REPORT OF THE ENQUIRY COMMITTEE

ON

GRID DISTURBANCE

IN NORTHERN REGION

ON 30th July 2012

AND

IN NORTHERN, EASTERN & NORTH-EASTERN REGION

ON 31st JULY 2012

16th AUGUST 2012
NEW DELHI

ACKNOWLEDGEMENT

The committee gratefully acknowledges the efforts put in by all assisting members to the enquiry committee namely :

a. Shri R. N. Nayak, CMD, POWERGRID
b. Shri S. K. Soonee, CEO, POSOCO
c. Shri Balvinder Singh, IPS Retired.

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(i) Shri Manjit Singh, Member (Thermal), CEA
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(iii) Dr. Anil Kulkarni, IIT-B, Mumbai,
(iv) Shri Ajit Singh, Ex-Addl. Secretary, Cabinet Secretariat
(v) Shri R.K. Verma, Chief Engineer I/c (DP&D), CEA
(vi) Shri Dinesh Chandra, Chief Engineer (I/C), GM Div., CEA
(vii) Shri Ajay Talegaonkar, SE (Operation), NRPC
(viii) Shri S. Satyanarayan, SE (Operation), WRPC,
(ix) Shri D. K. Srivastava, Director, GM Div., CEA

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Supplementary Volume:

A separate volume containing the relevant DR outputs during the grid disturbances on 30th and 31st July, 2012.

GLOSSARY:

ABT:	Availability Based Tariff
ATC:	Available Transfer Capacity
AUFLS:	Automatic Under Frequency Load Shedding
BLU:	Boiler Light Up
BTPS:	Badarpur Thermal Power Station
CB:	Circuit Breaker
CEA:	Central Electricity Authority
CERC:	Central Electricity Regulatory Commission
CESC:	Calcutta Electric Supply Company
CTU:	Central Transmission Utility
D/C:	Double Circuit
DMRC:	Delhi Metro Rail Corporation
DR:	Disturbance Recorder
df/dt:	Rate of change of frequency with time
EL:	Event Logger
ER:	Eastern Region
FGMO:	Free Governor Mode of Operation
FSC:	Fixed Series Compensation
GPS:	Gas Power Station
GT:	Gas Turbine
HVDC:	High Voltage Direct Current
MERC:	Maharashtra Electricity Regulatory Commission

NAPS:	Narora Atomic Power Station
NER:	North-Eastern Region
NR:	Northern Region
PMU:	Phasor Measurement Unit
PLCC:	Power Line Carrier Communication
POSOCO:	Power System Operation Corporation Ltd.
POWERGRID	Powergrid Corporation of India Ltd
PPA:	Power Purchase Agreement
PSS:	Power System Stabilizer
RAPP:	Rajasthan Atomic Power Plant
RPC:	Regional Power Committee
RLDC:	Regional Load Despatch Centre
SCADA:	Supervisory Control and Data Acquisition System
SIL:	Surge Impedance Loading
SR:	Southern Region
STOA:	Short Term Open Access
SVC:	Static VAR Compensator
TTC:	Total Transfer Capability
TCSC:	Thyristor Controlled Series Compensation
UI:	Unscheduled Interchange (under ABT)
VAR:	Volt Ampere Reactive
WAFMS:	Wide Area Frequency Measurement System
WR:	Western Region

EXECUTIVE SUMMARY

There was a major grid disturbance in Northern Region at 02.33 hrs on 30-07-2012. Northern Regional Grid load was about 36,000 MW at the time of disturbance. Subsequently, there was another grid disturbance at 13.00 hrs on 31-07-2012 resulting in collapse of Northern, Eastern and North-Eastern regional grids. The total load of about 48,000 MW was affected in this black out. On both the days, few pockets survived from black out. Ministry of Power constituted an Enquiry Committee, to analyse the causes of these disturbances and to suggest measures to avoid recurrence of such disturbance in future.

The Committee analysed the output of Disturbance Recorders (DR), Event loggers (EL), PMUs, WAFMS, SCADA data and reports submitted by various SLDCs , RLDCs /NLDC, POWERGRID and generation utilities to arrive at the sequence of events leading to the blackouts on 30th July, 2012 and 31st July 2012. The Committee also interacted with POWERGRID and POSOCO on various aspects of these grid disturbances. Some teams also made field visits to sub-stations, generating stations, NRLDC, NLDC, UPSLDC and Haryana SLDC.

The Committee is of the opinion that no single factor was responsible for grid disturbances on 30th and 31st July 2012. After careful analysis of these grid disturbances, the Committee has identified several factors, which led to the collapse of the power systems on both the days, as given below:

Factors that led to the initiation of the Grid Disturbance on 30th July, 2012

a. Weak Inter-regional Corridors due to multiple outages: The system was weakened by multiple outages of transmission lines in the WR-NR interface. Effectively, 400 kV Bina-Gwalior-Agra (one circuit) was the only main AC circuit available between WR-NR interface prior to the grid disturbance.

b. High Loading on 400 kV Bina-Gwalior-Agra link: The overdrawal by some of the NR utilities, utilizing Unscheduled Interchange (UI), contributed to high loading on this tie line.
c. Inadequate response by SLDCs to the instructions of RLDCs to reduce overdrawal by the NR utilities and underdrawal/excess generation by the WR utilities.
d. Loss of 400 kV Bina-Gwalior link: Since the interregional interface was very weak, tripping of 400 kV Bina-Gwalior line on zone-3 protection of distance relay caused the NR system to separate from the WR. This happened due to load encroachment (high loading of line resulting in high line current and low bus voltage). However, there was no fault observed in the system.

Factors that led to the initiation of the Grid Disturbance on 31st July, 2012

(i) Weak Inter-regional Corridors due to multiple outages: The system was weakened by multiple outages of transmission lines in the NR-WR interface and the ER network near the ER-WR interface. On this day also, effectively 400 kV Bina-Gwalior-Agra (one circuit) was the only main circuit available between WR-NR.

(ii) High Loading on 400 kV Bina-Gwalior-Agra link: The overdrwal by NR utilities, utilizing Unscheduled Interchange (UI), contributed to high loading on this tie line. Although real power flow in this line was relatively lower than on 30th July, 2012, the reactive power flow in the line was higher, resulting in lower voltage at Bina end.

(iii) Inadequate Response by SLDCs to RLDCs' instructions on this day also to reduce overdrawl by the NR utilities and underdrawal by the WR utilities.

(iv) Loss of 400 kV Bina-Gwalior link: Similar to the initiation of the disturbance on 30th July, 2012, tripping of 400 kV Bina-Gwalior line on zone-3 protection of distance relay, due to load encroachment, caused the NR system to separate from the WR system. On this day also the DR records do not show occurrence of any fault in the system.

Brief Sequence of Events leading to the Grid Collapse on 30th and 31st July 2012

(i) On 30th July, 2012, after NR got separated from WR due to tripping of 400 kV Bina-Gwalior line, the NR loads were met through WR-ER-NR route, which caused power swing in the system. Since the center of swing was in the NR-ER interface, the corresponding tie lines tripped, isolating the NR system from the rest of the NEW grid system. The NR grid system collapsed due to under frequency and further power swing within the region.

(ii) On 31st July, 2012, after NR got separated from the WR due to tripping of 400 kV Bina-Gwalior line, the NR loads were met through WR-ER-NR route, which caused power swing in the system. On this day the center of swing was in the ER, near ER-WR interface, and, hence, after tripping of lines in the ER itself, a small part of ER (Ranchi and Rourkela), along with WR, got isolated from the rest of the NEW grid. This caused power swing in the NR-ER interface and resulted in further separation of the NR from the ER+NER system. Subsequently, all the three grids collapsed due to multiple tripping attributed to the internal power swings, under frequency and overvoltage at different places.

(iii) The WR system, however, survived due to tripping of few generators in this region on high frequency on both the days.

(iv) The Southern Region (SR), which was getting power from ER and WR, also survived on 31st July, 2012 with part loads remained fed from the WR and the operation of few defense mechanism, such as AUFLS and HVDC power ramping.

(v) On both the days, no evidence of any cyber attack has been found by the Committee.

Measures that could have saved the system from collapse:

In an emergency system operating condition, such as on 30th and 31st July 2012, even some of the corrective measures out of the list given below might have saved the system from the collapse.

(i) Better coordinated planning of outages of state and regional networks, specifically under depleted condition of the inter-regional power transfer corridors.

(ii) Mandatory activation of primary frequency response of Governors i.e. the generator's automatic response to adjust its output with variation in the frequency.

(iii) Under-frequency and df/dt based load shedding relief in the utilities' networks.

(iv) Dynamic security assessment and faster state estimation of the system at load despatch centers for better visualization and planning of the corrective actions.

(v) Adequate reactive power compensation, specifically Dynamic Compensation.

(vi) Better regulation to limit overdrawal/underdrawl under UI mechanism, specifically under insecure operation of the system.

(vii) Measures to avoid mal-operation of protective relays, such as the operation of distance protection under the load encroachment on both the days.

(viii) Deployment of adequate synchrophasor based Wide Area Monitoring System and System Protection Scheme.

Restoration of the system

The Committee observed that on both the days unduly long time was taken by some of the generating units in starting the units after start up power was made available**.**

Recommendations of the Committee

Detailed recommendations of the committee are given in the main report, which are summarized below.

i) An extensive review and audit of the Protection Systems should be carried out to avoid their undesirable operation.

ii) Frequency Control through Generation reserves/Ancillary services should be adopted, as presently employed UI mechanism is sometimes endangering the grid security. The present UI mechanism needs a review in view of its impact on recent disturbances.

iii) Primary response from generators and operation of defense mechanisms, like Under Frequency & df/dt based load shedding and Special Protection Schemes, should be ensured in accordance with provisions of the grid code so that grid can be saved in case of contingencies.

iv) A review of Total Transfer Capability (TTC) procedure should be carried out , so that it can also be revised under any significant change in system conditions, such as forced outage. This will also allow congestion charges to be applied to relieve the real time congestion.

v) Coordinated outage planning of transmission elements need to be carried out so that depletion of transmission system due to simultaneous outages of several transmission elements could be avoided.

vi) In order to avoid frequent outages/opening of lines under over voltages and also providing voltage support under steady state and dynamic conditions, installation of adequate static and dynamic reactive power compensators should be planned.

vii) Penal provisions of the Electricity Act, 2003 need to be reviewed to ensure better compliance of instructions of Load Desptach Centres and directions of Central Commission.

viii) Available assets, providing system security support such as HVDC, TCSC, SVC controls, should be optimally utilized, so that they provide necessary support in case of contingencies.

ix) Synchrophasor based WAMS should be widely employed across the network to improve the visibility, real time monitoring, protection and control of the system.

x) Load Desptach Centres should be equipped with Dynamic Security Assessment and faster State Estimation tools.

xi) There is need to plan islanding schemes to ensure supply to essential services and faster recovery in case of grid disruptions.

xii) There is need to grant more autonomy to all the Load Despatch Centres so that they can take and implement decisions relating to operation and security of the grid

xiii) To avoid congestion in intra-State transmission system, planning and investment at State level need to be improved.

xiv) Proper telemetry and communication should be ensured to Load Despatch Centres from various transmission elements and generating stations. No new transmission element/generation should be commissioned without the requisite telemetry facilities.

xv) Start up time of generating stations need to be shortened to facilitate faster recovery in case of grid disruptions.

xvi) There is a need to review transmission planning criteria in view of the growing complexity of the system.

xvii) System study groups must be strengthened in various power sector organizations.

xviii) It was also felt that a separate task force may be formed, involving experts from academics, power utilities and system operators, to carry out a detailed analysis of the present grid conditions and anticipated scenarios which might lead to any such disturbances in future. The committee may identify medium and long term corrective measures as well as technological solutions to improve the health of the grid.

CHAPTER-1

INTRODUCTION

1.1 There was a major grid disturbance at 02.33 hrs on 30-07-2012 in Northern region and again at 13.00 hrs on 31-07-2012 resulting in collapse of Northern, Eastern, North-Eastern regional grids barring a few pockets.

1.2 The first disturbance which led to the collapse of Northern Regional Electricity grid occurred at 02.33 hrs on 30th July, 2012, in which all states of Northern Region viz. Uttar Pradesh, Uttarakhand, Rajasthan, Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir, Delhi and Union Territory of Chandigarh were affected. Northern Regional Grid's load was about 36,000 MW at the time of disturbance. Small islands which comprised of three units of BTPS with the load of approximately 250 MW in Delhi, NAPS on houseload, Area around Bhinmal (Rajasthan) with approximate load of 100 MW connected with Western Region survived the blackout. Restoration was completed by 16.00 hrs.

1.3 The second incident which was more severe than the previous one occurred at 13.00 hours on 31.7.2012, leading to loss of power supply in three regions of the country viz. Northern Region, Eastern Region and North Eastern Region affecting all states of Northern Region and also West Bengal, Bihar, Jharkhand, Odisha, Sikkim in Eastern region and Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland and Tripura in North-Eastern region. The total load of about 48,000 MW was affected in this black out. Islands comprising of NAPS, Anta GPS, Dadri GPS and Faridabad in Northern Region, Ib TPS / Sterite, Bokaro steel and CESC survived in Eastern Region. It has been reported that major part of the system could be restored in about 5 hrs, 8hrs and 2 hrs in Northern, Eastern and North-Eastern regions respectively.

1.4 To look into the detailed causes of these disturbances and to suggest remedial measures, Ministry of Power vide its OM No. 17/1/2012-OM Dt. 30-07-2012 constituted an Enquiry Committee headed by Chairperson, CEA and CEO, POSOCO and CMD POWERGRID as members. With the second major grid disturbance on 31-07-2012 involving three regions the Ministry of Power vide its OM No. 17/1/2012-OM Dt. 03-08-2012 modified the constitution of the above enquiry committee with following members:

(i)	Shri A.S. Bakshi, Chairperson, CEA	Chairman
(ii)	Shri A. Velayutham, Member (retd.), MERC	Member
(iii)	Dr. S. C. Srivastava, IIT Kanpur	Member
(iv)	Sh. K. K. Agrawal, Member (GO&D), CEA	Member Secretary

1.5 In addition, following members assisted the Committee:

(i) Shri R. N. Nayak, CMD, POWERGRID
(ii) Shri S. K. Soonee, CEO, POSOCO
(iii) Shri Balvinder Singh, IPS Retired.

1.6 The Terms of Reference of the Committee are as under:

a) To analyse the causes and circumstances leading to the grid disturbance affecting power supply in the affected region.
b) To suggest remedial measures to avoid recurrence of such disturbance in future.
c) To review the restoration of system following the disturbances and suggest measures for improvement in this regard, if any
d) Other relevant issues concerned with safe and secure operation of the Grid.

1.7 The Committee has been asked to submit its report by 16th August, 2012. A copy of MoP OM dated 3-8-2012 constituting the above Committee is given at **Annexure-1.1**.

1.8 First meeting of the initially constituted Enquiry Committee was held on 01-08-2012. Second meeting of the Enquiry Committee was held on 03-08-2012 which was attended by the members of the Committee and representatives of NLDC, all RPCs, RLDCs, POSOCO and POWERGRID.

1.9 The Committee constituted five sub-groups to facilitate detailed and quick analysis of various aspects of grid disturbances viz.

(i) 'Analysis of grid collapse on 30th& 31st July 2012 and simulation of the event' under Shri A. Velayutham, Ex. Member, MERC and Prof. S.C. Srivastava, IIT, Kanpur assisted by Dr. Anil Kulkarni, IIT, Bombay, Shri Ajay Talegaonkar, SE (Operation), NRPC & Shri S. Satyanarayan, SE (Operation), WRPC,

(ii) 'Islanding scheme for Railways & Delhi Metro' under Shri K.K. Agrawal, Member (GO&D), CEA,

(iii) 'Analysis of restoration process of thermal plants' under Shri Manjit Singh, Member (Thermal), CEA,

(iv) 'Islanding schemes in Northern Region' under Shri P.K. Pahwa, Member Secretary, NRPC,

(v) 'Cyber Security aspects' under Shri Ajit Singh, Ex-Addl. Secretary, Cabinet Secretariat and Shri R.K. Verma, Chief Engineer I/c (DP&D), CEA

1.10 In addition, a sub-group comprising Shri Dinesh Chandra, Chief Engineer I/c and Shri D.K. Srivastava, Director, Grid Management Division was formed to compile and prepare the report based on the progress made by the five sub-groups on day-to-day basis.

1.11 For secure grid operation after two grid collapses, following steps were taken immediately:

a) NLDC reduced the TTC of the Inter-Regional lines and other critical lines limiting to its SIL thereby necessary restrictions imposed on STOA.

b) CEA advised utilities that senior and experienced officials should be available in RLDCs, SLDCs, Generating Stations and Sub-Stations for at least one week.

c) CEA also advised to all generating stations to be responsive and develop a mechanism for bringing Units at the earliest in case of contingencies.

1.12 Enquiry Committee held its third meeting on 11-8-2012. On 12-8-2012, detailed discussions were held with POSOCO and POWERGRID at NLDC, New Delhi to have their view points on the causes of grid collapse. The Committee finalized its findings in its meetings on 14th and 15th August, 2012.

1.13 The Committee analysed the output of Disturbance Recorders (DR), Event loggers (EL), PMUs, WAFMS, SCADA data and reports submitted by various SLDCs , RLDCs /NLDC, POWERGRID and generation utilities to arrive at the sequence of events leading to the blackouts on 30th July, 2012 and 31st July 2012. The Committee also interacted with POWERGRID and POSOCO on various aspects of these grid disturbances. Some teams also made field visits to sub-stations, generating stations, NRLDC, NLDC, UPSLDC and Haryana SLDC.

Annexure 1.1

Most Immediate
By FAX / By Post

17/1/2012-OM
Government of India
Ministry of Power

Shram Shakti Bhawan, Rafi Marg,
New Delhi, dated 3rd August, 2012.

OFFICE MEMORANDUM

Subject: Constitution of a Committee to enquire into the Grid Disturbance that occurred in Northern, Eastern and North-Eastern Regions on 30th and 31st July, 2012

In modification of OM of even number dated 30th July, 2012, a Committee comprising following members is hereby constituted to enquire into the Grid Disturbances which occurred on 30th and 31st July, 2012 affecting the power supply in the Northern, Eastern and North-Eastern Regions :

(i)	Shri A.S. Bakshi, Chairman, CEA	Chairman
(ii)	Shri A. Velayutham, Member (Retd.), Maharashtra Electricity Regulatory Commission	Member
(iii)	Dr. S.C. Srivastava, IIT, Kanpur	Member

2. Shri K.K. Agarwal, Member (GO&D), CEA will be the Member Secretary of the Committee.

3. Following will be the Assisting Members :

(i) Shri R.N. Nayak, CMD, Power Grid Corporation of India Limited.
(ii) Shri S.K. Soonee, CEO, Power System Operation Corporation Limited.
(iii) Shri Balvinder Singh, IPS Retired

4. The Committee may co-opt other members as it may deem necessary.

5. The Terms of Reference of the Committee are as under :

(i) To analyse the causes and circumstances leading to the grid disturbance affecting power supply in the affected Region
(ii) To suggest remedial measures to avoid recurrence of such disturbance in future.
(iii) To review the restoration of system following the disturbances and suggest measures for improvement in this regard, if any.
(iv) Other relevant issues concerned with safe and secure operation of the Grid.

6. The Committee shall submit its Report by 16th August, 2012.

AKSaxena
03/8/12
(A.K. Saxena)
Director

CHAPTER-2

OVERVIEW OF REGIONAL GRIDS

2.1 Power system in the country is divided into five regional grids namely Northern, Western, Southern, Eastern and North Eastern grids. Except for Southern grid, remaining four regional grid operate in synchronism. Southern grid is connected to Eastern and Western grids through asynchronous links.

2.2 Northern Regional Grid

2.2.1 Northern Region is the largest in geographical area amongst the five regions in the country covering approximately 31% of the area and having largest number of constituents. It has largest sized hydro unit (250 MW at Tehri/ Nathpa Jhakri) in the country. Northern Grid has an installed generating capacity of about 56,058 MW as on 30.06.2012 comprising 34608 MW of thermal and 19830 MW of Hydro generation The Thermal-Hydro (including renewable) mix is of the order of 64:36. The installed capacity of nuclear stations is 1620 MW.

2.2.2 Major generating stations including Super Thermal Power Stations of NTPC at Rihand and Singrauli are located in the eastern part of the NR grid. Due to such concentration of generation in the eastern part of the grid and major load centers in the central and western part of the grid there is bulk power transmission from eastern to western part over long distances. To handle this bulk transmission of power, a point to point high voltage DC line viz. HVDC Rihand-Dadri bipole with capacity of 1500 MW exists and operates in parallel with 400 kV AC transmission network besides under lying 220 kV network.

2.2.3 During the month of July, 2012 the Peak demand of Northern Region was 41,659 MW against the Demand Met of 38,111 MW indicating a shortage of 3,548 MW (8.5%). The energy requirement of Northern Region was 29,580 MU against availability of 26,250 MU indicating shortage of 3,330 MU (11.3%.).

2.3 WESTERN REGIONAL GRID

The Western Grid has an installed capacity of 66757 MW (as on 30-06-2012) consisting of 49402 MW thermal, 7448 MW hydro, 1,840 MW nuclear and 7909.95 MW from renewable energy sources.

2.4 EASTERN REGIONAL GRID

The Eastern Grid has an installed capacity of 26838 MW (as on 30-06-2012) consisting of 22545 MW thermal, 3882 MW hydro and 411 MW from renewable energy sources. The Eastern Regional grid operates in synchronism with Western, Northern and North-Eastern Regional grids.

2.5 NORTH-EASTERN REGIONAL GRID

2.5.1 The North-Eastern Grid has an installed capacity of 2454.94 MW as on 31-03-2012 consisting of 1026.94 MW thermal, 1200 MW hydro and 228.00 MW from renewable energy sources. The North-Eastern Grid operated in synchronism with Northern Grid, Eastern Grid and Western Grid. North Eastern Regional Grid is connected directly only to the Eastern Regional Grid and any export of power to the other Regions has to be wheeled through the Eastern Regional Grid.

2.5.2 The power transfer from North-Eastern Region to Eastern Region is taking place over Bongaigaon – Malda 400 kV D/C lines and Birpara – Salakati 220 kV D/C lines.

2.6 Inter-regional interconnections

The interconnections between various regional grids is depicted in **Exhibit 2.1**

EXHIBIT – 2.1

2.1.1 Map indicating the IR links between NR, WR, ER and NER

Chapter-3

Analysis of Grid Disturbance on 30th July, 2012

3.1 Introduction

On 30th July, 2012 there was a grid disturbance in the NEW grid at 02:33:11 hrs that led to the separation of the NR grid from the rest of the NEW grid and eventually NR system collapsed. The pre-disturbance conditions, sequence of events and analysis of the disturbance are described below.

3.2 Pre-Disturbance Conditions

The details of the generation-demand and power export/import scenario in the four regions of the NEW grid on 30.07.2012 at 02:00 hrs are given below.

S.No.	Region	Generation	Demand	Import	Remarks
1	NR	32636 MW	38322MW	5686MW	
2	ER	12452 MW	12213MW	(-)239MW	Bhutan import 1127 MW
3	WR	33024 MW	28053MW	(-)6229MW	
4	NER	1367 MW	1314MW	(-) 53MW	
Total	NEW Grid	79479 MW	79902MW		

A number EHV lines were out prior to the disturbance and the same are listed in the enclosed Annexure- 3.1. The grid frequency, just prior to the disturbance, was 49.68 Hz.

3.3 Sequence of Events on 30th July, 2012

The committee studied the data provided by various SLDCs , RLDCs /NLDC , POWERGRID and generation utilities to analyse the sequence of events leading to the blackouts in Northern grid on 30th July, 2012. The committee experienced some difficulty in analysing the available information because of the time synchronisation problems at various stations. The committee, however, established the sequence of events based on correlation of the data from various sources like Disturbance Recorders (DRs), Event Loggers (ELs), few Phasor Measurement Units (PMUs) in the NR and WR at different stations and Wide Area Frequency Monitoring System (WAFMS) of IIT Bombay.

It may be noted that the NEW grid was operating in an insecure condition due to a large number of line outages particularly near the WR-NR interface. Though an exhaustive list of lines under outage is given at **Annexure-3.1**, it may be noted that the following lines had tripped within an interval of a few hours prior to the grid disturbance.

1. 220 kV Badod(WR)-Modak(NR)
2. 220 kV Badod (WR)-Kota (NR)
3. 220 kV Gwalior-Mahalgaon ckt 2 (in WR but near WR-NR interface)
4. 220 kV Gwalior(PG)-Gwalior(MP)(in WR but near WR-NR interface causing only 220 kV Gwalior-Malanpur as only 220 kV NR-WR interconnection, and 220 kV Bina-Gwalior was no longer in parallel with 400 kV Gwalior-Bina)

Following are the sequence of the events, which took place on 30th July, 2012, leading to the Northern Grid blackout:

Sl.No.	Date & Time	Event
1.	30/07/2012 02:33:11.907 AM	400kV Bina – Gwalior-1 Line Tripped, Zone 3 tripping, Main-II
2.	30/07/2012 02:34	220 kV Gwalior-Malanpur 1. As per MP SLDC time is 02:34, but is **manual timing**. (This line has tripped probably just prior to sl no 1 above causing Malanpur and Mehgaon loads to be fed from NR system.)
3.	30/07/2012 02:33:13.438 AM	220 kV Bhinmal-Sanchor line, Zone-1 Tripped on Power Swing.++
With the above events, practically all the AC links from the WR to the NR were lost.		
4.	30/07/2012 02:33:13:927 AM	400 kV Jamshedpur – Rourkela line-2 tripped on Zone-3
5.	30/07/2012 02:33:13:996 AM	400 kV Jamshedpur – Rourkela line-1 tripped on Zone-3
6.	30/07/2012 02:33:15:400 AM	400 kV Gorakhpur-Muzaffarpur-2 tripped on Power Swing
7.	30/07/2012 02:33:15:425 AM	400 kV Gorakhpur-Muzaffarpur-1 tripped on Power Swing at Gorakhpur end. Line remained charged upto 3.03 am at Muzaffarpur end.
8.	30/07/2012 02:33:15:491 AM	400 kV Balia – Biharsharif-2 line tripped on power swing.
9.	30/07/2012 02:33:15:491 AM	400 kV Balia – Biharsharif-1 line tripped on Power swing.

10.	30/07/2012 02:33:15:542 AM	400 kV Patna – Balia (1 & 2) tripped on power swing++.
With the above events, all the AC links from the ER to the NR were lost. NR was islanded from the rest of the NEW grid and ultimately collapsed on under frequency . ER-WR-NER survived as one system.		

Some of the subsequent events of cascaded tripping are listed in **Annexure-3.2**, which has led the NR system to practically total blackout except a few pockets, such as Badarpur and NAPS (only household loads), which survived in islanded mode.

++ Power Swings: The rotors of synchronous machines inter-connected by AC lines tend to run at the same electrical speed in steady state due to the underlying physics of this system. When this system experiences small disturbances, restorative torques bring back the machines to synchronism (i.e., the same electrical speed). This response is characterized by an oscillatory behaviour since the underlying equations which determine the transient behaviour are like those of a spring-mass system. The oscillations are called "**swings**" and are seen in practically all parameters including line power flows. The oscillations die down if damping is adequate.
For large disturbances (e.g faults, loss of critical transmission links), the behaviour is non-linear and the electrical torques may be unable to bring all the generators to the same electrical speed. If this happens the angular difference between the generators goes on increasing (**Transient Instability or Angular Separation**). This causes large variations in voltage and power flow in lines.
Other equivalent terms are "Loss of Synchronism", "Out of Step", "Pole slipping", although the latter two terms are typically used if only one machine loses synchronism. In a multi-machine system groups of machines may separate.

3.4 Analysis of the Disturbance on 30th July 2012

I. It is observed that even though the frequency of the NEW grid (49.68 Hz) was near to its nominal value (50 Hz), a number of lines were not available due to either forced outages, planned outages or kept out to control high voltages. This resulted in a depleted transmission network, which, coupled with high demand in the Northern Region, resulted in an insecure state of the system operation.

II. From WR-NR interface, 400 kV Gwalior-Agra line was carrying about 1055 MW and 400 kV Zerda-Bhinmal was carrying about 369MW, while 400 kV Gwalior-Bina was carrying about 1450 MW. The loading on 400 kV Gwalior-Agra was high. The Surge Impedance Loading (SIL) of the 400 kV Gwalior-Agra and also Gwalior-Bina lines, which are 765 kV lines charged at 400 kV, is about 691 MW (uncompensated), but its thermal loading limit is much higher (for quad Bersimis conductor).

III. NR constituents were instructed by NRLDC to carry out load shedding to relieve the Gwalior-Agra line loading. However, the quantum of load shedding undertaken by the NR constituents seems to be insignificant. WRLDC also issued similar instructions to its constituents for reduction in generation.

IV. The 400 kV Agra-Gwalior line is fed from 400 kV Bina-Gwalior line in the WR.

V. At 02:33:11:907 hrs, the 400 kV Bina-Gwalior line in WR tripped on Zone 3 protection, which is due to load encroachment (DR records do not show any evidence of fault or swing). Prior to tripping the voltage was 374 kV at Bina end and the line was carrying about 1450 MW approximately as per DR report of POWERGRID for this line.

VI. With the tripping of the above line, the supply to NR from 400 kV Agra-Gwalior was lost. 400 kV Zerda-Bhinmal-Bhinmal (220 kV)-Sanchore (220 kV) and Dhaurimanna (220 kV) was the only AC tie link left between WR-NR. Subsequently 220 kV Bhinmal–Sanchore line tripped on power swing, and as per SLDC Rajasthan 220 kV Bhinmal-Dhaurimanna tripped on Zone 1distance protection. This resulted in loss of the WR-NR tie links. A small load at Bhinmal remained connected with WR system through the 400 kV Zerda-Bhinmal line.

VII. In some cases the impedance measured by a distance relay at one end of the line may reduce to a point where it is less than the tripping condition for that relay for back-up protection (Zone 3). This may happen even if there is no fault in the nearby transmission system, and may occur when the line carries a very heavy load. This phenomenon of the mal-operation of the distance relays is known as **‘Load Encroachment’**. Generally, it is an unintended tripping for distance relays since no fault has actually occurred.

It may be noted that at the time of disturbance, the 400 kV Bina-Gwalior line experienced a lower voltage and higher load current (resulting in less impedance, seen by the relay, which, possibly, was below the zone-3 reach setting of the relay) caused the relay operation under load encroachment. It was informed by POSOCO that this line had not tripped earlier due to zone-3 operation under load encroachment, although few incidences of such operation of distance relays in Western Region are observed in prior disturbances.

VIII. The tripping of the 400 kV Bina-Gwalior line initiated a very large angular deviation between NR system on one side and ER+WR+NER system on the other side. The power from WR to NR was now routed via WR-ER-NR interface, which is a very long path.

IX. An illustrative simulation to understand angular separation of the WR and NR regions was carried out. The simulation confirms that the systems may separate under such conditions. The simulation details are given at **Annexure-3.3**

X. Due to large power flows in the WR-ER-NR route, 400 kV Jamshedpur-Rourkela double circuit (in ER) tripped on Zone 3 (**Exhibit 3.1** shows the angular separation).

XI. Though the NR system, at this stage, was still connected to the ER system (which was connected to the WR), the machines in the NR system had started to slow down as compared to those in rest of the NEW grid. Therefore, angular separation between NR and the rest of the grid continued to increase. This situation would eventually lead to angular instability (loss of synchronism).

XII. It is well established that under such situations, the distance relays near the electrical center of this separation are prone to pick up. Accordingly 400 kV ties between ER and NR (BiharSharif-Balia, Muzzafarpur-Gorakhpur, Patna-Balia, and Sasaram-Balia) tripped.

XIII. Since 220 kV Pasauli-Sahupuri (ER-NR) line was operated in radial mode, Sahupuri loads remained fed from the ER system and survived.

XIV. The NR system was thereby isolated from the rest of the grid. In the NR system, there was loss of about 5800 MW import and resulted in decline of frequency. NR System has Automatic Under Frequency Load Shedding Scheme (AUFLS), which can shed about 4000 MW of loads, and df/dt relays scheme, which can shed about 6000MW of loads, to improve the frequency and save the system under such emergency situations. However, not adequate load relief from the AUFLS and df/dt relays was observed and the NR system collapsed except for a few pockets at Badarpur and NAPS.

XV. With the separation of NR from the rest of the grid, the ER+WR+NER grid had a surplus of about 5800 MW power exported to NR prior to the separation. This system had more generation and the frequency rose to 50.92 Hz and stabilized at 50.6 Hz. There was tripping of Korba (E) 2*250 MW, APL Mundra 2*660 MW, Dhuvaran 80 MW, Parli 210 MW and Nasik 210 MW units in WR and Mejia-B 400MW, DSTPS 250 MW and MPL 450MW in ER took place. APL Mundra units tripped on Special Protection Scheme. The reported loss of generation is of the order of 3340 MW.

XVI. The sudden rise in frequency, close to 51Hz in the WR, also indicates inadequate primary response from generating stations. The primary response if enabled in NR could also have helped in curtailing the initial frequency dip in the Northern region.

XVII. During restoration, at 03:39 hours, several units and transmission lines at NTPC Vindhyachal STPS tripped in Western Region which also affected the start-up process.

After the grid was restored on 30.07.2012, another grid disturbance took place on 31.07.2012 , the details of which are given in the next chapter.

Annexure 3.1

List of EHV Lines Out on 30.07.2012 Prior to Disturbance
(400 kV and above and Inter-Region 220 kV and above)
(as furnished by NLDC)

Sl No	Line	Voltage (kV)	Region	Out From Date	Remarks
	NR				
1	Fatehpur-Gaya	765	NR	27/07/12	Planned
2	Agra-Bassi-3	400	NR	28/07/12	Planned
3	Agra-Bassi-2	400	NR	28/07/12	Planned
4	Agra-Gwalior 2	400	WR-NR	28/07/12	Planned
5	Zerda-Kankroli	400	WR-NR	28/07/12	Planned
6	Agra-Fatehpur	765	NR	26/07/12	Constr Work
7	Bhiwadi-Neemrana	400	NR	23/07/12	HV Trip
8	Barh-Balia	400	ER-NR	29/07/12	HV Trip
9	Bhinmal-Kankroli	400	NR	29/07/12	Forced
10	Badod-Kota	220	WR-NR	29/07/12	Forced
11	Manesar-Neemrana	400	NR	15/07/12	Control HV
12	Bhilwara-Chhabra	400	NR	20/07/12	Control HV
13	Neemrana-Sikar	400	NR	20/07/12	Control HV
14	Barh-Balia 2	400	ER-NR	28/07/12	Control HV
15	Akal-Barmer 1	400	NR	28/07/12	Control HV
16	Chhabbra-Hindaun 2	400	NR	30/07/12	Control HV
17	Jodhpur II – RajWest 2	400	NR	30/07/12	Control HV
	WR				
1	Bina-Gwalior 2	400	WR	27/07/12	Planned
2	Nagda-Shujalpur 1	400	WR	07/07/12	Forced
3	Parli-Parli 2	400	WR	19/07/12	Forced
4	Satna-Bina 2	400	WR	26/07/12	Control HV
5	Damoh-Birsingpur 2	400	WR	13/07/12	Control HV
6	NAgda-RAjgarh 1	400	WR	20/07/12	Control HV
7	Seoni-Bina 1	765	WR	03/07/12	Control HV
8	Seoni-Wardha 2	765	WR	23/07/12	Control HV
9	Bina – Indore	400	WR	21/07/12	Possibly Bina-Nagda
10	Korba-Birsingpur	400	WR	05.07.12	Control HV
11	Birsingpur-Balco	400	WR	22/06/12	Control HV
12	Raigarh-Raipur 1	400	WR	20/07/12	Control HV
13	Raigarh-Raipur 2	400	WR	21/07/12	Control HV

14	Jabalpur-Itarsi 2	400	WR	20/07/12	Control HV
15	Itarsi-Khandwa 2	400	WR	20/07/12	Control HV
16	Nagda-Dehgam 1	400	WR	28/07/12	Control HV
17	Wardha-Akola-1	400	WR	20/07/12	Control HV
18	Parl(PG)-Sholapur 1	400	WR	23/07/12	Control HV
19	Bhadrawati-Parli 1	400	WR	21/07/12	Control HV
20	Aurangabad-Bhusawal	400	WR	27/06/12	Control HV
21	Aurangabad-Deepnagar	400	WR	03/07/12	Control HV
22	Karad-Kolhapur	400	WR	28/07/12	Control HV
23	Birsingpur-Katni	400	WR	14/06/12	Control HV
24	SSP-Rajgarh 2	400	WR	25/07/12	Control HV
25	ISP-Nagda	400	WR	24/07/12	Control HV
26	Itarsi-Bhopal	400	WR	29/07/12	Control HV
	ER				
1	Ranchi-MPL D/c	400	ER	27/07/12	Planned
2	Binaguri-Purnea 1	400	ER	18/07/12	Planned
3	Sagardighi-Durgapur	400	ER	25/07/12	Forced
4	Maithon-Durgapur 1	400	ER	28/07/12	Forced
5	Baripada-Mendhasal	400	ER	14/07/12	Forced

Annexure 3.2

Subsequent tripping of lines in ER and NR systems after separation on 30/07/2012

(only those given in the DRs are listed below)

11.	30/07/2012 02:33:16:251 AM	Line1(RAPP-B to C tie line) and Line2 (to Kota) tripped
12.	30/07/2012 02:33:16:261 AM	Line6 (RAPS-B to Udaipur)tripped
13.	30/07/2012 02:33:17:221 AM	Line4(RAPS-B to Chittor-1) tripped
14.	30/07/2012 02:33:17:231 AM	Line5 (RAPS-B to Chittor-2) tripped As a result ofthe events Sl. No.13-16, RAPS-B moved to house loading.
15.	30/07/2012 02:33:18:508 AM	Biharshariff – Sasaram-4 tripped
16.	30/07/2012 02:33:20:667 AM	Kahalgaon – Biharshariff (3 & 4) tripped
17.	30/07/2012 02:33:19:830 AM	Ballabgarh – Kanpur-II line tripped due to over voltage protection and received direct trip from Kanpur.
	30/07/2012 02:33:20:830 AM	Ballabgarh – Kanpur-III line tripped due to over voltage protection and received direct trip from Kanpur.
18.	30/07/2012 02:33:20:714 AM	Biharshariff – Sasaram-3 tripped
19.	30/07/2012 02:33:22 AM	NAPS two units (150MW each) tripped by under frequency operation. 1. Frequency dipped to 47.7 Hz 2. The two units got isolated from grid and started operating in island mode supplying load to Simbholi and Khurja SSs.
20.	30/07/2012 02:33:24:965 AM	Tehri pooling – Meerut Line-1 tripped.
21.	30/07/2012 02:33:26:192 AM	Mandola – Bareilly Line-2 CB Operated PSB operated at 30/07/2012 02:33:15:142 AM and reset at 17.702 PSB operated at 30/07/2012 02:33:30:010 AM on Line-1.
22.	30/07/2012 02:33:28:172 AM	Mandola-Bawana-I tripped at Mandola end due to over voltage protection.
23.	30/07/2012 02:33:28:175 AM	Mandola-Bawana-II tripped
24.	30/07/2012 02:33:29.116 AM	Dadri – Maharanibagh Fault initiated, Appears Breaker was not opened.
With the available information, the Grid blackout started in some areas (as observed through the PMU frequency data) and the remaining events, listed below, are the cascading events resulting into the complete blackout.		

25.	30-07-2012 02:33:30.123 AM	Roorkee – Rishikesh and Roorkee-Muzaffarnagar lines tripped on SOTF
26.	30/07/2012 02:33:30.129 AM	Dadri – Rihand HVDC Pole-1 blocked Blocked from Rihand end
27.	30/07/2012 02:33:30.134 AM	Dadri – Rihand HVDC Pole-2 blocked Blocked from Rihand end
28.	30/07/2012 02:33:31.083 AM	Bassi – Agra-I CB652 Opened
29.	30/07/2012 02:43:33.589 AM	Bassi – Heerapura=II CB1252 Opened
30.	30/07/2012 02:33:36.617 AM	Tehri pooling – Koteshwar TOV1 Trip

Annexure-3.3

An Illustrative Example to demonstrate angular separation of NR-WR System

In order to illustrate that the angular separation can occur with the loss of a tie, a simplified two machine system was simulated, approximately representing NR and WR systems. We can look upon this system as a simplified representation of a two area system (NR and ER-WR-NER). We consider two tie lines, one short and one long.

In the simplified system, “NR” part draws 800MW on short tie and 400 MW on the longer tie. With the tripping of the shorter tie, Fig S-1 clearly shows that both systems go out of phase (in about 2.3 sec for this simplified Illustrative example). Fig S-2 shows severe power swings and oscillatory nature of voltage, MW and MVAR flows under this condition.

This simulation illustrates that angular separation between two systems followed by power swings is possible on loss of short tie. However as it is a simplified system, for specific answers to the collapse of the grids on 30th and 31st July 2012, a detailed load flow and transient stability simulation of the NR, ER, NER and WR grids is required.

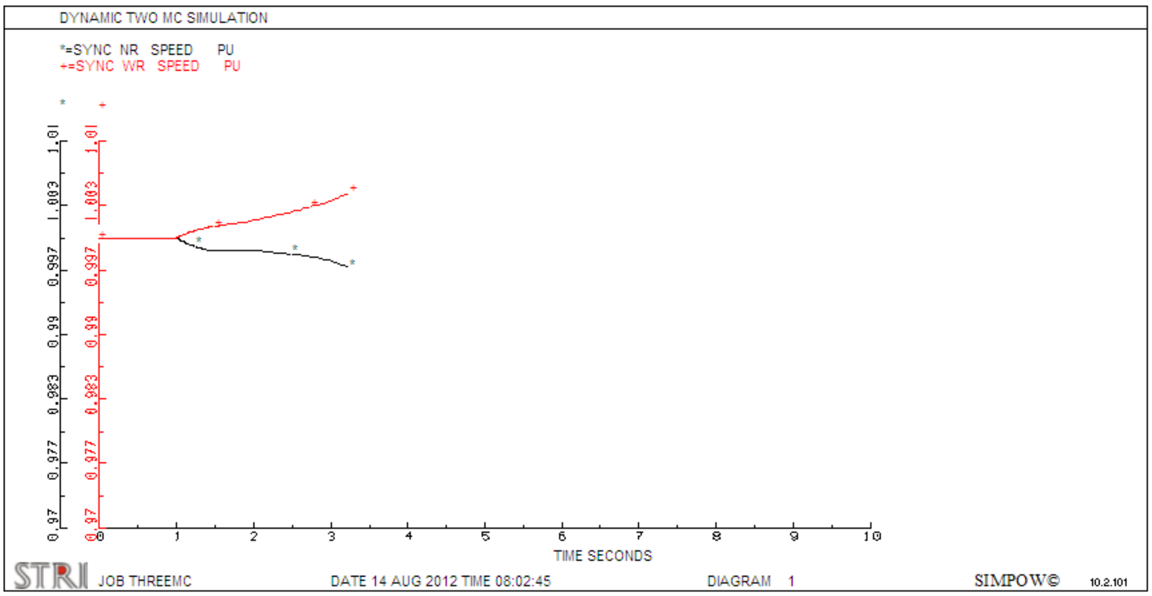

Fig S-1 : Loss of Short Tie Line
(Shows angles increasing continuously and later NR and WR are out of phase)

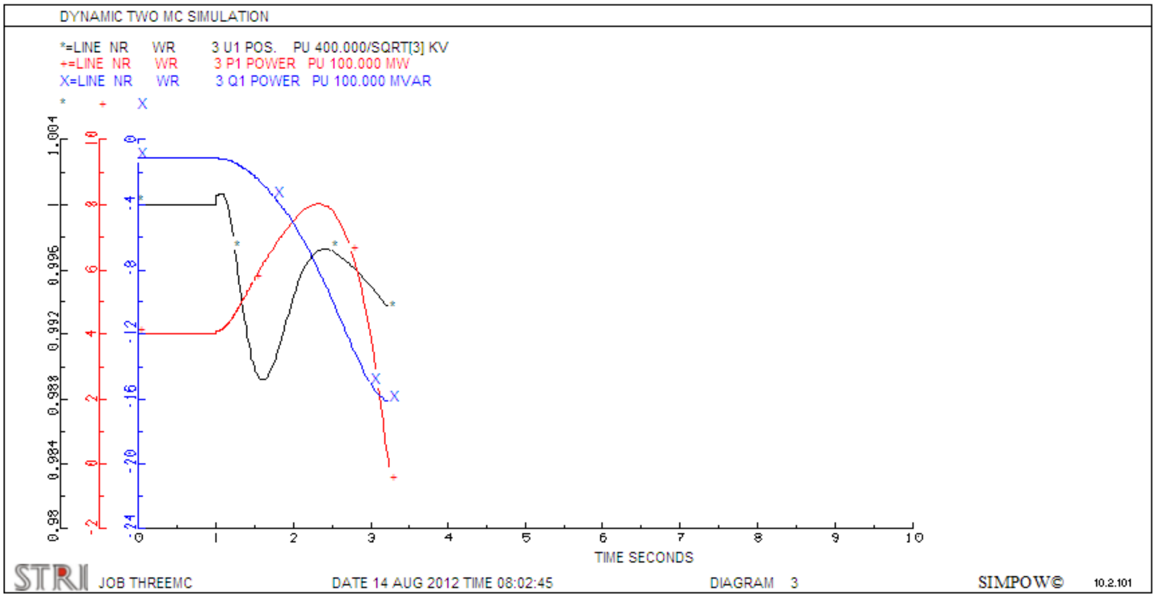

Fig S-2 : Loss of Short Tie Line
(Shows power swings between the two systems)

Exhibit 3.1

Recording Showing Angular Separation between NR and Rest of NEW Grid on 30/07/2012

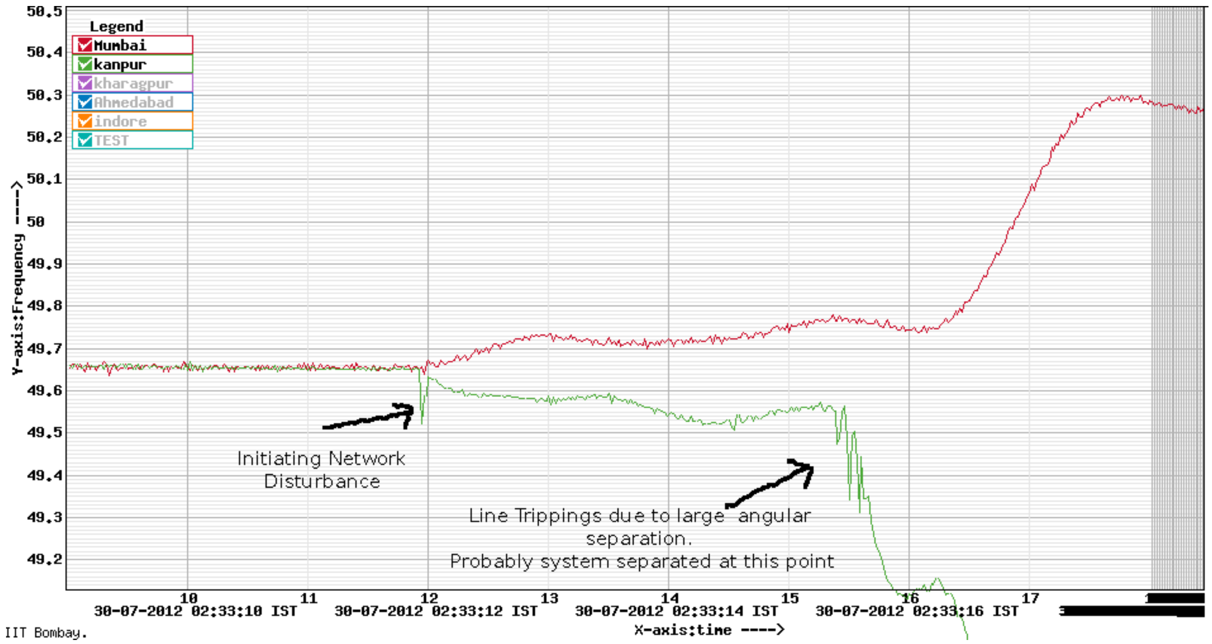

Fig 1: (source: Wide Area Frequency Measurement system developed by IIT-B, Mumbai.)

Exhibit 3.1 (contd..)

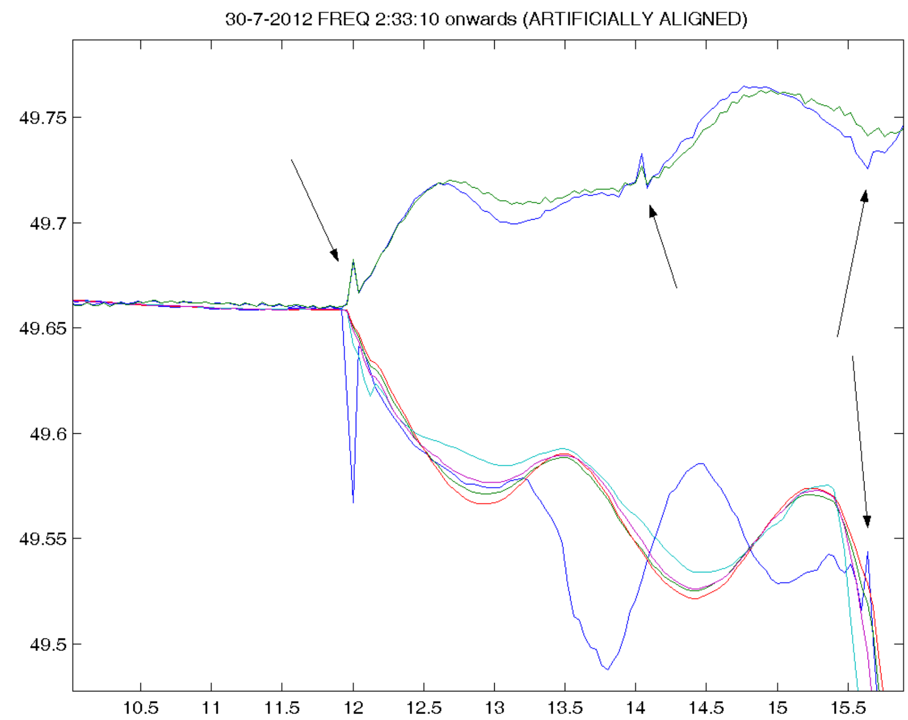

Fig 2: (source: PMU Data from WR and NR.) Note: There was time mismatch in WR PMUS and required to be logically aligned. Arrow indicates events.

Chapter-4

Analysis of Grid Disturbance on 31st July, 2012

4.1 Introduction

While the grid recovered from the black out of 30th July 2011, another major disturbance took place on 31st July 2012 in the NEW grid at 13:00:13 hrs that led to the separation of the NR, NER and ER from the WR and eventually led to the collapse of the NR, ER and NER grids. The pre-disturbance conditions, sequence of events and analysis of the disturbance are described below.

4.2 Pre-Disturbance Conditions on 31st July 2012

The details of the generation-demand as well as import/export of power in each of the four regions in the NEW grid on 31.07.2012 at 12:30 hrs are given below.

Sl. No	Region	Generation	Demand	Import	Remarks
1	NR	29884MW	33945MW	4061MW	
2	ER	13524MW	13179MW	(-) 345MW	Import from Bhutan 1114 MW.
3	WR	32612MW	28053MW	(-)4559MW	
4	NER	1014MW	1226MW	212MW	
Total	NEW Grid	76934MW	76403MW		

A number of EHV lines were out prior to the disturbance and the same are listed in **Annexure 4.1**. It may be noted that even after grid disturbance on the previous day, similar network operating conditions prevailed on this day as well. The frequency, just prior to the disturbance, was 49.84 Hz.

4.3 Sequence of Events on 31st July, 2012

It may be noted that the NEW grid was operating in an insecure condition even on 31st July 2012 due to a large number of line outages particularly near the WR-NR and ER-WR interfaces. Though an exhaustive list of lines under outage is given at **Annexure 4.1**, it may be mentioned that the following lines had tripped within an interval of a few hours prior to the grid disturbance.

1. 400 kV Zerda-Bhinmal
2. 400 kV Zerda- Kankroli
3. 220 kV Badod-Modak- tripped a few minutes before the event
4. 220 kV Badod-Kota- tripped a few mintutes before the event

In addition Surat Garh unit-1 also tripped around this time

The following are the sequence of events, which took place on 31st July 2012 leading to the blackouts in the Northern, North-Eastern and Eastern regions.

Sl.No.	Time	Event
1.	31/07/2012 13:00:13	400kVBina – Gwalior-1 line tripped at Bina end on Zone 3 Protection due to load encroachment, 400kV Bina-Gwalior-2 was already out of service.
2.	31/07/2012 13:00:13	220kV Bina – Gwalior-1 line tripped at Bina end due to R&B over current 220kV Bina – Gwalior-2 line tripped at Bina end due to R&B over current
3.	31/07/2012 13:00:13	220kV Shivpuri-Sabalgarh-1 tripped
4.	31/07/2012 13:00:13	132kV Pichhore-Shivpuri tripped
5.	31/07/2012 13:00:13	132kV Pichhore-Chanderi tripped ***Sequence of event nos 1-5 led to the isolation of the Gwalior region of MP from WR and formed part of the NR system.***
6. *	31/07/2012 13:00:15:548	220 kV bus coupler tripped at Tarkera tripped (details not available)
7. *	31/07/2012 13:00:13:600	400 kV Jamshedpur-Rourkela-1 tripped at Jamshedpur on Main-1 (RAZFEE) protection, appears to be due to load encroachment. The L-L voltage before trip was about 362 kV and line current as 1.98 kA (appx. loading 1241 MVA)
8. *	31/07/2012 13:00:17:948	400 kV Ranchi- Maithon-1 tripped due to Power Swing.
9.	31/07/2012 13:00:19.605	400 kV Rourkela -Sterlite-2 tripped due to Over voltage (timings need to be confirmed)
10.	31/07/2012 13:00:19.891	400 kV Rourkela-Talcher-2 tripped due to Power Swing
11.	31/07/2012 13:00:19.897	400 kV Rourkela – Talcher-1 tripped due to Power Swing
12.	31/07/2012 13:00:19.908	400 kV Rourkela – Raigarh-3 tripped due to Power Swing and Over voltage
13.	31/07/2012 13:00:19.925	400 kV Rourkela-Ranchi-1 tripped due to Power Swing, D/T received
14.*	31/07/2012 13:00:19:945	400 kV Ranchi-Sipat-2 tripped on Power Swing
15.*	31/07/2012 13:00:19:948	400 kV Raigarh-Rourkela-3 tripped on Power Swing

16.*	31/07/2012 13:00:19:974	400 kV Ranchi-Rourkela-1 tripped on Power Swing
17.*	31/07/2012 13:00:19:981	400 kV Talchar-Rourkela-2 tripped on Power Swing
18.*	31/07/2012 13:00:19:986	400 kV Talchar-Rourkela-1 tripped on Power Swing
19.*	31/07/2012 13:00:20:017	400 kV Ranchi-Raghunathpur tripped on Power Swing
With the above events, practically all the AC links from the WR to the rest of the grid were lost and WR got isolated along with Ranchi and Rourkela buses. *Events taken from the POSOCO & POWERGRID report submitted to CEA, which are based on the DR and EL reports.		
20.	31/07/2012 13:00:25.021	400 kV Rourkela-Raigarh-1 tripped on over voltage
21.	31/07/2012 13:00:26.091	400 kV Rourkela-Ranchi-2 tripped due to Power Swing
22.	31/07/2012 13:00:30.625	400 kV Ballabgarh-Kanpur ckt2, tripped due to reactance relay operation.
23.	31/07/2012 13:00:32.444	400 kV Ballabgarh-Kanpur ckt3, tripped due to reactance relay operation.
24.	31/07/2012 13:00:35.558	Suratgarh Unit-6 tripped due to Under frequency problem (timing to be confirmed)
25.	31/07/2012 13:01:14.788	Suratgarh Unit-2 tripped due to under frequency problem (timing to be confirmed)
26.	31/07/2012 13:01:23.793	Vindhyachal HVDC B/B block-1 AC bus north: abnormal frequency trip because of Vidhyachal-Singrauli line tripping, EL or DR not available for Vindhyachal-Singrauli line.
27.	31/07/2012 13:01:25.078	Suratgarh Unit-5 tripped due to Under frequency problem
28.	31/07/2012 13:01:26.003	Vindhyachal HVDC B/B block-2 AC bus north: abnormal frequency trip because of Vidhyachal-Singrauli line tripping
29.	31/07/2012 13:01:26.343	400 kV Kankroli-Jodhpur tripped ICT differential relay pickup due to dip in voltage, SOTF
30.	31/07/2012 13:01:26.633	Nathta-Jhakri Powe Plant U1 tripped due to under frequency.
31.	31/07/2012 13:01:26.779	Nathta-Jhakri Power Plant U3 tripped due to under frequency.
32.	31/07/2012 13:01:26.786	Nathta-Jhakri Power Plant U2 tripped due to under frequency
33.	31/07/2012 13:01:26.823	Nathta-Jhakri Power Plant U4 tripped due to under frequency

34.	31/07/2012 13:01:28.205	Muzaffarpur-Gorakhpur-2, 3ph protection operated and tripped the line
35.	31/07/2012 13:01:27.226	Bhiwadi-Bassi, 400kV line tripped , Z1, Three phase tripping, Bhiwadi end operated
36.	31/07/2012 13:01:27.228	Bhiwadi-Rewari, 220kV tripped, 3Ph distance protection, Z1 Operated
37.	31/07/2012 13:01:27.497	220kV Bassi-IG Nagar tripped, 3Ph fault
38.	31/07/2012 13:01:27.497	220kV Bassi-Bhagru tripped, Z1, three phase fault
39.	31/07/2012 13:01:27.940	220kV, Bassi-Dausa line tripped, Z1, three phase fault
40.	31/07/2012 13:01:28.031	Muzaffarpur-Gorakhpur-1 tripped, Z2 operated
41.	31/07/2012 13:01:28.224	400kV, Agra-Bhiwadi1 tripped, SOTF
42.	31/07/2012 13:01:28.226	400kV, Agra-Bhiwadi2 tripped, SOTF
43.	31/07/2012 13:01:28.363	Wagoora-Kishenpur (1&2) tripped, Power Swing
44.	31/07/2012 13:01:29.072	400kV, Meerat-Koteswar (1&2)tripped, Power swing detected
45.	31/07/2012 13:01:29.686	Mandola-Dadri (1&2) tripped
46.	31/07/2012 13:01:29.726	Kaithal-Patiala line-1 tripped
47.	31/07/2012 13:01:29.742	Dadri-Malerkotla line tripped, Power Swing
48.	31/07/2012 13:01:29.762	Agra-Auraiya-II tripped, Z3, Three Phase
49.	31/07/2012 13:01:29.777	Malerkotla-Patiala tripped, Power swing
50.	31/07/2012 13:01:29.780	Malerkotla-Ludhiana Tripped, Power swing
51.	31/07/2012 13:01:29.816	Moga-Jalandhar (1&2) triped, Power swing
52.	31/07/2012 13:01:29.832	Moga-Kishenpur-1 tripped, Power swing
53.	31/07/2012 13:01:29.920	Agra-Auraiya-I tripped, Z3, 3Ph
54.	31/07/2012 13:01:30.120	400kV, Ballabgarh-Maharanibagh Tripped, Z1, 3Ph tripping, SOTF
55.	31/07/2012 13:01:30.191	Kaithal-Kaithal-I tripped

56.	31/07/2012 13:01:30.276	Ballabhgarh-Gr Noida tripped, Z1, 3phase
57.	31/07/2012 13:01:30.320	Allahabad-Sasaram disturbance, PSB Operated. Another report is also available with different time stamping on the same event. Suspecting time synchronization problem.
58.	31/07/2012 13:01:30.368	Kanpur-Panki-1 tripped, Under voltage
59.	31/07/2012 13:01:30.630	Agra-Bassi-I, SOTF
60.	31/07/2012 13:01:30.689	Kaithal-Kaithal-II tripped
61.	31/07/2012 13:01:30.702	HVDC Balia-Bhiwadi tripped, AC under voltage protection
62.	31/07/2012 13:01:30.833	Balia-Biharshariff tripped, Power Swing
63.	31/07/2012 13:01:31.219	Meramundali-Jeypore tripped
64.**	31/07/2012 13:01:32.684	400kV, Patna-Balia-2 tripped, 3-ph fault
65.	31/07/2012 13:01:42.867	Dadri-Rihand HVDC pole-2 blocked
66.	31/07/2012 13:01:42.871	Dadri-Rihand HVDC pole-1 blocked
67.	31/07/2012 13:03:18.363	Kankroli-Debari, 220kV tripped, Under voltage protection

**After event 64, the NR got practically isolated from the ER+NER and frequency started dropping (observed in the NR system) after a gap of about 1 minutes from the previous major event.

The subsequent events of cascaded tripping led the NR, NER and ER system to practically total blackout.

4.4 ANALYSIS OF GRID DISTURBANCE ON 31st JULY, 2012:

I. It is interesting to note that on 31st July 2012 also, though the frequency of the NEW grid (49.84 Hz) was near to its nominal value (50 Hz), a large number of lines were not available due to either forced outages, planned outages or kept out to control high voltages which, coupled with high demand in the Northern Region, resulted in insecure state of the system operation.

II. NR constituents were instructed by NRLDC to carry out load shedding to reduce the over drawal. Similarly the WR constituents were also instructed by WRLDC to reduce generation to bring down the over injection of power.

However, the quantum of load shedding/generation reduction undertaken by the two constituents seems to be insignificant.

III. Just prior to the initiation of the major disturbance, NR-WR was connected through AC tie links between 400 kV Agra-Gwalior (one circuit), 220 kV Badod-Kota and 220 kV Badod-Modak lines.

IV. Badod-Modak line flow reached 288MW at about 12:58pm on 31st July, 2012 from

V. 103MW and got tripped due to overload. Similarly, 220 kV Badod-Kota line also reached a flow of 298MW from its earlier flow of 113MW and tripped due to overload. The rise in flow of these lines are possibly due to tripping of the Suratgarh generating unit-1 of 250 MW at about 12:50 hours in Rajasthan.

VI. At about 13:00:13 hrs, 400kV Bina-Gwalior-I line tripped on distance relay zone-3 protection, which is also due to load encroachment (as DR records do not show any evidence of fault or swing). As per DR report of PGCIL the loading on this line 1254 MVA and voltage was 362 kV at Bina end (Though the MW loading was less the previous tripping, due to lower voltage the MVAR flow was larger than previous incident).

VII. The load on the 220kV Bina-Gwalior-I&II suddenly increased to 447MW from 330MW and increased further. The power flow on 220kV Gwalior(PG)-Gwalior (MP) line-II was 188MW at 12:58:58pm and got reversed to -180MW. This resulted in the reverse flow of power from Gwalior (MP) to Gwalior (PG) and pumped in to 400kV system.

VIII. The power drawl of Auraiya from Mehalgaon resulted in the tripping of 220kV Bina-Gwalior- I&II, 220kV Shivpuri-Sabalgarh-I, 132kV Pichhore-Chanderi and 132kV Pichhore-Shivpuri. On 31.07.12 400kV Bina-Gwalior II and 400kV Gwalior-Agra II lines of POWERGRID were under shut down and 220kV Gwalior (PG)-Mahalgaon (GWL) -I, 220kV Gwalior-(PG) – Malanpur-II of MP were also under shut down since 29.07.2012. This situation led to the isolation of the Gwalior region of MP from WR and formed part of the NR system.

IX. The NR system was isolated from the WR system and the demand, which was earlier fed from the WR got routed through WR-ER-NR systems, causing increase in the angular separation between the NR and WR systems, similar to the disturbance on 30th July 2012.

X. However, unlike the pattern on 30th July 2012, the electrical center of the angular separation appears to be slightly inside the ER system from the WR-ER interface. This resulted in tripping of lines connecting unlike Ranchi and Rourkela to the rest of the ER. These buses formed part of the WR, which got separated from the rest of ER+NR+NER at about 13:00:20 hrs.

XI. The frequency plots are available from PMUs and the WAFMS from the NR and WR only (see **Exhibit 4.1**). This shows that the frequency in the WR rose to 51.4 Hz and that in the rest of the NEW grid stabilized close to 48.12 Hz. The sudden rise in frequency, close to 51.4 Hz in the WR, again indicates absence of FGMO controls being activated in several generating stations. In fact, the FGMO operation in the rest of the NEW grid could have possibly recovered the frequency which stayed at 48.12 Hz for about a minute and probably avoided the further catastrophic failure.

XII. The WR system survived with the tripping of Sipat 660MW, DSPM 2*250 MW ESSAR 125 MW and KLTPS 69 MW generating units. APL 660 MW generating unit tripped on Special Protection Scheme, associated with tripping of Adani-Manindragarh HVDC and frequency stabilized at around 51 Hz.

XIII. Further the loss of import from about 3000 MW import from WR resulted in decline of frequency in the rest of the NEW grid, which has Automatic Under Frequency Load Shedding Scheme (AUFLS), that can shed about 5600 MW of loads, and df/dt relays scheme, which can shed about 6020MW of loads, to improve the frequency and save the system under such emergency situations. However, not adequate load relief from the AUFLS and df/dt relays was observed on 31st July 2012 also.

XIV. Subsequently, possibly due to some generator trip in the NR+NER+ER grid led large angular oscillations and drop in system frequency, which resulted in a large number of trippings in the NR, ER and NR-ER links. This cascaded tripping of lines was on overvoltage at few places, power swing or zone-3 protection and tripping of generators on under frequency. This initially separated NR from NER+ER. From PMU records NR systems has collapsed on under frequency. There is no PMU installed so far in ER+NER system. The system is also smaller in size with small Power Number and ER+NER systems collapsed except for few islands, like CESC, NALCO and BSP.

XV. It may be mentioned that with the collapse ER, the Southern Region lost about 2000 MW in feed from Talchar-Kolar HVDC and frequency declined from 50.06 Hz to 48.88 Hz as per SRLDC SCADA. The frequency controller at HVDC Bhadrawati increased the flow of WR to SR from 880 MW to 1100 MW. System Protection scheme at Kolar did not operate. It was informed by the SRPC that there was AUFLS relief of about 984MW in the SR.

XVI. It may be noted that both on 30th and 31st July 2012, lot of tripping of lines were observed due to over voltage and also substantial under voltage at the tail end of the heavily loaded lines were observed, which caused operation of distance protection. These extreme voltage situations could have been avoided with the proper reactive power absorption/support from reactors/capacitors, dynamic compensators as well as synchronous generators.

Annexure 4.1

List of EHV Lines Out on 31.07.2012 Prior to Disturbance (400 kV and above and Inter-Region 220 kV and above) (as furnished by NLDC)

Sl No	Line	Voltage (kV)	Region	Out From Date	Remarks
	NR				
1	Bassi-Jaipur 1	400	NR	28/07/12	Planned
2	Agra-Bassi-2	400	NR	28/07/12	Planned
3	Agra-Gwalior 2	400	WR-NR	28/07/12	Planned
4	Zerda-Kankroli	400	WR-NR	28/07/12	Planned
5	Agra-Fatehpur	765	NR	26/07/12	Constr Work
6	Bhiwadi-Neemrana	400	NR	23/07/12	HV Trip
7	Barh-Balia	400	ER-NR	29/07/12	HV Trip
8	Bhinmal-Kankroli	400	NR	29/07/12	Forced
9	Badod-Kota	220	WR-NR	29/07/12	Forced
10	Manesar-Neemrana	400	NR	15/07/12	Control HV
11	Gorakhpur(PG)-Lucknow 2	400	NR	30/07/12	Forced and kept open
12	Kota-Merta 1	400	NR	30/07/12	Forced
13	Heerapura-Hindaun 2	400	NR	30/07/12	Forced
14	Neemrana-Sikar	400	NR	20/07/12	Control HV
15	Barh-Balia 2	400	ER-NR	28/07/12	Control HV
16	Akal-Barmer 1	400	NR	28/07/12	Control HV
17	Chhabbra-Hindaun 2	400	NR	30/07/12	Control HV
18	Barmer-RajWest2	400	NR	30/07/12	Control HV
19	Jodhpur II – RajWest 2	400	NR	30/07/12	Control HV
	WR				
1	Bina-Gwalior 2	400	WR	27/07/12	Planned
2	Parli-Parli 2	400	WR	19/07/12	Forced
3	Damoh-Birsingpur 2	400	WR	13/07/12	Control HV
4	Nagda-Rajgarh 1	400	WR	20/07/12	Control HV
5	Seoni-Bina 1	765	WR	03/07/12	Control HV
6	Seoni-Wardha 2	765	WR	23/07/12	Control HV
7	Bina – Indore	400	WR	21/07/12	Possibly Bina-Nagda
8	Korba-Birsingpur	400	WR	05.07.12	Control HV
9	Birsingpur-Balco	400	WR	22/06/12	Control HV

10	Raigarh-Raipur 1	400	WR	20/07/12	Control HV
11	Itarsi-Khandwa 2	400	WR	20/07/12	Control HV
12	Bachau-Ranchodpur	400	WR	30/07/12	Forced
13	Wardha-Akola-1	400	WR	20/07/12	Control HV
14	Parl(PG)-Sholapur 1	400	WR	23/07/12	Control HV
15	Bhadrawati-Parli 1	400	WR	21/07/12	Control HV
16	Aurangabad-Bhusawal	400	WR	27/06/12	Control HV
17	Aurangabad-Deepnagar 2	400	WR	03/07/12	Control HV
18	Karad-Kolhapur 2	400	WR	28/07/12	Control HV
19	Kolhapur-Mapusa 2	400	WR	26/07/12	Control HV
20	SSP-Rajgarh 2	400	WR	25/07/12	Control HV
21	ISP-Nagda	400	WR	24/07/12	Control HV
22	Itarsi-Bhopal	400	WR	29/07/12	Control HV
23	Adani-Sami 1	400	WR	31/07/12	Control HV
24	Amreli-Jetpur	400	WR	31/07/12	Control HV
25	Asoj-Chorani 1	400	WR	31/07/12	Control HV
	ER				
1	Ranchi-MPL D/c	400	ER	27/07/12	Planned
2	Binaguri-Purnea 1	400	ER	18/07/12	Planned
3	Sagardighi-Durgapur	400	ER	25/07/12	Forced
4	Baripada-Mendhasal	400	ER	14/07/12	Forced

EXHIBIT 4.1

Recording Showing Angular Separation between NR and Rest of NEW Grid on 31/07/2012

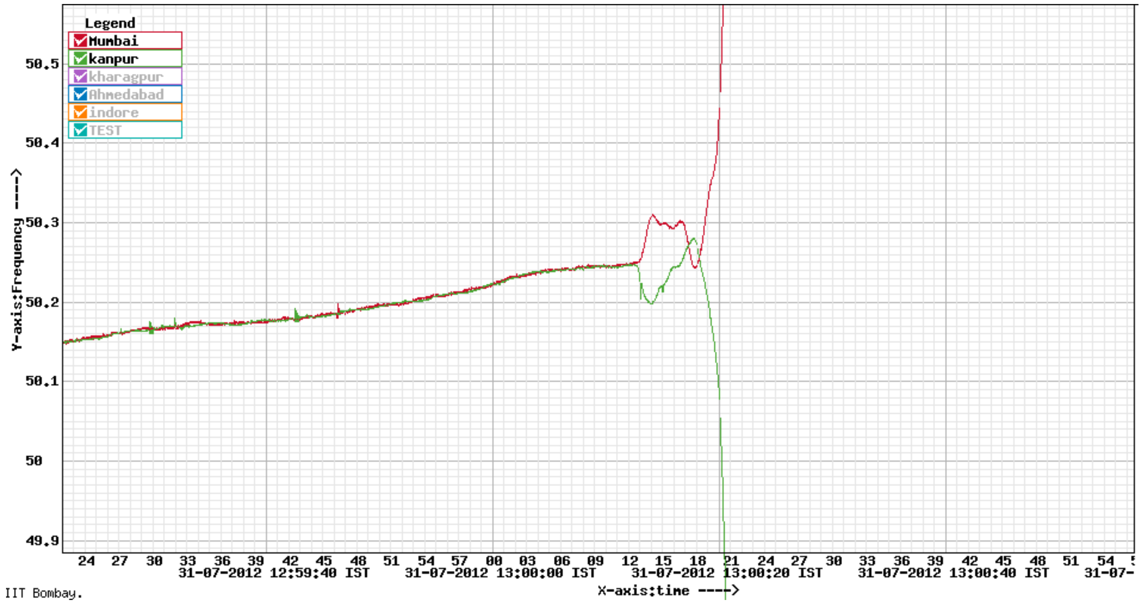

Fig 1: (source: Wide Area Frequency Measurement system developed by IIT-B, Mumbai.)

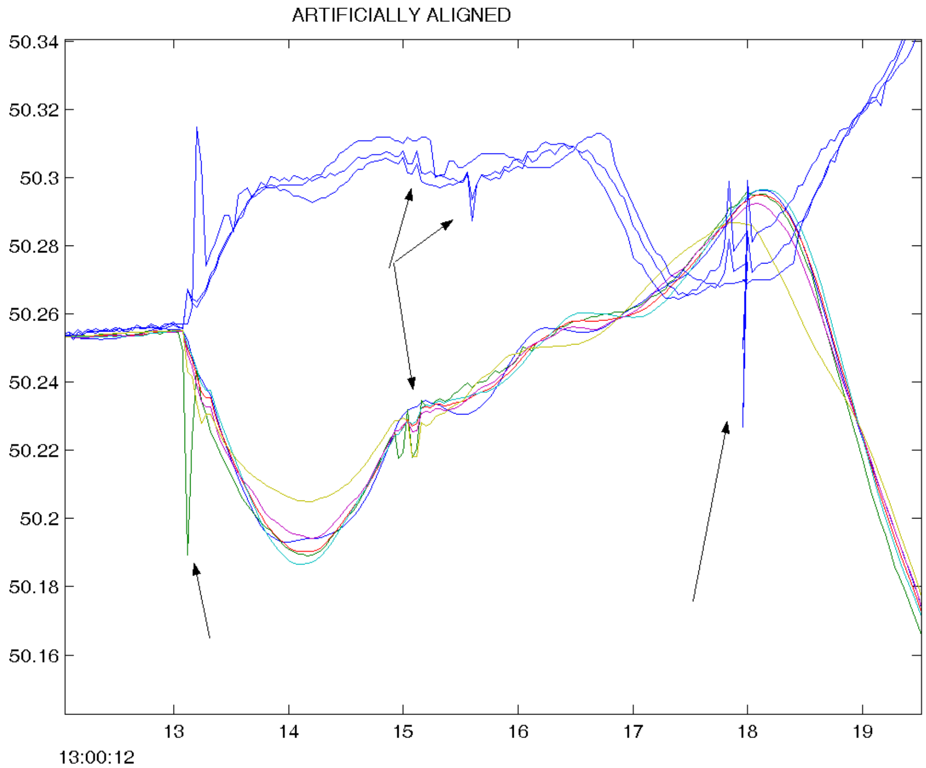

Fig 2: (source: PMU Data from WR and NR.) Note: There was time mismatch in WR PMUS and required to be logically aligned. Arrow indicates events.

Chapter- 5

FACTORS CONTRIBUTING TO GRID DISTURBANCES ON 30TH AND 31ST JULY 2012

5.1 As is the case with most system failures, no single factor was responsible for grid disturbances on 30th and 31st July 2012. After careful analysis of these grid disturbances, the Committee has identified several factors, which initiated collapse of power systems on these days. The Committee has also identified factors which could have saved the grids from total collapse. These factors are given below:

5.2 Factors that contributed to initiation of grid collapse

5.2.1 Depleted transmission network

It is observed that one circuit of 400 kV Bina-Gwalior-Agra section was taken under planned outage by POWERGRID from 11.47 AM of 28.07.2012 for up gradation to 765 kV level. A number of 400 kV lines were out prior to the incidence on both these days. The outage of 400 kV Bina-Gwalior–Agra for up-gradation work, non availability of 400 kV Zerda-Kankroli and 400 kV Bhinmal-Kankroli due to insulator problems in particular weakened the NR-WR Interface.

The availability of 400 kV Zerda-Bhinmal-Kankroli corridor requires to be improved by replacing porcelain insulators by polymer insulators at the earliest.

5.2.2 Overdrawals attributable to frequency control through commercial signals

5.2.2.1 One of the objectives of load despatch is to maintain power system parameters within permissible limits. The frequency, being one of the parameter has to be maintained at 50 Hz or close to 50 Hz. For historical reasons, the Indian grid Systems experienced poor frequency profile. In the 1990s, more loads were met with available generation at the cost of frequency. System was subjected to operate in the range of 48-51.5 Hz. Power quality and Grid security was compromised during this period. To enforce Grid discipline and to improve frequency profile, a new tariff mechanism was conceived in the early 1990s.The earlier PLF based tariff was replaced by Availability Based Tariff (ABT). Apart from fixed and variable charges, ABT had a third component, namely Unscheduled Interchange (UI) charge. UI charge is payable if an utility is deviating from schedule (Generation/drawal) depending on the frequency. ABT was first implemented in the WR on 1st,July 2002. It was possible to implement it with the regulatory support. There was positive improvement in the frequency profile. Initially the frequency band stipulated was 49.0-50.5 Hz and subsequently the range was tightened by Central Commission. The present range is 49.5-50.2 Hz. Further tightening of the frequency band by Central Commission has been challenged in the court. In the interest of power quality and grid security, there is a definite need to operate the system at and very close to 50 Hz. It is further observed that Utilities resort to load shedding to earn revenue through UI to compensate their poor financial management. If the frequency profile is close to 50 HZ, UI rate is nominal and utilities tend to over draw/under draw thereby completely deviating from the schedule. If more number of utility players resort to such activity, it may even lead to load encroachment phenomena and grid disturbance, as has been observed in recent grid disturbances. One has to draw power only through long term , medium term or short term contracts. UI mechanism, which helped the system initially, need to be reviewed now.

5.2.2.2 Electricity Act 2003 mandates that the operating frequency range defined in Grid standard(section73(d)) and Grid Code(section 79(1)(h)) has to be adopted by LDCs. Utilities rushing to court to define frequency range may not be in the interest of secured grid operation and power quality.

5.2.2.3 Just to give an example, it may be pointed out that the "Union for the Co-ordination of Transmission of Electricity" (UCTE), an association of transmission system operators in the Europe, operates at 50 Hz± 0.02 Hz . Similarly, North American Electric Reliability Council (NERC) ensures each balancing area to plan operation at 60 Hz. Though unintentional deviation take place, they are addressed without compromising the stipulated frequency. Intentional deviation is not being done as schedules are treated as binding contracts.

5.2.2. In the developed Systems, it is possible to operate at the stipulated frequency as the participating systems takes care of their load–generation balance at the stipulated frequency. In Indian Grid, Utilities have to adopt such practice for healthy system operation.

5.2.3 Inability to control flow on 400 kV Bina-Gwalior-Agra line

5.2.3.1 It is clear from the messages issued by NRLDC to various SLDCs and recorded telephonic conversations that regional load dispatcher had made desperate efforts for reduction of overdrawals by various States, which in turn would have led to relieving of loading of 400 kV Bina-Gwalior-Agra line. In spite of records of load shedding in log book of SLDCs, it is evident that there was hardly any reduction in flow on this line. It is observed that NLDC is revising TTC in case of planned outage of transmission elements and not in case of forced outage. During discussions, officials of NLDC had cited few reasons for not revising TTC on the day of disturbance. Firstly, in the opinion of NLDC, declaration of TTC is for the purpose of facilitating organized electricity trading contracts, which are cleared on day ahead basis and, therefore, revision of TTC in real time would not serve any purpose. Secondly, NLDC pointed out that calculation of TTC requires elaborate studies, which is a specialized task and cannot be performed by operators in real time. Thirdly, NLDC stated that regulatory provisions restrains them from applying congestion charges in case congestion is attributable to forced outage of transmission line in the corridor.

5.2.3.2 The very fact that provision to apply congestion charge forms part of the regulations on the issue of "*Measures to relieve congestion in real time*" indicates that security of the grid is main objective of such provision. However, the Committee tend to agree that calculation of TTC is a specialized task. However, ways and means can be found out to overcome this problem. The Committee has gone through relevant regulations of Central Commission. However, there is no provision which restrains NLDC from applying congestion charges. Further, para 5.4 of the "Detailed procedure for relieving congestion in real time operation" prepared by NLDC and approved by Central Commission does restrain NLDC from applying congestion charges in such situation but requires curtailment of transactions followed by revision of TTC. Thus, the procedure prepared under the provisions of a Regulation is not consistent with the Regulation. This aspect needs to be reviewed.

5.2.3.4 At present, there is no Automatic Generation Control (AGC)//tie line bias control in the network, which can automatically restrict the tie-line flows to the scheduled limit and also frequency at the nominal value.

5.2.4 Non-compliance of directions of LDCs and Regulatory Commissions

Non-compliance of instructions of RLDCs has been a problem since long. However, of late a disturbing trend of non compliance of directions of the Central Commission has been observed. The Committee is of the view that maximum penalty that can be imposed by Regulatory Commissions in accordance with the Electricity Act, 2003 is meager in comparison to damage that such non-compliance can cause to the grid. It is reported that in some cases, the penalty imposed by Central Commission has not been paid. States overdrawing from the grid often do not pay UI Charges which has contributed to infectiveness of ABT.

5.2.5 Protection System Issues

5.2.5.1 It is noted that on both days, the grid disturbance was initiated by tripping of 400 kV Bina-Gwalior line on zone-3 of Main-II protection, though there were several other concurrent conditions, which ultimately led to collapse of grid. There is no doubt that this tripping is attributable to load encroachment i.e. the current and voltage conditions were such that the protection system perceived it as fault (during fault, current becomes very high and voltage goes down to very low levels). Thereafter, there were several tripping on load encroachment and power swing. It is also noted that on both days, only Main-II protections operated and Main-I protection did not pick up.

5.2.5.2 It may also be noted that during the disturbances on 30th and 31st July, 2012, the 400 kV Bina-Gwalior line was not thermally overloaded i.e., the current rating (quad Bersimis conductor) of the line was not exceeded. However, the system was "insecure", i.e., the system was not stable for the loss of this line. System security requires that the system should be able to withstand credible contingencies.

5.3 Factors that could have saved the grid from collapse

5.3.1 Primary response from generators

5.3.1.1 The provision for putting all generating units on governor action has been part of Indian Electricity Grid Code (IEGC) for several years. However, this was not getting implemented as generators pointed out few difficulties including wide frequency fluctuations. However, in recent years, Central Commission has made concerted efforts to reduce the operating frequency band by periodically amending provisions in the IEGC and these regulatory provisions have been successful to large extent. Another difficulty cited in implementation of governor action was that the free governor action tries to lower the generation when frequency rises from a frequency lower than 50 Hz. This difficulty has also been addressed in the new IEGC issued in April 2010 by providing for restricting the governor action in such zone. In spite of the fact that impediments in implementation of governor action have been removed, there is still no evidence of governor action in Grid Disturbances on 30th and 31st July 2012. As mentioned elsewhere, had governor action been put into action during these disturbances, chances of survival of regional grid could have been more after isolation from NEW grid.

5.3.1.2 Another important aspect in relation to primary response is that it would be absolutely essential for survival of islands. In the wake of recent grid disturbances, the issue of formation of electrical islands as last resort to maintain essential services and quick restoration has come to fore. However, in case of imminent grid disturbance, if such electrical islands are formed, their chances of survival would be abysmally low if generating units included in these islands are not on governor action.

5.3.2 Optimum utilization of available assets

5.3.2.1 A large number of high capacity 400 kV lines have been added to the intra-regional and inter-regional systems in the recent past. However, a significant number of lines are generally kept open to contain high voltages. This makes system weak and such system may not be able to cope contingency. The widespread prevalence of high voltages is pointer of insufficient reactive compensation.

5.3.2.2 Practically all generating units are equipped with Power System Stabilizers (PSS), which can save the grid from several potential destabilizing conditions. However, there is need to tune PSS periodically. Similarly, various devices/equipment available in power system such as HVDC, TCSC and SVC have stability features, which need to be enabled. There is no evidence that these devices had any stabilizing influence during grid disturbances on 30th and 31st July 2012. The system requires a large of dynamic compensators, which need to be established through detailed study.

5.3.2.3 Presently, nine number of Phasor Measurement Units (PMUs) have been put in place in Northern Region and 3 PMUs have been installed in Western Region. Even these limited number of PMUs have been helpful in the past in understanding behavior of the system. Also, these PMUs have been of immense help to this Committee in analysis of grid failures on 30th and 31st July 2012. POWERGRID has plans to install PMUs in a big way, as they are bedrock requirement for development of smart transmission grids. However, it is matter of concern that on the days of disturbances, data from PMUs at Agra in Northern Region and Vindhyachal in Western Region is not available. It appears that the PMUs in Western Region are not time synchronized.

5.3.3 Operation of defense mechanism

Defense mechanisms like load shedding based on under frequency relays (UFRs) and Rate of change of frequency (df/dt) relays have been adopted in all Regional Power Committees (RPCs) in accordance with provisions of IEGC. Similarly, increasing number of Special Protection Schemes are being employed to save system in case of contingencies. However, the experience of the recent grid disturbances reveal that practically there was no load relief from these schemes. The case in point is Northern Region, where UFR based load shedding of 4000 MW (in 3 stages) and df/dt based load shedding of about 6000 MW has been agreed. The Committee is of the opinion that after loss of about 5000-6000 MW to Northern Region, had these relays operated, the grid could have been saved. The Committee has observed that so far violation of the various system security related provisions of IEGC issued by Central Commission and Grid Connectivity & Grid Standards issued by Authority has not been taken seriously and the attention has solely been on overdrawals from the grid.

5.3.4 Autonomy to Load Despatch Centres

5.3.4.1 The issue of lack of autonomy to Load Despatch Centres is on the horizon of policy makers for quite some time. In November 2007, Ministry of Power had constituted a Committee under Shri G.B. Pradhan, the then Additional Secretary in Ministry of Power. The mandate of this Committee was to examine issues relating to manpower, certification and incentives for the personnel employed on System Operation at various levels and also for ring-fencing the Load Despatch Centres to ensure their functional autonomy. This Committee had submitted its report in August 2008.

5.3.4.2 However, significant amount of efforts are required for implementation of recommendations of Pradhan Committee. One of the recommendations of the Pradhan Committee was to have qualified system operators. Towards this end, a certification programme has been started. But there is a need to provide incentives to those operators, who clear the certification examination as also recommended by the Pradhan Committee.

5.3.5 Intra-State transmission Planning and its implementation

In recent grid disturbances, it has been observed that overloading and consequent tripping of 220 kV system had pushed the system to the edge. It also appears that though inter-State system is being strengthened continuously, matching strengthening in intra-State transmission system has not been carried out. This not only limits ability of the States to draw power but also causes low voltage problems and unreliable supply to end consumers.

5.3.6 Dynamic security assessment and proper state estimation

At present the control centers do not have any tool to periodically assess the security condition of the system. They utilize only static state estimation results, which are being performed at 400 kV network at quite slow interval. The state estimator results are not quite reliable, due to non availability of data from a large number of RTUs. There is a need to arm the control centers with more advanced application functions and possibly perform the fast state estimation through synchrophasor measurements by deploying significant number of PMUs

The operators, at present, cannot readily determine whether the line loading will actually trip a relay. However, although they can, by doing an online contingency analysis, determine whether the system is secure or not. If the system is insecure (in an alert condition), the following preventive actions can be taken:

a) Use any controllable elements, like HVDC and TCSC, to re-route power flows. If continuous capability limits have been reached short time overload capabilities may be used to buy some time for other actions. The amount and effect of the rescheduling will have to be checked using online load flow/stability analysis.

b) Generation rescheduling may be attempted. An available hydro-generator may be called on to generate power.

c) Load tripping may be attempted to reduce line loading.

Chapter- 6

REVIEW OF ISLANDING SCHEMES

6.1 To avoid total blackout following a grid disturbance, a number of defense mechanisms and System Protection Schemes mainly comprising of generation backing down, contingency based load shedding, under frequency load shedding, df/dt load shedding etc already exist. The success of these schemes in avoiding grid disturbances to a large extent depends upon the severity, area of disturbance and system conditions prior to the disturbance. Also as a last resort some islanding schemes to save the generating stations are also in existence. During the disturbance which took place on 30th and 31st July 2012 some of the generators which survived in NR due to islanding or on house load were NAPP, BTPS , Dadri Gas, Faridabad Gas. The surviving generating units normally help in meeting essential loads and extending supply to other units within the same generating station and also to the nearby generators thereby helping in restoring the grid in reduced timeframe. The Committee reviewed the existing schemes and explored possibility of formulation of more islanding schemes in the NR.

6.2 A meeting in this regard was held on 7th August 2012 wherein members from various state utilities participated. After deliberations it was agreed that criteria for formation of islands should not be the geographical or electrical size but reliability of load-generation balance in the islands. There was agreement on the general philosophy on formation of islands, salient features of which are given below:

6.3 Guidelines for formation of islands

a) For the success of the islanding scheme, the load and generation of these islands should match and also it is necessary that generators within the island are operated with Governor action.

b) All control areas should endeavor to operationalize under frequency based load shedding scheme as first defense. Only if this defense mechanism fails and frequency continues its fall to dangerously low levels, formation of islands should be initiated as a last resort.

c) The probability of survival of islands will be realistic only when all the generating units are on free governor or on restricted governor mode in accordance with provisions of Indian Electricity Grid Code.

d) Islanding scheme could be a two-tier scheme. At frequency level of say 47.9 Hz, signal for formation of islands comprising of more than one generating stations along with pre-identified load could be initiated. However, if after the formation of island, frequency continues to fall further to say 47.7 Hz, these islands could be further broken into smaller islands comprising of single generating station with pre-identified loads.

e) For survival of the Islands, they should be created in such a manner that the possibility of generation exceeding load is more.

f) In case of hydro generators with limited pondage, islands should be created keeping peak generation in mind. This is because, in low hydro season, generation will practically be negligible during off-peak hours and hence creation of island may not serve any purpose.

g) Load-generation balance in pre-identified islands may change based on season, there would be need to review the scheme on seasonal basis. Such review should also capture network changes taking place in the interim period.

h) As far as possible, major essential loads such as hospitals etc should be incorporated in the islands. However, if this was not possible due to some reasons, efforts would be made to extend supply from these islands to essential loads on priority basis.

i) State load Dispatch Centers/ State Transmission Utilities along with the generating stations in their area should explore the possibility of formation of various islands.

6.4 Possibility of islanding of Delhi metro and Indian Railways

6.4.1 During the grid disturbances which occurred on 30th & 31st July 2012, Railways and Delhi Metro services were also affected. During the disturbance on 30th July 2012, Delhi Metro services were affected in the morning to the extent that services were delayed as the disturbance had occurred at 2:35 hours when metro services were off. This did not trouble the passengers. However, during second disturbance at 13:00 hours, the trains were in operation, and the passengers faced difficulties because of sudden stoppage of services. This problem could have been avoided if the metro network would have islanded with some generating station(s).

6.4.2 In view of the importance of Metro and other Rail network, the Committee held discussions with DMRC and Indian Railways on how islanding schemes could be developed for them.

6.5.3 Delhi Metro Rail Corporation (DMRC) have 200 trains running on 185 Kms metro rail network in Delhi fed from 13 nos. 220 kV substations, out of which one each was fed from UP and Haryana side and rest from DTL's 220 kV network in Delhi. DMRC was using its own 33 kV network for feeding stations and 25 kV network for meeting traction load. The distance between two metro power stations was in the range of 15 to 17 Kms as higher distance resulted in voltage drop and poor traction. The peak load of Delhi Metro was 120 MW with 50 MW station load and 70 MW traction load. Load per train was about 2 MW. DMRC had installed a DG set at each metro station to meet the load of lighting, ventilation and fire-fighting during main supply failures. They needed minimum 50 MW from at least 7 infeeds for traction purpose to keep their skeletal services running only for half an hour during contingencies like islanding of Delhi system from rest of the power grid for pulling the trains to the nearest station. Though they could feed their entire network from a single point, this would result into low voltage at distant locations. It was also noted that at any point of time, 10 trains are running inside the tunnels. If the power supply fails and the train stops inside the tunnel, then battery-backup is used to keep lights & fans running inside the compartments. In the event of power failure, it is not possible to open the doors of the compartments too. Batteries could provide backup supply for about half an hour only. Thereafter, fumes from the batteries start making the environment inside the tunnel suffocating. In view of this, it is essential to move the trains out of the tunnel and bring them to the nearest station within 15 minutes of supply-failure. In case, it is not possible, then passengers needed to be evacuated from the train under the guidance of trained metro staff.

6.5.4 Indian Railways were having a supply point every 30 – 50 Km distance to feed a section. In case of requirement of reduced load by the SLDCs / RLDC due to any contingency, they could manage to keep the trains running with availability of supply at each alternate section. They have allocation of 100 MW from NTPC's Dadri and Auraiya GPPs to meet the load of Delhi – Mughal Sarai section and their own dedicated transmission lines to draw power from the grid for the purpose. They also have supply from 2 locations in Delhi viz. Dhaula Kuan and Narela. Railways felt that this section could be considered for islanding during grid contingencies as this was one of the most important sections of Railways. They do not have allocation of power from any other central sector station to meet the load in any other section of their network in the country. For other sections, they have arrangement of supply from Distribution Companies of the concerned states and had a very good communication system between their control room and concerned SLDCs. During grid disturbances on 30th & 31st July 2012, Railways received full cooperation from SLDCs/RLDCs in restoration of supply to their network on priority, except in the Eastern Region, where supply was restored late reportedly due to non-availability of start-up power to the power stations in that region. Railways requested to get this examined and improve the arrangement of extending start-up supply in that region. Railways would abide by the advice of the power station / SLDC / RLDC in the matter of connecting load on restoration of supply after grid disturbance. They also requested their services to be given priority at the time of restoration of grid.

6.5.5 It was noted that subsequent to grid failure at 1300 hours on 31st July 2012, two gas turbines (30 MW each) were started by Delhi and charged DMRC-I & II feeders after charging other important feeders. However, within a few minutes of charging of DMRC feeders, large fluctuations in the load were observed and the GTs tripped due to fall of frequency to the level of 47.4 Hz. It was felt that this might have been caused due to sudden connection of large quantum of traction load. If the load was connected by DMRC gradually in close coordination with GT control room, the machines could have continued to operate.

6.5.6 The Committee also examined the possibility of islanding of states including Delhi in the Northern Region under a grid contingency and recommends creation of four islands in Delhi. Delhi Metro's emergency load and a part of Indian Railways load could continue to remain connected with these islands at its minimum four different sub-stations in case of grid contingencies.

6.5.7 In case of failure of formation of islands in Delhi, Delhi Metro while availing supply from any source e.g. IP GTs, Dadri GPS, etc., should connect load in small steps in close coordination with Delhi SLDC and the generating station to avoid the possibility of tripping of the generating station. DMRC should also make necessary changes in the technical and communication arrangements in their system to ensure this. There should be reliable communication arrangement between DMRC and GT station at IP extension in Delhi. DMRC should re-distribute its load so as to make it balanced in all three phases for stable operation of connected power stations. Power could be supplied to Delhi Metro from Rithala GT station of TPDDL (one of the Distribution Companies in Delhi) as well if this station had black-start facility. There being some possibility of malfunctioning of islanding of Delhi in case of grid disturbances and delayed extension of supply thereafter, DMRC might consider installation of DG set(s) of appropriate capacity to move the trains stuck in the tunnels so as to ensure safety of passengers.

6.4.8 As regards Indian Railways, islanding scheme could be prepared for Auraiya GPS along with Railways' and other loads. This could feed about half of Delhi-Mughal Sarai section. Remaining half could be fed from Dadri GPS, which is envisaged to be islanded with a part of Delhi's load. In case of failure of formation of Auraiya island, Railways while availing supply from Auraiya GPS after its black-start, should connect load in small steps in close coordination with the power station to avoid the possibility of its collapse again. Keeping in view the fluctuating nature of traction load, no unit should be started with such load. However, the supply should be extended to

Railways / DMRC by the power station / SLDC on priority after starting the unit(s) with other types of balanced and more or less constant loads.

6.5 As per the resolution adopted in meeting taken by Hon'ble Minister of Power with Chief Ministers and Power Ministers of Northern State on 6th August 2012 the schemes prepared by States would be deliberated by them with CEA, POWERGRID and NRPC. Indian Railway and DMRC may further firm up the islanding schemes in consultation with CEA, POWERGRID and RPCs. Other islanding schemes should also be prepared on similar lines.

Chapter- 7

REVIEW OF RESTORATION OF THERMAL POWER STATIONS

7.1 Background

The black start procedure has already been prepared by RLDCs and is available with all utilities. However, during the recent grid disturbances it has been observed that substantially longer time has been taken by certain generating stations to come on bars. In view of this, discussions were held with the utilities to review the time taken in restoration of generation after the recent grid disturbances. NRLDC, NLDC and UPSLDC also participated. Major observations and recommendations are given below:

7.2 Observations

i. Some of the utilities expressed that to initiate start up process, certain delays were encountered on account of commercial issues in obtaining the start- up power supply from other outside agencies.

ii. Most of hydro stations were ready to provide the start-up power immediately after the grid disturbance. However due to complete collapse of the entire grid, the required quantum of load commensurate with the generation build-up rate were not available despite close coordination and intimation given to the concerned load dispatch centres and personal contact with the counterpart distribution utilities. A pre-defined arrangement for availability of loads under such emergency conditions would have hastened the process of restoring the power supply. This may require to be looked into by the concerned agencies.

iii. NRLDC suggested that the load dispatch centres should be authorized to advise action to the concerned utilities for extending power supply immediately to the black-starting units through exchange of special emergency code between the concerned load dispatch centres. This process would facilitate quicker restoration by cutting down time required in taking administrative clearance which is otherwise obtained under normal grid operation conditions.

iv. Existing Black start procedures should be frequently reviewed in line with the fast changing grid scenario and addition of generation capacity. The facilities available with existing and upcoming IPPs should also form part of these procedures for the purpose of extending start up supply to black starting units in the vicinity.

v. All utilities felt the need to strengthen and have a dedicated communication network between SLDCs and all power plants in the respective control areas, which does not adequately exist at present and the agencies depend mainly on mobile phone facility, which is not completely reliable for such purposes. Availability of reliable and efficient communication facilities at all active installations connected to the grid is essential to ensure faster restoration.

vi. Various load dispatch centres, substations and generating stations, which are to implement the restoration operations in the real-time, upon receiving instructions from the apex load dispatch centres are not adequately managed in terms of experienced manpower and also particularly during odd hours. Utilities therefore expressed that the qualified operating personnel having undergone orientation courses under certification programme should be posted there.

vii. While examining the restoration data received from various utilities, it was observed that certain delays had occurred in lighting up the units, after start up supply was made available. The observed time duration ranged from 2 to 23 hours for Singrauli STPS and 2 hrs to 7 hrs for units at Unchhar, Rihand, Dadri(coal), Tanda and 1 to 16 hours for various units at Anpara, Obra, Paricha and Panki stations. At GGSSTP the time ranged from 2 to 9 hours. The utilities intimated that in case of some units LP diaphragms had burst during the occurrence, for which additional time was taken to rectify/replace the diaphragms.

viii. It was observed that after lighting up of the units, some of the units had taken longer time than others to synchronize with the grid. The observed time duration ranged from 2 hours to 4 hours in case of various generating units at Singrauli, Unchahar, Badarpur & Rihand TPSs and 2 hours to 9 hours for units at Anpara, Obra, Paricha and Panki stations. In case of gas based stations the time duration ranged between 1 to 6 hrs at Auraiya, Dadri and Faridabad for GTs and 3 to 7 hours for STGs.

On 30.7.2012, in DTL system GTs 1,2,5 were restored during 0250 to 0430 hours (generation of order of 80 MW) and later GT3 was synchronised at 0640 hours (30 MW) with STGs 1,2,3 resuming generation between 0810 to 0840 hours (order 60 MW). On 31.7.2012, in DTL system GTs 1,2,3,5,6 were restored during 1310-1445 hours (

order 141 MW) and STGs 1,2,3 resuming generation between 1615 to 1646 hours (order 51 MW)

Badarpur TPS had earlier survived and had operated in Island mode with units nos. 1,3 and 5 till 0658 hours on 30.7.2012 when the island collapsed and power was later extended to the station at 0710 hours from 220 kV DTL system at Sarita Vihar and unit no.3 was first synchronized at 1025 hours.

Faridabad GPS which had tripped at 0233 hours on 30.7.2012 was synchronized with grid at 0552 hours. It however tripped at 0658 hours with the collapse of Badarpur island. Faridabad GPS was later synchronized at 0844 hours with grid.

ix. While extending the power to Singrauli TPS, through HVDC Vindhyachal by pass route there had been tripping at Vidhyachal resulting delay in making start up power available to the station. The possibility of extending power to Singrauli from Pipri Hydro on 30th July in closer coordination between NRLDC, SLDC, UPJVUNL, UPRVUNL and NTPC would have resulted time-saving in affecting quicker start-up power to NTPC generating units. UPRVUNL suggested that Pipri-Hydel should be synchronized with Western grid through Vindhyachal-Shaktinagar-Anpara 400 kV line and 132 kV Anpara-Pipri line. This would ensure stability of voltage of Pipri machines and more machines of Pipri-Hydel could be started up.

x. In case of major hydro station, BBMB intimated that on 30th July 2012 the system was fully connected to grid by 0902 hours and on 31st July 2012 at 1553 hours. GGSSTP Ropar received start up power from Bhakra source at 0841 hours on 30th July 2012 and unit #2 boiler lighted up first at 1020 hours. The unit was synchronized at 1218 hours via Bhakra (220KV)-Ganguwal (220/132KV)-132KV Ropar-GGSSTP route and on 31st July 2012 unit # 2 boiler lighted up at 1640 hrs and synchronised at 1740 hours via Nalagarh(PG)-220KV Mohali-GGSSTP route.

xi. In ER, Kahalgaon and Farakka STPS received start up power from WR through Sipat-Ranchi and could not receive power earlier from hydro due to tripping of Teesta HPS on 3rd harmonic, over-voltages and under frequency and mismatch in generation with remote loads over long EHV lines. Despite multi-attempts of black starts at Tala, Chukha and Teesta, the startup power could not be extended to Farakka / Kahalgaon from the hydro sources.

xii. It was also brought out that start-up power could be extended to number of stations simultaneously so that stations could use them for preparatory activities like CW pumps, compressors etc. and actual start-up could be attempted after specific clearance from the source providing start-up power. This could considerably expedite the start-up as preparatory activities not needing much power could be taken up by number of stations simultaneously thus considerably reducing the start-up times.

7.3 Analysis of Restoration Process of Thermal Power Stations

Detailed analysis of start-up process for the grid disturbance of 30th July 2012 has been made so as to examine the restoration process and areas of possible improvements. The salient observations are given in subsequent paras:-

7.3.1 Availability of start-up power

Salient abstracts of the receipt of start-up power in the region are as under:-

Table 7.1: Availability of start-up power in Northern Region 30th July 2012

Time Elapsed Before Start-up power Became Available after Disturbance (Hrs)	Stations (Nos)	Cumulative number of Stations
< 1	2	2
1 to 1.5	4	6
1.5 to 2.0	5	11
2.0 to 2.5	2	13
2.5 to 3.0	0	13
3.0 to 3.5	3	16
3.5 to 4.0	2	18
4.0 to 4.5	4	22
4.5 to 5.0	3	25
5.0 to 6.0	1	26

It may therefore be seen that more than 50 % of the affected stations in the region received start-up power after 3hrs. Only 2 stations in the region could receive start-up power within 1 hour. Also 8 stations received start up power after 4 hours. Maximum time taken for any station to receive start-up power was 6 hours for Ropar TPS.

The reasons for delay in receiving start-up power by most of the thermal power stations may require to be looked into from grid system point of view. A normative or bench mark time frame for extending start-up power to each of the TPS may be evolved by the RPCs in consultation with the constituents and RLDC so as to ensure that significant delays are not encountered in extending start-up power. A fact that emerged during discussions was that since the present grid failure occurred after almost a decade, the preparedness and response was perhaps not upto the level expected. More frequent need of having periodic mock exercises to ensure preparedness of all stakeholders involved as actual grid disturbances needs emphasis.

7.3.2 Restoration of Thermal Power Stations

Coal fired thermal power stations involve considerable amount of preparatory actions before actual start-up like operationalizing major auxiliary systems like circulating water (CW) system, compressed air system. Also start-up power is required to be provided to each unit and station auxiliary which involves charging up of number of transformers within the station sequentially and in turn is time consuming. In the above context, suggestions made at Para B above that start-up power should be extended as soon as possible so that stations could initiate preparatory activities and actual start-up process could be attempted immediately upon receiving start-up power.

It was also brought out by the stations that sudden tripping of the unit at high load lead to bursting of LP Turbine diaphragms in many of the units requiring replacement before start-up could be taken up and involved about 4 hrs for replacement of diaphragms for each unit.

7.3.3 Start-Up And Restoration Times

With a view to analyze the restoration process of thermal stations, data regarding time of availability of start-up power, time of taking up Boiler light up (BLU), time till synchronization and time of achieving full load were sought from the stations. The status of receipt of data from the stations is furnished below in Table-7.2.

Table 7.2: Receipt of restoration data from stations

Station	Utility	Status of Receipt of Data	Remarks
BADARPUR TPS	NTPC Ltd.	√	
RAJGHAT TPS	IPGPCL	√	
I.P.CCPP	IPGPCL	√	Station Islanded
PRAGATI CCPP	IPGPCL	√	
PRAGATI CCGT-III	IPGPCL	**x**	
RITHALA CCPP	NDPL	√	Station not running
PANIPAT TPS	HPGCL	**X**	
YAMUNA NAGAR TPS	HPGCL	**X**	
RAJIV GANDHI TPS	HPGCL	**X**	
INDIRA GANDHI STPP	APCPL	**X**	
MAHATMA GANDHI TPS	JhPL(HR)	**X**	
FARIDABAD CCPP	NTPC Ltd.	√	
GND TPS(BHATINDA)	PSPCL	**X**	
GH TPS (LEH.MOH.)	PSPCL	**X**	
ROPAR TPS	PSPCL	√	
KOTA TPS	RRVUNL	√	
SURATGARH TPS	RRVUNL	√	
CHHABRA TPP	RRVUNL	√	
RAMGARH CCPP	RRVUNL	√	
DHOLPUR CCPP	RRVUNL	√	
ANTA CCPP	NTPC Ltd.	√	
OBRA TPS	UPRVUNL	√	
PANKI TPS	UPRVUNL	√	
HARDUAGANJ TPS	UPRVUNL	√	
PARICHHA TPS	UPRVUNL	√	
ANPARA TPS	UPRVUNL	√	
SINGRAULI STPS	NTPC Ltd.	√	
RIHAND STPS	NTPC Ltd.	√	
UNCHAHAR TPS	NTPC Ltd.	√	
DADRI (NCTPP)	NTPC Ltd.	√	
TANDA TPS	NTPC Ltd.	√	
AURAIYA CCPP	NTPC Ltd.	√	
DADRI CCPP	NTPC Ltd.	√	

As may be seen, while data has been received from most of the stations, the data from several other stations was not received and thus their restoration pattern could not be analyzed. The analysis for stations for which data for boiler light up was received have been made in respect of time of synchronization after BLU.

7.3.4 Initiation of Boiler Light Up

As brought out above, initiation of start-up of a coal fired station takes considerable time after receipt of start-up power due to preparatory activities involved. As the time for BLU have not been received from number of stations, the actual time taken for preparatory activities as also maintenance like replacement of diaphragms etc. could not be ascertained.

Details of BLU undertaken are furnished in Table-7.3. From the data on BLU available it is seen that there are considerable variations between the time taken for BLU of the first unit after receipt of start-up power.

Table 7.3: Time elapsed (Hrs) before BLU was undertaken after receipt of Start up power

Station	1st	2nd	3rd	4th	5th	6th	7th
Anapara	03:12	04:52	05:01	06:08	16:20		
Obra	01:00	01:58	05:55	07:23	15:25		
Paricha	03:45	07:30					
Panki	01:00	06:38					
Kota	N.A	N.A	N.A	SD	N.A	N.A	N.A
Suratgarh	N.A	N.A	SD	N.A	N.A	N.A	N.A
Chabra	SD	N.A					
Giral	N.A	SD					
RajWest	NA	SD	NA	NA			
Barsingsar	NA	SD					
Ropar	01:39	01:54	03:09	04:59	09:29	25.00	
Rajghat	SD	01:12					
Singrauli	01:36	04:06	07:53	09:56	10:56	15:34	22:51
Rihand	N.A	N.A	N.A	N.A			
Unchahar	02:35	04:52	05:08	06:00	06:29		
Tanda	N.A	N.A	N.A	N.A			
Dadri Coal	N.A	N.A	N.A	N.A	N.A	N.A	
Badarpur	N.A	N.A	N.A	N.A			

Note: Timelines indicate total elapsed time before successive units were taken for start up and DO NOT refer to unit numbers

From the table it may be seen that few Stations like Obra and Panki undertook first BLU after 1 hour of receipt of start-up power. Ropar and Singrauli attempted first BLU after 01:40 hrs after receiving start-up power. Several Stations could undertake first BLU only after 2.5 to 3 hrs of receiving start-up power.

Also large variations are seen in undertaking further unit start-ups after taking BLU of first unit. The data of time elapsed before undertaking subsequent BLUs have also been analysed and presented in the Table-7.4. From the table it may be seen that while for some of the units the BLU was taken up within very short interval of 10-20 minutes of BLU of previous unit, in most of the cases the BLU for subsequent unit was taken up 2 to 3 hours after the BLU of preceding unit and in many cases exceptionally large time of 8 to 10 hours have been taken. The utilities were asked for the reasons for delay in start up of the units; however no reasons for delay have been furnished. Further discussions need to be undertaken in this regard.

Table 7.4: Time interval between successive BLUs

Station	1st	2nd	3rd	4th	5th	6th	7th
Anapara	03:12	01:40	00:09	01:07	10:12		
Obra	01:00	00:58	03:57	01:28	08:02		
Paricha	03:45	03:45					
Panki	01:00	05:38					
Kota	N.A	N.A	N.A	SD	N.A	N.A	N.A
Suratgarh	N.A	N.A	SD	N.A	N.A	N.A	N.A
Chabra	SD	N.A					
Giral	N.A	SD					
RajWest	NA	SD	NA	NA			
Barsingsar	NA	SD					
Ropar	01:39	00:15	01:15	01:50	04:30	14.31	
Rajghat	SD	01:12					
Singrauli	01:36	02:30	03:47	02:03	01:00	04:38	07:17
Rihand	N.A	N.A	N.A	N.A			
Unchahar	02:35	02:17	00:16	00:52	00:29		
Tanda	N.A	N.A	N.A	N.A			
Dadri Coal	N.A	N.A	N.A	N.A	N.A	N.A	
Badarpur	N.A	N.A	N.A	N.A			

Note-Time for 1st unit indicates time taken after start-up power. Timelines for other units indicate time taken after BLU of previous unit.

7.3.5 Unit Synchronization after Boiler Light Up

The details of time taken for synchronization after BLU are furnished in Table- 7.5. Even from the limited number of Stations where data of both BLU time and synchronization time is available, it is seen that the time taken for synchronization after BLU varies considerably.

Table 7.5: Time taken for synchronization after BLU

Station	1st	2nd	3rd	4th	5th	6th	7th
Anapara	02:41	04:36	06:29	08:07	09:10		
Obra	01:43	03:55	04:07	04:52	05:30		
Paricha	04:04	05:23					
Panki	03:14	05:28					
Kota	N.A	N.A	N.A	SD	N.A	N.A	N.A
Suratgarh	N.A	N.A	SD	N.A	N.A	N.A	N.A
Chabra	SD	N.A					
Giral	N.A	SD					
RajWest	NA	SD	NA	NA			
Barsingsar	NA	SD					
Ropar	01:25	01:55	01:58	02:55	04:15	05:50	
Rajghat	SD	01:00					
Singrauli	01:21	01:42	02:08	02:10	02:28	03:21	03:51
Rihand	N.A	N.A	N.A	N.A			
Unchahar	01:46	01:57	02:04	03:03	03:51		
Tanda	N.A	N.A	N.A	N.A			
Dadri Coal	N.A	N.A	N.A	N.A	N.A	N.A	
Badarpur	N.A	N.A	N.A	N.A			

As may be seen that the time for synchronization after BLU varies from a low of 1.2 hrs to as high as 3 to 4 hrs and even exceptionally high at 8 to 10 hrs for some of the units. Many of the NTPC units took 3 to 4 hrs for synchronization after BLU.

It may be mentioned that time taken from BLU to synchronization is expected to be fairly comparable for the units of similar design with similar start up regimes and thus such large differences in timelines are not understood. Details of problems/constraints encountered during start-up process and delays occurred may require to be looked into further in respect of constraints bottlenecks faced in this context.

7.3.6 Time from start-up power to Unit Synchronization

Since timeline for undertaking BLU were not made available by most Stations, an analysis of total time taken upto synchronization from receipt of start-up power has been made to understand the trend that emerged. These timelines however would be indicative of combined impact of constraints/delays occurred in preparatory activities (before BLU) and during the start-up process. The details of time taken for synchronization after start-up power are furnished in Table-7.6

Table 7.6: Total Time S.U Power to Synchronization

Station	1st	2nd	3rd	4th	5th	6th	7th
Anapara	05:53	10:44	11:30	12:59	25.30		
Obra	03:41	06:30	09:50	11:30	20:17		
Paricha	07:49	12:53					
Panki	04:14	12:06					
Kota	**02:55**	03:43	03:48	05:34	07:08	11:28	SD
Suratgarh	06:26	09:44	11:05	12:39	39	SD	
Chabra	SD	05:24					
Giral	22:20	SD					
RajWest	11:43	13:08	23:07	SD			
Barsingsar	48.32	SD					
Ropar	**03:19**	03:37	08:59	09:14	11:24	27.55	
Rajghat	SD	02:12					
Singrauli	03:44	07:27	09:14	12:06	12:38	19:25	25.19
Rihand	04:40	06:38	11:54	SD			
Unchahar	04:32	06:56	07:46	08:11	10:20		
Tanda	**02:10**	02:45	04:09				
Dadri Coal	04:02	06:00	07:24	08:13	08:30		
Badarpur	03:15	03:47	04:19	08:00	10.50		

Note: Timelines indicate order of synchronization of units and not unit numbers

The variability seen here is similar to the variability seen in timelines from start-up power to BLU and BLU to synchronization – rather the variability seen here is much more prominent. Amongst the 210 MW units, Kota was the first station to achieve synchronization within 2.55 hrs from start-up power followed by Ropar achieving synchronization of one unit in 3.19 hrs. Singrauli achieved synchronization of first unit in 3.44 hrs. Rest of the Stations achieved first synchronization beyond 4 hrs and some Stations like Paricha and Anapara could achieve their first synchronization in 6 to 8 hrs. Badarpur could achieve synchronization of its 210 MW unit in 8 hrs.

Amongst the smaller size units, Tanda and Rajghat TPS achieved their first synchronization in 2.10 hrs after start-up power whereas other Stations like Badarpur and Panki took 3 to 4 hrs to achieve first synchronization. Obra achieved synchronization of 50 MW unit in 6.30 hrs though it was the second synchronization for the Station. The lignite fired Circulating Fluidized Bed Combustion (CFBC) units had taken exceedingly long time to achieve their first synchronization.

Further, analysis of time taken for subsequent synchronizations have also been analysed and presented in the Table-7.7. Here again similar large variability is seen. Ropar and Kota TPS achieved most rapid successive synchronizations with second and fourth synchronization at Ropar in 18 and 15 minutes and second and third synchronization at Kota in 48 minutes and 05 minutes, however the subsequent synchronizations took longer. Amongst the smaller size units, Tanda TPS achieved rapid second synchronization in 35 minutes.

Table 7.7: Time taken for successive Synchronizations

Station	1st	2nd	3rd	4th	5th	6th	7th
Anapara	05:53	04:51	00:46	01:29	12:31		
Obra	03:41	02:49	03:20	01:40	08:47		
Paricha	07:49	05:04					
Panki	04:14	07:52					
Kota	02:55	00:48	00:05	01:46	01:34	04:20	SD
Suratgarh	06.26	3.18	01.21	01.34	04.20	SD	
Chabra	SD	05:24					
Giral	22:20	SD					
RajWest	11:43	01:25	09:59	SD			
Barsingsar	48.32	SD					
Ropar	03:19	00:18	05:22	00:15	02:10	16.31	
Rajghat	SD	02:12					
Singrauli	03:44	03:43	01:47	02:52	00:32	06:47	05:54
Rihand	04:40	01:58	05:16	SD			
Unchahar	04:32	02:24	00:50	00:25	02:09		
Tanda	02:10	00:35	01:24				
Dadri Coal	04:02	01:58	01:24	00:49	00:17		
Badarpur	03:15	00:32	00:32	03:41	02.50		

Note-Time for 1st unit indicates time taken after start-up power. Timelines for other units indicate time taken after synchronization of previous unit

The large variations in synchronization times and successive synchronization times with many of the stations achieving timelines far better to others is indicative of the potential improvements possible in most of the stations with better/faster preparation.

7.3.7 Gas Based Stations

Gas fired stations are looked upon as rapid source of power after such grid disturbances as preparatory activities required are far less and start ups of Gas turbines (GTs) are fast. Details of time taken for synchronization of GT Stations a re given in Table-7.8.

Table 7.8: Gas fired stations - Time taken from start-up power to Synchronization

Station	Unit#1	Unit#2	Unit#3	Unit#4	Unit#5	Unit#6
Dholpur	03:29	SD	SD			
Ramgarh	09:08	08:28	SD			
Pragati CCPP	01:41	01:34	03:47			
IP CCGT	Islanded	Islanded	Islanded	Islanded	Islanded	Islanded
Anta	02:37	00:46	01:36	05:00		
Auraiya	02:14	00:53	03:32			
Dadri Gas	03:03	03:41	06:15	03:51	SD	08:00
Faridabad	02:52	04:10	06:38			

Note: Cells coloured yellow indicate Steam Turbine unit

It may thus be seen that even the Gas turbine units have taken unduly long time for start-up. While the first Gas turbine units could come up at Anta and Auraiya in about 50 minutes, the Gas turbine units at most other stations and even the subsequent Gas turbine units at these stations took far longer time of 2 to 4 hours. Such large start-up times for Gas turbine units need to be looked into with a view to make Gas turbine units a dependable source of rapid restoration power.

7.4 Conclusions and Suggestions

Based on the discussions brought out in the foregoing paragraphs, the suggestions for faster restoration of thermal power stations are as under:-

1. A well coordinated and documented process for supply of start-up power may be put in place under the overall coordination of NLDC clearly bringing out the following:

   a. Existing Black start procedures should be frequently reviewed in line with the fast changing grid scenario and addition of generation capacity. The facilities available with existing and upcoming IPPs should also form part of these procedures for the purpose of extending start up supply to black starting units in the vicinity.

b. Explicit instructions to all stake holders to supply start-up power without any commercial considerations that could be settled later.

c. Micro level load management for lines and loads may be envisaged for extending start-up power through pre-defined arrangement for availability of loads under emergency conditions so as to avoid frequent tripping while extending start-up supply.

d. Authorizing Load dispatch centres to advise action to the concerned utilities for extending power supply immediately to the black-starting units through exchange of special emergency code between the concerned load dispatch centres.

e. A normative or bench mark time frame for extending start-up power to each of the TPS. This may be evolved by the RPC in consultation with the constituents and RLDC so as to ensure that significant delays are not faced in extending start-up power.

2. There is a need to strengthen communication and have a dedicated communication network between SLDCs and all power plants in the respective control areas. The mobile phone facility presently used, is not considered reliable for such communication. Reliable and efficient communication facilities at all active installations connected to the grid is essential to ensure faster restoration.

3. Key installations/sub-stations should be managed by experienced manpower particularly during odd hours – like Qualified operating personnel having undergone orientation courses under certification programme.

4. A system to extend start-up power to number of stations simultaneously for preparatory activities could be considered. The actual start-up could be attempted after specific clearance from the source providing start-up power. This could expedite start-ups as preparatory activities not needing much power could be taken up by number of stations simultaneously.

5. Large variations are observed in time taken for initiation of unit start up (Boiler light up) by the stations after availability of start-up power and also for start ups/light up of subsequent units. Also, while subsequent start-ups were very fast (10-20 minutes) in some of the units, in other cases they took considerably longer – several hours.

   Reasons for the delays in attempting first start-up and subsequent start-ups may be examined by the utilities in consultation with CEA. A standard procedure for preparatory activities and sequence of start up may be put in place by the stations to restore units as early as possible.

6. Large variations have also been observed in time taken by the stations for synchronization after Boiler light up which are normally not expected. Detailed analysis of times taken especially from BLU to synchronization may be made by the utilities in consultation with CEA so as to identify constraints/bottlenecks faced during unit start-up for remedial action.

7. The large variations in synchronization times and successive synchronization times achieved with many of the stations achieving timelines far better to others is indicative of the potential improvements possible in most of the stations with better/faster preparation. Further, in most cases the start-up times appear to be considerably higher than the manufacturers/OEM recommendations. Optimal start-up/ restoration procedures by the stations in consultation with OEMs.

8. Long start-up times taken by most Gas turbine units need to be investigated to develop Gas turbine units as reliable source of fast restoration power.

Chapter- 8

CYBER SECURITY ASPECTS

8.1 With regard to cyber security, the Committee examined the apprehension that grid disturbances on 30th and 31st July 2012 could have been initiated by cyber attack. In addition the Committee also examined following aspects-

a) Status of IT intervention in the operation of Power Sector
b) Measures taken by various stakeholders to counter any possible cyber attack in their system
c) Communication facilities available between various stake holders

8.2 Field Visit

8.2.1 To assess the situation, visit to NRLDC, 400 kV sub-station of POWERGRID at Agra and Rihand Super Thermal Power Station was undertaken to examine the present automation & communication arrangements at the Power Sub stations & Thermal Power Plants.

8.2.2 During the visit to the 400 kV Grid Sub-station at Agra, it was observed that the switching for operation is independent of computer networking. The commands are issued locally to carry out switching operations at the sub stations and there is no automated system of event recording on a continuous basis. Similarly, in the case of generating plants, as observed during the visit, each unit has its own control and is no way connected with the outside network and the performance logging of the station data is recorded & archived for each generating unit separately.

8.2.3 During the visit to NRLDC and 400 KV sub station, it has been observed that there are no dedicated telecom facilities available between various control centres, and generating stations. If NRDLC observes any abnormality in the operation in the grid, they inform the same to the concerned SLDC/ Station either through public telephone or on leased line network. Since public telephone network may not be reliable in many cases specially in remote/ rural areas and more so in case of grid disturbance and total power failure like the present one, there is an urgent need to provide dedicated network for this purpose. It has also been observed that there may be errors/ loss of data received from remote (RTUs) at the data center and there may be failure of data coming from a station in case of power breakdown because of UPS not working properly or batteries being weak.

8.3 Discussion & findings

8.3.1 The matter was discussed with the representatives of POWERGRID, NTPC, NHPC and POSCO. The issue of cyber security was examined in detail to ensure that adequate mechanism is available with all the stakeholders to prevent any attack on the systems.

8.3.2 It was pointed out during the discussion that the Cyber attacks can be perpetrated from any side either by outsiders or by insiders and may have far–reaching and detrimental effects on power systems controls, that could lead to the destabilization of the supply capabilities of energy sector and may have a cascading effect on the national security /economy. Cyber security vulnerabilities in generation sector are localized and its impact can shut down one unit or plant. The affect of vulnerabilities in centralized systems e.g. SCADA etc used in transmission sector is wide and may have potential impact on the synchronous operation of entire Power System leading to Grid collapse. As far as distribution sector is concerned, where bulk of automation are visible, the impact of cyber attack on centralized SCADA /DMS can lead to disruption of services to critical customers like hospitals, metro etc. which is critical for the units involved but at the same time not global and widespread.

8.3.3 It was informed to all the stakeholders that CERT-In (Indian Computer Emergency Response Teams), Department of Information Technology, Ministry of Communication and Information Technology, Government of India has prepared a Crisis Management Plan (CMP) for countering cyber attacks and cyber terrorism for preventing the large scale disruption in the functioning of critical information systems of Government, Public and Private sector resources and services. Ministry of Power has also constituted CERT-Thermal, CERT-Hydro and CERT-Transmission with nodal agencies as NTPC, NHPC and POWERGRID respectively, to take necessary action to prevent cyber attacks on the Utilities under their jurisdiction.

8.3.4 The Committee in course of meeting with stakeholders, reviewed existence of appropriate security policies and procedures as envisaged in the Crisis Management Plan prepared and circulated by CERT- India. In course of discussion, it emerged that no abnormal cyber event was observed by the stakeholders prior to and during grid disturbances on both occasions. The matter was also discussed with the officers of CERT-In to asses the present arrangement and preparedness of the stack holders to avoid any cyber attack on their system.

8.3.5 After going through the records, discussion & field visits, it is observed that the operation of grid is primarily manual and operations are done locally except in case of few 400 kV S/Ss which are controlled from remote locations through dedicated networks. At present there is no wide area network at grid control level and there is no communication with power utilities using public domain. **The Committee is of the opinion that that Grid Disturbance could NOT have been caused by a cyber attack**.

8.4 Suggestions

8.4.1 During the discussions and according to the feed back provided by the stakeholders it emerged that Power Sector stack holders have taken adequate steps to prevent the cyber attack on their system and also have dedicated organisational polices in this regard.

8.4.2 The existing communication network should be maintained properly. RTUs and communication equipments should have uninterrupted power supply with proper battery back up so that in case of total power failure, supervisory commands & control channels do not fail.

8.4.3 Regular cyber vulnerability test/mock drills/cyber audit/and other measures as per the crisis management plan of CERT- In should be carried out regularly by all the stakeholders.

8.4.4 A cyber audit specifically to detect malware targeting Industrial Control Systems (ICS) should be conducted at critical plants and sub-stations after any abnormal event.

8.4.5 A dedicated team of IT Personnel for cyber security in all the Power Stations and Sub-stations should be developed and proper training for the team members should also be conducted regularly by the respective organizations to upgrade their skills.

8.4.6 Mitigation strategies for countering physical attacks have to be drawn by all the power utilities.

8.4.7 Regulatory framework should be created for cyber security in the power sector.

8.4.8 An Office/ Body of Cyber Security Auditors should be created within Power Sector.

8.4.9 Vendors for cyber security systems should be developed as per International / National standards.

8.4.10 For smooth operation of grid systems, it is absolutely important that all the power generating and distributing stations are connected on a very reliable telecom network.

i) A proper network may be built up preferably using MPLS (Multi Protocol Label Switching) which is simple, cost effective and reliable. In remote place where connectivity is a problem, the stations can use dedicated fibre cable from the nearest node

ii) Since POWERGRID has its own fibre optic cables, practically covering all major nodes and power stations, a proper communication/IT network may be built using dedicated fibres to avoid any cyber attack on the power system.

Chapter- 9

RECOMMENDATIONS

9.1 Review of Protection Systems

9.1.1 There is a need to review protection schemes. This Committee concurs with recommendation of previous enquiry committees that a thorough third party protection audit need to be carried out in time bound manner. This exercise should be repeated periodically and monitored by RPCs.

Action: RPCs, CTU, STUs
Time Frame: 1 year

9.1.2 Till protection audit is taken up, there is need to take immediate review of zone-3 philosophy in particular. Techniques are available to modify characteristics of the relay so that it can distinguish between load encroachment and faults. These techniques and other alternatives should be explored immediately.

Action: RPCs, CTU, STUs
Time Frame: Immediate

9.1.3 The application of synchrophasor measurements from PMUs should be explored for protection systems. There is also an urgent need to deploy Special Protection System (SPS) in critical transmission elements. Also there is need to make already approved SPS operational.

Action: RPCs, CTU
Time Frame: 1 year

9.1.4 A complete independent audit of time synchronization of DRs, ELs and PMUs should be carried out.

Action: Generators, CTU, STUs
Time Frame: 1 month

9.2 Frequency Control through Generation reserves/Ancillary services

9.2.1 Frequency band needs to be further tightened and brought close to 50 Hz. POSOCO may file an urgency application in Supreme Court for early resolution of the issue in view of the recent grid disturbances.

Action: POSOCO
Time Frame: 1 month

9.2.2 A review of UI mechanism should be carried out in view of its impact on recent grid disturbances. Frequency control through UI may be phased out in a time bound manner and Generation reserves/Ancillary services may be used for frequency control. Appropriate regulatory mechanism needs to be put in place for this purpose. POSOCO should take up the matter with CERC.

Action: POSOCO
Time Frame: 3 months

9.3 Ensuring proper functioning of defense mechanism

All STUs should immediately enable under frequency and df/dt based load shedding schemes. Central Commission should explore ways and means for implementation of various regulations issued under the Electricity Act, 2003. Any violation of these regulations can prove to be costly as has been the case this time. RPCs need to take up the matter for compliance. In case non-compliance persists, POSOCO should approach Central Commission.

Action: STUs, RPCs, POSOCO
Time Frame: Immediate

9.4 Ensuring primary frequency response from generators

All out efforts should be made to implement provisions of IEGC with regard to governor action. Central Commission needs to look into ways and means to hasten implementation of provisions of IEGC including that on governor action. POSOCO need to take up the matter with Central Commission.

Action: POSOCO
Time Frame: 3 months

9.5 Revising Total Transfer Capability (TTC) based on change in system conditions

9.5.1 POSOCO should take up with Central Commission the issue of inconsistency between Congestion regulation and the detailed procedure framed there under so that congestion due to forced outages and Unscheduled Interchange (UI) can be handled effectively.

Action: POSOCO
Time Frame: 1 month

9.5.2 NLDC and each RLDC should have one real-time security desk in all the shifts to be manned by engineer capable of carrying out TTC calculations. To facilitate this, manpower at NLDC and RLDCs need to be enhanced with regulatory support to take care of financial aspects. Till this arrangement can be firmed up, various scenarios of outages could be built, which then can be used by despatcher in real time. Faster algorithm for calculation of TTC may be adopted by the load despatchers to update it in real time under outage conditions.

Action: POSOCO
Time Frame: 6 months

9.6 Coordinated outage planning of transmission elements

Outage planning of inter-State and inter-regional transmission elements should be carried out in a coordinated manner at RPC fora (say Operation Co-ordination sub-committee of RPCs) in accordance with regulation 5 of Central Electricity Authority (Grid Standards) Regulation, 2010 and Section 5.7.1 of Indian Electricity Grid Code. In case need for emergency maintenance arises in between two meeting of Operation Co-ordination sub-committee, NLDC and RLDCs should allow such maintenance after carefully looking at prevailing system conditions under intimation to RPC Secretariat.

Action: RPCs
Time Frame: Immediate

9.7 Reactive power planning

In order to avoid frequent outages/opening of lines under over voltages and also providing voltage support under steady state and dynamic conditions, installation of adequate static and dynamic reactive power compensators should be planned.

Action: CEA, CTU, STUs
Time Frame: 6 months

9.8 Review of penal provisions of the Electricity Act, 2003

The powers of Load Despatch Centres and Regulatory Commissions related to non-compliance of statutory/regulatory provisions including that for non-compliance of directions and non-payment of UI charges, need review. Appropriate amendments need to be carried out in the Electricity Act, 2003 after such review.

Action: Ministry of Power, Govt. of India
Time Frame: 6 months

9.9 Optimum utilization of available assets

9.9.1 The regulatory provisions regarding absorption of reactive power by generating units needs to be implemented.

Action: POSOCO
Time Frame: Immediate

9.9.2 An audit of devices such as HVDC, TCSC, SVC and PSS should be done immediately to ensure that their stability features are enabled. Further, exercise of PSS tuning should be planned and implemented. Settings of these dynamic stabilizing devices should be reviewed at appropriate intervals.

Action: CTU, STUs, Generators
Time Frame: 6 months

9.9.3 Functioning of existing PMUs and availability of their output to RLDCs and accuracy of time synchronization should be monitored on daily basis and, if required, corrective actions should be taken on priority basis.

Action: CTU, POSOCO
Time Frame: Immediate

9.10 Deployments of WAMS

9.10.1 The synchrophasor based WAMS employing PMUs offer a wide applications for real time monitoring and control of the system, specially under the dynamic conditions. Adequate number of PMUs should be installed to improve the visibility and real time monitoring of the system. Further the applications related to the synchrophasor based wide area monitoring, protection and control should be embedded in the system.

Action: CTU
Time Frame: 1 year

9.10.2 Possibility of voltage collapse prediction, sensing global power system conditions derived from local measurements may be explored.

Action: RPCs
Time Frame: 1 year

9.11 Need of Dynamic Security Assessment and review of State Estimation

In order to assess the system security in real time and assess the vulnerability condition of the system, dynamic security assessment need to be periodically carried out at the control centers. A proper review and upgradation of the state estimation procedure is required to improve the visibility and situational awareness of the system.

Action: POSOCO
Time Frame: 6 months

9.12 Implementation of islanding schemes

Efforts should be made to design islanding scheme based on frequency sensing relays so that in case of imminent grid failure, electrical islands can be formed. These electrical islands can not only help in maintaining supply to essential services but would also help in faster restoration of grid.

Action: CEA, RPCs, POWERGRID, STUs, SLDCs and Generators
Time Frame: 6 months

9.13 Autonomy to Load Despatch Centres

9.13.1 As National Grid is on the horizon, homogenization of system operation philosophy is need of the hour. The present organizational set up of Load Despatch Centres need to be reviewed. System operation needs to be entrusted to Independent System Operator (ISO). In addition, SLDCs should be reinforced and ring fenced for ensuring functional autonomy.

Action: Govt. of India, State Govts.
Time Frame: 1 year

9.13.2 Training and certification of system operators need to be given focused attention. Sufficient financial incentives need to be given to certified system operators so that system operation gets recognized as specialized activity.

Action: Govt. of India, State Govts.
Time Frame: 3 months

9.14 Development of Intra-State transmission system

Intra-State transmission system needs to be planned and strengthened in a better way to avoid problems of frequent congestion.

Action: STUs
Time Frame: 2 years

9.15 Network visualization

9.15.1 Appropriate amendments should be carried out in Grid Connectivity Standards to restrain connectivity of a generating station or a transmission element without required communication and telemetry facilities.

Action: CEA,
Time Frame: 6 months

9.15.2 The Communication network should be strengthened by putting fibre optic communication system. Further, the Communication network should be maintained properly to ensure reliability of data at Load Despatch Cenres.

Action: CTU and STUs
Time Frame: One years

9.15.3 RTUs and communication equipments should have uninterrupted power supply with proper battery backup so that in case of total power failure, supervisory control and data acquisition channels do not fail.

Action: CTU and STUs
Time Frame: 3 months

9.15.4 In case of existing generating stations or transmission elements without telemetry facility, the same should be put in place at the earliest. If prolonged operation without telemetry continues, POSOCO should approach Central Commission.

Action: RPCs, POSOCO
Time Frame: 6 months

9.16 Reduction in Start-up time for Generators:

Large variations are observed in time taken for initiation of unit start up (Boiler light up) by the stations after availability of start-up power and also for start ups/light up of subsequent units. While subsequent start-ups were very fast (10-20 minutes) in some of the units, in other cases they took considerably longer time – several hours. Reasons for the delays in attempting first start-up and subsequent start-ups may be examined by the utilities in consultation with CEA. A standard procedure for preparatory activities and sequence of start up may be put in place by the stations to restore units as early as possible particularly in contingencies.

Action: CEA, Generating Utilities and RLDCs
Time Frame:one year

9.17 Review of Transmission Planning Criteria

At inter-State level, the entire landscape has changed over past few years. With de-licensing of generation and provision of open access in Electricity Act, 2003 and development of organized electricity markets, lot of generation is coming in the form of merchant generation. Four out of the five regions have been integrated and formation of National Grid is on the horizon. Under such scenario, there is need review the Transmission Planning criteria.

Action: CEA
Time Frame: 3 months

9.18 Strengthening of system study groups in various power sector organizations:

There is need to reinforce system study groups in power sector organisations to analyse the system behaviour under different network status/ tripping of lines/outage of generators. Where these do not exist, these should be created.

Action: CEA, CTU and STU
Time Span: one year

9.19 Formation of a task force to study the grid security issues:

It was felt that a separate task force may be formed, involving experts from academics, power utilities and system operators, to carry out a detailed analysis of the present grid conditions and anticipated scenarios which might lead to any such disturbances in future. The committee may identify medium and long term corrective measures as well as technological solutions to improve the health of the grid.

Action: MOP, CEA
Time Frame: 1 month

9.20 Improved telecom infrastructure for cyber security

For smooth operation of grid systems, it is absolutely important that all the power generating and distributing stations are connected on a very reliable telecom network.

(i) A proper network may be built up preferably using MPLS(Multi Protocol Label Switching) which is simple, cost effective and reliable. In remote place where connectivity is a problem, the stations can use dedicated fibre cable from the nearest node

(ii) Since POWERGRID has its own fibre optic cables, practically covering all major nodes and power stations, a proper communication/IT network may be built using dedicated fibres to avoid any cyber attack on the power system.

Action: CTU, STUs
Time Frame: 1 year

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