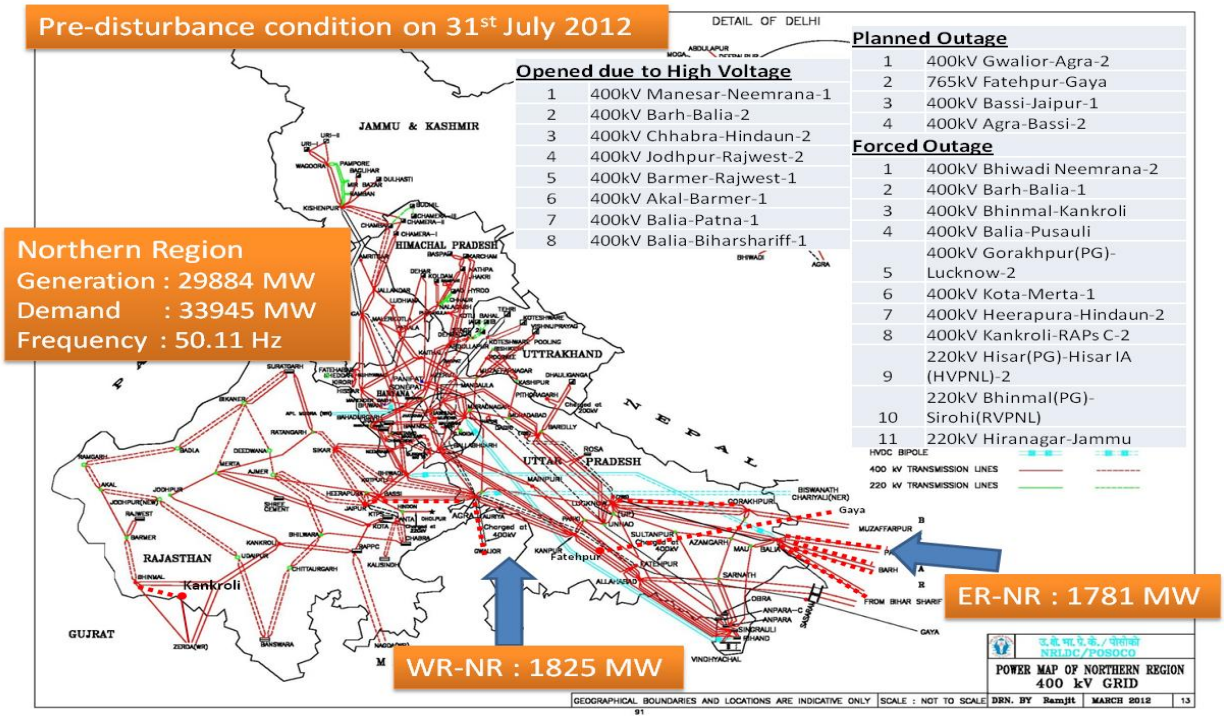
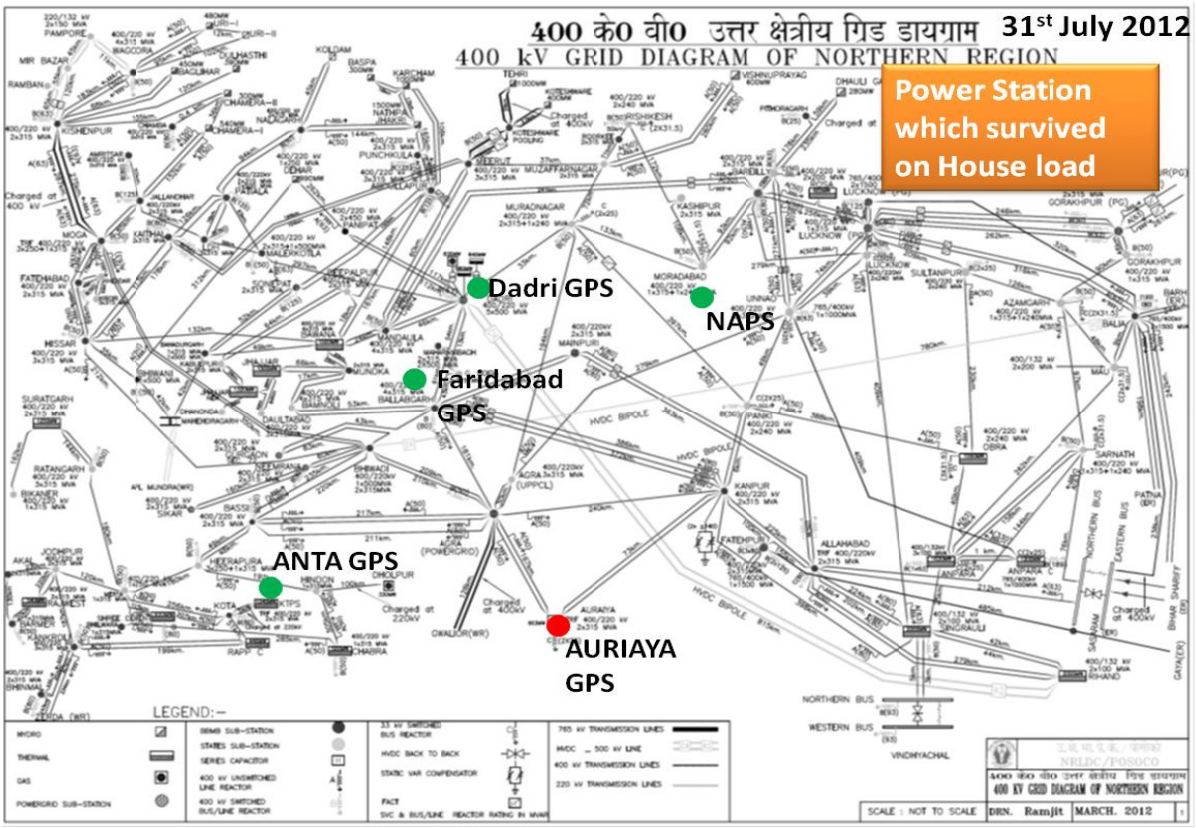
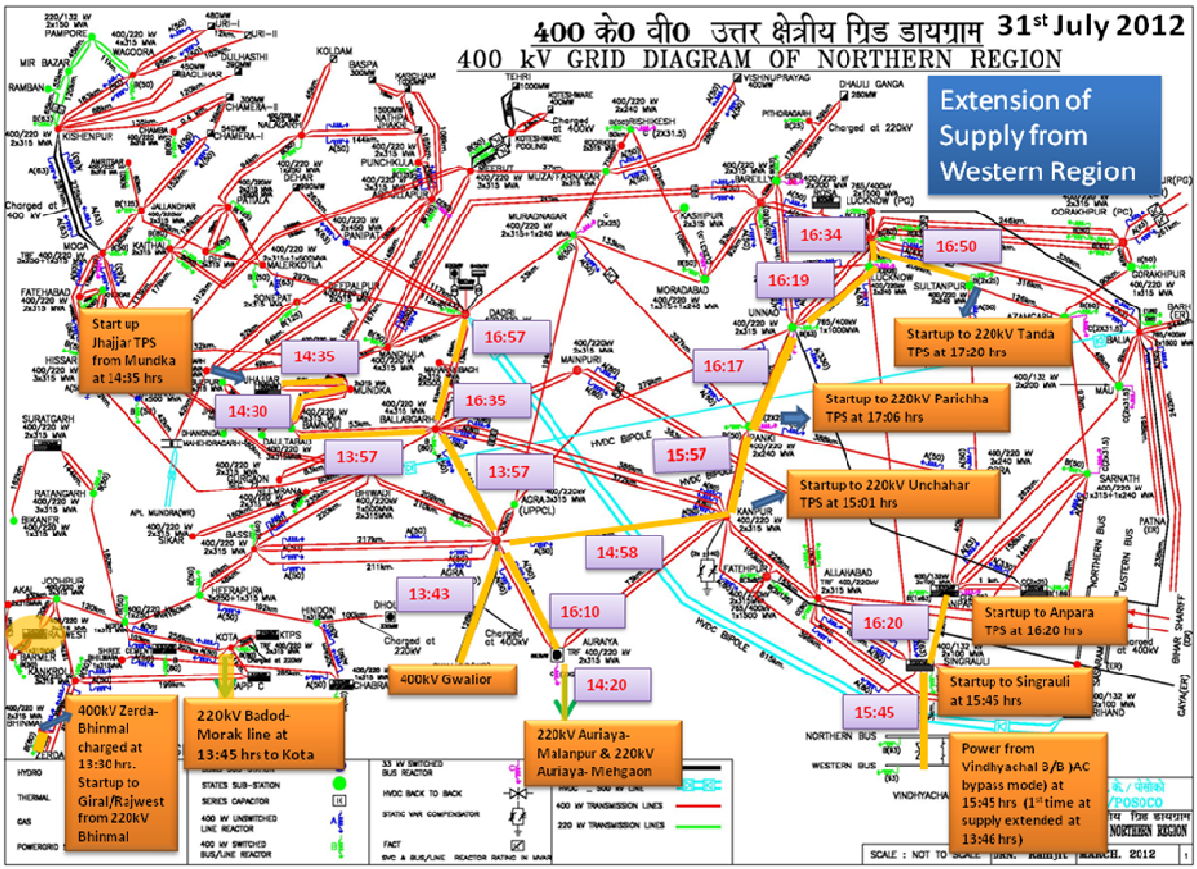


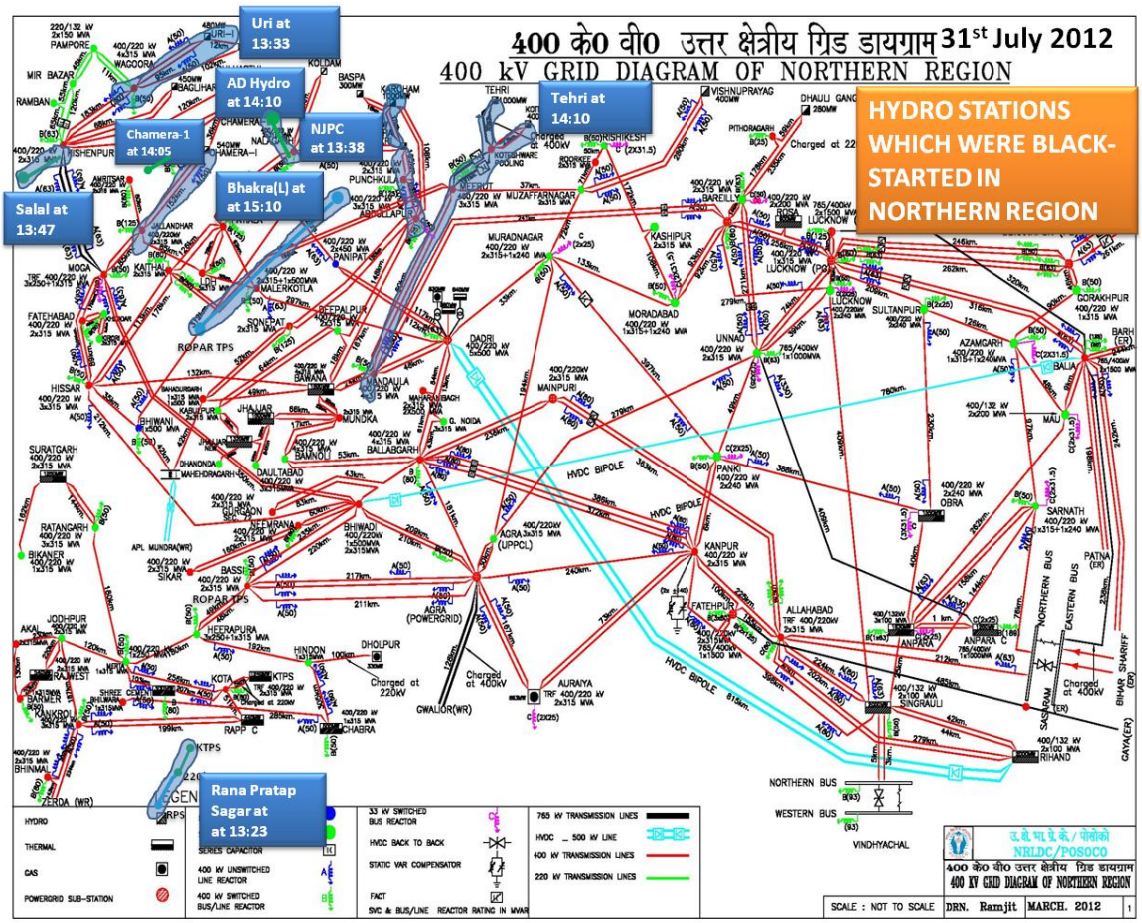
Chart: 7.2

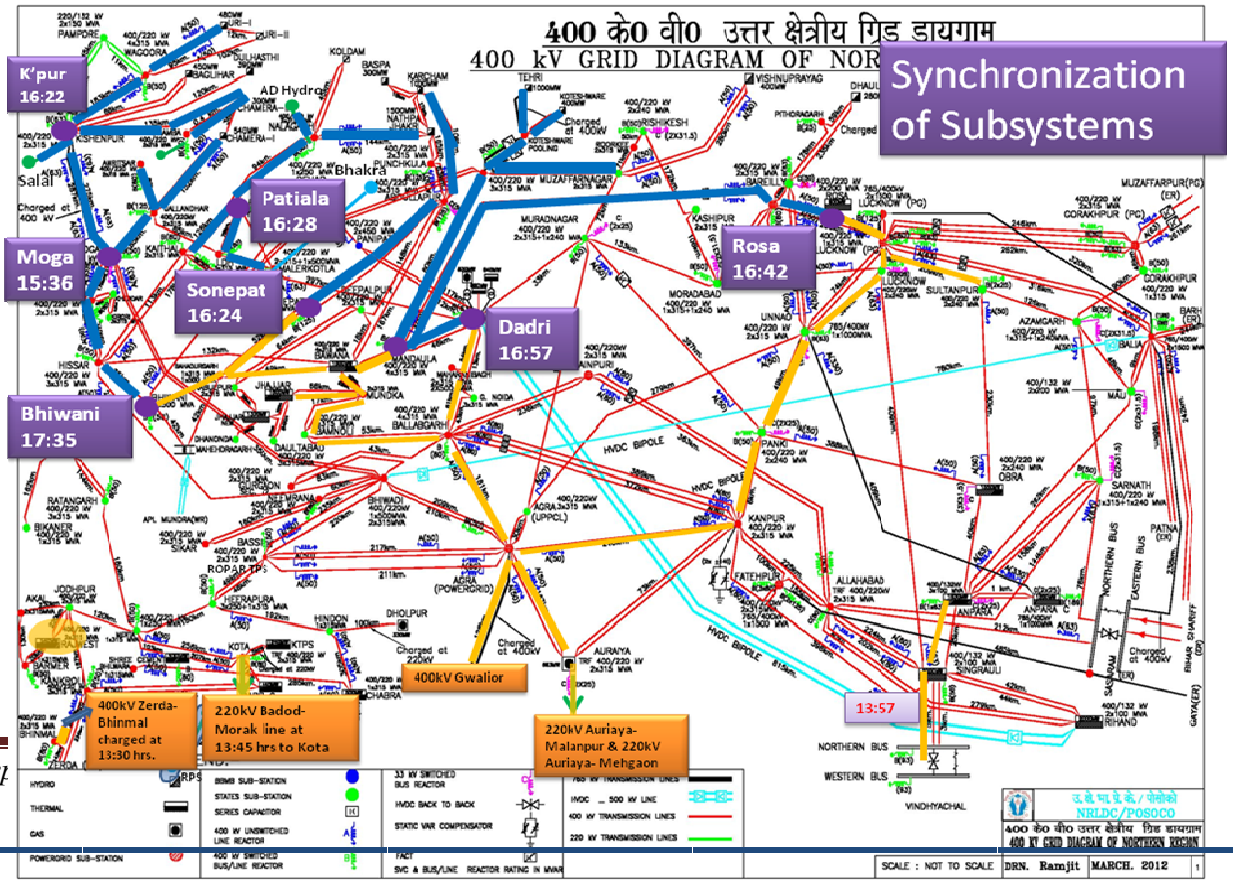
7.1.5 Pictorial Representation of Restoration in Northern Region




400 के0 वी0 उत्तर क्षेत्रीय ग्रिड डायग्राम 31st July 2012
400 kV GRID DIAGRAM OF NORTHERN REGION
Power Station which survived on House load
Dadri GPS
NAPS
Faridabad GPS
ANTA GPS
AURIAYA GPS
LEGEND:-


400 के0 वी0 उत्तर क्षेत्रीय ग्रिड डायग्राम 31st July 2012
400 kV GRID DIAGRAM OF NORTHERN REGION
Extension of Supply from Western Region
Start up Jhajjar TPS from Mundka at 14:35 hrs
14:35
14:30
16:57
16:35
13:57
13:57
13:43
14:58
16:10
14:20
16:34
16:50
16:19
16:17
15:57
16:20
15:45
Startup to 220kV Tanda TPS at 17:20 hrs
Startup to 220kV Parichha TPS at 17:06 hrs
Startup to 220kV Unchahar TPS at 15:01 hrs
Startup to Anpara TPS at 16:20 hrs
Startup to Singrauli at 15:45 hrs
400kV Gwalior
400kV Zerda-Bhinmal charged at 13:30 hrs. Startup to Giral/Rajwest from 220kV Bhinmal
220kV Badod-Morak line at 13:45 hrs to Kota
220kV Auriaya-Malanpur & 220kV Auriaya- Mehgaon
Power from Vindhyachal B/B HVDC (bypass mode) at 15:45 hrs (1st time at supply extended at 13:46 hrs)


400 के0 वी0 उत्तर क्षेत्रीय ग्रिड डायग्राम 31st July 2012
400 kV GRID DIAGRAM OF NORTHERN REGION
HYDRO STATIONS WHICH WERE BLACK-STARTED IN NORTHERN REGION
Uri at 13:33
AD Hydro at 14:10
NJPC at 13:38
Tehri at 14:10
Chamera-1 at 14:05
Bhakra(L) at 15:10
Salal at 13:47
Rana Pratap Sagar at at 13:23
NRLDC /POSOCO
SCALE : NOT TO SCALE
DRN. Ramjit
MARCH. 2012


400 के0 वी0 उत्तर क्षेत्रीय ग्रिड डायग्राम
400 kV GRID DIAGRAM OF NOR
Synchronization of Subsystems
K'pur 16:22
Patiala 16:28
Moga 15:36
Sonepat 16:24
Dadri 16:57
Rosa 16:42
Bhiwani 17:35
400kV Gwalior
400kV Zerda-Bhinmal charged at 13:30 hrs.
220kV Badod-Morak line at 13:45 hrs to Kota
220kV Auriaya-Malanpur & 220kV Auriaya- Mehgaon
13:57
NRLDC /POSOCO
SCALE : NOT TO SCALE
DRN. Ramjit
MARCH. 2012

7.2 Restoration Process in Eastern Region

I. All the major generating stations in Eastern Region tripped along with the entire 400kV network that lost total supply. However, Sterlite Energy limited, Burla HPS and IB thermal survived the collapse and remained connected with the Western Grid along with Western Orissa load. CESC system also could island itself from the system and Kolkata City load was not affected. Bokaro Steel Limited, TISCO and NALCO also survived with own load and generation.

II. Extension of Power Supply from Southern Region (HVDC Gajuwaka AC Bypass)

a. Startup power was availed at 13:36 hrs from Southern grid through 400kV Jeypore-Gajuwaka-I after bypassing HVDC Gajuwaka through AC mode and 200 MW power was extended to Southern part of Odisha.

b. Power was extended to Upper Kolab and Balimela power stations from Jeynagar and finally the load was extended upto Narendrapur via 220kV network from Jeypore-Jeynagar-Therubali-Bhanjnagar and Narendrapur.

c. The supply was further extended to Mehndasal and Chandka.

d. **Indravati HPS** was first brought into service with its black start facility and could extend power upto Therubali but tripped due to overvoltage.

e. Startup power was then extended to Indravati HPS from Theruballi and synchronized with the island connected to Southern source. This island was gradually developed up to a size of more than 600MW by around 14:30 hrs which remained connected with Southern grid.

III. Extension of Power Supply from Western Region (Route-I)

a. Power was also availed at 400kV bus at Rourkela at 13: 40 Hrs by charging Tarkera-Rourkella 220kV and back charging ICT of Rourkela. Sterlite-Rourkela II was further closed at 13: 40 Hrs. Western supply source was thus strengthened from both 400kV (Rourkela) and 220kV (Budhipadar) side.

b. **Startup Power to Talcher STPP and TTPS**: Startup power was extended to Talcher STPP and TTPS Through 220 kV Tarkera – Barkot – Rengali(O) – Rengali (PH) – TSTPP – TTPS, at 14:10 and 14:20 Hrs respectively.

c. Rengali HPS was started at 14:10 Hrs. Thus Orissa system was ready with all its sources for restoring its load. By around 16:00 Hrs essential Orissa load with traction was almost fully recovered.

d. At 18:54 Hrs HVDC Talcher-Kolar was closed and power from Kolar (Southern Grid) was availed to the tune of 200MW.

IV. Extension of Power Supply from Western Region (Route-II)

a. 400kV Sipat-Ranchi-MPL corridor was charged between 14:20 to 15:55 Hrs. Thus MPL was extended with startup power at 15:55 Hrs.

b. **Startup Power to Kahalgaon STPS**: Power supply was extended to Maithon 400kV at 16:35 Hrs and start up power to Kahalgaon was extended at 16:52 Hrs through Maithon-Kahalgaon I.

c. **Startup Power to Farakka STPS**: Startup Power was extended to Farakka STPS through 132kV Kahalgaon-Lalmatia-Farakka at 17:35 Hrs.

d. From Ranchi loads at Chandil / Hatia of Jharkhand was extended and JSEB received its supply from Ranchi. By around 17:00 Hrs JSEB could meet its full demand including traction.

e. Rourkela-Jamshedpur I was charged at 17:03 Hrs. and subsystem formed with Western Region assistance was further strengthened.

V. Building of DVC Subsystem and synchronization with Western Region Supply

a. DVC started its system by availing power from Bokaro Steel at Panchet via 132kV Bokato-CTPS-Ramkanali-Panchet route and extended power to Maithon HPS and Chandrapura TPS by 13: 20 Hrs.

b. The island so developed was synchronized with Western Region supply at Maithon system at 16: 39 Hrs through Maithon-Kalyaneswari 220kV system. Thus DVC started releasing its mines and traction load in a gradual manner.

VI. Extension of Power Supply from North Eastern Region

a. **Extension of Startup Power to Teesta. Tala and Chukha HPS**

b. Teesta Unit #3 was black started at 13:43 hrs and supply was extended to Binaguri at 13:58 hrs through 400 kV Teesta-Binaguri-I.

c. However, Unit #3 tripped on generator protection at 14:02 hrs. Again Unit #3 started at 14:28 hrs and power was extended to Binaguri at 14:32 hrs but the generator once again tripped on generator protection.

d. Subsequent attempts were also made by Teesta with combination of Unit #3 & Unit #2 at 15:43hrs & 16:21 hrs

e. Teesta supply was once again extended to Binaguri and loads of North Bengal was connected in consultation with WBSETCL but the island could not survive and collapsed/tripped immediately at 15:46 & 16:21 hrs.

f. Chukka Unit #1 black started at13:50hrs & synchronized to Basuchu (Bhutan).
g. At 15:30hrs. Chukha HPS U#1 tripped but Chukha HPS remain synchronized with Basuchu (Bhutan).
h. At 16:08hrs power extended to Chukha HPS bus through 200kV Birpara-I.
i. At 16:32hrs Chukha HPS synchronized to Indian system by closing bus coupler at CHPC.
j. At 19:09hrs Unit#3 synchronized.
k. Chukha and Tala HPS of Bhutan could not bring their respective units through black start.
l. **Due to the above constraint in black start of Tala, Teesta and Chukha, the startup power was not extended to Farakka / Kahalgaon from the shortest route.**
m. Power was availed from NER at Birpara from 220kV Salakati at 15:58Hrs and extended power at Birpara.
n. 132kV load at Birpara was released to control overvoltage and power extended to Chukha and Malbase of Bhutan.
o. Basochu survived as an island with North Bhutan Load. Power from Chukha was also extended to Basochu and units at Basochu (Bhutan) could be started and Birpara started receiving power from Basochu to the tune of 22 MW.
p. Power was then extended to Binaguri and load at Binaguri was released.
q. Tala received power from Malbase and units of Tala HPS were brought at 17:27 Hrs
r. Tala Unit #6 started generation at 17:40hrs.
s. 400kV Malbase-Binaguri charged at 17:49hrs.
t. 400kV Tala-Binaguri charged at 19:46hrs.
u. The power was extended to NJP and then to Gangtok of Sikkim as well as Rangit HPS of NHPC at 18: 30 Hrs. Sikkim demand of around 100MW was fully released.
v. The 220kV CTS system was thereafter charged and power was extended upto Malda by 18:39 Hrs. The loads of North Bengal were gradually released also.
w. Purnea (BSEB) received power by 18:24Hrs through Dalkhola – Purnea 220kV line and 400/220kV kV Binaguri-Purnea- Malda loop was closed by 19:25 Hrs.
x. In the meantime power was extended to Bidhannagar via Maithon-Durpagur 400kV section. Further Durgapur –Farakka 400kv was closed.

y. Start up power was extended to Santaldih at 15:04 hrs via 132 kV Bandel-Satgachia-Mahachanda-Mankar-Bidhannagar-220kVBidhannagar-Santaldih

z. Start up power was extended to Bakreswar at 14:25 hrs via 132 kV Via 132 kV Satgachia -220 kV Satgachia-Bakrewar.

aa. Biharshariff – Extended power to Biharshariff, BSEB at 19:34 Hrs and Biharsahariff – Fatuah loads of South Bihar were gradually released. Biharshariff further extended power to Pusauli and loads at Dehri, Arah and Khagaul were released by 22:12 Hrs.

bb. Power extended to Muzaffarpur via 400kV Purnea-Muzaffarpur at 21:02 Hrs and North Bihar load was released through Muzaffarpur at 21:15 Hrs.

cc. The radial load fed to Northern Grid from Pusauli was released at 23:01 Hrs.

dd. BSEB thus received full supply and it started meeting its full demand of over 1600 MW by 22:30 Hrs.

VII. Synchronisation of NER System with WR/ER System

a. 400kV Malda-Farakka was charged at 20:10 Hrs and NER system was synchronized with WR/ER system at Farakka at 20:35 Hrs.

b. Load at DVC system and loads from Bidhannagar could be gradually released.

VIII. Extension of Power to West Bengal through CESC System

a. The West Bengal received power from CESC source via from Howrah /Dhrampur and extended power to Kolaghat and Bandel and a part of West Bengal system was developed in synchronism with CESC.

IX. Synchronisation of Southern Orissa with rest of the system

a. At 21:28 Hrs the Gazuwaka-Jeypore was opened from Jeypore after balancing of 100-150MW of drawal from Southern Grid.

b. This part of the island was synchronized with the rest of the grid by closing Mehndashal-Meramundali at 21:30 Hrs.

X. Synchronisation of part island of west Bengal including CESC with rest of the system

a. The part island of West Bengal including CESC was synchronized with rest of the Grid at Bakreswar by closing Bidhannagar-Bakreswar 220kV at 23:04 Hr.

XI. At around 21:00 Hrs 70 % of the ER demand around 8000 MW with full traction and essential loads released. The Major 400 kV tie lines were restored gradually and at 02:00 Hrs ER system was meeting around 9700 MW of demand. Generation at Farakka, Kahalgaon and Talcher STPPs were progressively increasing.

XII. Closing of loop between NR and ER

a. Eastern Region was finally connected with Northern Region by closing Muzaffarpur-Gorakhpur I at 03:59 hrs of 01st August 2012.

A comparison of the time taken in extension of startup power and time taken for synchronization by major thermal generating station is depicted in the chart below:

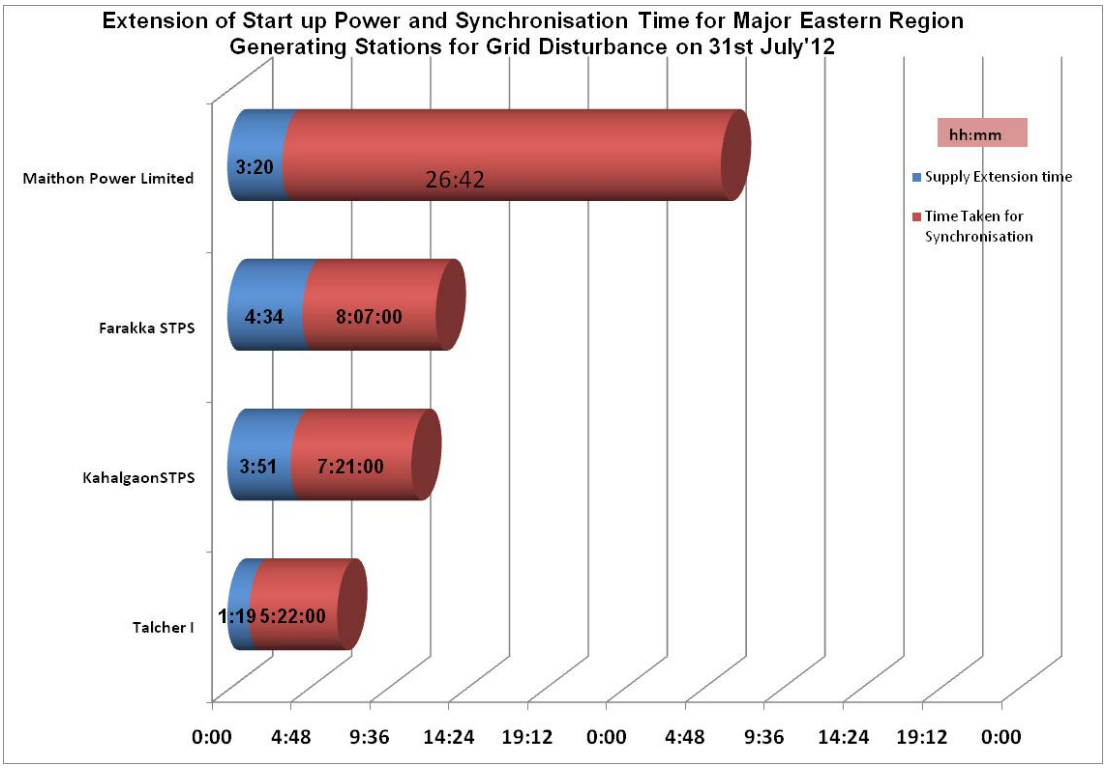


Chart: 7.3

Detailed sequence of events are attached as Exhibit 7.1

XIII. Restoration of Traction Supply

I. Bihar Control Area (East Central Railway)

i. Power supply was extended to Khursrupur traction substation from Fatuha at 19:15 hrs.
ii. Power supply was extended to Paharpur traction substation from Bodhgaya at 19:35 hrs.
iii. Power supply was extended to Mokama traction substation from Hatidah at 19:40 hrs.
iv. Power supply was extended to Lakhisarai traction at 19:45 hrs.
v. Power supply was extended to Jhajha traction substation from Jamul at 19:55 hrs.
vi. Power supply was extended to Gaya traction substation from Chandauti at 19:56 hrs.
vii. Power supply was extended to Jehanabad traction substation at 20:06 hrs.
viii. Power supply was extended to Rafiganj traction substation at 20:07 hrs.
ix. Power supply was extended to Japla traction substation from Sonenagar at 20:22 hrs.
x. Power supply was extended to Sonenagar traction substation at 20:25 hrs.
xi. Power supply was extended to Chapra traction substation at 21:56 hrs.
xii. Power supply was extended to Hazipur traction substation at 22:02 hrs.
xiii. Power supply was extended to Kudra traction substation at 22:20 hrs.
xiv. Power supply was extended to Karamnasa traction substation at 22:25 hrs.
xv. Power supply was extended to Arrah traction substation at 22:30 hrs.
xvi. Power supply was extended to Danapur traction substation from Khagaul at 22:35 hrs.
xvii. Power supply was extended to Dumroan traction substation from Dumroar at 22:40 hrs.

II. JSEB Control Area (South Eastern Railway)

i. Power supply from 220kV Ranchi-PG was extended to Hatia at 15:02 hrs and further traction power was restored at 15:11 hrs. The power was further extended to 132 kV Hatia-Lodhma Traction feeder extn.
ii. Power supply was extended to 132 kV Namkum S/S from Hatia at 15:07.
iii. Power supply was extended to 132 kV Chandil S/S from Ranchi at 15:20 hrs
iv. Power supply was extended to 132 kV Rajkharsawan S/S from Chandil at 15:25 hrs.

25 kV Rajkharsawan traction S/S received power at 15:27 hrs.

v. Power supply was extended to 132 kV Golmuri S/S at 15:25 Hrs. Power was further extended to 132 kV Golmuri Salgajhari traction feeder extn. at 15:25 hrs

vi. Power supply was extended to 132 kV Goelkera S/S at 15:27. Power was further extended to 132/25 kV Goelkera traction feeder at 15:30 hrs.

vii. Power supply was extended to 33 kV Chakradharpur traction feeder at 15:30 hrs.

viii. Power supply was extended to 132 kV Kendposi S/S power from Rajkharsawan. Power was extended to 132 kV Kendposi traction feeder at 15:42 hrs.

ix. Traction load at Namkum was released at 16:00 hrs

x. Power supply was extended to 132 kV Deoghar S/S from Lalmatia at 18:15 hrs. Power extended to 132 kV Deoghar Sankarpur traction feeder at 18:40 hrs.

xi. Power supply was extended to 132 kV Jamtara S/S from Maithon DVC at 19:25 hrs. Power extended to Jamtara traction.

xii. Power supply was extended to 132 kV Garwah S/S from Rihand (NR). Garwah traction power was further extended at 19:46 hrs.

III. DVC Control Area (Eastern Central Railway)

i. Power Supply was extended from CTPS (DVC) to Rajohara traction substation at 15:32 hrs.

ii. Power Supply was extended from BTPS (DVC) to Barhi & Koderma traction substation at 16:02 hrs.

iii. Power Supply was extended from Maithon HPS to Patherdih to Pradhankhanta traction sub station at 16:50 hrs

IV. Orissa (East Coast Railway)

i. Power Supply was extended from Narendrapur to Solari traction substation at 15:30 hrs

ii. Power Supply was extended from Narendrapur to Jagnnathpur traction substation at 15:30 hrs

iii. Power Supply was extended from Baripada to Balasore to Bhadrak traction substation at 15:30 hrs.

V. West Bengal (Eastern Railway)

i. Power Supply was extended from Howrah (CESC) to Howrah traction substation at 13:40 hrs.

ii. Power Supply was extended from Howrah (WB) to Liluah traction substation at 14:10 hrs.

iii. Power Supply was extended from Howrah (WB) to Rishra to Bandel TPS to Satgachia traction substation at 15:00 hrs.

Station wise Details of Restoration of Traction Supply in Eastern Region				
SL. NO	**Feeding point from Grid to Railway Traction**	**Time**	**Railway Traction supply extended**	**Time**
			BIHAR	
1	Arrah(PG)	22:14	Dumraon	22:40
2	Arrah(PG)	22:14	Arrah	22:30
3	Arrah(PG)	22:14	Danapur	22:35
4	Biharsariff(PG)	18:48	Khusurpur	19:15
5	Biharsariff(PG)	18:48	Mokama	19:40
6	Biharsariff(PG)	18:48	lakhisarai	19:45
7	Biharsariff(PG)	18:48	Jhajha	19:55
8	Sasaram(PG)	21:55	Karmanasa	22:25
9	Sasaram(PG)	21:55	Kudra	22:20
10	Biharsariff(PG)	18:48	Sonenagar	20:25
11	Biharsariff(PG)	18:48	Japla	20:22
12	Biharsariff(PG)	18:48	Rafiganj	20:07
13	Biharsariff(PG)	18:48	Gaya	19:56
14	Biharsariff(PG)	18:48	Paharpur	19:35
15	Biharsariff(PG)	18:48	Jehnabad	20:06
16	Muzaffarpur(PG)	21:25	Hazipur	22:02
17	Muzaffarpur(PG)	21:25	Chapra	21:56
			JHARKHAND	
1	Ranchi(PG)	14:58	Hatia	15:11
2	Ranchi(PG)	14:58	Lodhama	15:11
3	Ranchi(PG)	14:58	Namkum - I	14:30
4	Ranchi(PG)	14:58	Namkum - II	15:07
5	Rihand(NR)	19:40	Garwa	19:46
6	Ranchi(PG)	14:58	Rajkharsawan	15:27
7	Ranchi(PG)	14:58	Kenduposi traction	15:42
8	Ranchi(PG)	14:58	Salgajhari	15:25
9	Ranchi(PG)	14:58	Chakradharpur	15:34
10	Ranchi(PG)	14:58	Goilkera	15:29
11	Ranchi(PG)	14:58	Minique	15:25
12	Lalmatia (NTPC)	16:52	Sankarpur	18:40
13	Maithon power(DVC)	16:39	Jamtara	19:25
			DVC	
1	Panchet HPS	14:25	Ramkanali	17:05
2	Chandrapura TPS	15:28	Pathardih	16:50
3	Durgapur TPS	15:30	Burdwan	17.24
4	Durgapur TPS	15:30	Belmuri	17:40
5	Mosabani (132KV)	16:30	Mosabani (132KV)	16:40
6	Chandrapura TPS	15:28	Koderma	16.02
7	Durgapur TPS	15:30	Durgapur (DTPS)	16.16
8	Chandrapura TPS	15:28	CTPS, Rajabera (132KV)	15.32
9	Maithon HPS	15:43	Kumardubi	16:40
10	Chandrapura TPS	15:28	Nimiaghat	16:55

11	Chandrapura TPS	15:28	Konar	17:20
12	Chandrapura TPS	15:28	Sindri, (Pradhankhanta)	17:00
ODISHA				
1	Jeypore(PG)	13:36	Jaynagar (T) 132 kV	13:53
2	Jeypore(PG)	13:36	Narendrapur (T) 132 kV	13:54
3	Jeypore(PG)	13:36	Rambha(T)	14:35
4	Jeypore(PG)	13:36	Solari (T) 132 kV	14:39
5	Jeypore(PG)	13:36	Kaipadar (T) 132 kV	14:20
6	Rourkela(PG)	13:40	Joranda (T)	16:11
7	Rourkela(PG)	13:40	Meramundali (T) 132 KV	15:35
8	Rourkela(PG)	13:40	Chodwar (T) 132 KV	16:43
9	Rourkela(PG)	13:40	Chandiposh(T) 220/27kV	13:38
10	Rourkela(PG)	13:40	Jakhapura (T)	16:12
11	Chandil - Ramchndrapur(JSEB)	15:18	Bansapani (T)	17:05
12	Chandil - Ramchndrapur(JSEB)	15:18	Barjamunda 132/25 KV (T)	17:38
13	Chandil - Ramchndrapur(JSEB)	15:18	Polaspanga 132/25 kV (T)	17:25
14	Rourkela(PG)	13:36	Jaleswar(T) 132 kV	16:28
15	Rourkela(PG)	13:36	Bhdrak RLY. FEEDER	16:11
16	Rourkela(PG)	13:36	Balasore	16:01
WEST BENGAL				
1	Howrah	13:17	Howrah	13:30
2	Howrah	13:17	Liluah	16:05
3	Adisaptagram	15:44	Adisaptogram	19:05
4	Satgachia	14:27	satgachia	20:03
5	Titagarh	14:09	Titagarh	14:44
6	New Haldia	14:50	Hizli	23:31
7	Chandrakona	20:55	C.K.road	20:55
8	Bankura	20:32	Bankura	20:45
9	debogram	20:38	debogram	20:50
10	Beherampur	21:16	Beherampur	21:19
11	Sonarpur	19:21	Sonarpur	19:33
12	Lakhikantapur	19:41	Lakhikantapur	19:50
13	Pingla	22:05	Pingla	23:20
14	Balichak	21:35	Balichak	23:20
15	kolaghat	20:16	kolaghat	20:40
16	Ashoka Nagar	20:33	Ashoka Nagar	20:35
17	katwa	14:27	katwa	20:05
18	Barasat	20:05	Barasat	20:10
19	dankuni	13:17	Dankuni	02:24:00(01/08/12)
20	Haldia	14:55	Haldia	21:20

Table: 7.3

The time taken for power supply restoration at traction sub station in Bihar is depicted in the chart below:

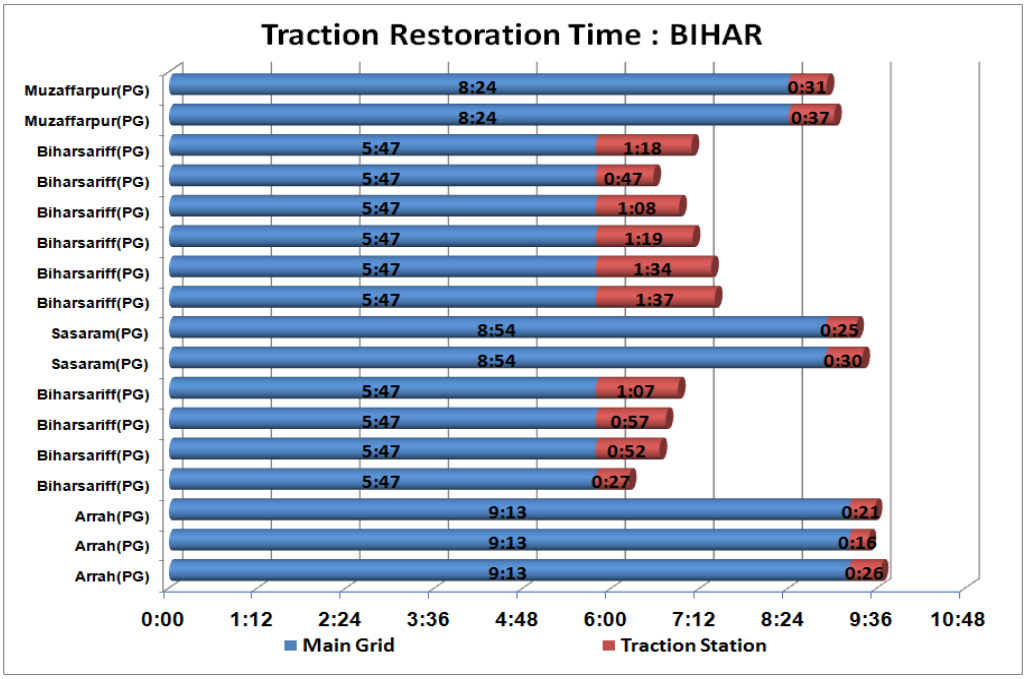


Chart-7.4

The time taken for power supply restoration at traction sub station in Jharkhand is depicted in the chart below:

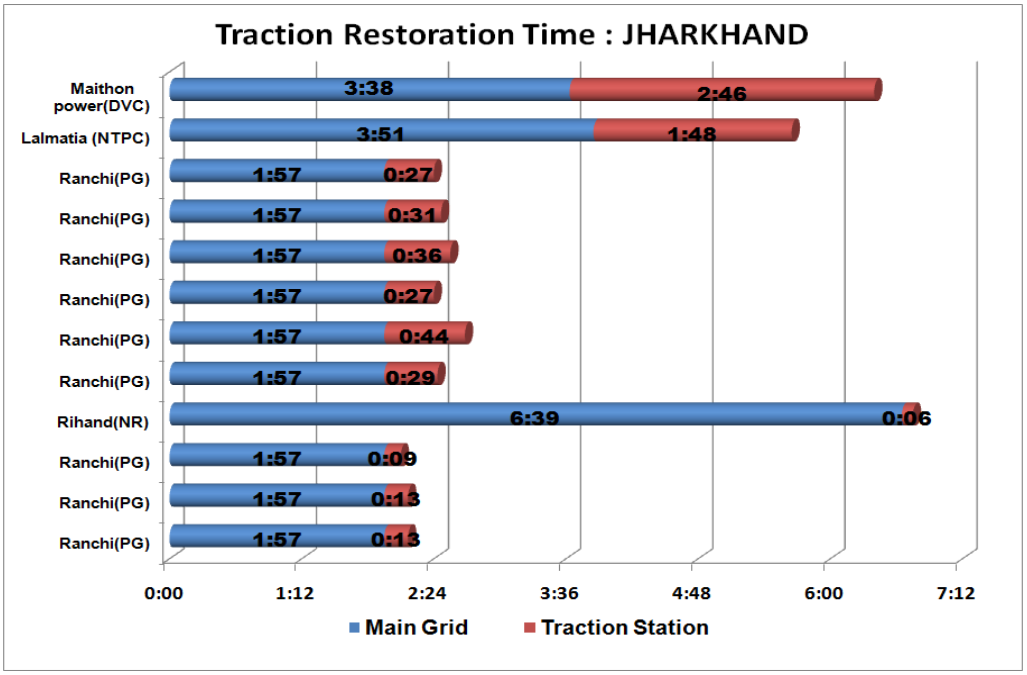


Chart 7.5

The time taken for power supply restoration at traction sub station in DVC is depicted in the chart below:

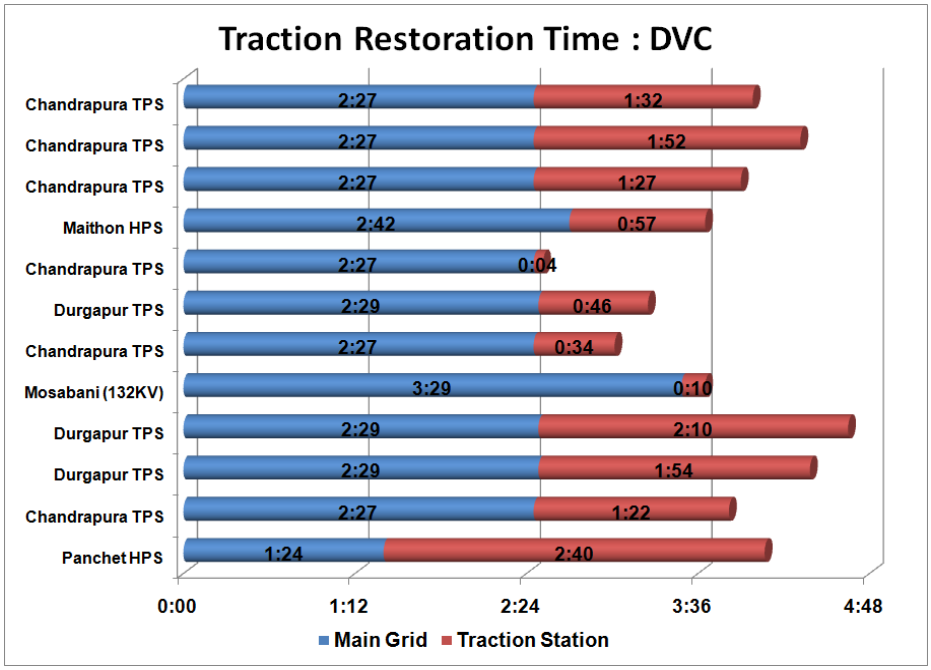


Chart 7.6

The time taken for power supply restoration at traction sub station in Odisha is depicted in the chart below:

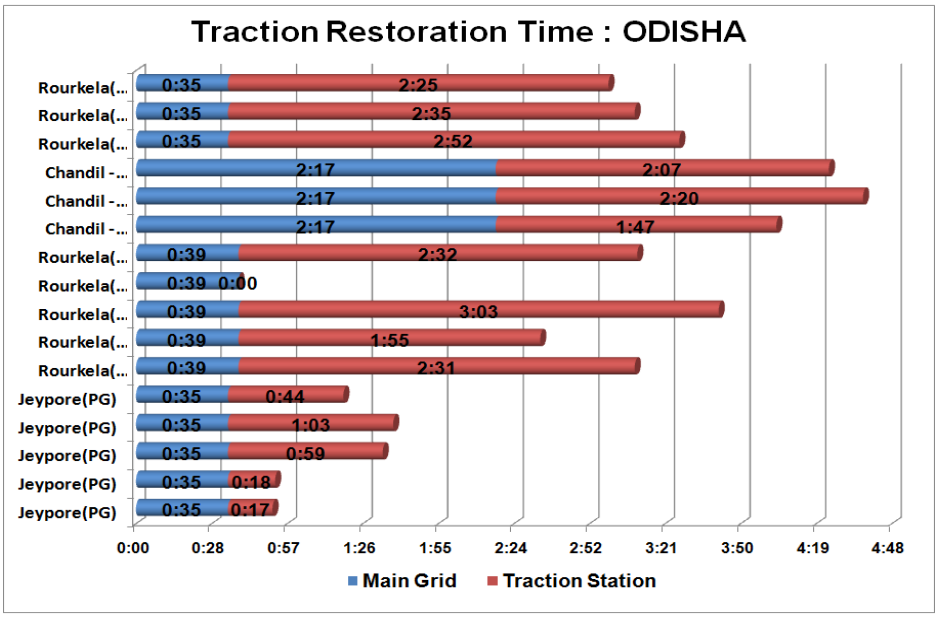


Chart 7.7

The time taken for power supply restoration at traction sub station in West Bengal is depicted in the chart below:

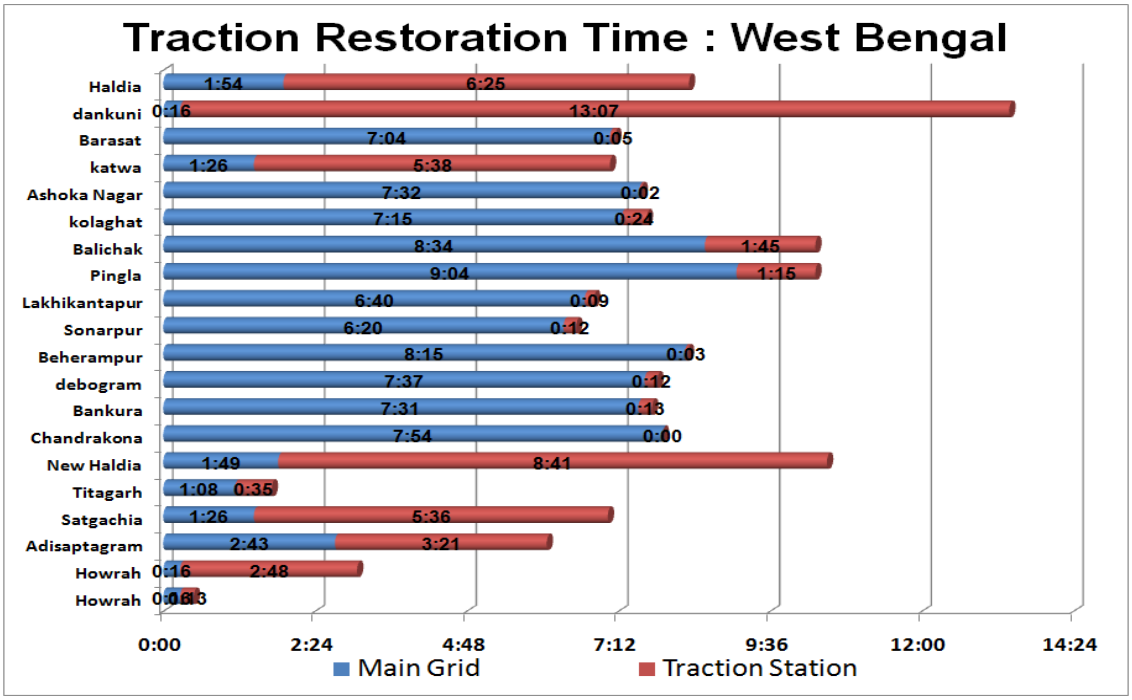
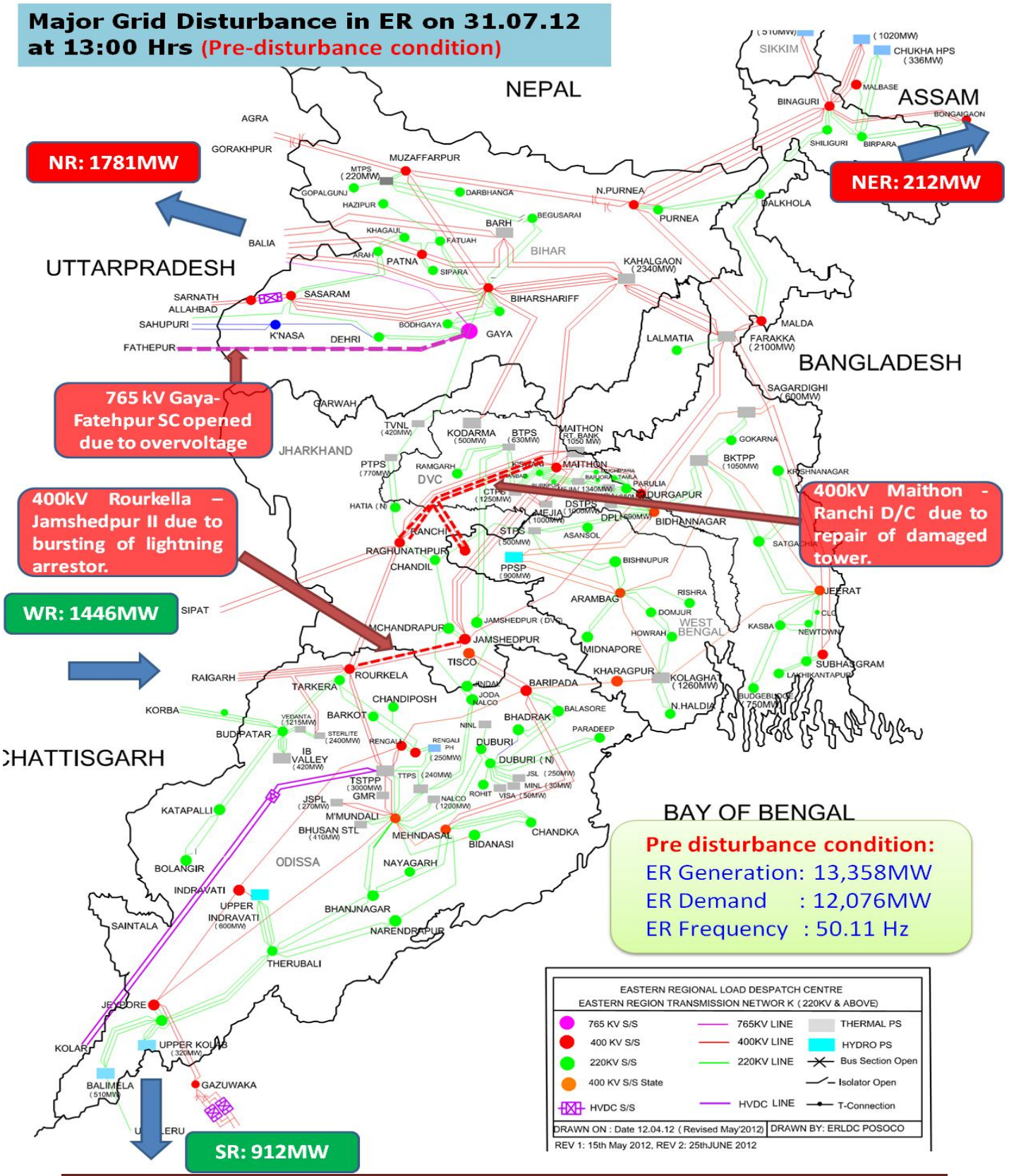
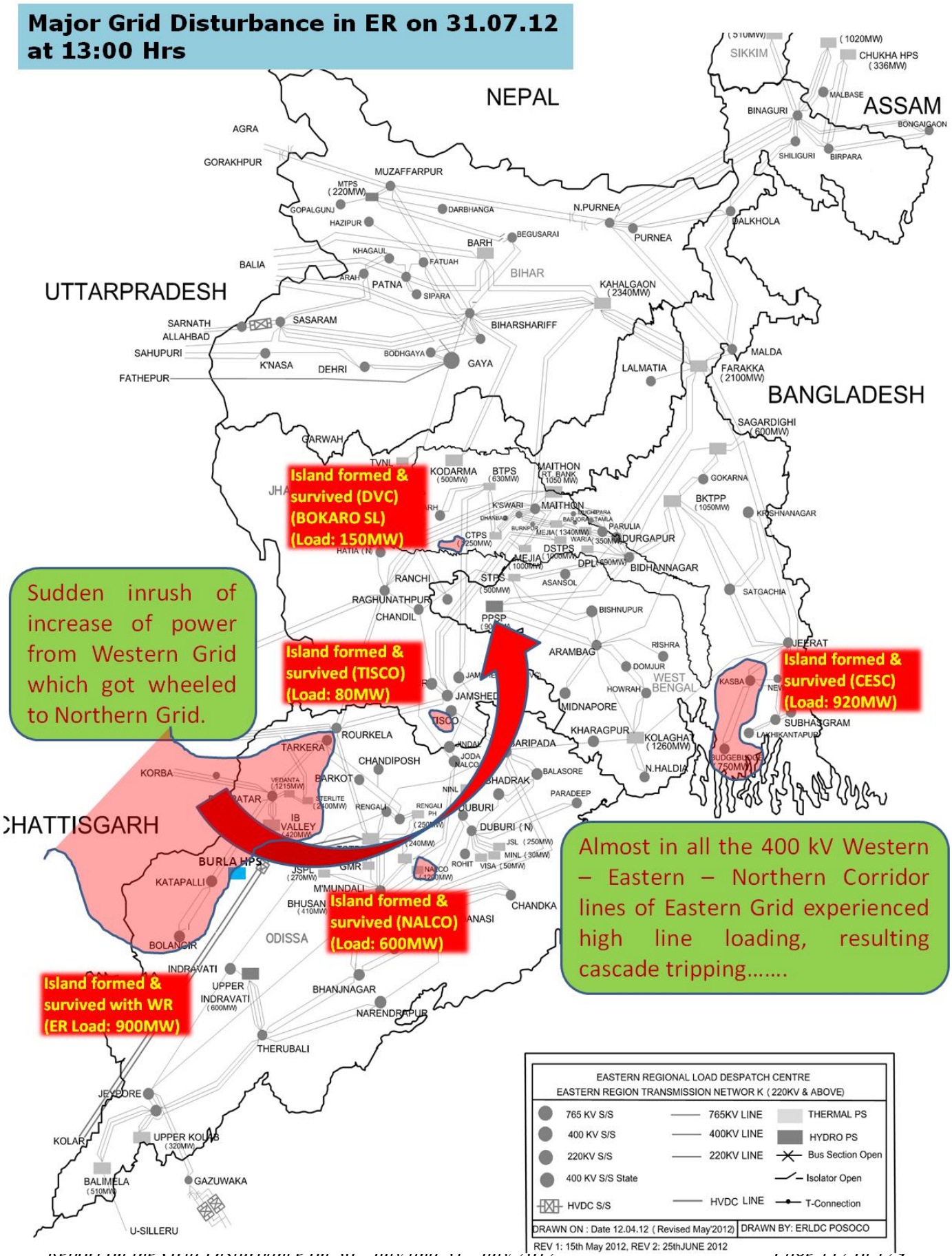
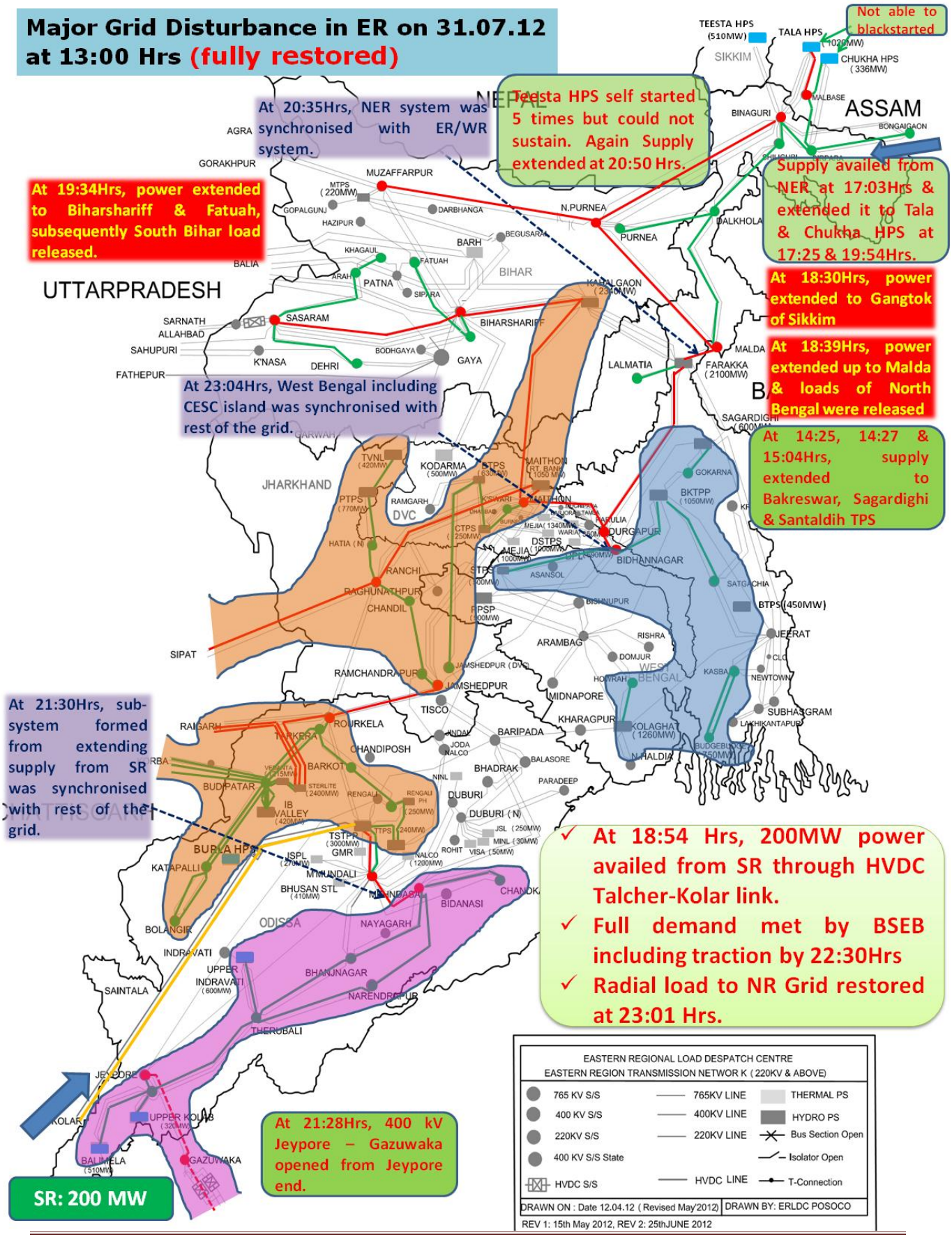


Chart 7.8

The Pictorial representation of restoration in Eastern Region is given below:




Major Grid Disturbance in ER on 31.07.12 at 13:00 Hrs
NEPAL
SIKKIM
CHUKHA HPS (336MW)
(1020MW)
ASSAM
MALBASE
BINAGURI
BONGAIGAON
SHILIGURI
BIRPARA
AGRA
GORAKHPUR
MUZAFFARPUR
MTPS (220MW)
GOPALGUNJ
DARBHANGA
N.PURNEA
HAZIPUR
PURNEA
DALKHOLA
BEGUSARAI
BARH
KHAGAUL
FATUAH
BALIA
ARAH
PATNA
BIHAR
SIPARA
KAHALGAON (2340MW)
UTTARPRADESH
SARNATH
SASARAM
BIHARSHARIFF
ALLAHBAD
SAHUPURI
BODHGAYA
MALDA
K'NASA
DEHRI
GAYA
LALMATIA
FARAKKA (2100MW)
FATHEPUR
BANGLADESH
SAGARDIGHI (600MW)
GARWAH
TVNL
KODARMA (500MW)
BTPS (630MW)
MAITHON (RT. BANK (1050 MW)
GOKARNA
Island formed & survived (DVC) (BOKARO SL) (Load: 150MW)
K'SWARI
MAITHON
BKTPP (1050MW)
KRISHNANAGAR
PARULIA
CTPS (250MW)
MEJIA (1340MW)
DURGAPUR
DSTPS
MEJIA (1000MW)
DPL (690MW)
BIDHANNAGAR
RANCHI
STPS (500MW)
ASANSOL
SATGACHIA
RAGHUNATHPUR
CHANDIL
BISHNUPUR
PPSP
Sudden inrush of increase of power from Western Grid which got wheeled to Northern Grid.
Island formed & survived (TISCO) (Load: 80MW)
ARAMBAG
RISHRA
JEERAT
DOMJUR
Island formed & survived (CESC) (Load: 920MW)
WEST BENGAL
HOWRAH
KASBA
JAMSHED
MIDNAPORE
TISCO
SUBHASGRAM
ROURKELA
KHARAGPUR
KOLAGHAT (1260MW)
LAKHIKANTAPUR
TARKERA
BARIPADA
CHANDIPOSH
JODA NALCO
KORBA
BARKOT
BALASORE
N.HALDIA
BUDGEBUDGE (750MW)
VEDANTA (1215MW)
BHADRAK
PARADEEP
STERLITE (2400MW)
RENGALI
RENGALI PH (250MW)
DUBURI
IB VALLEY (420MW)
DUBURI (N)
CHATTISGARH
JSL (250MW)
MINL (30MW)
VISA (50MW)
BURLA HPS
JSPL (270MW)
GMR
ROHIT
KATAPALLI
M'MUNDALI
BHUSAN (410MW)
Island formed & survived (NALCO) (Load: 600MW)
CHANDKA
ANASI
Almost in all the 400 kV Western – Eastern – Northern Corridor lines of Eastern Grid experienced high line loading, resulting cascade tripping…….
ODISSA
BOLANGIR
INDRAVATI
Island formed & survived with WR (ER Load: 900MW)
UPPER INDRAVATI (600MW)
BHANJNAGAR
NARENDRAPUR
THERUBALI
JEYPORE
KOLAR
UPPER KOLAB (320MW)
BALIMELA (510MW)
GAZUWAKA
U-SILLERU
EASTERN REGIONAL LOAD DESPATCH CENTRE
EASTERN REGION TRANSMISSION NETWORK (220KV & ABOVE)
765 KV S/S
400 KV S/S
220KV S/S
400 KV S/S State
HVDC S/S
765KV LINE
400KV LINE
220KV LINE
HVDC LINE
THERMAL PS
HYDRO PS
Bus Section Open
Isolator Open
T-Connection
DRAWN ON : Date 12.04.12 (Revised May'2012)
DRAWN BY: ERLDC POSOCO
REV 1: 15th May 2012, REV 2: 25thJUNE 2012


Major Grid Disturbance in ER on 31.07.12 at 13:00 Hrs (fully restored)
At 20:35Hrs, NER system was synchronised with ER/WR system.
Teesta HPS self started 5 times but could not sustain. Again Supply extended at 20:50 Hrs.
Not able to blackstarted
Supply availed from NER at 17:03Hrs & extended it to Tala & Chukha HPS at 17:25 & 19:54Hrs.
At 19:34Hrs, power extended to Biharshariff & Fatuah, subsequently South Bihar load released.
At 18:30Hrs, power extended to Gangtok of Sikkim
At 18:39Hrs, power extended up to Malda & loads of North Bengal were released
At 23:04Hrs, West Bengal including CESC island was synchronised with rest of the grid.
At 14:25, 14:27 & 15:04Hrs, supply extended to Bakreswar, Sagardighi & Santaldih TPS
At 21:30Hrs, sub-system formed from extending supply from SR was synchronised with rest of the grid.
✓ At 18:54 Hrs, 200MW power availed from SR through HVDC Talcher-Kolar link.
✓ Full demand met by BSEB including traction by 22:30Hrs
✓ Radial load to NR Grid restored at 23:01 Hrs.
At 21:28Hrs, 400 kV Jeypore – Gazuwaka opened from Jeypore end.
SR: 200 MW
NEPAL
SIKKIM
ASSAM
UTTARPRADESH
JHARKHAND
BIHAR
ODISSA
WEST BENGAL
TEESTA HPS (510MW)
TALA HPS (1020MW)
CHUKHA HPS (336MW)
BINAGURI
MALBASE
BONGAIGAON
AGRA
GORAKHPUR
MUZAFFARPUR
MTPS (220MW)
GOPALGUNJ
HAZIPUR
DARBHANGA
N.PURNEA
PURNEA
DALKHOLA
BARH
BEGUSARAI
KHAGAUL
FATUAH
BALIA
ARAH
PATNA
SIPARA
KAHALGAON (2340MW)
SARNATH
ALLAHBAD
SASARAM
BIHARSHARIFF
SAHUPURI
K'NASA
DEHRI
BODHGAYA
GAYA
FATHEPUR
MALDA
LALMATIA
FARAKKA (2100MW)
SAGARDIGHI (600MW)
GARWAH
TVNL (420MW)
KODARMA (500MW)
BTPS (630MW)
MAITHON (RB, BANK) (1050 MW)
PTPS (770MW)
RAMGARH
DVC
KSHAURI
MAITHON
GOKARNA
BKTPP (1050MW)
DURGAPUR
MEJIA (1340MW)
CTPS (250MW)
DSTPS (1000MW)
MEJIA (1000MW)
HATIA (N)
RANCHI
RAGHUNATHPUR
CHANDIL
STPS (500MW)
ASANSOL
BIDHANNAGAR
SATGACHIA
RPSP (500MW)
BISHNUPUR
BTPS (450MW)
SIPAT
ARAMBAG
RISHRA
JEERAT
DOMJUR
RAMCHANDRAPUR
JAMSHEDPUR (DVC)
JAMSHEDPUR
HOWRAH
KASBA
NEWTOWN
MIDNAPORE
TISCO
SUBHASGRAM
LAKHIKANTAPUR
KHARAGPUR
KOLAGHAT (1260MW)
RAIGARH
ROURKELA
TARKERA
BARIPADA
CHANDIPOSH
JINDAL
JODA
NALCO
N.HALDIA
BUDGEBUDGE (750MW)
RBA
BARKOTE
BHADRAK
BALASORE
VEDANTA (1215MW)
STERLITE (2400MW)
BUDIPATAR
IB VALLEY (420MW)
RENGALI (250MW)
NINL
PARADEEP
DUBURI
DUBURI (N)
JSL (250MW)
MINL (30MW)
VISA (50MW)
TSTPP (3000MW)
TTPS (240MW)
GMR
ROHIT
NALCO (1200MW)
ISPL (270MW)
BURLA HPS
KATAPALLI
MAHANADI
BHUSAN STL (410MW)
MAHINDASAL
BIDANASI
CHANDK
BOLANGIR
NAYAGARH
INDRAVATI
UPPER INDRAVATI (600MW)
BHANJNAGAR
SAINTALA
NARENDRAPUR
THEROBALI
JEYPORE
KOLAR
UPPER KOLAB (320MW)
BALIMELA (510MW)
GAZUWAKA
EASTERN REGIONAL LOAD DESPATCH CENTRE
EASTERN REGION TRANSMISSION NETWORK K (220KV & ABOVE)
765 KV S/S
400 KV S/S
220KV S/S
400 KV S/S State
HVDC S/S
765KV LINE
400KV LINE
220KV LINE
HVDC LINE
THERMAL PS
HYDRO PS
Bus Section Open
Isolator Open
T-Connection
DRAWN ON : Date 12.04.12 (Revised May'2012)
DRAWN BY: ERLDC POSOCO
REV 1: 15th May 2012, REV 2: 25thJUNE 2012

7.3 Restoration Process North Eastern Region

I. NER Grid was running in synchronism with N-E-W Grid through 220 kV Birpara – Salakati (D/C) & 400 kV Bongaigaon - New Siliguri (D/C). At 1301 hrs NER Grid along with ER & NR collapsed. NTPS of Assam survived with part of upper Assam load (around 40 MW).

II. All power stations having black start facilities were asked to be ready to start their units at the earliest as per advice from NERLDC.

III. **AGTPP black started** unit # 2 at 1302 hrs.

IV. **Extension of Startup Power to Tripura**: AGTPP extended power to Tripura at 1308 hrs though 132 kV AGTPP – Agartala-I. AGTPP power was extended to Mizoram & south Assam at 1315 hrs & 1323 hrs respectively.

V. Then, power was extended to Khliehriat (Meghalaya), Khandong (PH) & Kopili (PH) at 1334 hrs, 1326 hrs, and 1337 hrs respectively. Kopili & Khandong synchronized their units at 1408 hrs & 1412 hrs respectively.

VI. LTPS (Assam) received start up power from NTPS at 1312 hrs. At 1402 hrs 132 kV NTPS – Tinsukia was charged. LTPS extended its power to Mariani (Assam) at 1413 hrs.

VII. Meghalaya black started Umiam Stage -1 unit # 2 at 1350 hrs.

VIII. **Extension of Startup Power to Loktak**: AGTPP system extended power to Loktak at 1355 hrs through 132 kV Jiribam – Loktak II. Loktak synchronised unit # 3 at 1402 hrs.

IX. **Extension of Power to Manipur**: Loktak extended power to Manipur at 1403 hrs through 132 kV Loktak – Imphal(PG)-Imphal(S).

X. **Extension of Power to Nagaland**: Then, power was extended to Nagaland at 1418 hrs through 132 kV Imphal – Dimapur(PG) – Dimapur(s).

XI. Kopili extended power to Misa at 1413 hrs. Misa extended power to Samaguri(Assam) & Dimapur(PG) at 1422 hrs & 1427 hrs respectively. Samaguri extended power to Balipara (PG) at 1429 hrs.

XII. Again, Samaguri extended power to Sarusajai through 220 kV Samaguri – Sarusajai -I 1426 hrs.Then power was extended to Guwahati (Assam) & Langpi at 1428 hrs & 1435 hrs respectively. Langpi Unit # 1 synchronized at 1456 hrs.

XIII. Balipara extended power to Gohpur (Assam) & Itanagar (Arunachal) through 132 kV Balipara – Gohpur – Nirjuli at 1458 hrs & 1500 hrs respectively. With this 75 % of NER load was restored.

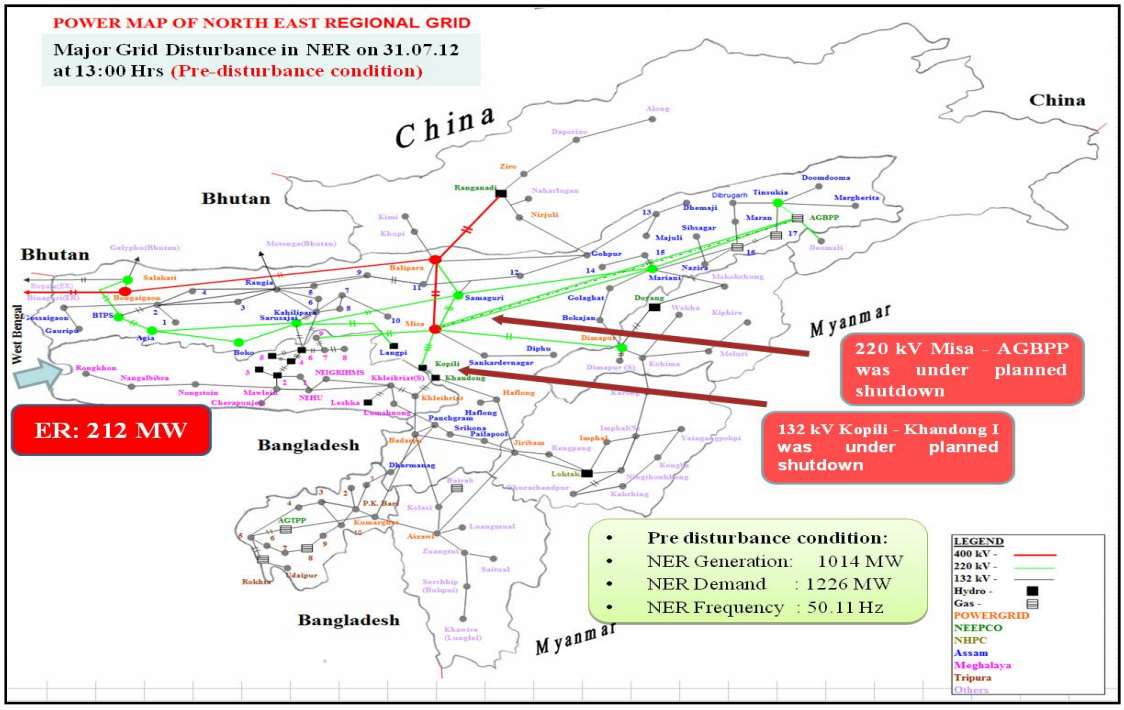
XIV. **Extension of Power to ER**: 400 kV Misa – Balipara-I was charged at 1457 hrs. 400 kV Bongigaon – Balipara I was charged at 1544 hrs. Then, 400/220 kV ICT at Bongaigaon was charged at 1546 hrs & power extended to Salakati (PG). At 1558 hrs, Power was extended to ER through 220 kV Salakati – Birpara-I.

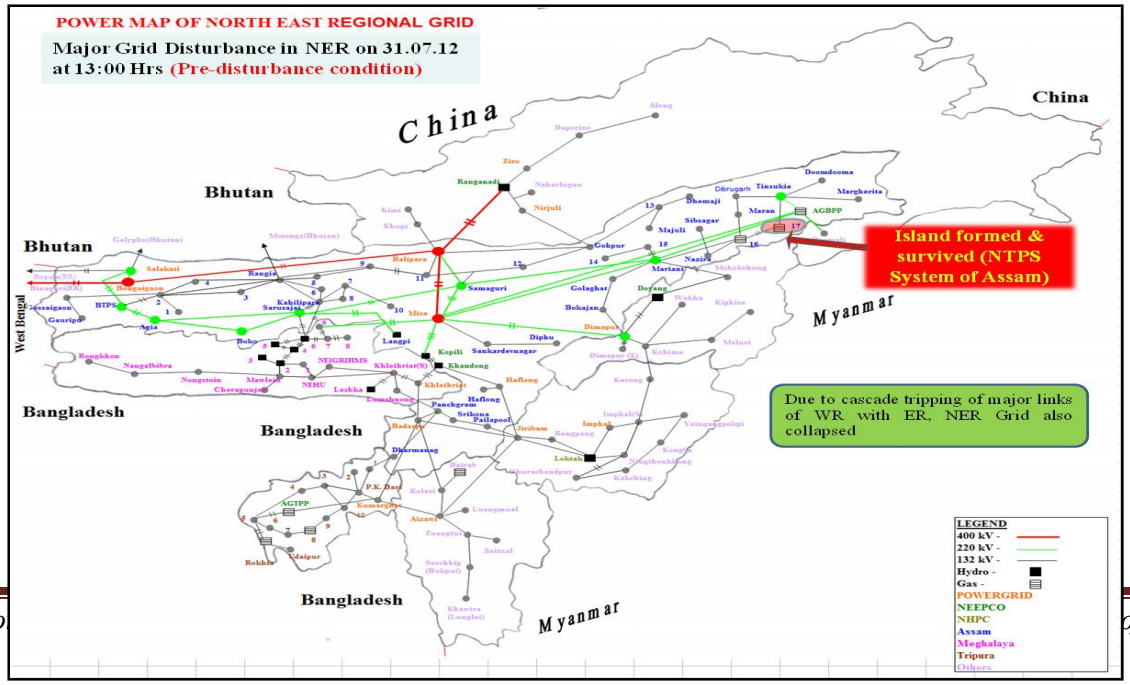
XV. **Startup Power to Ranganadi**: Startup power was extended to Ramganadi HPS by charging Balipara - Ranganadi II at 1649 hrs. Ranganadi Unit 1 was synchronized at 1715 hrs.

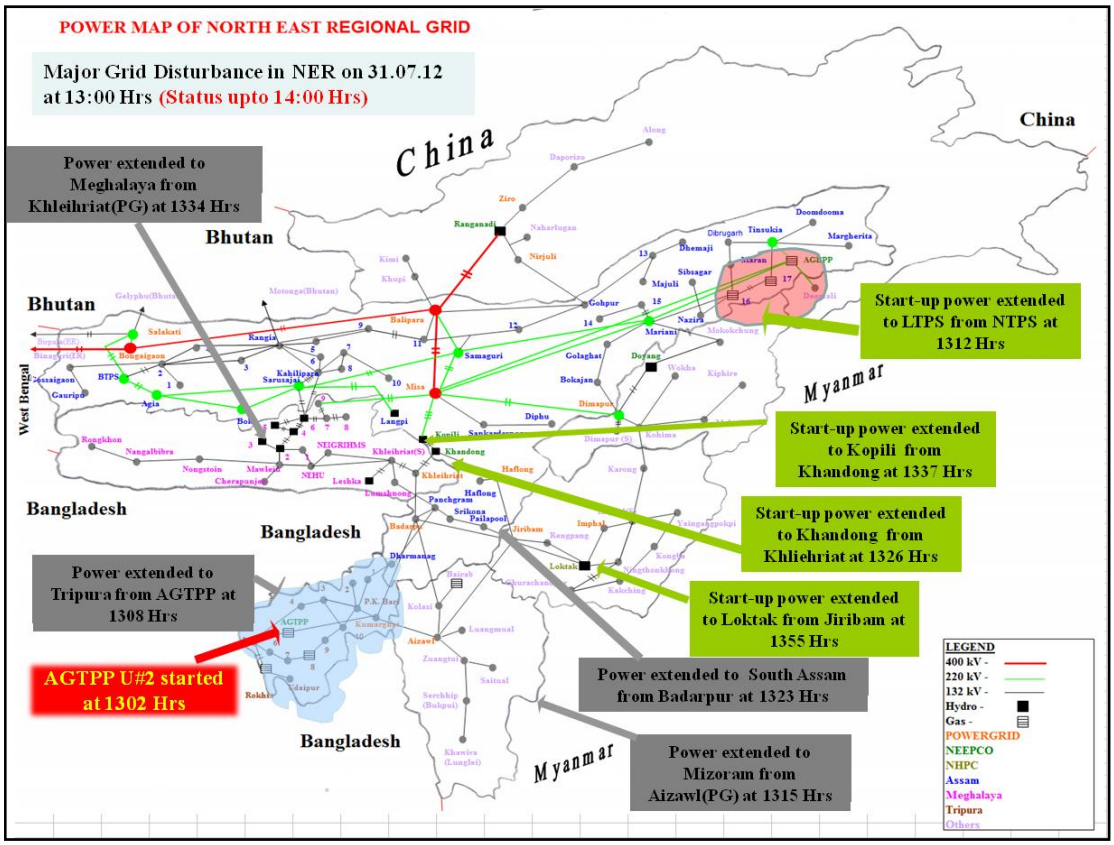
XVI. **Synchornisation of NER with rest of the system**: NER System was synchronized with ER, WR System at 20:35 hrs via 400 kV Farakka-Malda.

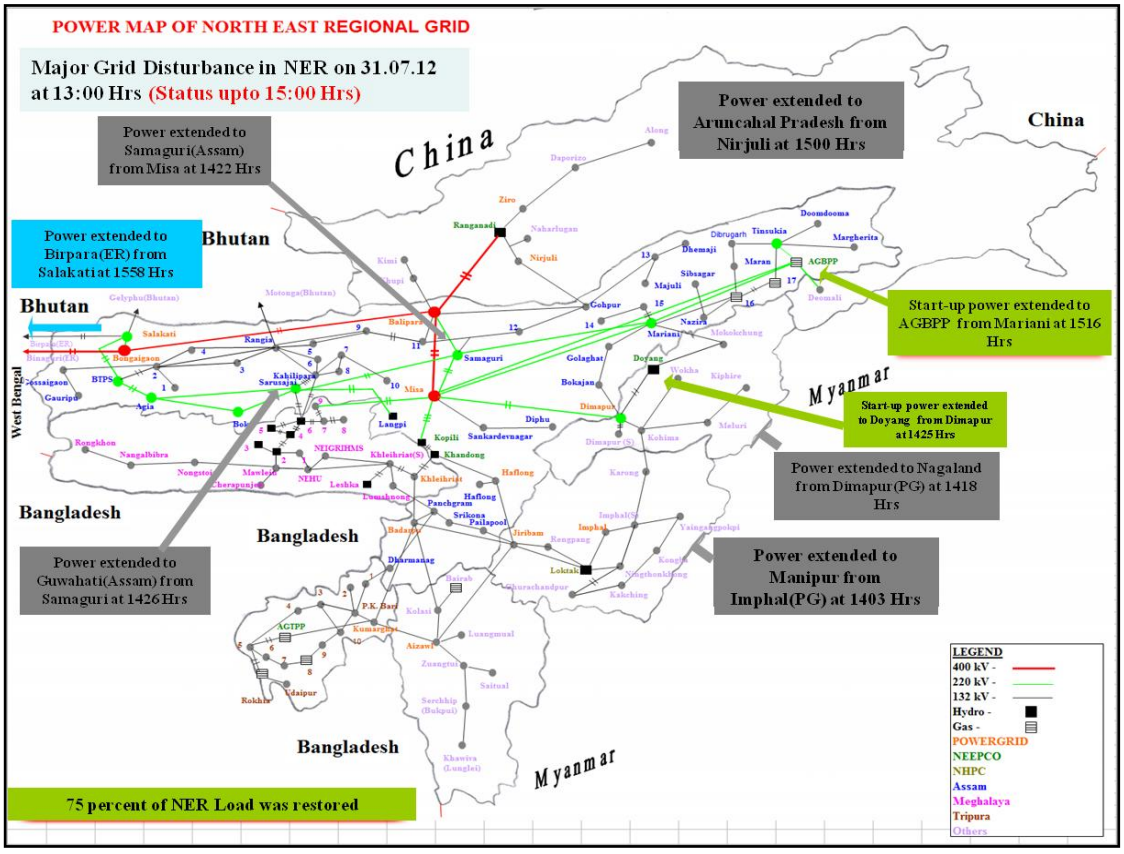
Detailed sequence of events are attached as Exhibit 7.1

Pictorial Representation of Restoration Process in North Eastern Region is given below:






POWER MAP OF NORTH EAST REGIONAL GRID
Major Grid Disturbance in NER on 31.07.12
at 13:00 Hrs (Status upto 14:00 Hrs)
China
Power extended to Meghalaya from Khleihriat(PG) at 1334 Hrs
Bhutan
Start-up power extended to LTPS from NTPS at 1312 Hrs
Myanmar
Start-up power extended to Kopili from Khandong at 1337 Hrs
Start-up power extended to Khandong from Khliehriat at 1326 Hrs
Bangladesh
Power extended to Tripura from AGTPP at 1308 Hrs
Start-up power extended to Loktak from Jiribam at 1355 Hrs
AGTPP U#2 started at 1302 Hrs
Power extended to South Assam from Badarpur at 1323 Hrs
Power extended to Mizoram from Aizawl(PG) at 1315 Hrs
LEGEND
400 kV -
220 kV -
132 kV -
Hydro -
Gas -
POWERGRID
NEEPCO
NHPC
Assam
Meghalaya
Tripura
Others


POWER MAP OF NORTH EAST REGIONAL GRID
Major Grid Disturbance in NER on 31.07.12
at 13:00 Hrs (Status upto 15:00 Hrs)
Power extended to Arunachal Pradesh from Nirjuli at 1500 Hrs
China
Power extended to Samaguri(Assam) from Misa at 1422 Hrs
Power extended to Birpara(ER) from Salakati at 1558 Hrs
Bhutan
Start-up power extended to AGBPP from Mariani at 1516 Hrs
Myanmar
Start-up power extended to Doyang from Dimapur at 1425 Hrs
Power extended to Nagaland from Dimapur(PG) at 1418 Hrs
Bangladesh
Power extended to Guwahati(Assam) from Samaguri at 1426 Hrs
Power extended to Manipur from Imphal(PG) at 1403 Hrs
75 percent of NER Load was restored
LEGEND
400 kV -
220 kV -
132 kV -
Hydro -
Gas -
POWERGRID
NEEPCO
NHPC
Assam
Meghalaya
Tripura
Others

Chapter – 8

Status of Communication and Telemetry

8.1 Communication System for Data and Voice

Wide Band Communication systems consisting of Fibre Optic System for facilitating operation of power system has been established for all the regions of the country. Some of the RTUs use Power Line Carrier Communication (PLCC) data transfer from RTU locations to the nearest wideband/control centre locations. The requirement of Communication system for Power system operation and maintenance has increased with the advent of Special protection Schemes, PMU, Wide Area Measurement Technology and requirement for Remote Operation.

The backbone communication network is being provided and maintained by CTU which is primarily based on fiber optic communication. The last mile connectivity is being provided by PLCC communication. Apart from the above, other communication media such as VSAT, GPRS, and leased lines are also being used.

Availability of communication system is essential for data availability at the Control Center. Further, voice communication is also essential. The reliability of data transmission to the RLDCs depends on the availability of redundant channel and the route diversity provided in the communication network. The route diversity ensures availability of data in case of outage of wideband route. Redundant communication channels are needed as failure of the single communication channel leads to data interruption to the RLDCs. However, in the present setup a number of RTUs are integrated through single link.

During the period of the grid disturbance, data from some of the RTUs became non-current for reasons attributable to communication failure after the grid disturbance.

8.2 Power System Visualization and Situational Awareness

Visualization tools and techniques provide the vital inputs to the operator for assessment of the situation and taking remedial measures. The focus is on identification and resolution of the problem with speed and accuracy. Data converted into information must be presented to the operator in a meaningful way, which facilitates easy comprehension, assimilation of the existing situation and facilitates quick response. It is in an emergency or contingent situation that the real importance of the visualization tools is felt as compared to the peacetime scenario.

The RLDCs and NLDC are provided with SCADA systems which have a hierarchical structure of reporting from the RTUs to the Control Center i.e., RTU – Sub-LDCs – SLDCs – RLDCs – NLDC. RTUs installed at CTU substations report directly to the concerned RLDC. The users (Transcos, Gencos including IPPs/MPP, state utilities and others) are responsible for provision of data and voice communication for their respective areas of responsibility.

It may also be appreciated that the Indian Electricity Grids have become large interconnection and the System Operator in the Control Center needs appropriate tools in real time to perform the dispatch functions effectively. Non-availability of the SCADA data including absence of status data also results in the operator's inability to run tools such as the State Estimator, Contingency Analysis and other tools which are designed to assist him the operation of the grid. It is pertinent to mention here that given the large percentage of data which is not available to the System operator, none of the above mentioned tools give satisfactory results.

8.3 SCADA Data Availability at Control Centres (NLDC/RLDCs) on 30th July and 31st July 2012

Non-availability of the SCADA data leads to incomplete visualization and situational awareness for the system in the control center. Further, at the time of restoration, this also results in delays in the restoration process.

The summary of the status of the data availability before the grid disturbances on the 30th and the 31st July 2012 is given below in Table – 1.

Table – 1: Stations not visible (non-current) prior to disturbance

Control Centre	Date	Total Integrated	Central Sector	State Sector	Total	%age not visible
NRLDC	30.07.12	426	25	66	91	21%
	31.07.12		21	78	99	23%
ERLDC	30.07.12	232	6	82	88	38%
	31.07.12		4	69	73	31%
NERLDC	30.07.12	88	-	28	28	32%
	31.07.12		0	29	29	33%
WRLDC	30.07.12	84	6	1	7	8%
	31.07.12		8	0	8	10%

The summary of the status of the data availability after the grid disturbances on the 30th and the 31st July 2012 is given below in Table – 2.

Table – 2: Stations not visible (non-current) after disturbance

Control Centre	Date	Total Integrated	Central Sector	State Sector	Total	%age not visible
NRLDC	30.07.12	426	45	233	278	65%
	31.07.12		42	239	281	66%
ERLDC	30.07.12	232	13	89	102	44%
	31.07.12		12	82	94	41%
NERLDC	30.07.12	88	-	28	28	32%
	31.07.12		7	49	56	64%
WRLDC	30.07.12	84	7	3	10	12%
	31.07.12		9	1	10	12%

The details of the status of the telemetry/data availability before and after the grid disturbances are attached at Exhibit 8.

8.4 Data Availability from PMUs in NR and WR

Nine PMUs are installed in the Northern Region, three PMUs are installed in Western Region and three PMUs are installed in Southern Region. Data from all PMUs was available except from Vindhyachal and Agra, where PMU data was not received at NRLDC due to communication issues.

In the near future, more and more PMUs would get installed and communication would be a key to ensure data availability at the Control Center.

8.5 Expanding Grids and Urgent Need for Coordinated Planning and Implementation of Communication Infrastructure

The power system is expanding at a fast rate and new generation and transmission infrastructure is being commissioned. Further, with the restructuring of the power sector many new entities are entering the arena specially a large number of private sector participants. Visualization and analysis of the results of advanced applications such as Contingency Analysis, Optimal Power Flow, etc. is extremely important considering the large volume of data. As the complexity and the size of the power system continue to grow, it would be necessary to adopt advanced visualization tools and techniques to visualize the large amount of power system data.

As per Para 4.6.2 of IEGC 2010, the associated communication system to facilitate data flow up to appropriate data collection point on CTU's system shall also be established by the

concerned user or STU as specified by CTU in the connection agreement. Many stations are coming up without putting in place proper voice and data communication infrastructure.

There is also a need for a comprehensive institutional mechanism regarding planning, implementation, up-gradation, operation & maintenance, resource & cost sharing of a high capacity, fast & reliable communication system for power sector. In view of fast technological advancements in communication, the life of the equipment is less, particularly in terms of spares and services availability.

Considering the difficulties being faced in visualization of the power system and the usage of the SCADA/EMS tools, all the RLDCs have filed petitions before CERC form time to time seeking directions to the users to provide telemetry to the RLDCs for visualization of the Power System.

CHAPTER-9

SUBMISSION

9.1 Two consecutive Grid Disturbances that occurred on 30th and 31st July 2012 affected the power supply across large parts of the Northern, Eastern and North eastern grid in India. The underlying causes and the suggested measures to avoid its re-occurrence are discussed below:

9.2 Skewed load generation balance across the regional grids

The load generation scenario in the synchronous Northeast-East-West-North (NEW) grid was highly skewed in the month of July. There was spurt in agricultural/weather beating demand in Northern Region (NR) on account of failure of South West monsoon, large gap between requirement and availability on account of high demand growth and aspiration to meet more customer load. On the other hand there was surplus condition in the Western Region (WR) due to high generation availability and heavy under drawal by the constituents of WR. This unscheduled interchange resulted in heavy power flow towards the Northern region from Western and Eastern Region in the antecedent conditions. The large quantum of power flow from WR to ER in real-time was opposite to the power flow from ER to WR envisaged in planning time horizon.

In order to address the above, adequacy norms for regional as well as State control area for all scenarios are important to reduce the security threat arising from such skewed dispatch scenario.

9.3 Grid indiscipline

The Regulations allow deviations from the schedule as long as the operating parameters are within the prescribed standards. There have been occasions when the utilities have continued to overdraw/ under inject even at low frequency or over generate/ under draw at high frequency. The various instances of grid indiscipline in the form of non-compliance of various provisions of the IEGC and the directions of RLDCs have been brought to the notice of the Hon'ble CERC in the form of petitions. The Hon'ble Commission has imposed penalties in large number of case. Yet the problem of grid indiscipline continues to be a large concern. On 30th July 2012 at 02:30 hrs, just before the disturbance the under drawal/over injection by the constituents of Western Region and the overdrawal by the constituents of Northern Region was as under:

Western Region constituents	Under drawal / Over injection		Northern Region constituents	Overdrawal
Madhya Pradesh	876 MW		Uttar Pradesh	861 MW
Gujarat	799 MW		Haryana	518 MW
Maharashtra	517 MW		Punjab	325 MW
Chattisgarh	104 MW		Uttarakhand	161 MW
Korba STPS	166 MW			
Sipat STPS	398 MW		(all figures based on SCADA)	

Similarly on 31st July 2012 at 12:57 hrs, just before the disturbance the under drawal/over injection bythe constituents of Western Regionand the overdrawal by the constituents of Northern Region was as under:

Western Region constituents	Under drawal / Over injection		Northern Region constituents	Overdrawal
Gujarat	1063 MW		Haryana	1270 MW
Maharashtra	698 MW		Rajasthan	762MW
Chattisgarh	373 MW		Uttarakhand	179 MW
Korba STPS	187 MW		Uttar Pradesh	99 MW
Kawas GPS	152 MW			
Sipat STPS	429 MW			
Gandhar GPS	104 MW		(all figures based on SCADA)	

The underdrawal/over injection by the Western Region constituents and the over drawal by the Northern Region constituents continued despite several appeals and directions to restrict the deviation from schedule by the utilities indulging in grid indiscipline.Thus grid indiscipline was a major cause for both the grid disturbances.

Grid discipline is of paramount importance and needs to be adhered to by all Users.

9.4 Depleted reliability margins

In a large system random tripping of one or more elements may occur dynamically. The reduction in the available reliability margins due to the contingencies are difficult to assess and it may take some time to recoup it by suitable generation re dispatch/load shedding.

On 30th July, 400 kV Bina-Gwalior-Agra-II was under planned shutdown, while 400 kV Zerda-Kankroli was taken under emergency shutdown. On 31st July also 400 kV Bina-Gwalior-Agra-II was under planned shutdown, and subsequently 400 kV Zerda-Kankroli and Zerda-Bhinmal went under forced outage. This resulted in significant reduction in reliability margins.

The NEW grid is a large meshed network of around 150 GW installed capacity and it is proposed to be synchronised with the Southern Regional grid of around 50 GW installed capacity in the near future. In a small system, the impact of outage / contingencies is limited to a small area. As per provision of Clause 4(j) of NLDC Rules, NLDC has been giving feedback to planners at regular intervals. In the feedback dated 14.7.2011, it had been suggested to follow n-1-1 criteria instead of n-1 criteria followed now.

Thus in fast developing large system,N-G-1 / N-1-1 contingency criteria may be considered to secure the system even under extreme dispatch.

9.5 **Failure of Defense mechanisms**

In both the grid disturbances, failure of defence mechanisms/safety net in the form of load shedding schemes through Under Frequency Relays, Rate of change of frequency relays and islanding schemes in the Northern and Eastern Region were observed. The approved self-healing mechanisms in the form of System Protection Schemes envisaged to take care of the contingency of 400 kV Gwalior-Agra was yet to be implemented.

These defense mechanisms are extremely important and need to be provided at all strategic locations.

9.6 Absence of Primary Response from generators

During the grid disturbance on 30th July 2012, the frequency in the 41 GW of the combined Western/Eastern/North-eastern grid that separated from the Northern Region increased to 50.95 Hz. Similarly during the grid disturbance on 31st July 2012, the frequency of the 28 GW of the Western Region rose to 51.4 Hz. Thus the absence of the primary response from the generators was evident in both the grid disturbances. On both the days any further rise in frequency could have caused blackout due to cascade tripping of generators even in the areas that survived.

Therefore the mandatory primary response by the generators needs to be enforced urgently.

9.7 Insufficient visibility and situational awareness at the Load Despatch Centres

Visualization and situational awareness at the Load Despatch Centres in the antecedent condition as well as during restoration was severely constrained owing to non-availability of real time data at the Load Despatch Centres from a large number of locations. The State Estimator and other EMS applications such as contingency evaluation etc. also could not be run due to SCADA related deficiencies. The respective Regional Load Despatch Centres have filed petition before the Hon'ble CERC for maintaining the data telemetry and communication facilities in line with the Indian Electricity Grid Code, Grid Standards and other Regulations issued by the Commission and the efforts towards upgradation of the existing SCADA/EMS systems are underway. Similarly efforts are being made to provide wide area visibility along with the associated applications at the Load Despatch Centre with the help of Phasor Measurement Unit (PMU) based Synchrophasor technology.

Further thrust is required to enhance the visibility and situational awareness at all levels.

9.8 Inadequate appreciation of Transfer Capability vis-a-vis transmission capacity

Ever since the formation of the synchronous NEW grid in August 2003, concerns have been expressed by most of the stakeholders regarding the difference in the transfer capability vis-a-vis the transmission capacity and the legitimacy of reliability margins. The process of transfer capability assessment helps in envisaging the transmission constraints for the scheduled power flows in the operating time horizon. However the constraints arising from the Unscheduled Interchanges are difficult to forecast and foresee.

As a part of the assessment of transfer capability the operating limits of the various transmission facilities are computedby RLDCs/NLDC and compared with the power flows arising from the anticipated scenario. Requests for scheduling Open Access transactions at the inter-State level are approved only if there are margins in the system. Similar mechanisms are required to be in place at the planning as well as at intra State level by the SLDCs as per the procedures. During the antecedent conditions of both the grid disturbances, the loading of transmission lines was below the thermal limit.

The operators were concerned on increase in the loading of the WR-NR inter regional link owing to the depleting transmission and large unscheduled interchange by utilities. Congestion charge for alleviation of congestion in real time could have been invoked but for the limiting provisions in para 5.4 of the Procedure for Relieving Congestion in Real Time Operations. Therefore as per the regulation 6.4.12 in case of overloading of lines, the NLDC/RLDCs were giving directions to curtail deviations from schedule. However even as the collective actions taken for curtailment of the overdrawl in the Northern Region and reduction of injection in the Western Region were being taken, multiple contingencies occurred in a short span of time.

In a large system, the adequate appreciation of the transfer capability is essential at all control centres.

9.9 Inadequate Dynamic Reactive Reserves

When lines operate beyond surge impedance loading, reactive power is consumed by the line and voltage drops. High MW flow, coupled with MVAR loss/flow in the line, leads to low voltage and high current. This may cause load encroachment in the relays, i.e. normal load may be seen as fault and tripping of lines would be a surprise in real-time operation. On both the occasions, i.e. on 30th and 31st July 2012, there was high loading on WR-NR corridor, especially 400 kV Bina-Gwalior, which was carrying more than SIL rating and this led to low voltages at the Gwalior end in the event of high line loading.

Dynamic reserve can be provided by generators or SVCs. At present only 2 SVCs of $\pm$140 MVAR capacity are available at Kanpur substation. In order to take care of contingencies like fault, high line loading, large load throw-off, dynamic reactive reserve is required at strategic locations in the grid. Feedback in this regard had been sent to CEA and CTU by NLDC vide letter dated 24.6.2010.

9.10 Performance of the Protection System

Under stressed network conditions, proper behavior of protective systems installed on transmission lines and generating units are vital. However in actual practice there are instances where settings of relays are corrected/changed with change in the fast expanding network.

However, a thorough audit of protective systems and encompassing all related areas is urgently required.

9.11 Impediments to the Speedy Restoration of Systems

Restoration was taken up post grid disturbance as per the procedures. However difficulties were experienced on account of constraints in extension of start-up supply, difficulties in black start, load generation-imbalance, reactive energy imbalance, failure of built up subsystems/islands, deficiencies in communication, inadequate telemetry and inadequate reactive resources.

Renewed emphasis on mock trial of the contingency plans may be given.

9.12 Distortions arising from existing Regulations for grant of connectivity

The existing provisions in the regulations for (Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and related matters) permitting connectivity to the grid even without identification of beneficiaries at the time of application are resulting in unforeseen power flows across the synchronous grid. This coupled with unrestricted injection / drawal as Unscheduled Interchange (UI) within the IEGC frequency band results in large difference in power flow in real-time as compared to what was envisaged during planning stage and thereby results in critical loading of the transmission that endangers grid security.

Further large capacity dedicated lines built within the meshed system without adequate redundancies could endanger grid security.

The distortions discussed above need to be suitably addressed.

9.13 Excessive reliance on unscheduled interchange rather than organized markets

Unlike power purchase through Short Term Open Access, Medium Term Open Access or Long Term Access, payment can be delayed in case of drawal in the form of Unscheduled Interchange. Though there is provision of Letter of Credit (LC), many of the utilities have not opened LC. As a consequence, some utilities prefer to draw power from the grid in the form of Unscheduled Interchange rather than availing power from organized market through long term, medium term and short term contracts without much consideration to the grid security. Suitable deterrent mechanism needs to be put in place measures to discourage such exploitation of the UI mechanism and bring about financial discipline.

Under the present regulations there is no cap on the volume of Unscheduled Interchange as long as the frequency is within the stipulated operating range. In the antecedent conditions of both the grid disturbances, the efforts to curtail deviations from schedule failed to bring about the desired results probably because the frequency was within the stipulated operating range. Thus the prevailing mechanism of Unscheduled Interchange may be reviewed to address the security concerns emerging from the growth in the size of the synchronous interconnection and the behaviour of the market participants in the existing market design in India.

9.14 Tightening of the stipulated range for Grid Frequency

As per the Clause 5.2(m) of the CERC (Indian Electricity Grid Code) Regulations, 2010 the prevailing stipulated range for grid frequency in India is 49.5-50.2 Hz. In view of the security threats arising from large variation in trans-regional power flow for a small variation in grid frequency the CERC (Indian Electricity Grid Code) (First Amendment) Regulations, 2012 envisaged tightening of the permissible range of frequency to 49.7-50.2 Hz. However, the above Regulation has been stayed by the Hon'ble Madras High Court and is being agitated at the Hon'ble Supreme Court.

The Central Advisory Committee in its 16th meeting held on 14th March 2012 had also opined that the higher range of permissible frequency could be reduced from the existing 50.2 Hz to 50.1 Hz. Thus the permissible range of the operating grid frequency should be narrowed to 49.8 Hz to 50.1 Hz and subsequently tightened to 49.9 Hz to 50.1 Hz with a step of 0.01 Hz prior to the synchronization of Southern Regional grid with NEW grid.

The larger integrated grid has a huge power number, i.e. the change in frequency even for a large change in Load or Generation is small. This situation may lead to dangerously high line loading at far end in case of contingencies like tripping of generating units, as the State utilities operate the grid with limited visibility of the State network and system frequency. This situation may end up with major grid disturbance if the frequency band is wider. Even in the present scenario, some of the critical transmission lines / transformers are loaded to such a level that any incremental loading due to contingencies may lead to cascade tripping. The State utilities continue to draw more just by keeping the minimum mandated frequency level as reference for their demand management.

The narrowing of the frequency band would be a step towards ensuring secure grid operation and quality of power. Most of the large power systems in the world operate at near constant frequency and only very small deviations are allowed. In India, looking into the huge mismatch between generation and demand, more deviation was allowed earlier;

especially when grids were not integrated and size was relatively smaller. With regional grid being inter-connected and grid sizes increasing steadily, it is necessary to tighten the frequency band for secure grid operation.

9.15 Institutional issues

Ensuring integrated operation is a collective responsibility. The strengthening of Load Despatch Centres in terms of adequacy and competence of manpower as well as availability of suitable tools would enhance the effectiveness and efficiency of Load Despatch Centres. While several initiative are being taken for empowerment of the Load Despatch Centres, the grid disturbance has emphasized the need for a greater thrust at institutional capacity building of the Load Despatch Centres in India.

9.16 Actions taken after grid disturbances to ensure secure operation

Following actions have been taken up post grid disturbance to ensure secure operation

1. Special Protection Scheme to shed load in Northern Region in case of loss of injection from Gwalior through 400 kV Agra-Gwalior lines has been implemented.
2. In a meeting taken by Secretary (Power) on 31.7.2012 at NLDC, it was decided that transfer capability of inter-regional links and other critical links would be reviewed in consultation with CEA and CTU and implemented within 24 hours. Accordingly, assessment of Transfer capability based on SIL limits of the lines instead of stability limit evaluated from St Clair's curve or thermal limit depending on the line length has been implemented and has been uploaded on the website of NLDC.
3. 765 kV Bina-Gwalior-Agra-II (charged at 400 kV), was under shutdown at the time of disturbance. The line has since been restored on 7.8.2012.
4. Extensive audit of protection system has been initiated. List of sub-stations where protection audit is to be undertaken on priority basis has been prepared.
5. Zone-III setting of 400 kV Bina-Gwalior-Agra has been modified to minimize load encroachment in case of low voltage conditions.
6. Utilities/generators are being asked not to deviate from schedule irrespective of system frequency.
7. A meeting of States had been convened by Ministry of Power on 6th August 2012 where the following resolutions were adopted:
    a. Adequate defense plans and protection system shall be put in place to ensure integrated operation of the National/ Regional Grids in adherence with the Indian Electricity Grid Code (IEGC). All the states shall ascertain preparedness of power system defense plans and cooperate at the Regional level for coordinating their Protection systems.

b. Defense plans of the states must include islanding schemes, under frequency relays, rate of change of frequency relays, special protection schemes and automatic demand management schemes. The defense plans shall also include restoration procedures that shall be updated and reviewed regularly.
c. States will prepare their islanding schemes in consultation with PGCIL, CEA and NRPC within the next 3 months and ensure their implementation within the next 6 months.
d. Independent third party audit of the protection systems shall be carried out within 1 month and the Regional Power Committees (RPCs) shall monitor the same. PGCIL would fund and carry out the audit in the first instance.
e. All the utilities shall also adopt good operation and maintenance practices and random checks of these shall be carried out by the Regional Power Committees.
f. States shall prepare plans in long term, medium term and short term horizons for procurement of power, network and demand management in accordance with the Indian Electricity Grid Code (IEGC), which shall be reviewed by the RPCs.
g. States shall carry out periodically Power system studies for operation planning and Transfer Capability determination. PGCIL would assist the states in this regard.
h. States shall take all necessary steps for strengthening and upgrading the State Load Despatch Centres and training of system operators. There should be manpower capacity building by way of training and certification.
i. The personnel manning the LDC control rooms should be equipped with proper tools to facilitate the discharge of the functions. Appropriate compensation structure, including Certification linked incentive scheme must be designed to attract and retain best talent in the field of system operations.
j. The States requested that Government of India may draw up a scheme for supporting the states in strengthening their SLDCs and for capacity building.
k. POSOCO would evolve a contingency load shedding protocol, especially when non frequency related load shedding is required.
l. All States resolved to adhere to the Indian Electricity Grid Code (IEGC) and take all requisite measures for its effective enforcement. It was agreed that all instructions of NLDC / NRLDC will be implemented immediately by SLDCs without waiting for further instructions from any other authority.