Report on

Improvements on Usage of State Estimation In Load Dispatch Centers In India

JUNE - 2015

Revision History

Revision	Author	Date	Remarks
Rev0	NLDC, POSOCO	17-02-2015	Initial version
Rev1	NLDC, POSOCO	24-06-2015	Revised version

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List of Acronyms

A	
AC	Alternating Current
ATC	Available Transfer Capacity
C	
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CMR	Contact Multiplication Relays
D	
DIC	Designated ISTS Customers
E	
EMS	Energy Management System
F	
FOLD	Forum of Load Despatchers
FSC	Fixed Series Compensation
H	
HVDC	High Voltage Direct Current
I	
IA	Implementing Agency
ICT	Inter Connecting Transformers
IEEE	Institute of Electrical and Electronics Engineers
IEGC	Indian Electricity Grid Code
K	
KV	Kilo Volt
L	
LDC	Load Despatch Center
M	
MVAR	Mega Var
MW	Mega Watt
P	
PDF	Probability Density Function
PES	Power and Energy Society
PMU	Phasor Measurement Unit
PNA	Power Network Analysis

POSOCO	Power System Operation Corporation Limited
POWERGRID	Power Grid Corporation of India Limited

R

RAP	Remedial Action Plan
RAS	Remedial Action Schemes
REC	Renewable Energy Certification
RLDC	Regional Load Despatch Center
RRF	Renewable Regulatory Fund
RTU	Remote Terminal Unit

S

SAS	Substation Automation System
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition
SE	State Estimation
SERC	State Electricity Regulatory Commission
SLDC	State Load Despatch Center
SPS	Special Protection Schemes

T

TCSC	Thyristor Controlled Series Compensation
TRM	Transmission Reliability Margin
TTC	Total Transfer Capacity

U

ULDC	Unified Load Despatch and Communication
URTDSM	Unified Real Time Dynamic State Measurement

Z

ZBR	Zero Impedance Branch

Disclaimer

This document is an attempt to compile various concepts and practices related to State Estimator in Load Despatch Centers of Indian Power System. The compilation is intended for discussion purposes only. The document is not for commercial sale.

EXECUTIVE SUMMARY

Indian power system is one of the largest Power System Networks in the world. It has installed capacity of about 245 GW. Indian power system has complex transmission network and many cross border connections. It is monitored by a multi-level integrated Supervisory Control & Data Acquisition (SCADA)/ Energy Management System (EMS) installed at many control centers dispersed all over India. SCADA/EMS of National control center is integrated with SCADA/EMS systems of five regional control centers. SCADA/EMS systems of regional control centers in turn are integrated with SCADA/EMS systems of lower 35 state control centers.

It is important to use all real-time tools to help the operator in operating the grid in a highly secure and reliable manner. An exercise was taken up by Power System Operation Corporation Limited (POSOCO) with an objective of improving the usage of State Estimation in Load Despatch Centers in India. In this process it has been interacting with experts both in India and abroad with the objective of learning and making continuous improvement. Dr. NDR Sarma, who works as Principal Engineer at Electric Reliability Council of Texas, Inc., USA visited India to attend the 2014 National Power Systems Conference at Guwahati. Dr. NDR Sarma is a renowned expert in State Estimation and EMS areas. He recently led an IEEE Task Force on State Estimation Concepts and Terminology and currently heading an IEEE Task Force of Contingency Analysis. During his visit to India during Dec'14-Jan'15, he visited all the Regional Load Dispatch Centers of POSOCO and had two day sessions at each location with all the engineers of RLDCs and respective SLDCs on basics of State Estimation and suggested methods to improve usage of State Estimation in LDCs.

Key observations in the initial study are summarized as follows:

a) State Estimation is available along with the EMS package at NLDC, RLDCs and SLDCs. However, there are some issues with regard to getting proper telemetry from all the substations which has impact on successful state estimation. It is a well known fact that 'Not using State Estimation' can lead to 'poor visualization and Situational Awareness which can be catastrophic under alert/emergency conditions in the grid.
b) There is limited awareness on effective use and tuning of State Estimation and other EMS tools for engineers at RLDCs and SLDCs.
c) There is need to relook at the staff requirements and enhance the EMS teams with more engineers for effective usage of EMS tools at all LDCs.
d) Effective regulation and enforcement at both national level and state level with regard to availability of required telemetry for SCADA system is of prime importance. Availability of SCADA and quick restoration of data (in case it is not available), is the key input for effective running of State Estimation and other EMS tools at RLDCs and SLDCs.
e) There is a strong commitment from POSOCO management and engineers for effective use of State Estimation and EMS tools at NLDC, RLDCs and SLDCs. However to translate this commitment to reality would necessitate a good ecosystem in terms of a similar vision amongst all stakeholders which would provide the necessary encouragement to the EMS teams at control centers.

Based on the initial study, the following action items are suggested:

a) Need to enhance the design and enforcement of regulations at both Central Electricity Regulatory Commission (CERC) and respective State Electricity Regulatory Commissions (SERCs) with regard to availability of required telemetry for SCADA system. Availability of SCADA and quick restoration of data (in case it is not available), is the key input for effective running of State Estimation and other EMS tools at RLDC and SLDCs. Running State Estimation and other EMS tools is essential for reliable and secure operation of the grid. 'Not using State Estimation' can lead to ‘poor visualization and Situational Awareness which can be catastrophic under alert/emergency conditions in the grid.
b) Initially the RTU/SAS connectivity analysis should be done to establish if sufficient measurements are available (system is observable) to perform state estimation. This should be accomplished within three months (after the release of this report). If the study indicates that there are no sufficient measurements then steps are to be taken to enhance the measurement set by adding more RTU/SAS to make the system observable. This study would also help to identify new location for placement of RTU/SAS. This is to be treated as very crucial for running state estimation and essential for establishing the current operating state of the system.
c) Monthly reports on status of RTU/SAS should be published and circulated among concerned authorities for immediate action.
d) A formal process of chasing the telemetry issues should be drafted, approved and followed. This is crucial in handling telemetry issues in timely manner. Appropriate regulatory requirements for proper availability of data should be defined and enforced. Non-compliance of data availability requirements should be taken seriously and defaulters shall be severely penalized for non-compliance.
e) Monthly reports on SE results should be published and circulated with concerned authorities for immediate action. Reports shall include hourly/daily convergence details, residuals for line/unit/transformer/load details, etc. These reports shall also include the details of manual overrides of data done to get correct SE results. If required, the State Estimation Tool should be enhanced to have the capability of providing the summary of its performance such as hourly/daily convergence details, residuals for line/unit/transformer/load details, etc.
f) A user group on State Estimation should be formed in order to develop team-building among the people working in this specialized field. Bi-monthly conference call shall be organized for this group.
g) Review of staff requirements should be done in order to provide adequate man-power for EMS. Appropriate training shall be provided to all engineers.
h) The availability of digital data and analog data is also important when we are talking about the synchrophasor measurements which would be coming under the Unified Real Time Dynamic State Measurement (URTDSM) project under execution by POWERGRID. Linear State Estimator being developed as an application would be useful only if the digital status and analog data from the Phasor Measurement Units (PMUs) is available. This would also serve as a back-up for the conventional State Estimation in the EMS System.
i) World-wide research is on a Real Time State Estimator (instead of the 3 to 5 minute conventional EMS based SE) and Load Despatch Centers in India would not be able to achieve it if it doesn’t catch up fast in the conventional EMS space.

j) POSOCO may provide Research Funds for academic institutions and do research in addressing the problem related to implementation of State Estimation in India. POSOCO may also consider organizing panel sessions focusing on Implementation of State Estimation in India at the National Power System Conferences in India. It may also consider organizing an International Symposium/conference focusing on State Estimation by inviting renowned experts across the world. This may serve as an opportunity for young engineers to interact with experts from all over the world.

1. INTRODUCTION

An effective on-line power system study ensures confidence in the grid operation and business-critical electrical system. It is also subjected to wide range of operating conditions. Such a study is essential on real-time system to achieve the ultimate goal of power system operation viz, security, reliability, continuity and optimum cost. Power system operation in India is passing through a crucial phase of modernization and up-gradation. It can be said that extensive understanding of Indian power programs has enabled the conceptualization and implementation of state-of-art SCADA and EMS at a crucial time of power system operation. Real time power system tools are available at all Load Dispatch Centers (LDCs). Constructing and maintaining the power system network model that is used by the network applications is important for ensuring reliable results.

POSOCO has been interacting with experts both in India and abroad for improving Visualization and Situational Awareness at NLDC/RLDCs/SLDCs. Dr. NDR Sarma, Principal Engineer at Electric Reliability Council of Texas, USA visited all the Regional Load Dispatch Centers (RLDCs) and National Load Dispatch Center (NLDC) for suggesting improvements in the usage of State Estimation and other tools that are available at these LDCs and at other State Load Dispatch Centers. This report summarizes the outcome of these visits and suggests some recommendations to improve the usage of State Estimation in load dispatch centers in India.

Indian power system is monitored by an integrated SCADA/EMS installed at several control centers dispersed all over the geographical territory of the country. SCADA/EMS of National control center is integrated with SCADA/EMS systems of five regional control centers which are further integrated with SCADA/EMS systems of 32 state control centers in lower hierarchy.

RTU/SAS of the stations belonging to State utilities report to the Sub LDC or directly to its State Load Despatch Center. The RTU/SAS installed at the stations of Central Sector and entities directly under jurisdiction of RLDCs report directly to the Regional Load Despatch Center (or the respective CPCC). No RTU/SAS directly reports to National Load Despatch Centre.

Reporting of RTUs (or SAS)		
RTU/SAS Status	**Data Ownership**	**Hierarchical forward flow of data**
Reporting directly to Sub LDC	Sub LDC	Sub LDC →SLDC→RLDC→NLDC
Reporting directly to SLDC	SLDC	SLDC→RLDC→NLDC
Reporting directly to RLDC (or CPCC)	RLDC (or CPCC)	RLDC → NLDC

Table 1: Reporting of RTUs (or SAS) in LDCs

SCADA/EMS systems of regional control centers were implemented one by one between year 2002 to 2006 under the Unified Load Dispatch and Communication (ULDC) scheme executed by POWERGRID. National Load Despatch Center (NLDC) was established in 2009. Purpose of national control center is mainly to monitor inter-regional and international transfer of power for best utilizing the generating resources by balancing deficit/surplus, diversity in peaking times and seasonal variations in demand of different regions. With effect from 1st October 2010, Government of India has assigned the responsibility of operating the five (5) RLDCs and NLDC to Power System Operation Corporation Limited (POSOCO), a wholly owned subsidiary of Power Grid Corporation of India Limited (POWERGRID).

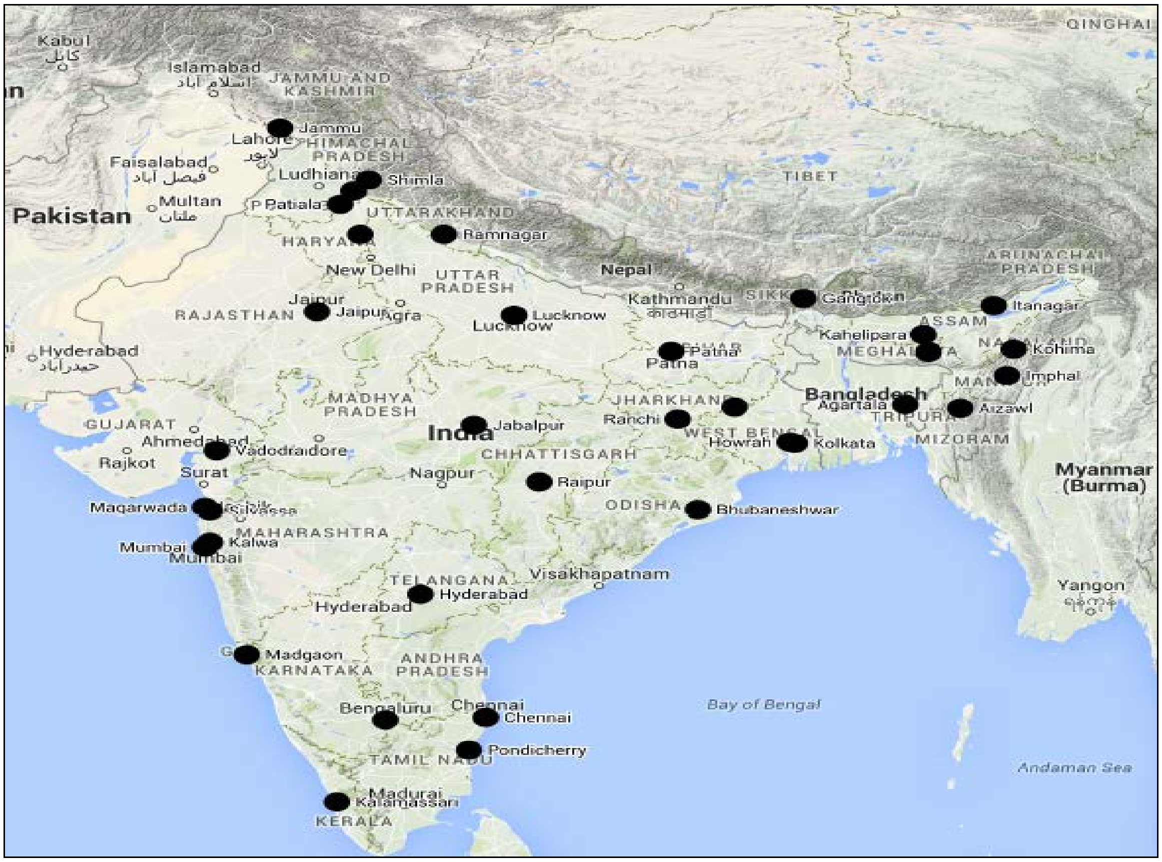


Figure 1: Locations of Load Despatch Centers in India

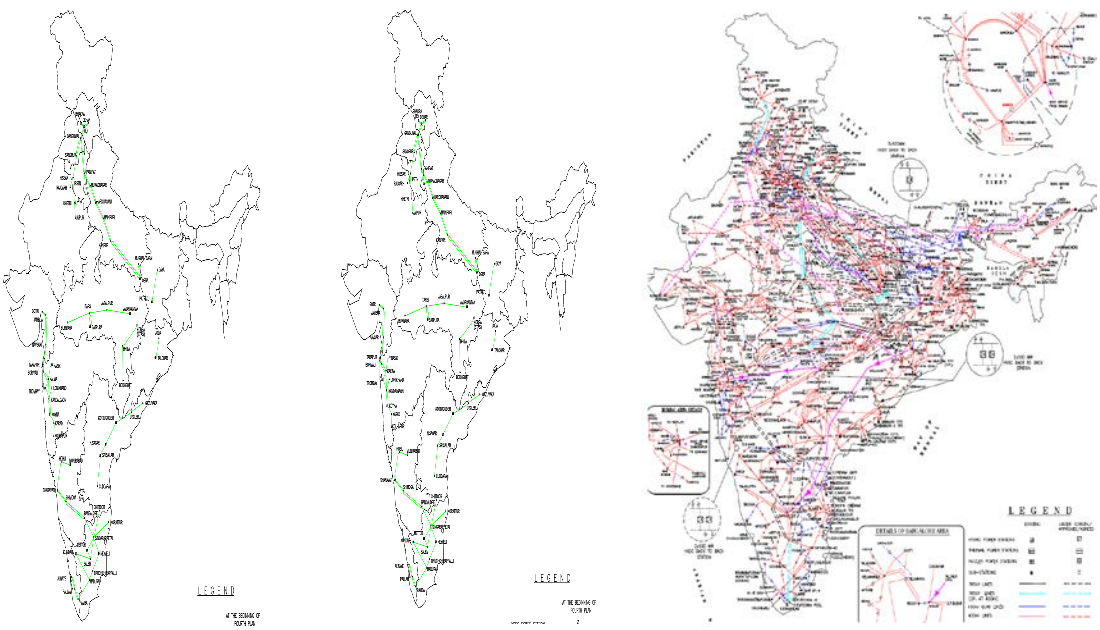
2. NEED FOR STATE ESTIMATION

State Estimation was introduced by Gauss and Legendre (around 1800) [1]. The basic idea was to "fine tune" State Variables (Voltage and Angle at each bus) by minimizing the sum of the residual squares. This is the well-known Least Squares (LS) method. The reason for its popularity is easy to understand: At the time of its invention there were no computers, and the fact that the Least Squares estimator could be computed explicitly from the data made it the only feasible approach.

State Estimation was applied to Power Systems by Schweppe and Wildes in the late 1960s in a real-time environment. But the State Estimation Weighted Least Square Algorithm directly applied to Power system may not work as per the expectations. It needs to be customized by SCADA and supported by certain assumptions.

2.1 Complex power system

There has been rapid expansion in the Indian Power system during the last two decades.



1) Grid in 1970s 2) Grid in 1980s 3) Grid in 21st Century

Figure 2: Expansion of Indian Power system

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[1] A. P. Sakis Meliopoulos, Bruce Fardanesh, Shalom Zelingher "Power System State Estimation: Modeling Error Effects and Impact on System Operation". *Proceedings of the Hawaii International Conference On System Sciences, January 3-6, 2001, Maui, Hawaii*

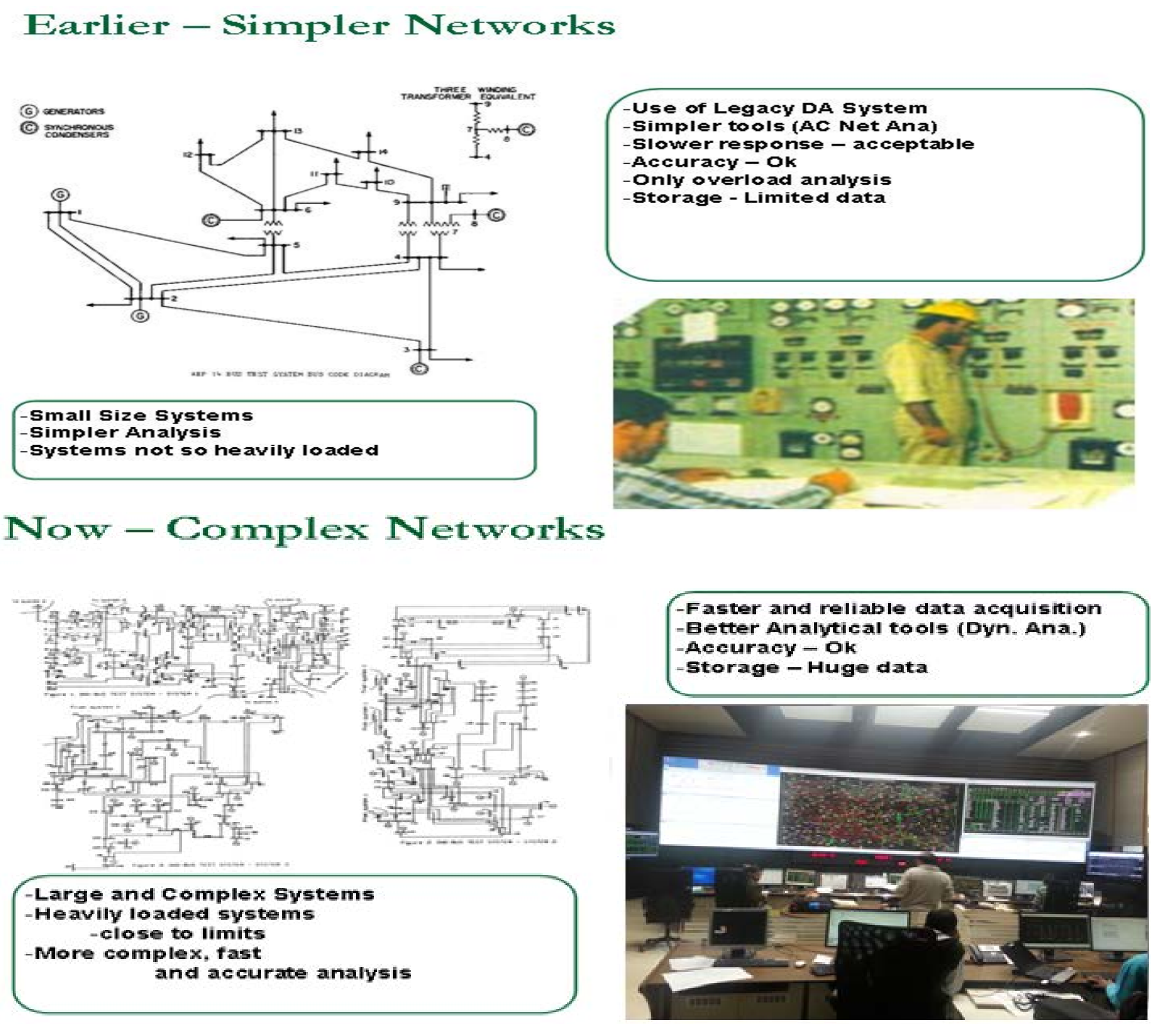

Figure 3: Increasing complexity in Load Despatch

The huge volume of data is acquired at the Load Despatch Centers and it is not possible for the operator to analyze each and every analog and digital point to detect the problem and take decision accordingly.

2.2 Security and reliability of Grid

While operating the grid, the operator needs to know the status of the grid and make sure of its secure operation. Operator has to ensure that it is secure not only in the base case but also for any contingencies in the system. If any contingency causes any operating limit violations, operator needs to take actions to take care of the violations. Operator may modify the pre-contingency state to eliminate the potential emergency in case contingency really occurs. There could be some Special Protection Schemes (SPS) or Remedial Action Schemes (RAS) which are programmed in the system so that when any operation limits are violated, it may trigger the control action as per SPS/RAS. Remedial Action Plans (RAPs) could also be there which are defined to be implemented manually to take care of some violations. Contingency Analysis would have to consider these SPS/RAS and RAPs.

The concept of security is associated with the probability of maintenance of adequate supply. Higher the security level, lower is the probability of loss of supply. Security oriented control actions are aimed at avoiding blackout and equipment damage.

Fig.4 shows one way of looking at different security levels in which the system can be operated as defined by Tomas Dy-Liacco who is referred to as the father of modern energy control centers[2a, 2b].

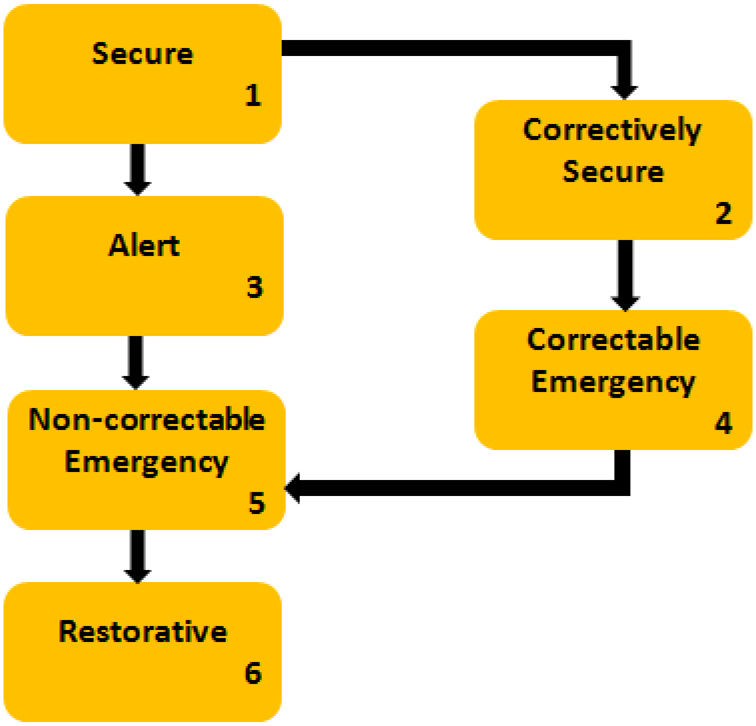

Figure 4: Security Levels of grid operation

Level 1 – Secure: When the system is operating at this level the following conditions apply:

- All Loads supplied without operation limit violations
- In the case of contingency, no violations will occur
- In this level, the network survives any of the contingencies postulated without the need to reply on any post-contingency action

Level 2 – Correctively Secure: When the system is operating at this level the following conditions apply:

- All Loads supplied without operation limit violations (same as level 1)
- Contingencies cause no loss of load as long as appropriate control action is taken to correct them
- This level is more economical than level 1, but relies on post-control actions being performed by the operator.

[2a]Dy-Liacco, Tomas,"Control centers are here to stay". *Computer Applications in Power* (Institute of Electrical and Electronics Engineers) Vol **15**, No. 4, pp 18–23, Oct 2002.
[2b]Felix F. Wu, Khosrow Moslehi and Anjan Bose, "Power System Control Centers: Past, Present, and Future", Proceedings of IEEE, Vol. 93, No. 11, pp 1890-1908, November, 2005.

Level 3 – Alert: When the system is operating at this level the following conditions apply:

- All Loads supplied without operation limit violations (same as level 1 and Level 2)
- Contingencies cannot be corrected without loss of load
- The system can be brought back to Level 1 or 2 by preventive rescheduling using an optimal power flow with contingency constraints

Level 4 – Correctable Emergency: When the system is operating at this level the following conditions apply:

- All Loads supplied but operation limits are violated
- These can be corrected without loss of load
- The system can be brought back to Level 3 by corrective actions

Level 5 – Non-Correctable Emergency: When the system is operating at this level the following conditions apply:

- All Loads supplied but operation limits are violated
- These cannot be corrected without loss of load

Level 6 – Restorative: When the system is operating at this level the following conditions apply:

- No operation limits are violated, but loss of load has occurred
- Restorative control aims to return the system to Levels 1 or 2

It is important for the operator to operate the system in a secure state or correctively secure state. If the system is in some other state it is important to bring it back to the secure or correctively secure state as quickly as possible. Since power systems have become very complex operator needs support tools to help in taking proper decisions to operate the system in desired secure state. Supervisory Control and Data Acquisition (SCADA) systems are installed in the system to facilitate data acquisition and control of devices. Remote Terminal Units (RTUs) or SAS are installed at substations to acquire various parameters such as bus voltages, line power flows, generation MW and MVAR values, status of circuit breakers and isolators, etc. RTU/SAS also provide interface to control circuit breakers and other devices at substations.

Traditionally SCADA has been used to know the status of the system. But SCADA has the following issues:

- Data received from the network is not always complete, due to telemetry or transducer failures.
- Even if complete data is received, sometimes it could include erroneous data due to faulty metering, communication noise, etc.
- Though all possible measurements are available, it may not be economically feasible to bring all the data to the control center.

However, all the application functions (part of power system security analysis function), require reliable real-time data. Fred Schweppe[3,4,5,6] initially proposed State Estimation methodology which enables to estimate bus voltage magnitudes and angles at all buses in the system with set

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[3] Fred C. Schweppe and J. Wildes, "Power System Static-State Estimation Part I: Exact Model", IEEE Trans on Power Apparatus and Systems, vol. PAS-89, no. 1, January 1970.

[4] Fred C. Schweppe and J. Wildes, "Power System Static-State Estimation Part II: Approximate Model", IEEE Trans on Power

Apparatus and Systems, vol. PAS-89, no. 1, January 1970.

[5] Fred C. Schweppe and J. Wildes, "Power System Static-State Estimation Part I: Implementation", IEEE Trans on Power

Apparatus and Systems, vol. PAS-89, no.1, January 1970.

[6] Chapter 15, State Estimation of Power Systems, "Power System Analysis" by John J. Grainger and William D. Stevenson, Jr..

of measurements as input. Based on the estimated bus voltages one can easily estimate the flows on the lines and subsequently able to determine if there are any operational limit violations. It is also possible to detect any bad data in the measurements set and helps to provide good and reliable real-time data set. Based on this reliable data, security assessment functions can be reliably deployed in order to analyze contingencies, as well as corrective actions. With the availability of State Estimation, old SCADA systems were replaced by new generation Energy Management Systems (EMS) equipped with on-line state estimator.

It is the responsibility of any Load Despatcher to drive the power system in a stable, reliable, secure and optimal manner. In order to achieve this operator should have complete knowledge about the system (Parameters and models of the system components) and knowledge of the situation (by comprehending the real time data). Energy Management System (EMS) is the mechanism to capture "system knowledge" and "situational awareness" and provide some key indicators to help the Load Despatcher in real-time decision making. Running State Estimation and other EMS tools is essential for reliable and secure operation of the grid. 'Not using State Estimation' can lead to 'poor visualization and Situational Awareness which can be catastrophic under alert/emergency conditions in the grid.

EMS applications can be divided into two parts –

a) **Generation Applications** which includes Unit commitment/scheduling, Reserve/Cost monitoring, Economic Despatch, etc.
b) **Network Applications** which includes fault analysis, contingency analysis, Powerflow, optimal powerflow, Data Validation (by State Estimation), etc.

Energy Management System (EMS) has a system of computer-aided tools used by operators of electric utility grids to monitor, control and optimize the performance of the generation and/or transmission system. The monitor and control functions are known as SCADA. This computer technology is also referred to as SCADA/EMS or EMS/SCADA. In these respects, the terminology EMS then excludes the monitoring and control functions, but more specifically refers to the collective suite of Power Network Applications (PNA) and to the generation control and scheduling applications.

State Estimator provides a base-case for all the Network Applications and some of the generation applications.

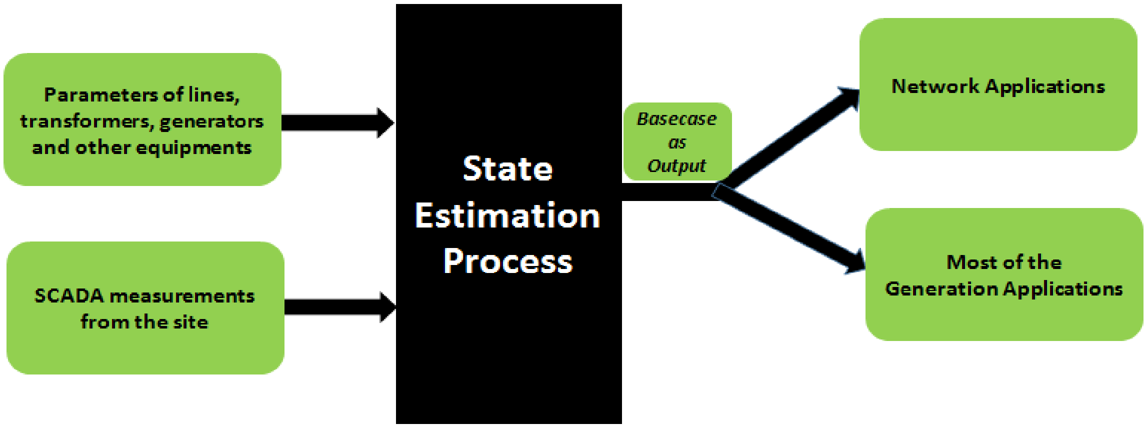


Figure 5: Base-case generation from State Estimation process

The output of the state estimator application acts as a base-case for the other applications to carry out various studies in order to help grid operator in real-time operation.

2.3 Contingency analysis for (n-1) secure operation

It is a mandate for grid operators that at any point of time the system should be (n-1) secure i.e. the power system should be operated in such a manner that outage of any element should not lead to violation of any other parameter in grid.

In Contingency Analysis application, the base-case taken from the state estimator/powerflow application is solved for various contingencies defined in the Contingency database using Newton Raphson/Decoupled powerflow. Its objective is to evaluate the system performance under outages.

Its inputs are –

- System information (Parameters and connectivity info)
- Load and generation profile
- Voltage set-points
- Component modeling
- Rating of the equipment

Its output is –

- List of critical contingencies leading to violations.

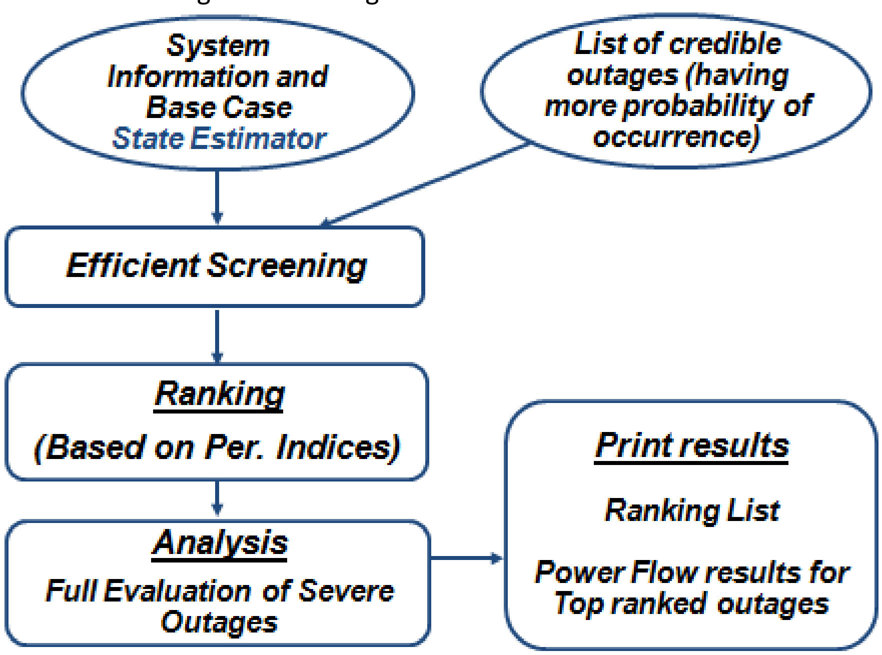


Figure 6: Contingency Analysis – Flow Chart

In order to use this application in a useful manner we need to follow a proper processing approach to see which contingencies are credible (most likely to happen) and follow some criteria to rank them in order of their severity.

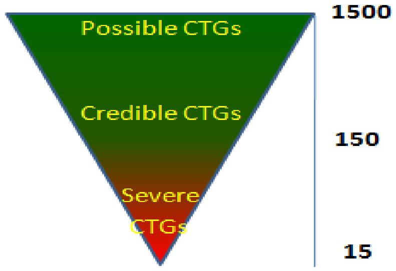


Figure 7: Processing approach

We can filter the contingencies based on the following criteria –

a) Probability of occurrence
b) Use of approximate analysis (like powerflow with less tolerance, network equivalents, etc.)

One of the most commonly used ways is to rank the contingencies as per their severity based on the performance indices of –

- Overload index

$$P_{i\_overload} = \sum_{j=1}^{nline} \left(\frac{f_{lj}}{f_{lj\_max}} \right)^2$$

- Voltage index

$$P_{i\_voltage} = \sum_{j=1}^{nbus} \left(\frac{\Delta V_j}{\Delta V_{j\_max}} \right)^2$$

Based on type of limit violated and %violations,

Index = 1000*Type of limit violated + (100 + %violation)

The constants "1000" and "100" can be changed to any other value as per the user requirement.

Limits type are generally taken as
"1" for Normal
"2" for Emergency
"3" for Loadshed

For eg. – Emergency limit violated by 12% has an Index = 1000***2** + (100 + **12**)
= 2112

2.4 Multi-vendor system in India

SCADA/EMS systems are under the process of up-gradation in all the five regions. Different vendors are executing the up-gradation projects; three regions are being executed by one vendor while other two regions by other two different vendors.

S. No.	RLDC/SLDC	Present Location		After Up-gradation Location	
		Main	Back-up	Main	Backup
1	**NRLDC**	**New Delhi**	**--**	**New Delhi**	**ERLDC, Kolkata**
2	**BBMB**	Chandigarh	--	Chandigarh	Patiala
3	**Delhi**	New Delhi	--	New Delhi	Heerapura
4	**Haryana**	Panipat	--	Panipat	Shimla
5	**Himachal Pradesh**	Shimla	--	Shimla	Panipat
6	**J&K**	Jammu	--	Jammu	Srinagar
7	**Punjab**	Patiala	--	Patiala	Chandigarh
8	**Rajasthan**	Jaipur	--	Jaipur	Delhi
9	**Uttar Pradesh**	Lucknow	--	Lucknow	Modipuram
10	**Uttarakhand**	Rishikesh	--	Dehradun	--
11	**ERLDC**	**Kolkata**	**--**	**Kolkata**	**New Delhi**
12	**Bihar**	Patna	--	Patna	--
13	**DVC**	Maithon	--	Maithon	Kolkata
14	**Jharkhand**	Ranchi	--	Ranchi	--
15	**Odisha**	Bhubaneshwar	--	Bhubaneshwar	Meramundali
16	**Sikkim**	Gangtok	--	Gangtok	--

S. No.	RLDC/SLDC	Present Location		After Up-gradation Location	
		Main	Back-up	Main	Backup
17	**West Bengal**	Howrah	--	Howrah	Kolkata
18	**WRLDC**	**Mumbai**	**--**	**Mumbai**	**NRLDC, New Delhi**
19	**Chhattisgarh**	Raipur	--	Raipur	Bhilai
20	**Dadar & Nagar Haveli**	--	--	Magarwada	--
21	**Daman & Diu**	--	--	Silvassa	--
22	**Goa**	Panjim	--	Madgaon	Cuncolim
23	**Gujarat**	Vadodara	--	Vadodara	Gandhinagar
24	**Madhya Pradesh**	Jabalpur	--	Jabalpur	Bhopal
25	**Maharashtra**	Kalwa	--	Kalwa	Ambajhari (near Nagpur)
26	**SRLDC**	**Bengaluru**	**--**	**Bengaluru**	**NRLDC, New Delhi**
27	**Andhra Pradesh**	Hyderabad	--	Hyderabad	Tirupati
28	**Karnataka**	Bengaluru	--	Bengaluru	Neelamangala
29	**Kerala**	Kalamassari	--	Kalamassari	Trivendrum
30	**Puducherry**	Puducherry	--	Puducherry	--
31	**Tamil Nadu**	Chennai	--	Chennai	Madurai
32	**Telangana**	Hyderabad	--	Hyderabad	Tirupati
33	**NERLDC**	**Shillong**	**--**	**Shillong**	**Guwahati**
34	**Assam**	Kahelipara	--	Kahelipara	--
35	**Arunachal Pradesh**	--	--	Itanagar	--

S. No.	RLDC/SLDC	Present Location		After Up-gradation Location	
		Main	Back-up	Main	Backup
36	**Manipur**	--	--	Imphal	--
37	**Meghalaya**	Nehu	--	Nehu	--
38	**Mizoram**	--	--	Aizawl	--
39	**Nagaland**	--	--	Kohima	--
40	**Tripura**	Agartala	--	Agartala	--

Table 2: Location of Main and Back-up Control Centers in India

Fig.8 shows the vendors and the regions in which they are executing the up-gradation projects.

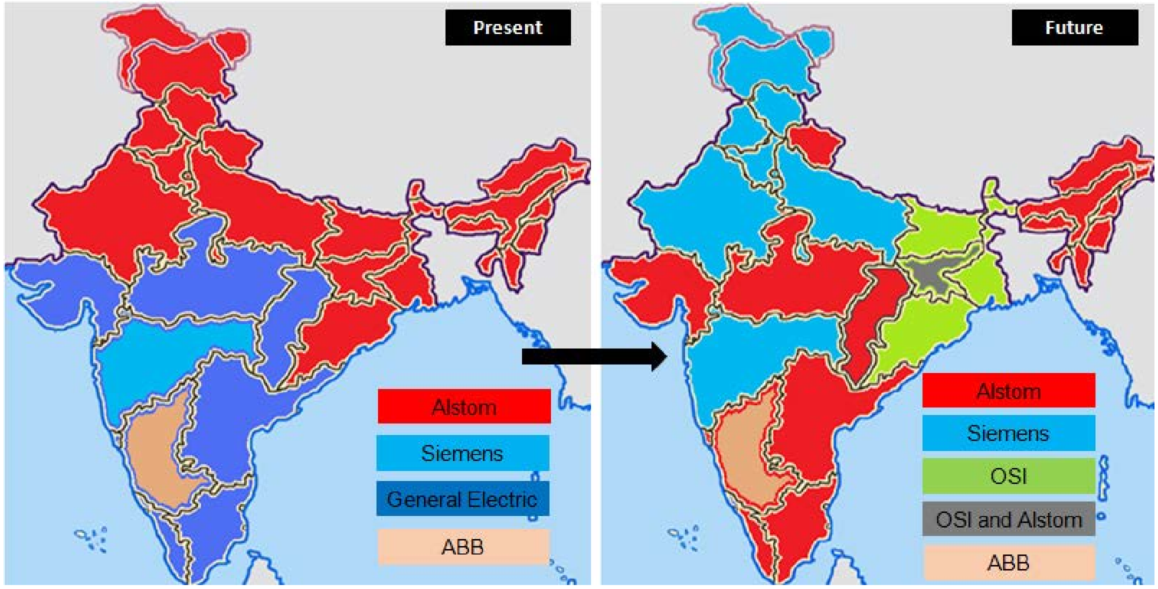


Figure 8: Vendor distribution of SCADA systems after up-gradation project.

2.5 SCADA Vs State Estimator

State Estimation has become a very important tool for the operators in control centers across the world. Operator can no longer just depend on SCADA data for operating the grid due to the issues discussed earlier. If operator depends just on SCADA, it is not possible for the operator to know what is happening in the system when SCADA data is not available. Further, if SCADA data is not correct, operator cannot know the actual state of the system. It is possible that operator may not be able to notice a potential overload in the system. This may lead to cascade outages and a potential blackout of the system. On the other hand, with the help of state estimation, one can isolate bad data and also be able to estimate the state even if there is no SCADA data at a given station (provided there is sufficient redundancy and spread of measurements in the system). Running State Estimation and other EMS tools is essential for reliable and secure operation of the grid. 'Not using State Estimation' can lead to 'poor visualization and Situational Awareness which can be catastrophic under alert/emergency conditions in the grid.

State Estimator application uses SCADA analog measurements such as Active Power (MW), Reactive Power (MVAr) and Voltage (kV) available on all the Power system equipments (such as lines, transformers, generators, etc.) and SCADA digital measurements such as Circuit Breaker & Isolator status (either open or closed), tap position of transformers, etc. as an input. It forms that part of the SCADA database which State Estimator application uses in its algorithm.

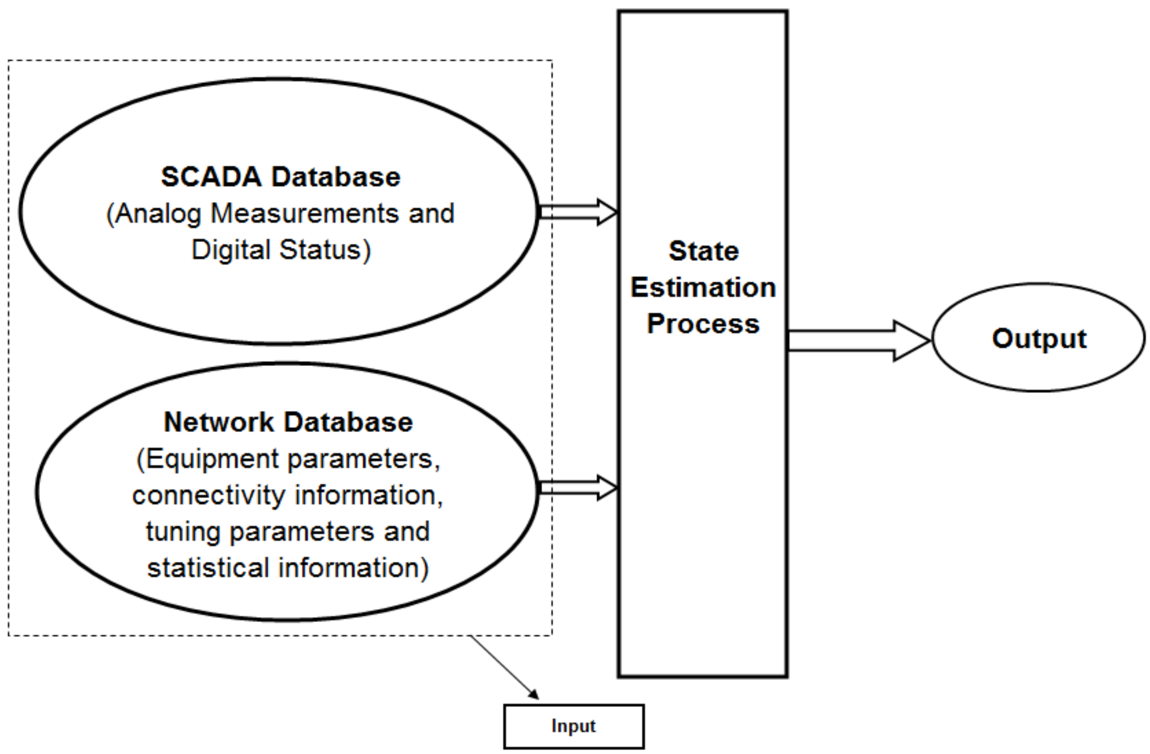


Figure 9: Inputs to State Estimation process

It is the error in SCADA and Network database only which leads to an *Erroneous* or *Invalid Solution* in State Estimator application.

In the real-time display the state estimator result can be displayed along with the SCADA data as shown below in ***fig.10*.**

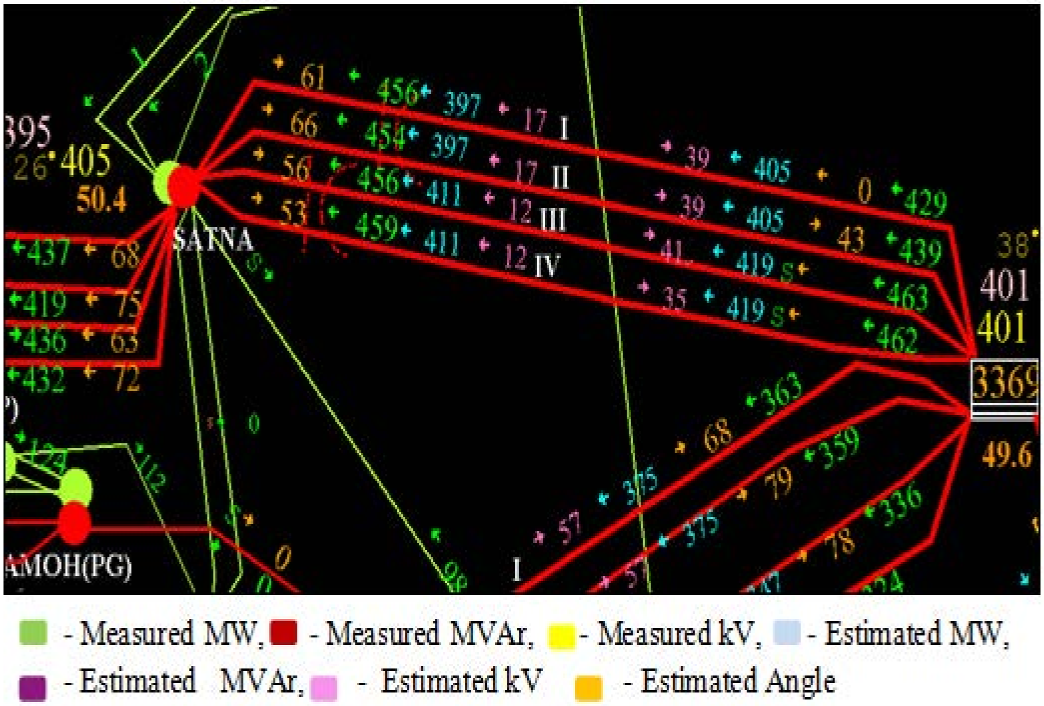


Figure 10: Real-Time snapshot containing SCADA & Estimated values

3. STEPS INVOLVED IN STATE ESTIMATION

State Estimation is the process of assigning a value to an unknown system state variable based on measurements from that system according to some criteria [7]. State Estimation is based upon Weighted Least Square Algorithm.

The basic equations involved are –

$[z] = H[x] + e$

$f = \Sigma\, W_j.e_j^2$ (j=1 to n)

where,

z is the vector of measured state variables

H is measurement function coefficient matrix

x is the vector of estimated state variables

e is the error

W_j is the weight assigned to error e_j

n is the number of measurements

It is the function 'f' which is minimized using Weighted Least Square algorithm.

Over the past 25 years, the basic structure of power system state estimation has remained practically the same:

- Single phase model
- P,Q,V measurement set

[7] Chapter 12, Introduction to State Estimation in Power Systems, "Power Generation, Operation, and Control" 2nd edition by Allen J. Wood and Bruce F. Woollenberg, John Wiley & Sons, Publishers, 2012.

- Non-simultaneousness of measurements
- Single frequency model

The assumptions made in the real-time Power system application of State Estimation are –

a) Voltage and Current waveforms are purely sinusoidal
b) Balanced 3-Ø system
c) Power system is a symmetric 3-Ø system which is fully described by its positive sequence network

These assumptions lead to a result which slightly differs from the actual scenario. We can say that the Estimator results are slightly biased due to these assumptions.

State Variables: Voltage and Angle at each node are the state variables. By estimating these two parameters we can calculate line flows, injection, drawls, etc.

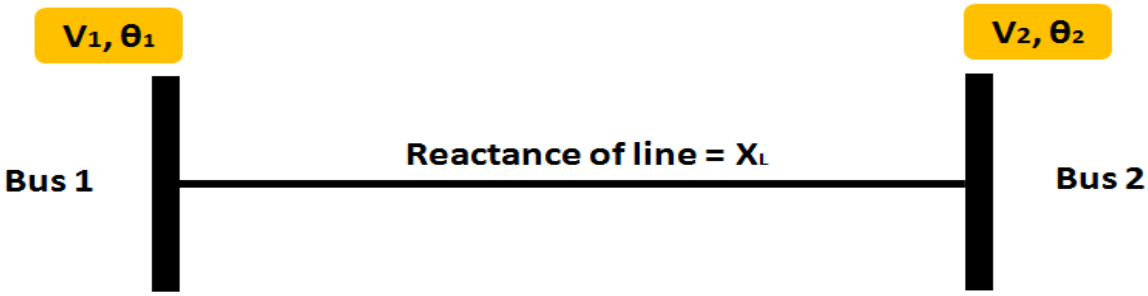


Figure 11: Common Bus diagram showing state variables

$$\text{Real Power, } P = \frac{V_1 * V_2 * \sin(\theta_1 - \theta_2)}{X_L}$$

$$\text{Reactive Power, } Q = \frac{V_1^{\ 2} - V_1 V_2 \cos(\theta_1 - \theta_2)}{X_L}$$

3.1 System Modeling

The operation team at control centers is more concerned with real time and near term studies of the power system. The device oriented model contains adequate information to provide the system operator with details for that portion of the network over which he has responsibility. This is achieved by exclusive representations of all electrical devices and establishing the interconnectivity depicting the true system at the filed for sub-station, generating station and network boundary conditions.

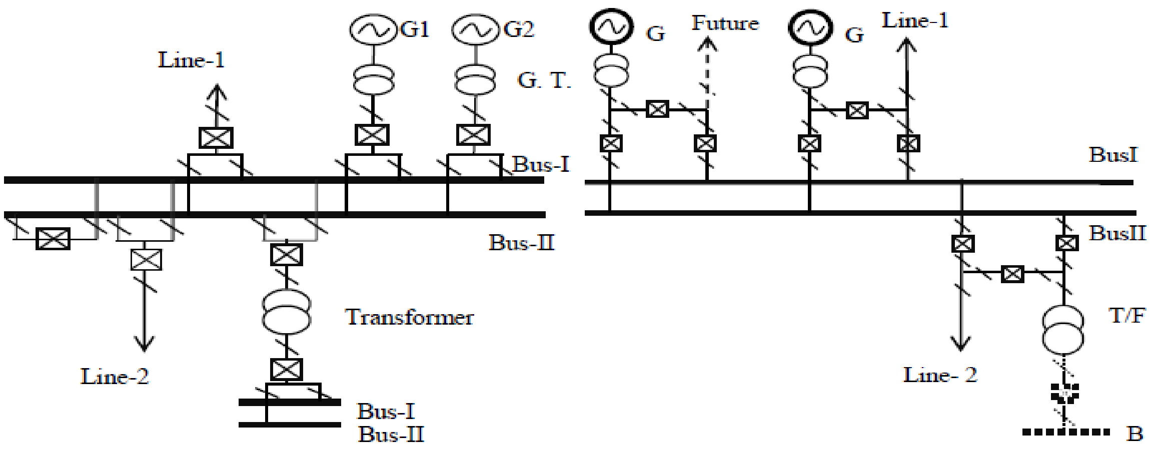
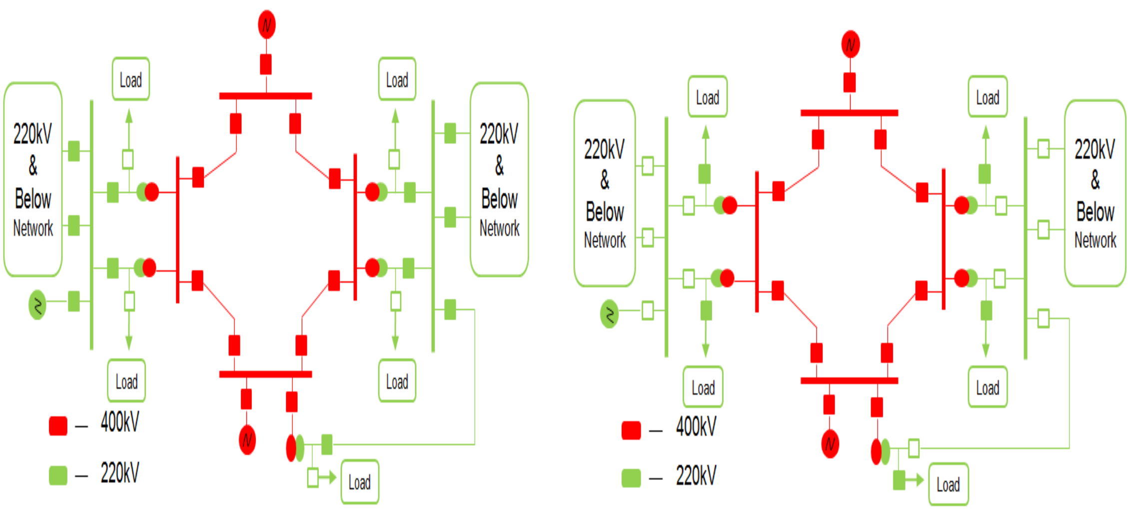


Figure 12: Substation bus arrangement

The state estimator output primarily depends upon the real-time data availability and hence it is important to depict observable portion of network for obtaining a solution. The non-telemetered part of network needs to be represented as external area in order to achieve observability of the complete model with acceptable matching boundary flow. It can be done through Network Equivalencing and Network Truncation.

While carrying out network equivalencing; the external model has to be represented with sufficient details so that the accuracy of the internal model is consistent when topological changes occur. In the proposed case, the external model representations may be achieved through fixed MW / MVAR fictitious generator/load with +/- generator/load capacity.



(a) Network before truncation *(b) Network after truncation*

Figure 13: Truncation of network at 400kV and above voltage level at NLDC

While carrying out network truncation; the external model is ignored and a Load/Injection is modeled at the point of truncation with the real-time MW and MVAR data of the mapped to it.

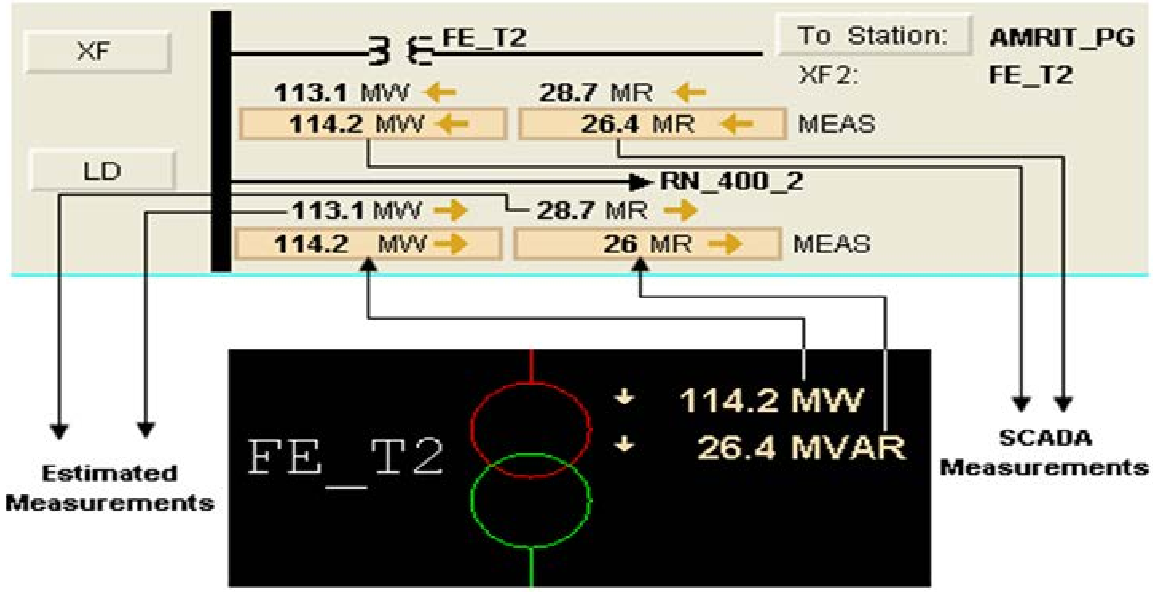


Figure 14: Mapping of real-time ICT data at truncated loads at NLDC

3.2 Topology processing

In **Topology Processing**, based on the Circuit Breaker and Isolator status, dead components are filtered out and connectivity is established to form the live energized network on which state estimator algorithm will run. Topology processor determines connectivity of the network to be used in SE process.

TOPOLOGY PROCESSING	
Objective	Filter Live system components and Define the LIVE (Energized) network
Inputs	System component details, Switch statuses
Output	Live (energized) network details

Table 3: Objective, Input and Output of Topology Processing

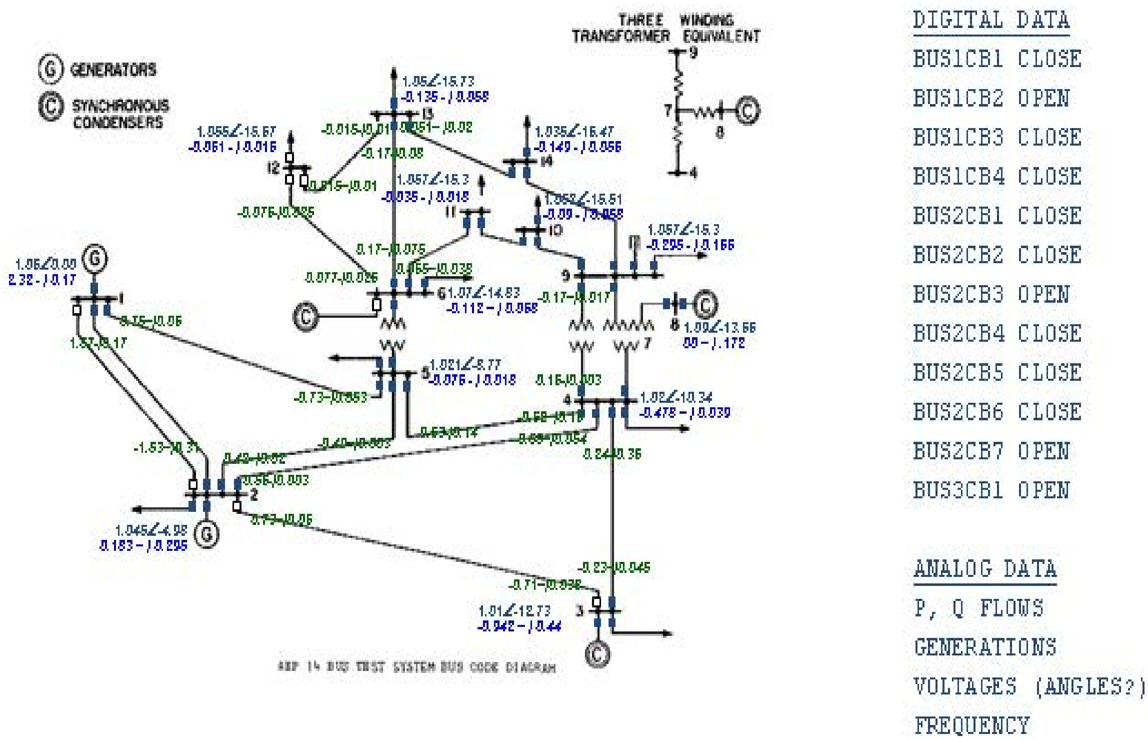


Figure 15: Total system with status of switching devices obtained from SCADA system

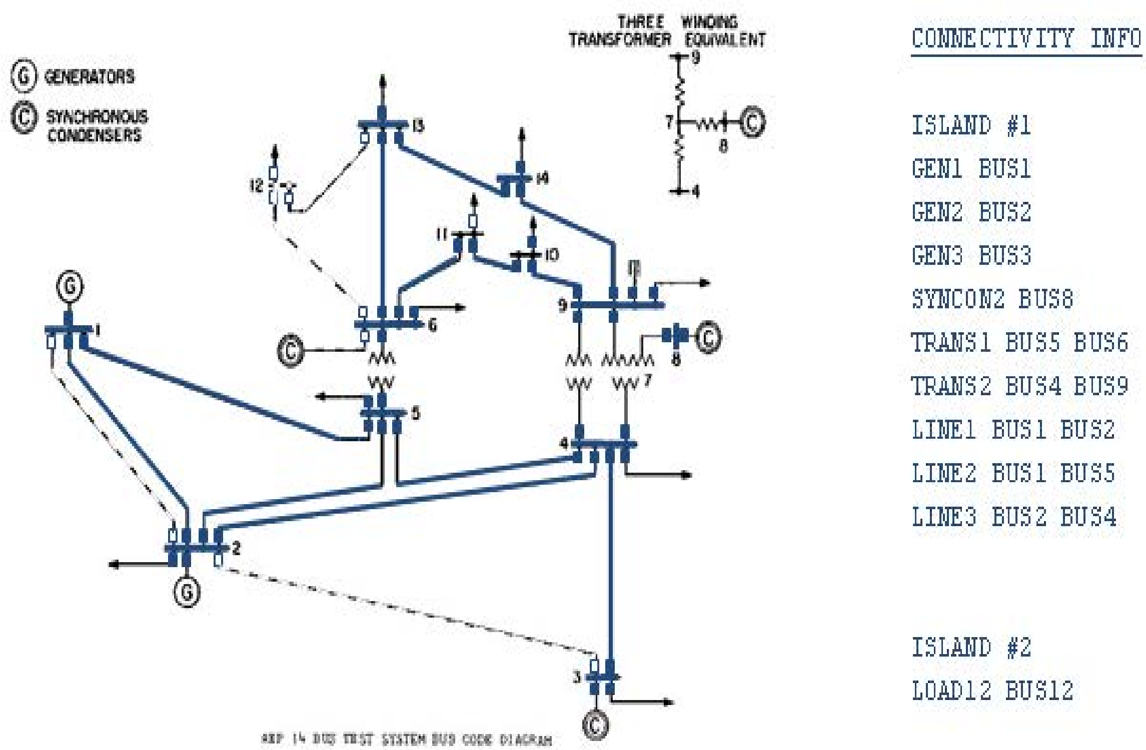


Figure 16: Output of Topology Processor after filtering dead components

State Estimator application runs on the energized network provided by the Topology Processor.

3.3 Observability analysis

In **Observability Analysis**, it is determined whether the currently available set of measurements provides sufficient information to allow computation of state variables. Since the availability of real time measurements can change because of failures in the telemetry equipments, an observability check is made before the state estimator solution is executed. When sufficient measurements are available so that the entire state vector of bus voltage magnitudes and angles throughout the network can be estimated, the network is said to be observable. If the network is observable, state estimation may proceed; otherwise, pseudo-measurements must be added to the measurement set to allow an estimate of the state vector.

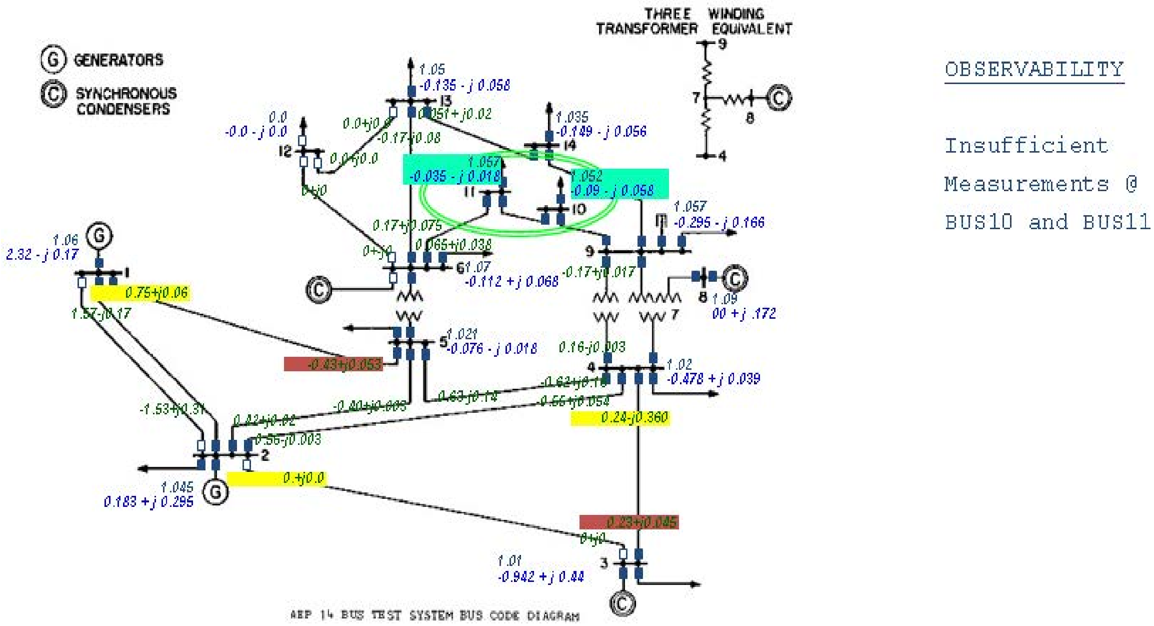


Figure 17: Network with some unobservable part

To make the observability analysis more clear let us consider the following flow chart –

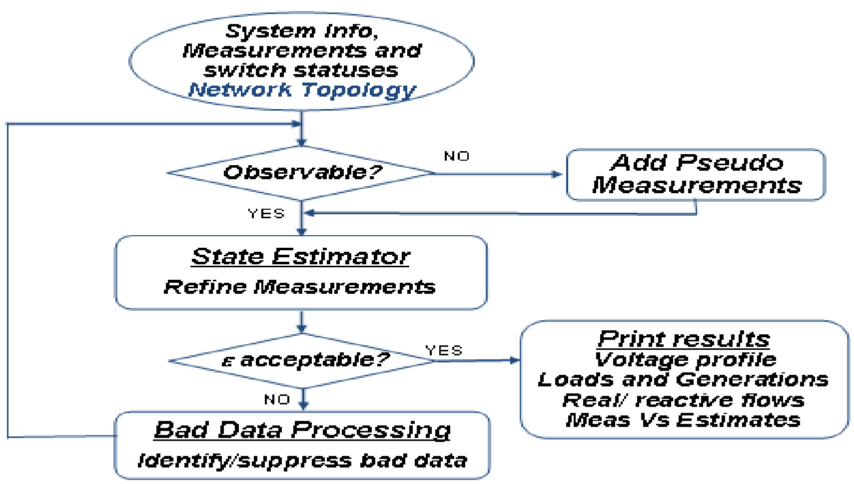


Figure 18: Observability flow chart of a Network

Difference between terms “Observable” and “Solvable” – Portions of the network where State Estimator can estimate the state using only actual measurements is observable. Whereas portions of the network where State Estimator can calculate the state using available measurements complemented by PSEUDO measurements is solvable.

3.4 Use of Pseudo measurements to attain observability

Pseudo-measurements are used to complement actual measurements in order to allow full network solution by making it Observable (or strictly speaking “solvable”).

Pseudo-measurements are generated from:
- generation and load models and schedules
- voltage regulation schedules
- past records
- non real-time information exchanged with neighboring utilities

Above information translates into a single type of pseudo-measurement i.e. unit and load injections. Measurement vector Y is extended to include minimal number of pseudo-measurements and Pseudo-measurements are given greater uncertainty than actual measurements.

3.5 Weighted Least Square Algorithm

Weighted Least Square Algorithm is the most widely used algorithm for State Estimation in Power systems. The measurement equations are:

$$\mathbf{Y = h(X) + V}$$

where,

X = column-vector of state variables

Y = column-vector of measurements

V = column-vector of measurement errors

(***Note***: The equation mentioned above is same as the equation in ***Section 4*** with different notation of variables.)

This is an over-determined powerflow problem:

- using the information from *M* independent measurements, $Y = \{ y_j \}$
- to solve for *N* unknowns (state X or solution variables),
- where *M* is greater than *N* (*M*-*N* = degree of freedom)

The best estimate of the state X is the solution of a least squares problem:

$$\mathbf{Min\ J(X,Y) = Sum\ \{ [\ y_j - h_j(X)\ ] / sigma_j\ \}^2}$$

The value of J is sometimes called the “cost” of the solution.

This estimate of X is obtained by the well known Generalized Least Squares (GLS) method:

$$\mathbf{X = [\ H^T W^{-1} H]^{-1}\ H^T W^{-1} Y}$$

suitably adapted to deal iteratively with non-linear equations:

$$X_{k+1} - X_k = [H^T W^{-1} H]^{-1} \; H^T W^{-1}[Y-h(X_k)]$$

In the case of independent measurement errors, this reduces to the Weighted Least Squares WLS, in which W^{-1} is diagonal with:

$$W_{jj} = 1/sigma_j^2$$

“sigma” reflects the measurement uncertainty.
“W” reflects the measurement confidence.

3.6 Parameters for State Estimation

Various parameters are generally defined for State Estimation in order to provide flexibility or tighten the limit in order to get better SE output. Each EMS vendor may have their own way of solving state estimation problem. Some of the parameters in Alstom’s SE application (known as RTNET) are given below –

- Voltage Convergence threshold
- Angle Convergence threshold
- Real Power Mismatch Tolerance
- Reactive Power Mismatch Tolerance
- Maximum iterations for Convergence
- Maximum Cost Residual for convergence
- ….. various other parameters

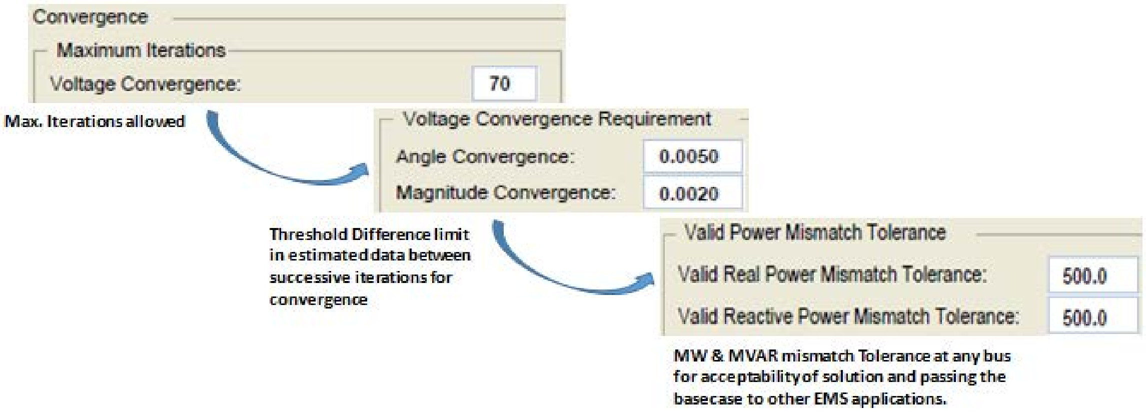


Figure 19: Parameters for State Estimation

3.7 Voltage and Angle Convergence

The state variables which are estimated by the State Estimator application are “Voltage” and “Angle” at each bus. State Estimator solves the equations of Weighted Least Square Algorithm in an iterative manner and Voltage & Angle after each iteration is compared with that of the previous iteration.

If ***{Voltage (‘k+1’ iteration) – Voltage (‘k’ iteration) < Voltage Magnitude Convergence Threshold}***, then Voltage Convergence is achieved.

If ***{Angle ('k+1' iteration) – Angle ('k' iteration) < Angle Convergence Threshold}***, then Angle Convergence is achieved.

3.8 Bad data processing

Different vendors have different methodology to detect and handle bad-data. Bad-data detection in most of the vendor's products is based on the equation residuals evaluated at the calculated network state.

Residual = Estimated value - Measured value

Sum of all Residuals = Cost of the solution

Large residuals generally indicate that the associated measurement (or bus equation) is grossly in error or anomalous. Also, the total cost "J" of the solution will be too high in the presence of errors and solution may be invalid if it exceeds the tolerance defined for Cost of Solution.

Individual equation residual is analyzed whose value is larger than expected and propose weight adjustment is done to reduce the influence of those measurements upon the solution. Sensitivity analysis of equation residuals to the proposed weight adjustments is done and weight changes are implemented. Weighted Least Square algorithm is re-solved to obtain new state solution. The total cost of solution and equation residuals are checked again and if acceptable then the solution is said to be valid and if not, the error processing is repeated with subsequent weight changes.

The bad-data is identified by statistical analysis using Chi-square test which indicates if any bad-data is present in the measurement set or not. If it indicates the presence of bad-data then the measurement with highest residual is considered as the bad-data.

Bad data identification identifies the bad data and marks it as anomalous. It is indicated in a real time display as shown in the diagram (corresponding to Alstom system in NLDC) below –

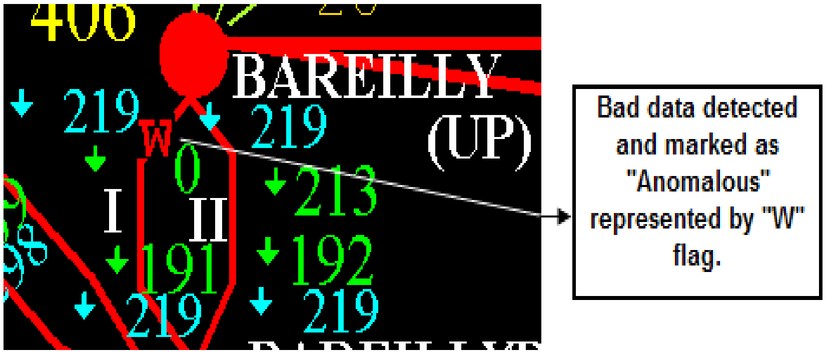


Figure 20: Bad data detection indication in SCADA display

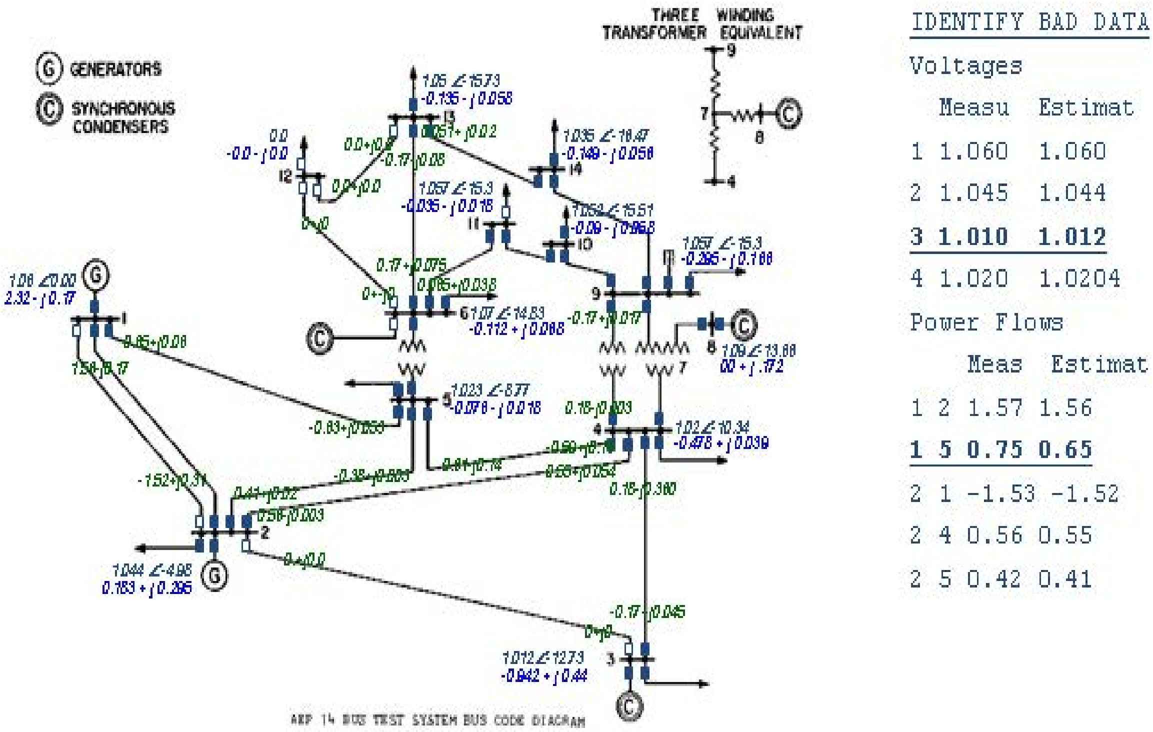


Figure 21: Network with Bad data

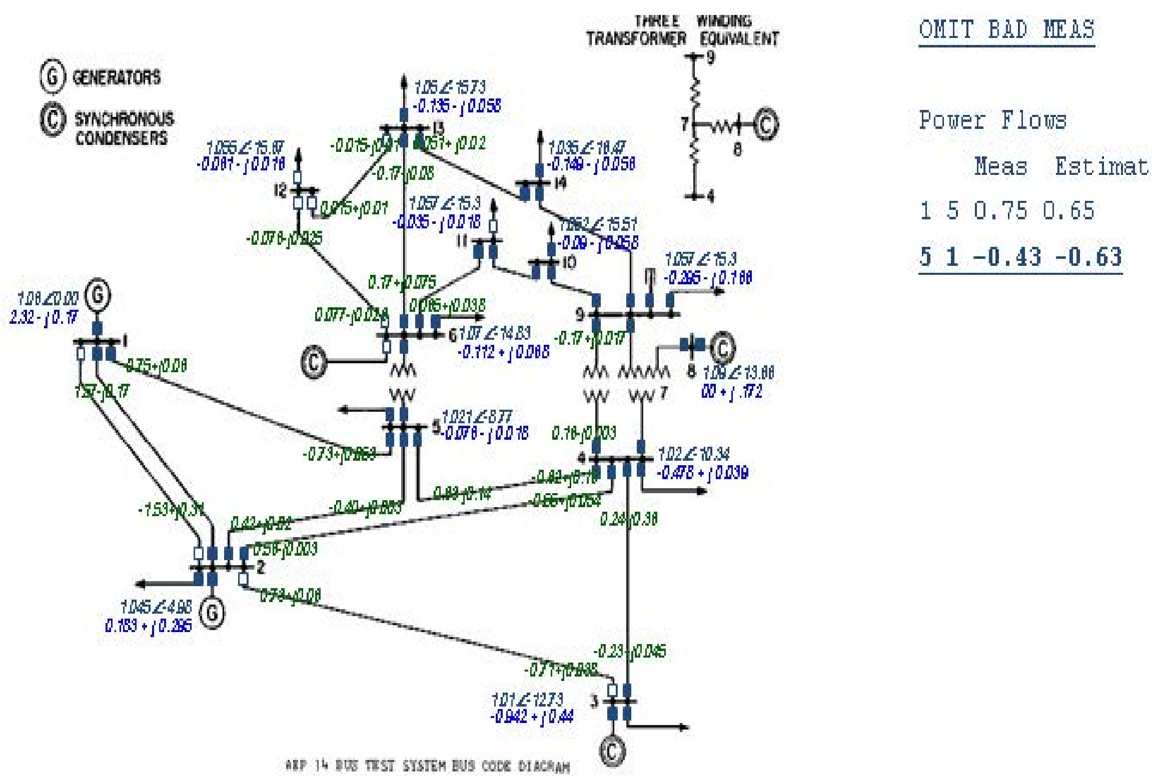


Figure 22: Bad data identification and Bad data suppression

List of bad data in State Estimator display (corresponding to Alstom system) is shown below –

Telemetered Network Data

By Station | -- Sorted/Filtered -- | Anomalous | Special | Status

Time: 25-Jul-2011 14:52:22 RTNET REALTIME SOLVD W. MISMTCH

INCLUDE - Anomalous: ☑ Suspect: ☐ Abnormal: ☐ Man Disabled: ☐ Auto Disabled: ☐ Available: ☐

ORDER BY - Station: ☑ Standard Deviation: ☐ Bias: ☐ Weighted Residual: ☐

Station	Device Type	Device	Analog	Quality SCADA / Estimated	Value SCADA / Estimated	Weighted Residual	Standard Deviation
AMRIT_PG	XFMR_S	FE_T2	MW	Good / Anomaly	135.87 / -132.86	35.990	
BHIWA_PG	LINE	F_BHIWA_GURGN	MW	Good / Anomaly	317.61 / -33.41	20.096	
BRELY_PG	ZBR	F_BRELY_MANDU1	MW	Good / Anomaly	338.00 / -377.66	29.524	
BRELY_PG	ZBR	F_BRELY_MANDU2	MW	Good / Anomaly	341.00 / -379.12	29.708	
CHINT_UP	LINE	E_CHINT_HRDOI	MW	Good / Anomaly	0.00 / 167.81	-29.545	
CHINT_UP	LINE	E_CHINT_HRDOI	MVAR	Good / Anomaly	0.00 / 113.65	-20.009	
D_THM_NT	XFMR_S	FE_T4	MW	Good / Anomaly	-0.00 / 263.85	-18.846	
D_THM_NT	XFMR_S	FE_T3	MW	Good / Anomaly	-0.00 / 262.28	-18.734	
GRKPR_PG	LINE	F_GRK_1_GRKPR2	MVAR	Good / Anomaly	-739.00 / 26.21	-56.376	
GRKPR_PG	LINE	F_GRKPR_LKNOW3	MVAR	Good / Anomaly	-537.40 / -96.04	-18.959	
HRDOI_UP	LINE	E_CHINT_HRDOI	MW	Good / Anomaly	-40.06 / -166.42	22.247	
LKNOW_PG	ZBR	F_GRKPR_LKNOW4	MW	Good / Anomaly	-242.40 / 124.34	-27.020	
LKNOW_PG	ZBR	F_GRKPR_LKNOW3	MW	Good / Anomaly	-205.00 / 124.33	-24.263	
LUCK2_UP	LD	RN_220_UNNA01	MW	Good / Anomaly	-26.66 / -214.24	49.739	
LUCK2_UP	LD	RN_220_UNNA01	MVAR	Good / Anomaly	0.00 / -184.80	49.004	
LUCK2_UP	LD	RN_220_UNNA02	MW	Good / Anomaly	-25.47 / -213.04	49.739	
LUCK2_UP	LD	RN_220_UNNA02	MVAR	Good / Anomaly	0.00 / -184.80	49.004	
MAINP_PG	ZBR	F_ALBAD_MAINP1	MW	Good / Anomaly	-264.39 / 255.85	-38.328	
MAINP_PG	ZBR	F_ALBAD_MAINP2	MW	Good / Anomaly	-272.59 / 255.85	-38.933	
MBAGH_PG	XFMR_S	FE_T1	MW	Good / Anomaly	82.00 / -205.09	32.525	
MBAGH_PG	XFMR_S	FE_T2	MW	Good / Anomaly	82.50 / -205.09	32.582	
MLERK_PG	LINE	F_MLERK_PATIA	MVAR	Good / Anomaly	138.25 / -123.90	19.314	
OBRAB_UP	UNIT	F_U09	MW	Good / Anomaly	0.00 / 149.43	-23.815	
OBRAB_UP	UNIT	F_U13	MW	Good / Anomaly	0.00 / 123.11	-19.621	

Figure 23: List of Anomalous data

These measurements are omitted from the State Estimator process and are not used again in its algorithmic equations until we re-initialize certain parameters of State Estimation process.

The Final Estimated result would be as shown below –

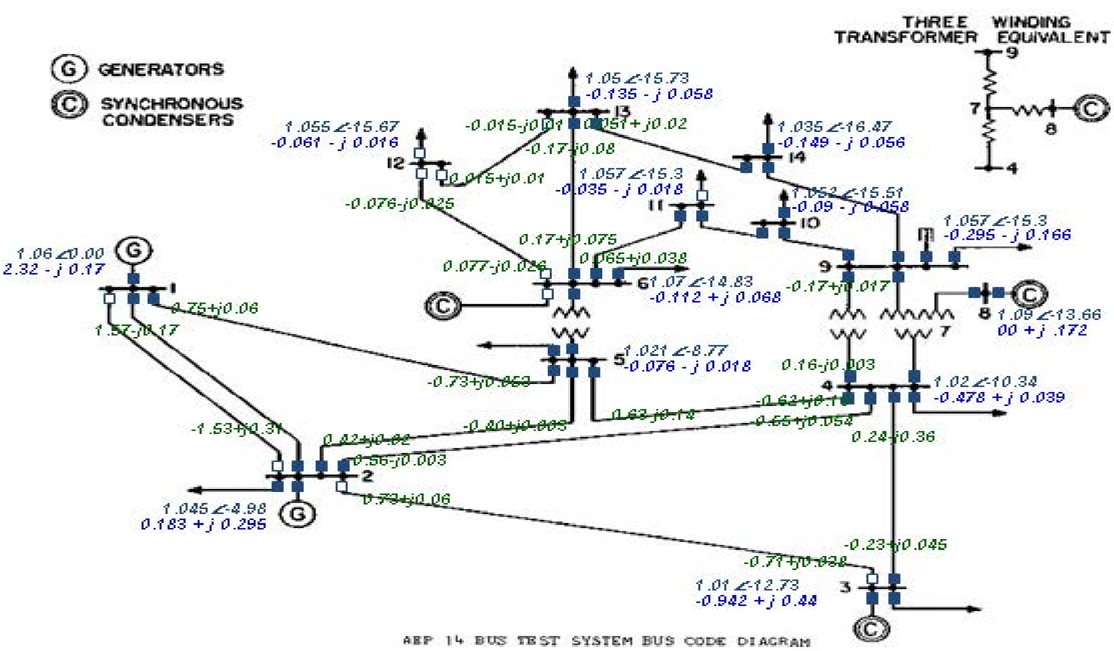


Figure 24: Final Estimated result of the Network

3.9 Chi-square Test

One of the methods used for detecting bad data is the Chi-squares test. Once bad data is detected, it needs to be identified and eliminated or corrected, in order to obtain an unbiased state estimate.

Chi-squares χ^2 Distribution:

Consider a set of N independent random variables X_1, $X_{2,}$ ……, X_N; where each X_i is distributed according to the Standard Normal distribution:

$$X_i \sim N(0,1)$$

Then, a new random variable Y defined by:

$$Y = \sum_{i=1}^{N} X_i^2$$

will have a χ^2 distribution with N degrees of freedom, i.e.

$$Y \sim \chi_N^2$$

The degrees of freedom N, represents the number of independent variables in the sum of squares. This value will decrease if any of the X_i variables form a linearly dependent subset.

Now, let us consider the function f(x), written in terms of the measurement errors:

$$f(x) = \sum_{i=1}^{m} R_{ii}^{-1} e_i^2 = \sum_{i=1}^{m} (\frac{e_i}{\sqrt{R_{ii}}})^2 = \sum_{i=1}^{m} (e_i^N)^2$$

where e_i is the i^{th} measurement error, R_{ii} is the diagonal entry of the measurement error covariance matrix and m is the total number of measurements. Assuming that e_i's are all Normally distributed random variables with zero mean and distribution, i.e. variance, e_i^N's will have a Standard Normal Distribution, i.e.,

$$e_i^N \sim N(0, 1)$$

Then, f(x) will have a χ^2 distribution with at most (m - n) degrees of freedom. In a power system, since at least n measurements will have to satisfy the power balance equations, at most (m - n) of the measurement errors will be linearly independent. Thus, the largest degree of freedom can be (m - n), i.e. the difference between the total number of measurements and the system states.

Use of χ^2 Distribution for Bad Data Detection:

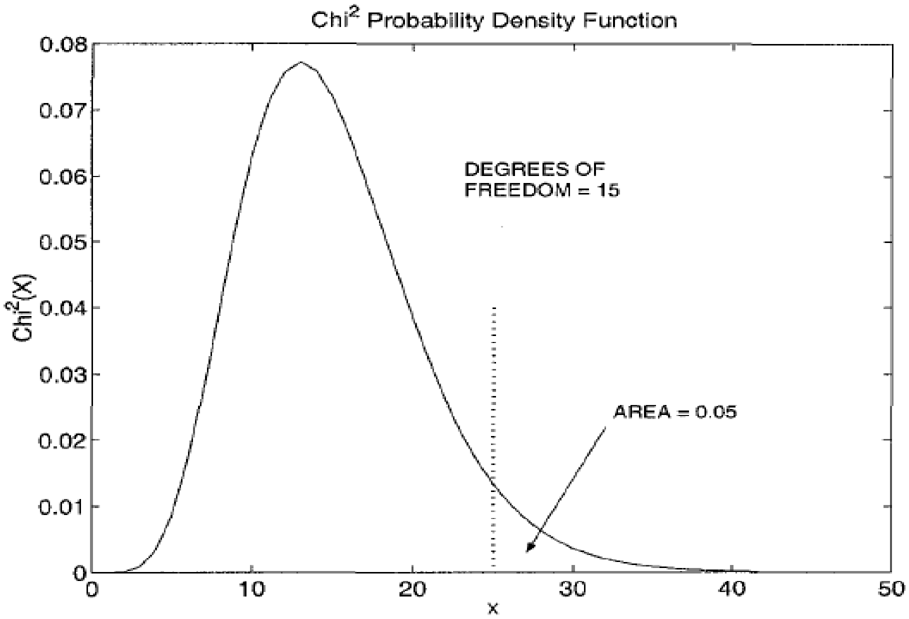


Figure 25: χ^2 Probability Density Function

A plot of the χ^2 probability density function (p.d.f) is shown in ***fig.25*** above. The area under the p.d.f. represents the probability of finding X in the corresponding region, for example:

$$Pr\{X \geq x_t\} = \int_{x_t}^{\infty} \chi^2(u) \cdot du$$

represents the probability of X being larger than a certain threshold x_t. This probability decreases with increasing values of x_t, due to the decaying tail of the distribution. Choosing a probability of error, such as 0.05, the threshold x_t can be set such that:

$$Pr\{X \geq x_t\} = 0.05$$

In ***fig.25***, this threshold corresponds to x_t = 25 indicated by the vertical dotted line. The threshold represents the largest acceptable value for X that will not imply any bad data. If the measured value of X exceeds this threshold, then with 0.95 probability, the measured X will not have a χ^2 distribution, i.e. presence of bad data will be suspected.

Tables containing Chi squares cumulative distribution function values for different degrees of freedom can be found in various statistical publications.

χ^2 Test for Detecting Bad Data in WLS State Estimation:

The WLS state estimation objective function J(x) can be used to approximate the above function f(x) and a bad data detection test, referred to as the Chi-squares test for bad data, can be devised based on the properties of the χ^2 distribution.

The steps of the Chi-squares χ^2 test are given as follows:

Step 1: Solve the WLS estimation problem and compute the objective function as given below –

$$J(\hat{x}) = \sum_{i=1}^{m} \frac{(z_i - h_i(\hat{x}))^2}{\sigma_i^2}$$

where,
$x^{\wedge}$ estimated state vector of dimension n.
h_i ($x^{\wedge}$) : estimated measurement i.
z_i : measured value of the measurement i.
σ_i^2 = R_{ii} : variance of the error in measurement i.
m : number of measurements.

Step 2: Look up the value from the Chi-squares distribution table corresponding to a detection confidence with probability p (e.g. 95%) and (m — n) degrees of freedom. Let this value be $\chi^2_{(m-n),\ p}$.

Here $p = \Pr\ (J(\hat{x}) \leq \chi^2_{(m-n),p})$.

Step 3: Test if J(x^) ≥ $\chi^2_{(m-n),\ p}$.
If yes, then bad data will be suspected.
Else, the measurements will be assumed to be free of bad data.

Example 1: Consider 5 independent measurements of a quantity, given as follows:

Measured variable	X_1	X_2	X_3	X_4	X_5
Measured value	0.5	-1.2	0.80	0.20	-3.1

Assume that the measurements are taken from a sample which is known to have a Standard Normal distribution, i.e.

$$X_i \sim N(0,1) \quad \text{for all } i$$

Use χ^2 distribution to check for bad data with 99% confidence.

Solution:
Let us form the sum of squares of the measured variables:

$$y = \sum_{i=1}^{5} x_i^2 = 11.98$$

The probability of obtaining this value (11.98) when Y indeed has a χ_4^2 distribution can be found by using the following –

Matlab Software Statistical Toolbox function CHI2CDF(Y, DF).

where,
DF is the degrees of freedom (which is ***4*** for this example)

This probability, denoted by P will be obtained as:

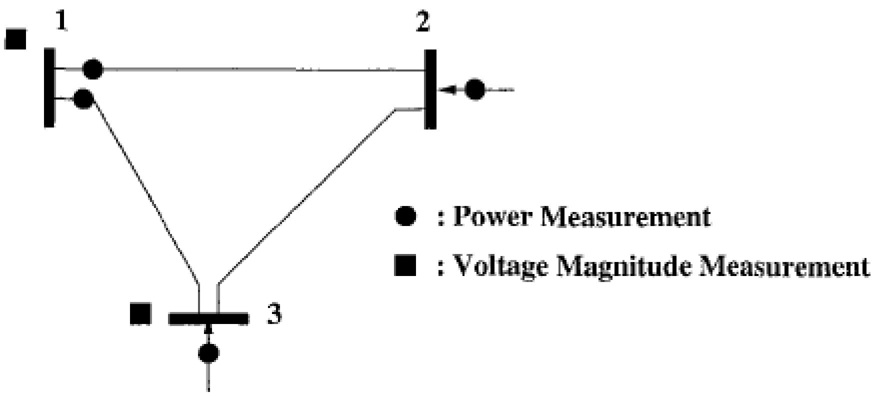
P = CHI2CDF (11.98, 4) = 0.9825

Since 0.9825 < 0.99, bad data will not be suspected with 99% confidence. Alternatively, the test threshold at the 99% confidence level can be obtained by using another one of the Matlab functions called CHI2INV (P, DF) where P is the confidence probability level, which is 0.99 for this example. Execution of this function yields the corresponding threshold y_t, which represents the largest acceptable value for y, without suspecting any bad data with 99% confidence:

$$y_t = \text{CHI2INV}(0.99, 4) = 13.28$$

Again, since y_t = 13.28 > y = 11.98, bad data will not be suspected for this example.

Example 2: Consider the 3-bus system and its measurement configuration shown in the figure.



The corresponding network data are given below:

Line		Resistance R (pu)	Reactance X (pu)	Total Susceptance $2b_s$ (pu)
From Bus	To Bus			
1	2	0.01	0.03	0.0
1	3	0.02	0.05	0.0
2	3	0.03	0.08	0.0

Check the bad-data as per the Chi-square test.

Solution:
The number of state variables, n for this system is 5, made up of three bus voltage magnitudes and two bus voltage phase angles, slack bus phase angle being excluded from the state list. There are altogether m = 10 measurements, i.e. 2 voltage magnitude measurements, 2 pairs of real/reactive flows and 2 pairs of real/reactive injections. Therefore, the degrees of freedom for the approximate χ^2 distribution of the objective function J(x^) will be:

m –n = 10 – 5 = 5

Measurements are generated by solving the base case power how and then adding Gaussian distributed errors. One of the measurements P_2, is then changed intentionally, to simulate bad data. The state estimation solution and the objective function values that are obtained for both cases, are shown in the tables below:

From Bus	To Bus			
	No bad data		**One bad data**	
	V	**θ°**	**V**	**θ°**
1	1.0000	0	1.0000	0.00
2	0.9886	-0.84	0.9886	-0.67
3	0.9834	-1.19	0.9834	-1.20

Measurement No.	Measurement Type	Measured Value	
		No bad data	One bad data
1	V_1	1.0065	1.0065
2	V_3	0.9769	0.9769
3	P_2	-0.4007	**-0.3507**
4	P_3	-0.4857	-0.4857
5	Q_2	-0.3052	-0.3052
6	Q_3	-0.3850	-0.3850
7	P_{12}	0.4856	0.4856
8	P_{13}	0.4054	0.4054
9	Q_{12}	0.3821	0.3821
10	Q_{13}	0.3367	0.3367
J(x^)		6.1	22.8

Using MATLAB software, the test threshold at 95% confidence level is obtained by Matlab function CHI2INV as:

$$\mathbf{Y_t = CHI2INV\ (0.95,\ 5) = 11.1}$$

In the first case, since J(x^) =6.1 < 11.1, bad data will not be suspected. However, the test will detect bad data for the second case, since the corresponding value of J(x^) = 22.8 exceeds the χ^2-test threshold of 11.1.

3.10 Output of State Estimator

The Output of State Estimator contains Estimated Complex Voltages, Estimated Real Power “P” and Reactive Power “Q” injections and flows, Error Analysis and list of Bad Bata.

It can be diagrammatically represented as shown in ***fig.26*** below.

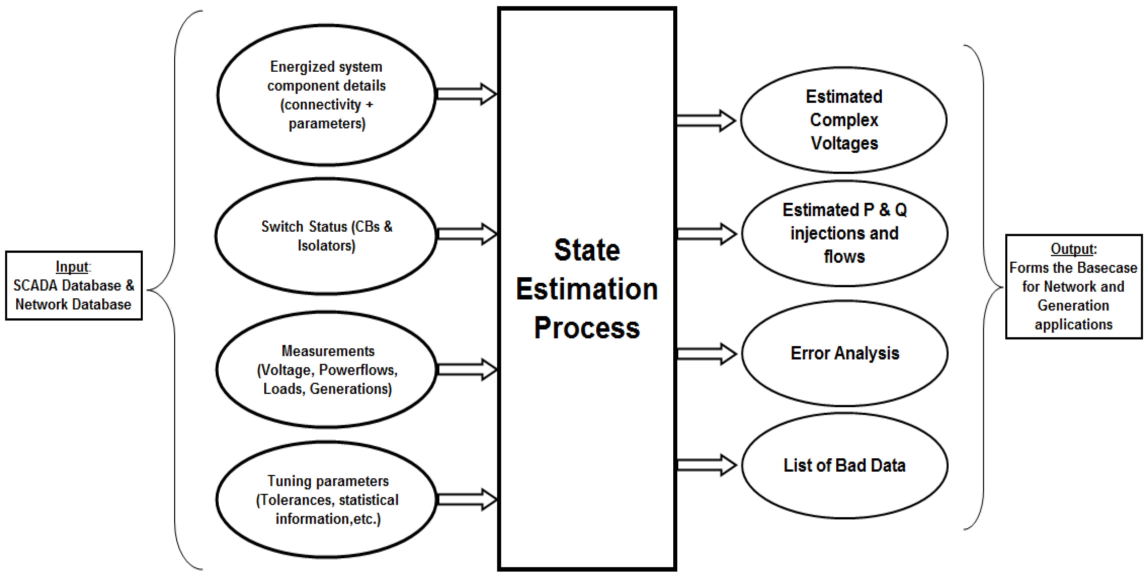


Figure 26: Output of state Estimation process

The Output of the state estimator application acts as a Base-case for other applications.

3.11 Quality of State Estimator solution

The quality of the state estimator solution can be analyzed by the total system cost of the solution**.** It is generally calculated by the following methodology:

Residual = Estimated value - Measured value

Sum of all Residuals = Cost of the solution

If the cost of the solution is high then we can say that the solution quality is poor. Hence, lower is the cost of the solution; better is the state estimator output.

4. FACTORS AFFECTING STATE ESTIMATOR OUTPUT IN INDIA

The various factors affecting the output of State Estimator are discussed in the sections below.

4.1 Topology Errors

Topological errors usually cause the state estimate to be significantly biased. Topology of the system is determined based on the status position of circuit breakers and isolators acquired by the SCADA system. It is understood that main reason for such errors are poor potential free contacts for isolators at substation especially for feeders below 400 kV.

Potential free contacts are used to transfer switch position to control centre. Rusting or mal-operation of these contacts is main cause of incorrect status acquisition and thus determining incorrect power system topology.

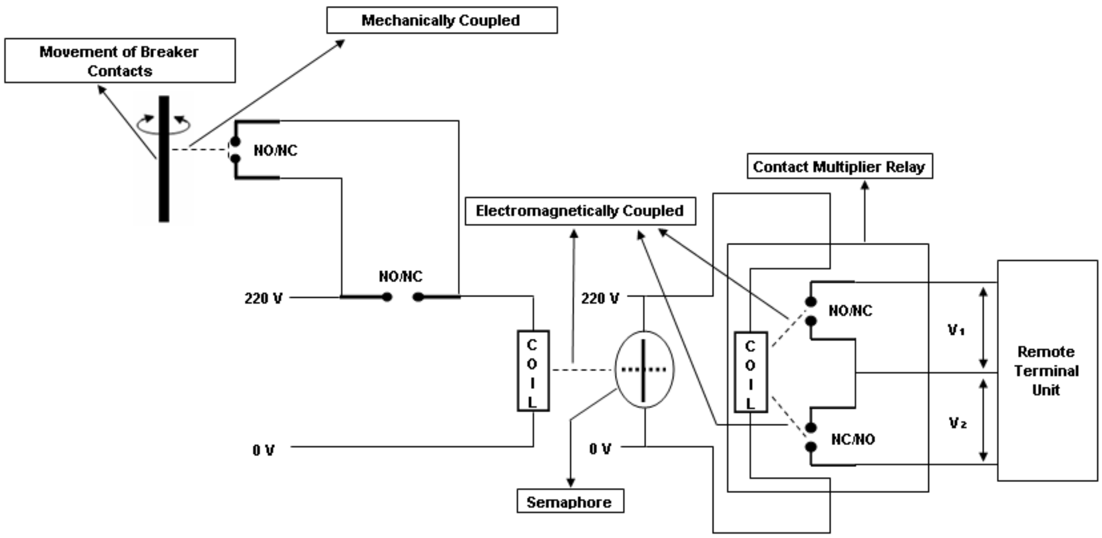


Figure 27: Digital data acquisition

Many times it is also found that whenever potential free contacts are not available Contact multiplying relays (CMR) is used and for a circuit breaker status indication two numbers of CMRs are required. Due to shortage of CMRs only closed position of CB status is wired and open status is left unwired. This results into suspect open condition of CB causing incorrect topology. In case of suspect switch position, depending upon the vendor, state estimator may assume closed position or assume the last good value as the current position. ***Table 4*** gives some of the impacts of incorrect status indication on State Estimation.

Incorrect status of switching device connecting to	Impact on State Estimation
Line	Change in MW and MVAR flows on neighboring lines, or cause of new Island
Generator	Change in flows in the lines connecting to the plant, and increased or decreased generation of nearby generating units/stations.
Load	Change in flows in the lines connecting to the station, and if the load is removed cause of less total system generation.
Reactor	Change in MVAR flow in the lines of the station, and improper voltages
TCSC/FSC bypass switching device	Change in MW flow through the line containing the TCSC or FSC.

Table 4: Errors in digital status and its impacts on State Estimation

Errors due to status coding at NLDC: During implementation of NLDC SCADA/EMS system, it is found that coding and naming of measurements received from one vendor system to other vendor system are different and needs to be mapped as per the recipients philosophy for both analog measurements as well status measurements.

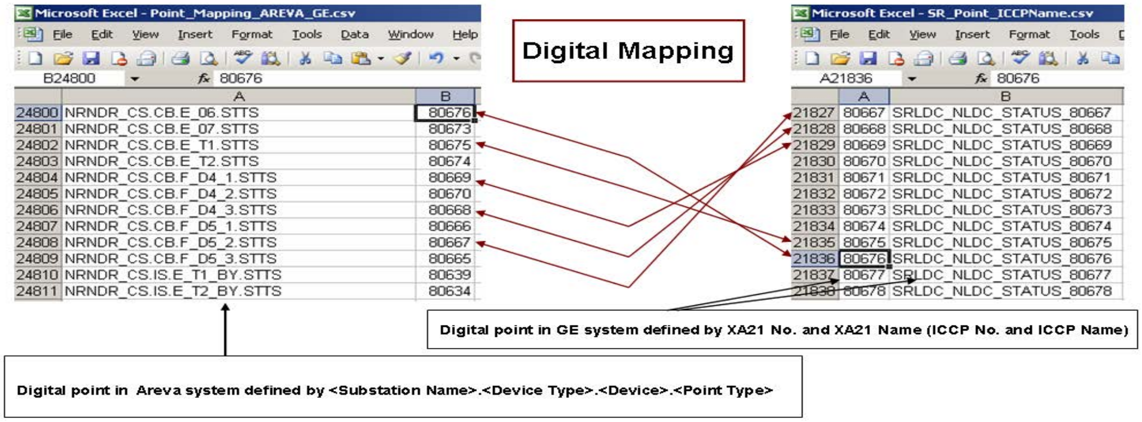
Hence, if philosophy used for coding bits by two vendors does not match with each other, conversion tables are used for mapping different philosophies. Any wrong selection of conversion table can lead to topological errors in the SCADA/EMS system.

It is decided to follow a common status bit coding convention mentioned in ***table 5*** in order to avoid such errors.

Status Points	Device Status	Bits Codes (Digital)	Value Codes (Analog)	Bits Coding at Control Center 1	Status Interpretation at Control Center 1	Values transferred to other Control Center-2	Bits Coding at Control Center 2	Status Interpretation at Control Center 2
Double point status	BETWEEN	00	0	00	BETWEEN	0	00	BETWEEN
	OPEN	01	1	01	OPEN	1	01	OPEN
	CLOSE	10	2	10	CLOSE	2	10	CLOSE
	INVALID	11	3	11	INVALID	3	11	INVALID
Single point status	OPEN	0	0	0	OPEN	0	0	OPEN
	CLOSE	1	1	1	CLOSE	1	1	CLOSE

Table 5: Standard convention for 1-bit and 2-bit status to be used

Mapping errors in digital data at NLDC: The Load Despatch Centers in India have a multivendor proprietary SCADA/EMS system and each system has a different naming convention of SCADA and ICCP tags. At the time of integration of NLDC with RLDCs ICCP mapping was done at NLDC end in order to get the data. This mapping was done in ".csv" files (shown in ***fig.28***) of MS-Excel software and populated in the database while SCADA/EMS on-lining. Any error in the digital data mapping could lead to erroneous analog data.



- Mapping is done in Excel sheets (as shown above).
- 6 Excel sheets are maintained (3 for analog mapping, 3 for digital mapping).
- 1 excel sheet is maintained for Reverse database (i.e. the data which the RLDC want to acquire from NLDC through ICCP).

Figure 28: Digital Mapping of database in ".csv" files for GE system in WRLDC and SRLDC.

4.2 Observability of the network

If the real-time measurements are not sufficient to analyse the entire network then the network is said to be un-observable and State Estimator cannot be solved. Therefore, it is important to have sufficient measurements at suitable locations should be available in the network in order to make it observable. Sometimes if there is loss of measurements or insufficient measurements to make the system observable, appropriate pseudo measurements will be used to make the system observable.

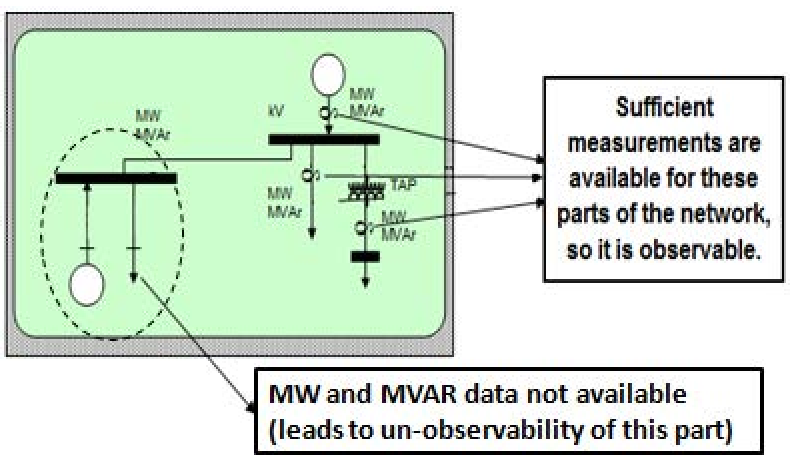


Figure 29: Non-observability of a Network

In the above network "δ" symbol represents the observable part of the network. Load MW and MVAr cannot be estimated and hence PSEUDO measurements are used to make that part observable (or solvable).

4.3 Equipment Parameters Errors

Since State Estimation requires correct model of the network, incorrect parameters of various power system equipment impact the State Estimator output. ***Table 6*** indicates some of the impacts due to incorrect parameters in State Estimation.

Error in modeling related data	Impact on State Estimation
Incorrect Line Parameter	Causes change in impedance of paths, hence different flows than actual, and change in the estimated angles at the station buses.
Incorrect Transformer Parameters and Taps	Changes in voltage drops across the transformers.
Missing reactors or incorrect nominal MVAR rating	Contribute to voltage problems.

Table 6: Errors in other data and its impacts on State Estimation

4.4 Different sign conventions of analogs

Analog Data transfer includes data such as Active Power, Reactive Power, voltage, Amperes, Frequency, etc. Different sign convention of data is followed at many SLDCs and RLDCs. A compilation of sign convention followed at RLDCs is given in ***Table 7***.

Analog data							
Analog Data	**Positive Sign possibility**	**Negative Sign possibility**	**Sign convention at NRLDC**	**Sign convention at ERLDC**	**Sign convention at WRLDC**	**Sign convention at SRLDC**	**Sign convention at NERLDC**
Line MW	Yes	Yes	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve
Line MVAR	Yes	Yes	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve
Line Amp.	Yes	Yes	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve
Bus KV	Yes	No	+ve	+ve	+ve	+ve	+ve
Bus HZ	Yes	No	+ve	+ve	+ve	+ve	+ve
Trf. Pri. MW/ MVAR	Yes	Yes	Export: +ve Import: +ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve
Trf. Sec. MW/ MVAR	Yes	Yes	Export: +ve Import: +ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve
Gen. Trf. Pri. MW/ MVAR	Yes	Yes	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve
Gen. Trf. Sec.	*Same as unit MW/*	*Same as unit MW/*	*Same as unit MW/*	*Same as unit MW/*	*Same as unit MW/*	*Same as unit MW/*	*Same as unit MW/*

MW/ MVAR	*MVAR*	*MVAR*	*MVAR*	*MVAR*	*MVAR*	*MVAR*	*MVAR*
Unit MW/ MVAR	Yes	Yes	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve	Export: +ve Import: -ve
Load MW/ MVAR	Yes	Yes	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve
Reactor MVAR	Yes	No	+ve	+ve	+ve	+ve	+ve
Capacitor MVAR			+ve	+ve	+ve	+ve	+ve
IR Exch.	Yes	Yes	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve	Export: -ve Import: +ve

Table 7: Sign convention of analog data in RLDCs

Different sign conventions used for import and export of power is shown in the ***fig.30*** below.

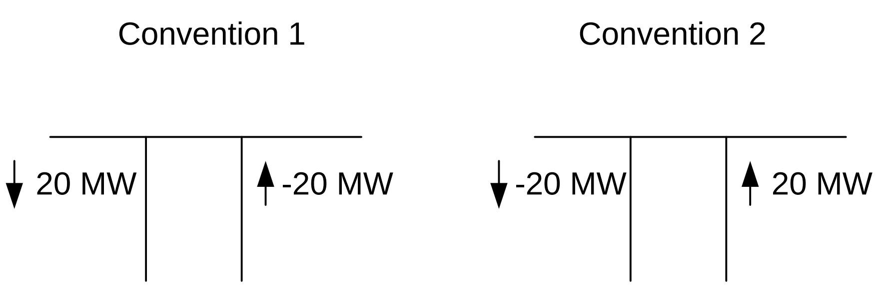


Figure 30: Two cases of sign convention for import/export of power

The sign conventions should be taken care of as it gets transferred to SE application and can cause serious mismatch and act as feeding bad-data to the SE. If the proper sign convention is missed during assigning telemetry values, a wrong starting point is given to the state estimator which may result in non-convergence.

4.5 Analog data errors

Incorrect or erroneous measurement needs to be identified and corrected in order to improve the state estimator solution.

Error in analog measurement in	Impact on State Estimation
Line	If the redundant measurement is available then it may reduce the error as in subsequent iterations the weightage of that erroneous measurement would be reduced by the SE application. If the redundant measurement is not available then the result depends upon the availability and quality of neighboring measurements.
Bus Voltage	It will affect the solution by acting as a bad input to the state Estimator

	equation corresponding to that measurement. The Estimate of this measurement will largely depend on Line and Transformer Parameters, Transformer Taps and Quality and accuracy of other measurements on that node.
Generator	Might force increased or decreased generation at the station, and change in generation of other units or plants.
Load	Change in power consumption, hence change in flows, and total generation.

Table 8: Impact of incorrect analog data on state estimation

Errors due to mapping errors in analog data at NLDC: The Load Despatch Centers in India have a multivendor proprietary SCADA/EMS system and each system has its own methodology in naming convention of SCADA and ICCP tags. At the time of integration of NLDC with RLDCs ICCP mapping was done at NLDC end in order to get the data. This mapping was done in ".csv" files (shown in ***fig.31***) of MS-Excel software and populated in the database while SCADA/EMS on-lining. Any error in the mapping could lead to erroneous analog data.

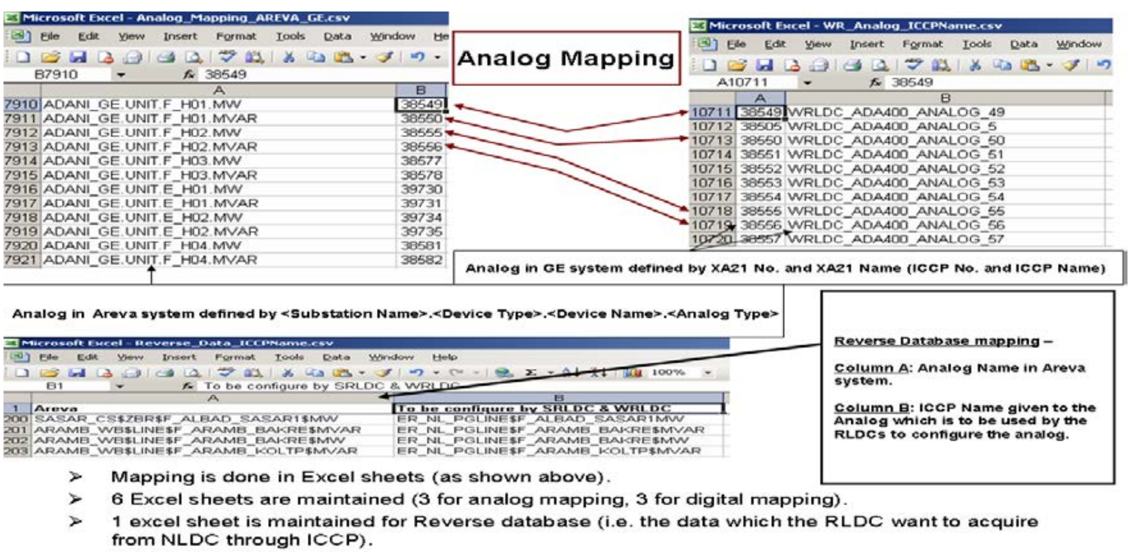


Figure 31: Analog Mapping of database in".csv" files for GE system in WRLDC and SRLDC

4.6 Impact of incorrect model

In State Estimator output it is many-a-times found that even after closing the circuit breaker and isolator position the corresponding device does not connect to the bus due to incorrect modeling.

The following example case describes the issues in state estimation due to wrong modeling.

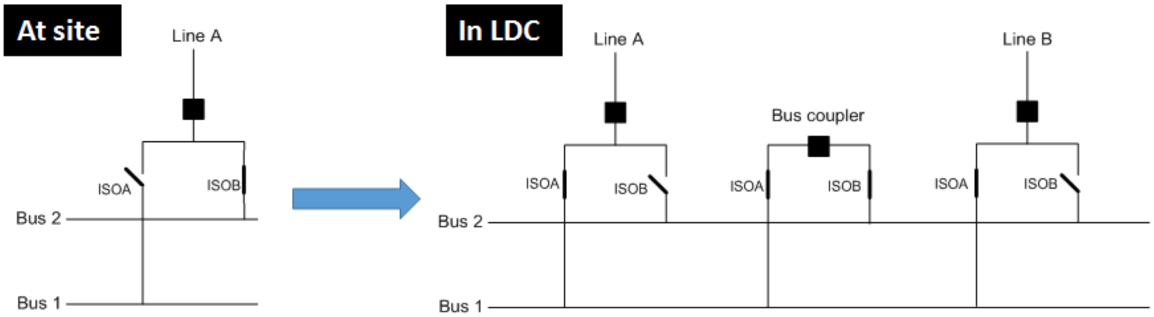


Figure 32: Double main bus with wrong isolator connectivity

For a double main bus system as shown in the above case, the line A is connected to Bus 2 in field through ISOB feeding the load A. Suppose say, that in state estimation model (in LDC) it is modeled as connected to bus 1. As long as the bus coupler is closed, this error has no effect on the connectivity since both the buses are connected together and Line A would be feeding both the loads. But if the bus coupler is open, in the field, Line A is actually feeding only Load A. However due to incorrect modelling in State Estimation (in LDC), Line A would be feeding Load B (instead of Load A). This may lead to incorrect State Estimation results. This is a case of modeling error of the network.

It is important to make sure the model that is used for State Estimation is correct. State Estimation will help to identifying such model errors.

5. SUGGESTIONS FOR TUNING OF STATE ESTIMATOR

Proper tuning of state estimator is required in order to get result close to the actual scenario. All the analog and digital status required as an input for state estimation is acquired from site and transferred to Control Centre with the help of a sophisticated SCADA system but there may be some errors, discrepancies, etc. which needs to be addressed.

By proper tuning of State Estimator application, maintaining SCADA database and network database (network parameters), we can get very good results in the state estimator application and use it for further studies in order to assist the Grid Operator in real time monitoring and decision making.

5.1 Topology Correction

One of the major factors which let the State Estimator solution deviate from the actual scenario is the incorrect topology which depends upon the status of switching devices. Due to some telemetry errors, sometimes, the status information (for Circuit breakers and isolators) may not be telemetered correctly (open status may come in as closed and vice versa) to the control centers. Sometimes, the status information may not be coming in at all and may show up as 'Suspect'. Sometimes, the analog measurement corresponding to a line may come as a non-zero value but the corresponding status information may come as 'open' (with good quality flag). Different vendors handle these different situations differently.

We can use Topology correction approach in which we *CLOSE* all switching devices which have "Suspect", "Between" or "Garbage" status.

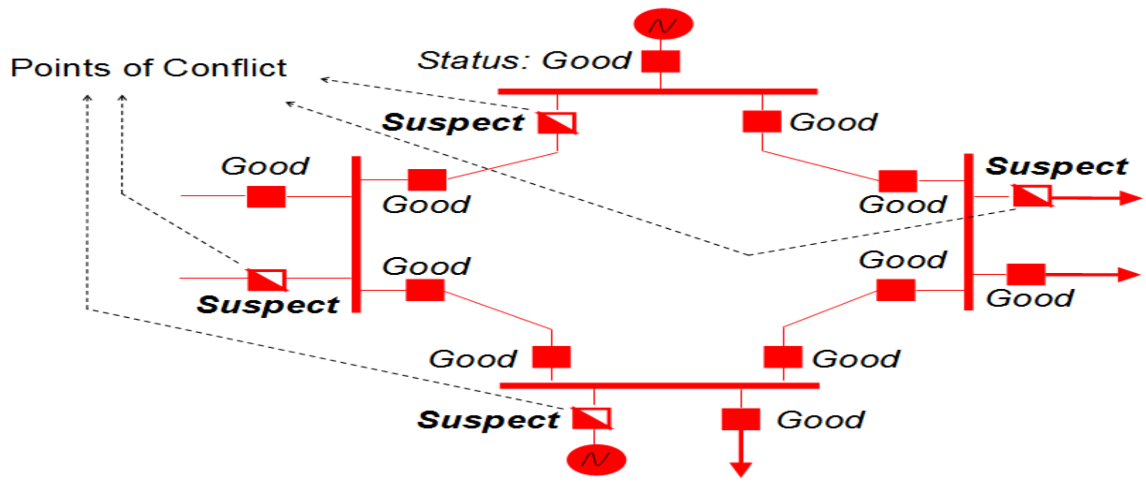


Figure 33: Network before Topology Correction

Switching devices with "Suspect" quality status leads to point of conflict as it is not possible to make out whether the associated line is charged or under outage/tripping.

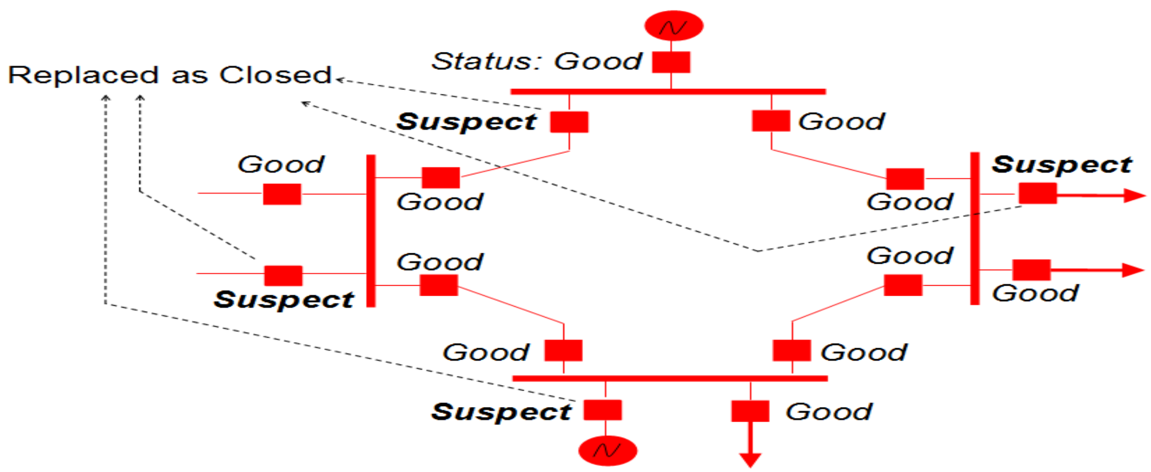


Figure 34: Network after Topology correction

Status of switching devices with "Suspect" quality can be replaced as closed for State Estimator application. Another approach is to keep the last good value. Different vendors may have different approached to handle this. Whatever approach is chosen one has to look at such device status and validate them and get the telemetry issue fixed. ***Fig.34*** shows one approach of correcting the status information to establish the topology.

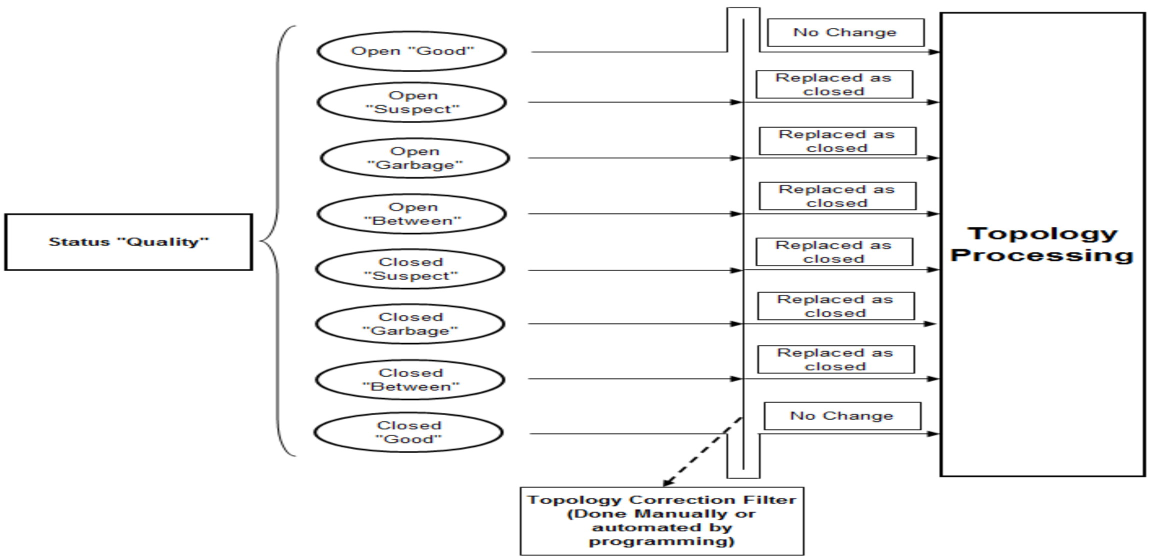


Figure 35: Topology correction

The status of switching devices with "Good" Quality remains unchanged.

Using Topology Correction as described earlier we can estimate the status of the switching devices with Suspect/Garbage status quality upto the extent of either opening or closing them. Suppose we close all the switching devices with "Suspect/Garbage" status quality then it will close those switching devices also which have "Suspect" status but are actually OPEN in the field. Another problem arises when the Status Quality of the switching device is "Good" but incorrect. Hence, some manual intervention is also required after this step.

Let us consider two cases as shown below:

	MW	Switching Device OPEN	Switching Device CLOSED
Case 1	= 0	Correct	Ambiguous
Case 2	≠ 0	Ambiguous	Correct

Table 9: Ambiguous situation in digital data

In case 1 the problem arises when switching device is in closed position and in Case 2 the problem arises when the switching device is in Open position. We need to use our own judgment in these two cases and manually replace the status of the switching device as Open or Closed.

The judgment could be made on the following basis –

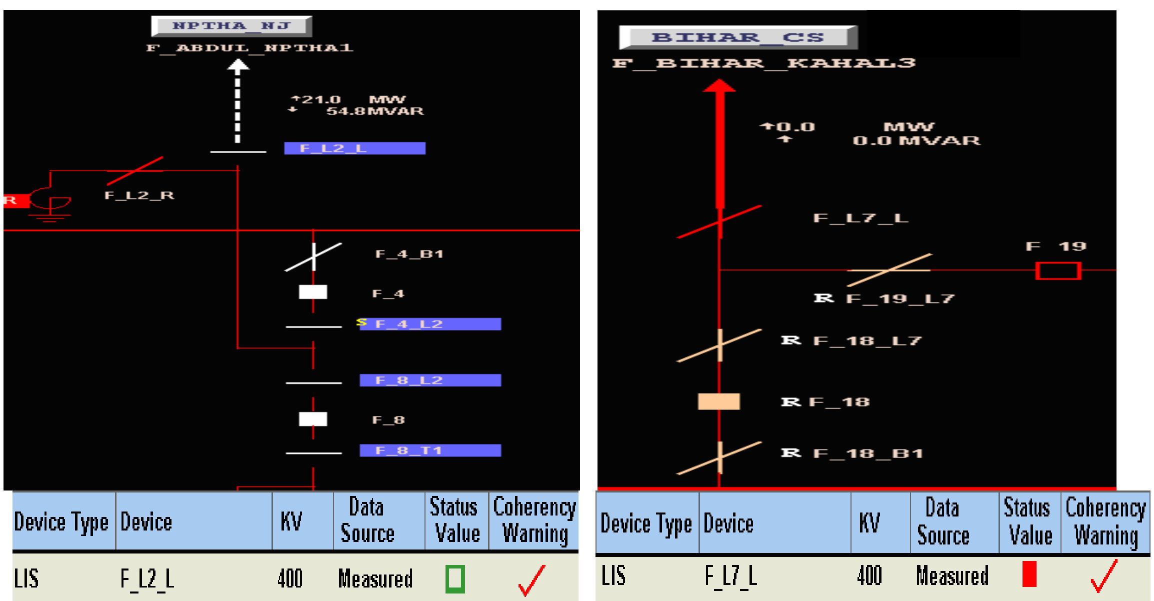
Basis 1	Calculate Σ MW at that station/bus and if it close to 0 MW including the MW flow through the line associated with that suspected switching device then it needs to be closed otherwise open. *This way of judgment will not work if the line is in floating condition or some Analog MW data in that substation is of "Suspect" quality and its other end data is also suspect which kills the redundancy. It will also not work if some MW data is

	highly erroneous or some line is not modeled in the database.
Basis 2	If the entire Analog and Digital data in the substation is of "Suspect" quality then do the ΣMW=0 by taking the other end measurements on those lines which are terminating in the neighboring stations. Do the remaining action as per Basis 1.
Basis 3	Get the status of that line from the Daily Outage status report of the Load Dispatch Centers. If the line associated with that switching device is in that report and it is under long outage plan then replace the status as open. * Do not close the switching device if the line is not in the list of trippings, as it could be one of the recent trippings not reported/documented yet.
Basis 4	Communicate with Control Room at the site and get the real status of the switching device (or associated line) and replace the status of the switching device accordingly. *[Note: Ideally the Control Centre where the RTU/SAS reports shall have the prime responsibility for manual substitution after checking from the field. For instance if the sub-LDC corrects the topology at the sub-LDC all the other control centers upward in hierarchy viz. SLDC, RLDC and NLDC would get the correct indication (provided there is no manual substitution at these control centers).]*

Table 10: Judgment basis to correct digital data

Topology estimation checks could be performed on network to find ambiguity with respect to the line flows and status of the corresponding switching devices. Coherency warnings generated could be used to tune the network.

The drawback of topology estimation checks in Alstom system is that is does not consider the entire connectivity of the equipment to the bus. It only checks the coherency with the switching device (say Line Isolator) directly connected with the equipment.



(a) Case I- Line flow non-zero switching devices Open

(b) Case II- Line flow Zero switching devices closed

Figure 36: Topology Estimation in Alstom system at NLDC

In case I, the line MW and MVAR are non-zero with "Good" status and the corresponding isolator "F_L2_L" is OPEN. So a coherency warning is obtained on this device.

In case II, the line MW and MVAR is Zero with "Good" status and the corresponding isolator "F_L7_L" is closed. So a coherency warning is obtained on this device.
By observing and correcting the topology as per these coherency checks the State Estimation solution can be improved.

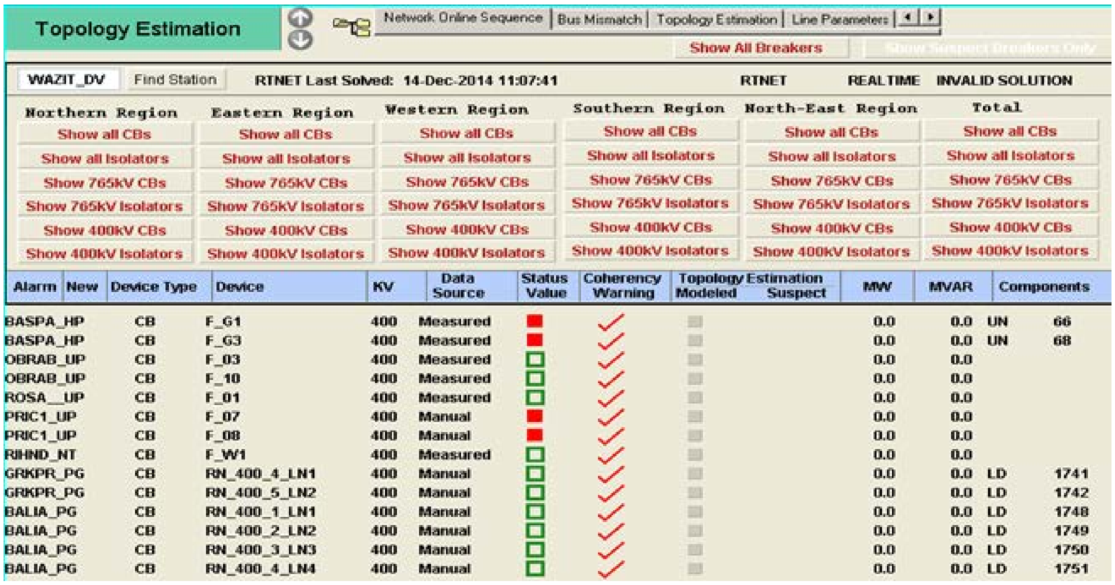


Figure 37: Coherency warnings for digital data

By attending all the Coherency warnings as described above, the topology can be further corrected.

5.2 Adding Pseudo measurements

In case of un-observable network due to insufficient real-time telemetry available at the control center, pseudo measurements will be used to make the system observable. There are different approaches of providing pseudo measurements[8]. Different vendors may provide different approaches. One approach is to manually replace the unavailable measurements by some significant value based on operator's experience or some historical data.

Sometimes based on the vendor, State Estimation will add Pseudo measurements[8].

Use of Pseudo measurements in Alstom system at NLDC: In case load measurements are not available in real time, modeled load is taken by the State Estimator as pseudo measurements for estimation purpose. These modeled loads are fraction of forecasted area load. The measurements associated with Loads of the area are archived and summed to get the total area load of any area. This is done for all the areas defined in NLDC. The areas defined are the constituents of all 5 RLDC. Last year area load is used as scheduled area load for the current year. During non-availability of any load, the individual load is calculated as fraction of that load.

[8]IEEE State Estimation Working Group Panel Session on "**Experiences of Using Pseudo Measurements in State Estimation in Control Centers", IEEE PES General Meeting, July 2011. (http://www1.ece.neu.edu/~abur/ieee/wg.html)**

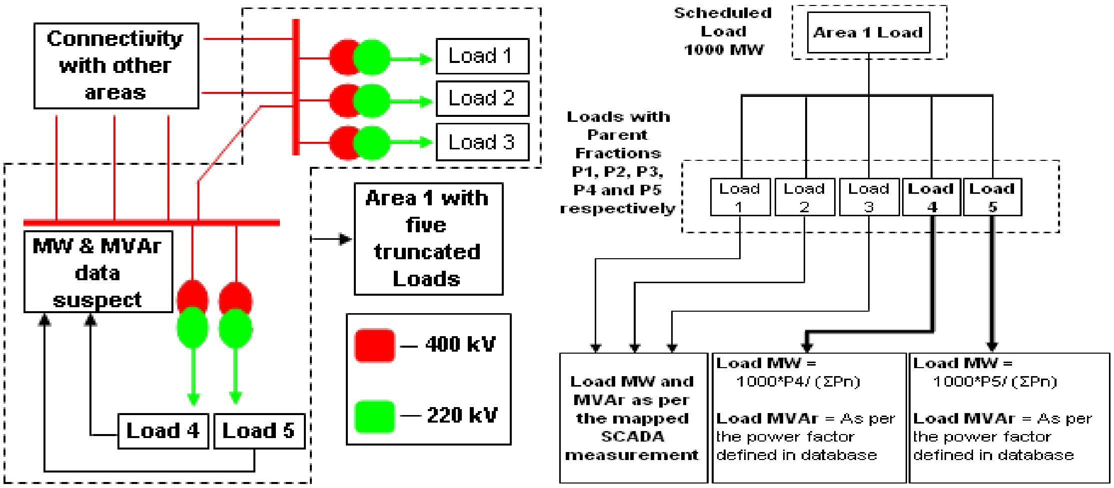


Figure 38: Calculation of Pseudo measurements for Loads

5.3 Parameters verification

In order to correct the parameters of the equipments it is required to have a display in which the parameters can be changed in real-time without requirement of any database on-lining.

A sample snapshot taken from NLDC EMS (Alstom system) is given below –

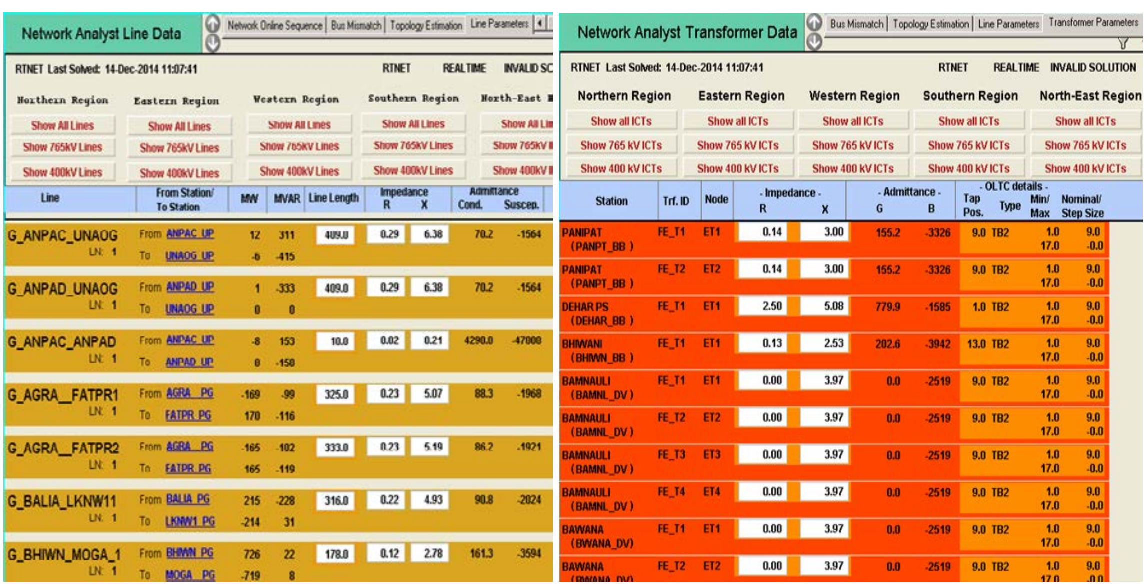
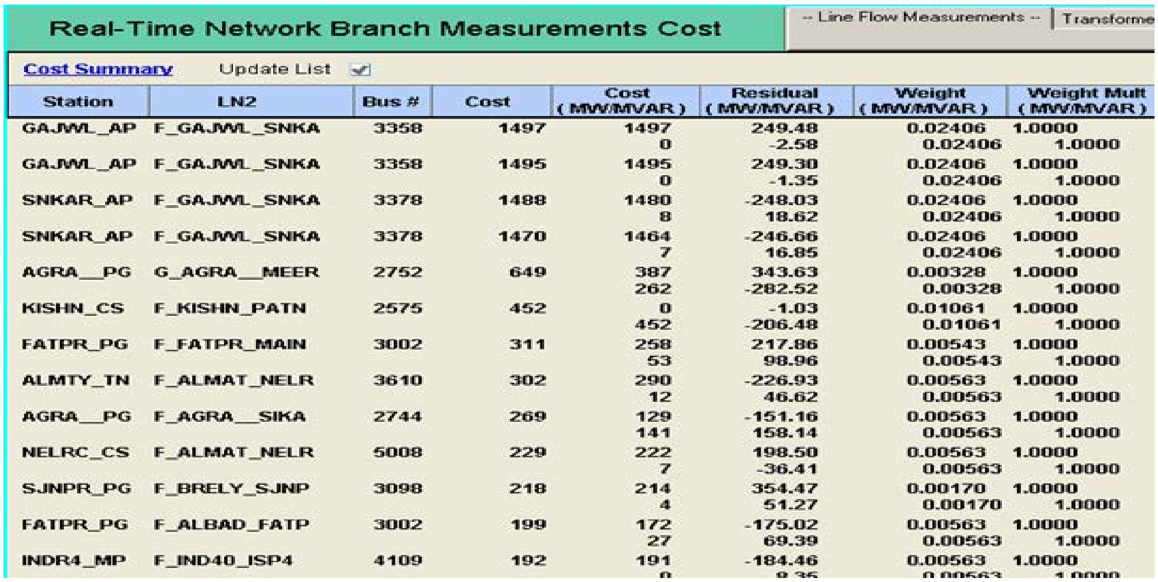


Figure 39: Online editing of equipment's parameters

5.4 Residual check of measurements

For each measurement used in the state Estimator algorithm a residual is computed which is the difference between measured value and estimated value. The list of such residuals should be seen in order to check such cases of bad data. It is expected that the good SE solution for a good measurement set, would have small residuals. Large residual indicates a potential wrong state estimation results. Sometimes the measurements may not be correct. Therefore large residuals need to be investigated. Each vendor may provide displays to look at residuals.

A sample snapshot taken from NLDC EMS (Alstom system) is given below –



Real-Time Network Branch Measurements Cost

-- Line Flow Measurements -- | Transforme

Cost Summary   Update List

Station	LN2	Bus #	Cost	Cost (MW/MVAR)	Residual (MW/MVAR)	Weight (MW/MVAR)	Weight Mult (MW/MVAR)
GAJWL_AP	F_GAJWL_SNKA	3358	1497	1497	249.48	0.02406	1.0000
				0	-2.58	0.02406	1.0000
GAJWL_AP	F_GAJWL_SNKA	3358	1495	1495	249.30	0.02406	1.0000
				0	-1.35	0.02406	1.0000
SNKAR_AP	F_GAJWL_SNKA	3378	1488	1480	-248.03	0.02406	1.0000
				8	18.62	0.02406	1.0000
SNKAR_AP	F_GAJWL_SNKA	3378	1470	1464	-246.66	0.02406	1.0000
				7	16.85	0.02406	1.0000
AGRA__PG	G_AGRA__MEER	2752	649	387	343.63	0.00328	1.0000
				262	-282.52	0.00328	1.0000
KISHN_CS	F_KISHN_PATN	2575	452	0	-1.03	0.01061	1.0000
				452	-206.48	0.01061	1.0000
FATPR_PG	F_FATPR_MAIN	3002	311	258	217.86	0.00543	1.0000
				53	98.96	0.00543	1.0000
ALMTY_TN	F_ALMAT_NELR	3610	302	290	-226.93	0.00563	1.0000
				12	46.62	0.00563	1.0000
AGRA__PG	F_AGRA__SIKA	2744	269	129	-151.16	0.00563	1.0000
				141	158.14	0.00563	1.0000
NELRC_CS	F_ALMAT_NELR	5008	229	222	198.50	0.00563	1.0000
				7	-36.41	0.00563	1.0000
SJNPR_PG	F_BRELY_SJNP	3098	218	214	354.47	0.00170	1.0000
				4	51.27	0.00170	1.0000
FATPR_PG	F_ALBAD_FATP	3002	199	172	-175.02	0.00563	1.0000
				27	69.39	0.00563	1.0000
INDR4_MP	F_IND40_ISP4	4109	192	191	-184.46	0.00563	1.0000
				0	[illegible]	0.00563	1.0000

Figure 40: Residual check of measurements

5.5 Iterations check for measurements

The State Estimator application uses Weighted Least Square algorithm in an iterative manner. By considering the various information available for each iteration step it is easy to track the problematic area.

A sample snapshot taken from NLDC EMS (Alstom system) is shown as ***fig.41*** below.

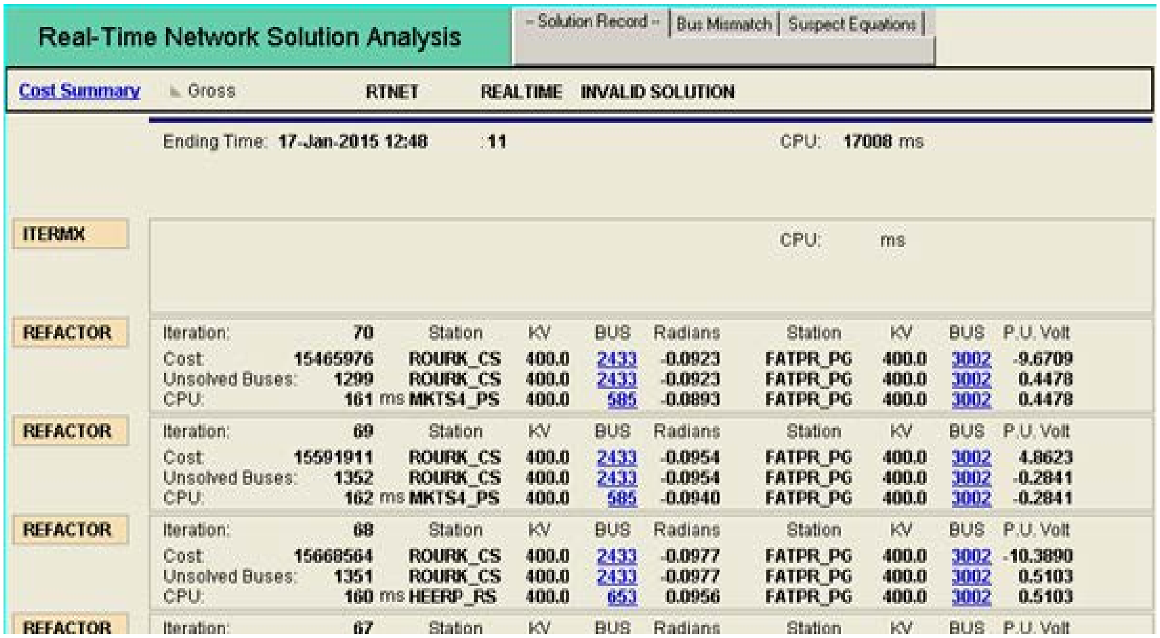
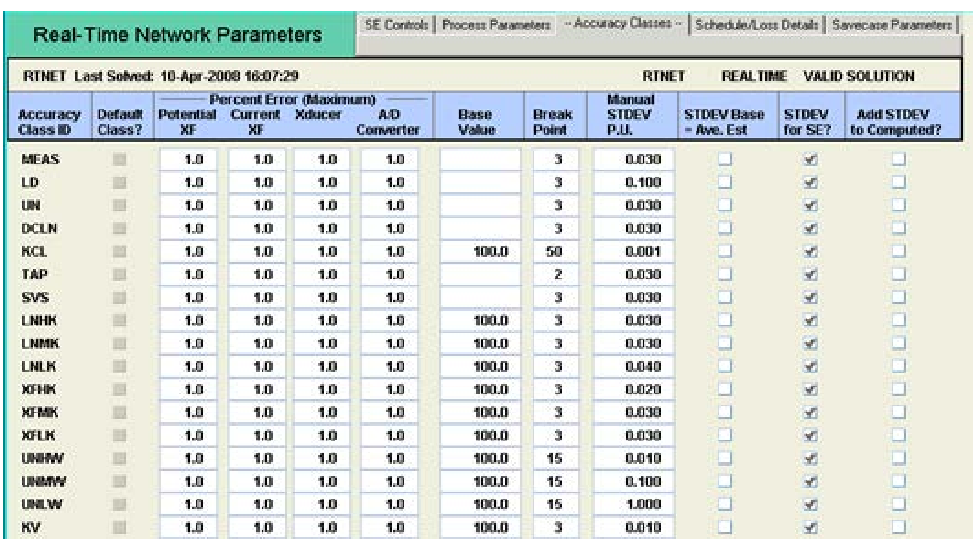


Figure 41: Iterations check of measurements

5.6 Accuracy class assignments

Various accuracy classes are used for the analog data and it is generally defined in groups of identical type of equipments such as Units, Lines, ICTs, etc. Each analog data is assigned an accuracy class as per its defined group.

A sample snapshot taken from Alstom system shows different accuracy classes.



Real-Time Network Parameters — SE Controls | Process Parameters | -- Accuracy Classes -- | Schedule/Loss Details | Savecase Parameters

RTNET Last Solved: 10-Apr-2008 16:07:29 RTNET REALTIME VALID SOLUTION

Accuracy Class ID	Default Class?	Percent Error (Maximum) Potential XF	Current XF	Xducer	A/D Converter	Base Value	Break Point	Manual STDEV P.U.	STDEV Base = Ave. Est	STDEV for SE?	Add STDEV to Computed?
MEAS	☐	1.0	1.0	1.0	1.0		3	0.030	☐	☑	☐
LD	☐	1.0	1.0	1.0	1.0		3	0.100	☐	☑	☐
UN	☐	1.0	1.0	1.0	1.0		3	0.030	☐	☑	☐
DCLN	☐	1.0	1.0	1.0	1.0		3	0.030	☐	☑	☐
KCL	☐	1.0	1.0	1.0	1.0	100.0	50	0.001	☐	☑	☐
TAP	☐	1.0	1.0	1.0	1.0		2	0.030	☐	☑	☐
SVS	☐	1.0	1.0	1.0	1.0		3	0.030	☐	☑	☐
LNHK	☐	1.0	1.0	1.0	1.0	100.0	3	0.030	☐	☑	☐
LNMK	☐	1.0	1.0	1.0	1.0	100.0	3	0.030	☐	☑	☐
LNLK	☐	1.0	1.0	1.0	1.0	100.0	3	0.040	☐	☑	☐
XFHK	☐	1.0	1.0	1.0	1.0	100.0	3	0.020	☐	☑	☐
XFMK	☐	1.0	1.0	1.0	1.0	100.0	3	0.030	☐	☑	☐
XFLK	☐	1.0	1.0	1.0	1.0	100.0	3	0.030	☐	☑	☐
UNHW	☐	1.0	1.0	1.0	1.0	100.0	15	0.010	☐	☑	☐
UNMW	☐	1.0	1.0	1.0	1.0	100.0	15	0.100	☐	☑	☐
UNLW	☐	1.0	1.0	1.0	1.0	100.0	15	1.000	☐	☑	☐
KV	☐	1.0	1.0	1.0	1.0	100.0	3	0.010	☐	☑	☐

Figure 42: Accuracy class assignments of measurements

5.7 Bus Measurement Mismatch

After the State Estimator gives its output then a list the mismatches at each bus is generated and it can be seen in order to find the areas to focus upon for tuning.
A sample snapshot taken from Alstom EMS system is given below:

Real-Time Network Solution Analysis

Network Online Sequence | Bus

Solution Record – Bus Mi

Residual Tolerance is: 1 MW / MVAR RTNET REALTIME

Station	Voltage	Bus #	MW Residual	Station	Voltage	Bus #	MVAR Residual
D_THM_NT	16	2700	1332.1	AMRIT_PG	220	5835	2559.7
AMRIT_PG	220	5835	1285.7	ALMTY_TN	110	3613	2418.4
UNAOG_UP	765	1218	825.8	KODAM_DV	11	1792	767.8
SMDR2_CS	11	4953	680.9	ANPAC_UP	11	1205	712.8
VIND4_CS	11	5240	604.6	SASAN_CS	11	5229	639.8
ANPAC_UP	11	1204	562.5	D_THM_NT	16	2700	381.7
JPNGR_CS	11	5506	528.8	GJKPS_CS	400	5060	344.0
VTPS4_AP	11	3365	448.5	BRSGP_MP	11	4090	101.9
KRPTM_AP	11	3392	434.1	ROSA__UP	11	1211	94.8
VIND__CS	11	5193	423.7	ROSA__UP	11	1212	67.0
VIND__CS	11	5194	419.7	RAJWT_RS	11	807	40.9
VADIN_GE	11	4786	389.8	KISHN_CS	400	2575	12.1
SASAN_CS	11	5228	309.0	NALAG_PG	400	2837	9.5
ADANI_RS	11	866	252.8	RAMPR_NJ	400	2643	9.5
SINGR_NT	11	2722	247.6	NALAG_PG	400	2838	9.3
CHM_1_NH	400	2613	239.0	NALAG_PG	400	2836	9.3
ANPAR_UP	21	891	213.6	IL_FS_CS	11	4968	8.7
SUGEN_IP	11	5221	207.4	BHIWN_BB	400	65	7.2
RAPPC_NP	16	2659	180.0	GAYA__CS	765	2533	6.1
GAJWL_AP	220	3360	175.7	TCRNC_CS	400	5030	5.6

Figure 43: Bus measurement mismatch

5.8 External Network Modeling

The external network modeling for every LDC is important in order to get proper results in Contingency Analysis. The external network may not be updated frequently and the topology of equipments at low voltage levels need not be very accurate but it is should be done at each LDCs upto some extent. Some of the discussions at IEEE Panel sessions[9,10,11,12] may serve as good reference material to understand good industry practices in external network modeling.

Presentations at the IEEE Panel Session on External model and internal model inaccuracies impacting State Estimator Solution Quality for Reliability and Market Operations, 2014 IEEE PES General meeting, July 2014:

[9] *Hongming Zhang, Slavin Kincic," West wide System Model (WSM): Present Challenges, Continued Improvements & Solution Accuracy"*

[10] *Jay Dondeti, Pavan Addepalle, Chungling Yang, Blake Buescher, "MISO Experiences of Network Model Maintenance – State Estimator and Contingency Analysis".*

[11] *Ankit Mishra, Veera Raju Vinnakota, James Bonham, Sirajul Chowdhury, Brian Cummins," Experiences at California ISO in supporting State Estimator solution accuracy due to external model for reliability and market operations".*

[12] *Sriram Ramesh, Tim Murphy, Dave Krueger, Yuan Li, Audrey Newcomb," ISO NE Experiences with Internal and External Model Impacts on the State Estimator".*

5.9 Inserting calculated values on non-measured loads

Some of the State Estimation Algorithms does not try to change the MW and MVAR corresponding to loads. It either uses the real-time data-telemetry assigned to it or a Pseudo measurement taken from Load Scheduling (or any other source). If a Pseudo measurement is used then it has a high uncertainty level. In order to improve the State Estimator solution the value of Load can be calculated online and inserted into the measurement of truncated loads.
The most common way to calculate the Loads is by Bus Summation and equating the same to Zero.

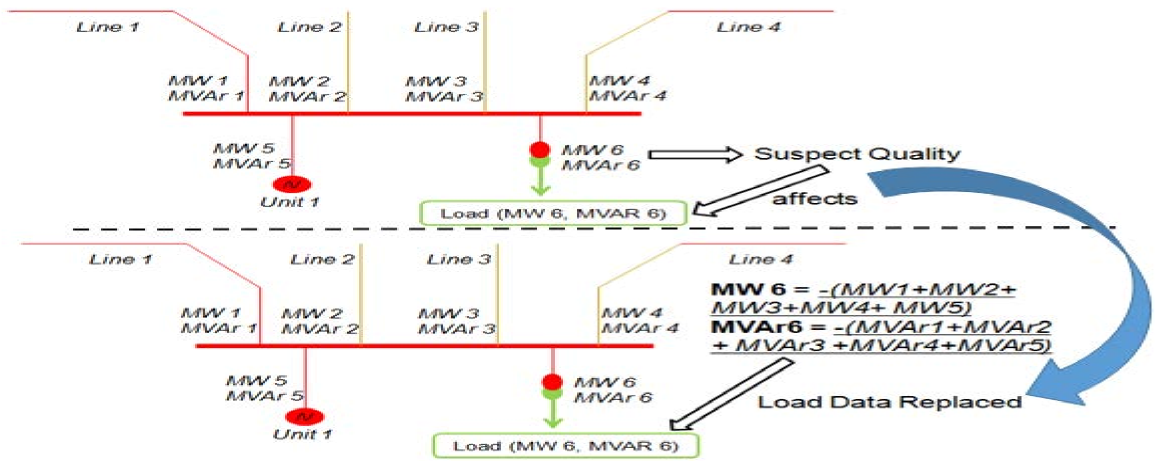


Figure 44: Inserting calculated values on non-measured loads

6. SPECIAL CASES OF MODELING

A number of Power System components needs to be modeled in a special manner in order to get the appropriate functional behavior out of it as per the operational design.

6.1 Units of Pump Storage plants

The generating units of the pump storage plants also have a capability to act as a motor and pump back water from downstream area to the reservoir.

At present the only modification done in the modeling of such units is by specifying its minimum generating capacity as – P (where 'P' is the maximum generating capacity as per the ratings).

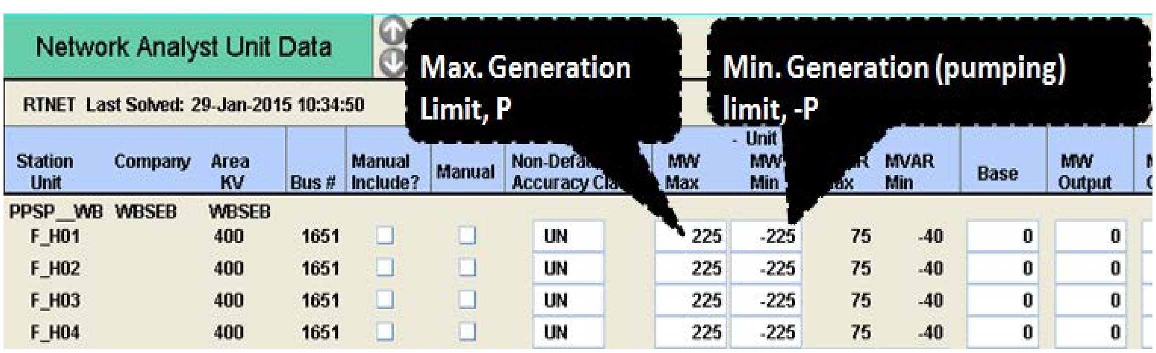


Figure 45: Specifying the Unit MW limits for units of pump storage plants

6.2 Inter-area truncated points

In order to run State Estimator on a limited network, it is required to define the truncated boundary for the same. At the points of truncation at this boundary either the power would be imported or exported based on the Load-Generation balance of the connected power system. So, at the point of truncation either a load needs to be present or a generator. Some of the discussions at IEEE Panel sessions (as indicated in ***Section 5.8***) may serve as good reference material to understand good industry practices in external network modeling.

Case at the truncated point	In case a load is modeled	In case a Generator is modeled	In case both Load and Generator are modeled
Export	In service	Out of service	Load – In service Generator – Out of service
Import	Out of service	In service	Generator – In service Load – Out of service

Table 11: Modeling of load and generation at Inter-area truncated points

The philosophy followed at NLDC is that only a Load is modeled at the point of truncation and based on the sign convention it acts as either a load or an injection. Though modeling as a load and generator would work for truncation, depending on the system interconnection of the truncated network with the local network, external network modeling may be required.

Case at the truncated point	Only Load is modeled
Export	In service Mapped data with “positive” value and hence acts as Load
Import	In service Mapped data with “negative” value and hence acts as Injection

Table 12: Modeling of load only at Inter-area truncated points

6.3 FSC and TCSC

The FSC/TCSCs are the series capacitive device which change the effective Reactance of the transmission line and facilitates more power transfer through it.

At NLDC the FSC is modeled as a line segment is series with the transmission line with negative reactance. An illustrative representation is shown in ***fig.46*** below.

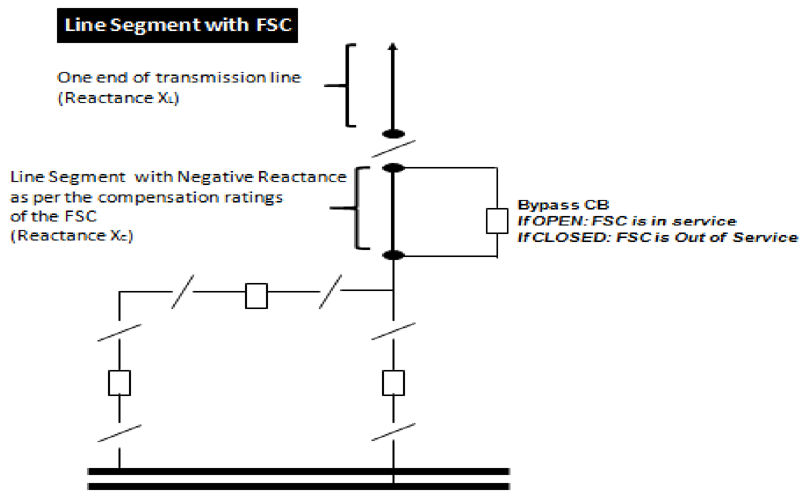


Figure 46: Modeling of FSC in series with the line

6.4 HVDC Lines

The HVDC lines are generally modeled as Truncated Loads/Injections with the real-time power flow data on the convertor transformers mapped onto it. The AC filter banks are modeled as a set of Capacitors connected directly to the bus in order to provide the required MVARs. Refer to ***Section 9.5*** for details.

6.5 Modeling of line in case of a Line Reactor associated with it

At most of the places the Line Reactor is placed on the bus side of the Line Isolator so that it can be used as a Bus Reactor also if required. Moreover the MVAR telemetry received from the site is taken after the point where the Line Reactor has absorbed the rated MVARs from it.

Telemetered Line MVAR from site = Actual Line MVAR – Reactor MVAR

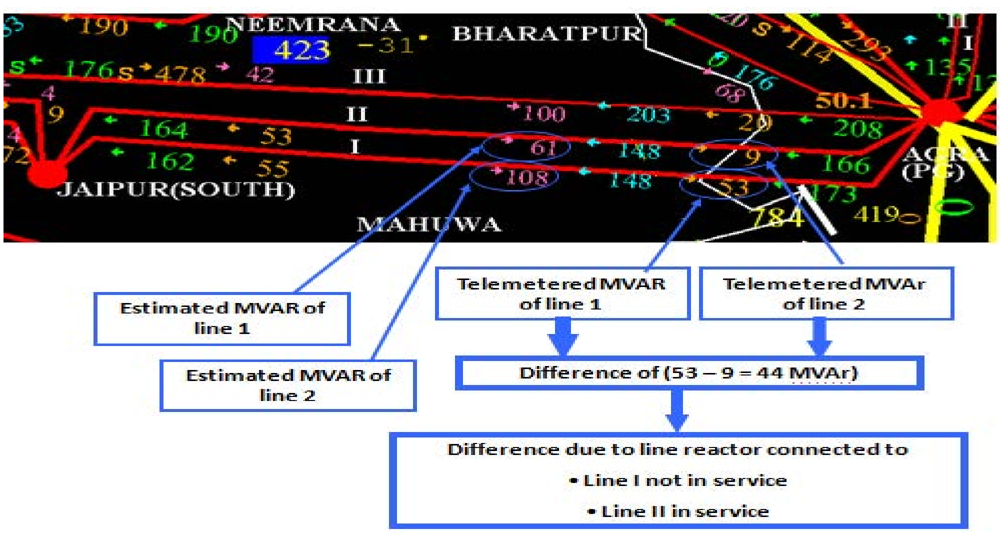


Figure 47: Snapshot of two parallel lines with different MVAr measurements

Different vendors use different methods to handle this condition. Methodology used by M/s Alstom is given below –

One of the ways of handling such cases is by creating such Bus-branch model in which the line entering the station first hits the Line Reactor on a dedicated bus and then gets connected to the main bus.

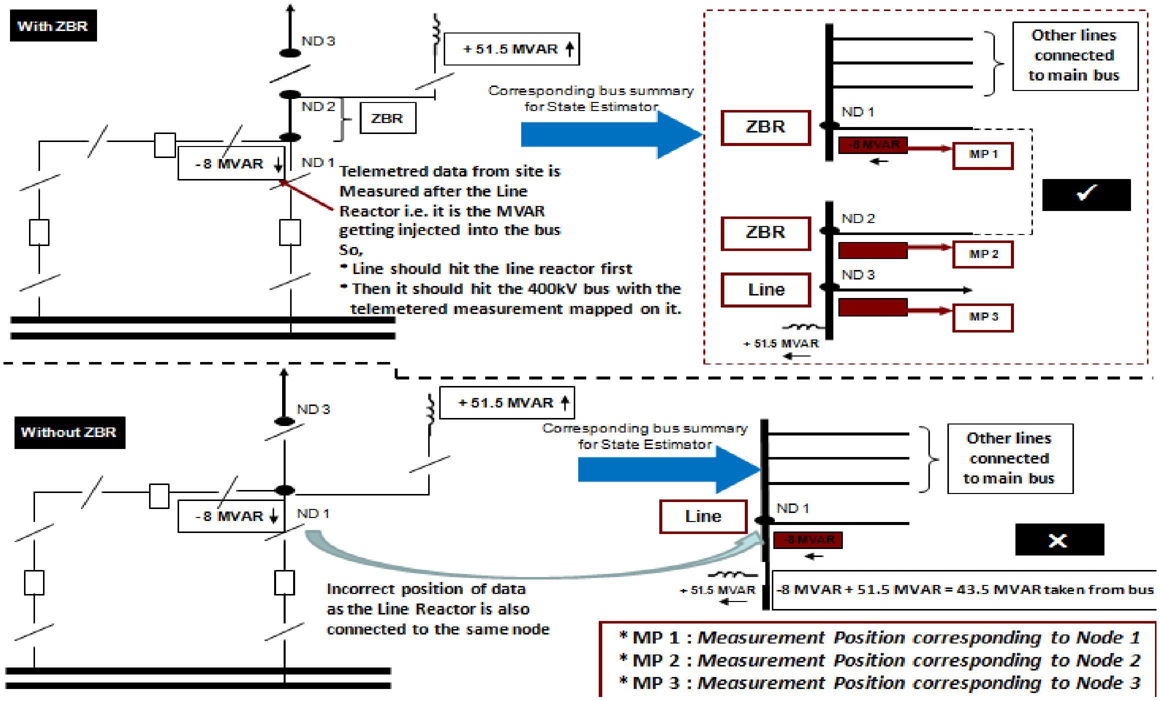


Figure 48: Modeling comparison with ZBR

In Alstom EMS, a Zero Impedance Branch (termed as ZBR) is modeled along with the line and the measurement from the site is mapped onto the bus end node of it. When a corresponding Bus-Branch model is formed in the SE algorithm then a different bus is formed which separates the Line reactor from the main bus. A snapshot is shown as ***fig.49*** below.

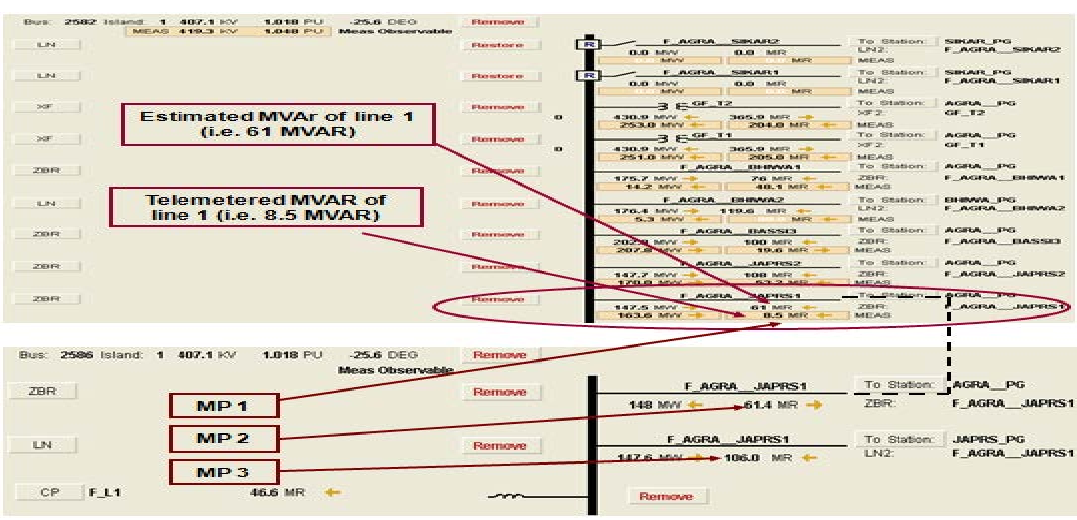


Figure 49: Snapshot of Bus Summary in Alstom system with modeling of ZBR

7. FACTORS TO IMPROVE USAGE OF STATE ESTIMATION

Currently at all RLDCs and SLDCs, EMS systems are being upgraded by new systems. It is right time to look at factors that would improve the usage of State Estimation at all Load Dispatch Centers.

Some of the factors that would improve the usage of State Estimation and other application functions are presented below:

- Get the EMS product customized as per the specifications and requirements.
- Detailed Training on EMS System to the Core Engineers will be very useful to perform effective testing of the system. There could be training for all the engineers after SAT as well.
- Adequate man-power dedicated to SCADA-EMS should be provided in all SLDCs, RLDCs and NLDC. Management may review the objectives of using the EMS system and assess the man-power requirement. Initial study indicated the necessity of increasing the man-power to improve the usage of State Estimation and other EMS Application functions in RLDC/SLDCs.
- Training on EMS should be organized at regular intervals.
- Generating EMS performance reports on a daily basis and its review by the management on weekly basis.
- A process to chase the unavailable telemetry should be developed among the LDCs.

8. PRESENT STATUS OF THE STATE ESTIMATOR AT ALL LDCs

The proper functioning and utilization of State Estimator needs to be ensured at each Load Despatch Centre of state level, regional level and national level.

In most of the State Load Despatch Centres the solution of State Estimator application is Invalid for most of the time. In Regional and National Load Despatch Centres also the State Estimator solution is not satisfactory due to several reasons such as telemetry errors, modeling issues in database, unavailability of real-time telemetry due to communication or other issues, etc.

9. SUGGESTIONS ON VARIOUS ISSUES

A number of issues related to State Estimator database modeling, tuning, validation, etc. needs to be kept in mind while working with EMS applications. Some key issues are discussed below.

9.1 Truncation level of network

The truncation of network affects the significance of output of Contingency analysis as the parallel flows of the network cannot be taken into account after truncation. Some of the discussions at IEEE Panel sessions (as discussed in ***Section 5.8***) may serve as good reference material to understand good industry practices in external network modeling.

The truncation of network may be done at the LDCs as per the following ***table 13***:

Load Despatch Center	Network to be considered after truncation	Remarks
NRLDC	400kV level and above	Large 400kV level and above network. If required, as per industry practices, some part of the 220 kV level may need to be modeled.
ERLDC	400kV level and above	Large 400kV level and above network. If required, as per industry practices, some part of the 220 kV level may need to be modeled.
WRLDC	400kV level and above	Large 400kV level and above network. If required, as per industry practices, some part of the 220 kV level may need to be modeled.
SRLDC	400kV level and above	Large 400kV level and above network. If required, as per industry practices, some part of the 220 kV level may need to be modeled.
NERLDC	132kV level and above	--
NLDC	400kV level and above	Huge mesh of 400kV level and above network. If required, as per industry practices, some part of the 220 kV level may need to be modeled.
All SLDCs	At least entire State Network upto 132kV	If required, as per industry practices, some part of the 132 kV level may need to be modeled.

Table 13: Truncation level for SE at various LDCs

9.2 Load and Injection at truncated points

The easiest way to address and accommodate the change in power flow at the truncated points on the criteria of whether the truncated point is injecting power or drawing power from the network is by Modeling a Load at that truncated point and mapping the real-time measurement on it as indicated in ***Table 14***. Another practice is model it as a load and generator based on the direction of power flow as indicated in ***Table 15***. However, as per industry practices, some part of the truncated network (example 220 kV level network) level may need to be modeled. This has to be properly reviewed in each case and proper truncation should be done for modeling the network.

Case	Sign of analog mapped on Load as received from SCADA	Behaviour
Import of power at	Negative	Injection of Power into the network (acts as generator)

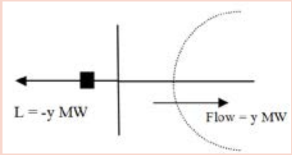
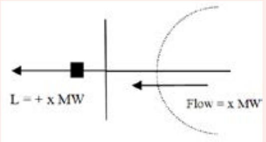
truncated point		
Export of power at truncated point	Positive 	Drawl of power from the network (acts as load)

Table 14: Modeling of Load at truncated points for SE

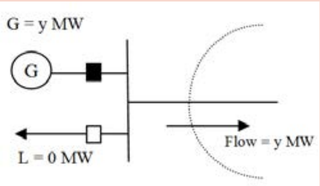
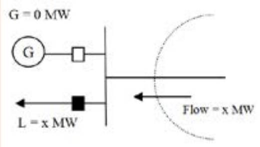
Case	Sign of analog mapped on Load as received from SCADA	Sign of analog mapped on Generator as received from SCADA	Behaviour
Import of power at truncated point	Zero	Positive 	Injection of Power into the network (acts as generator)
Export of power at truncated point	Positive 	Zero	Drawl of power from the network (acts as load)

Table 15: Modeling of Load *and generator at truncated points for SE*

9.3 Pump Storage Plants

In case of pump storage plants the minimum generation value (refer to ***fig.45***) should be put as negative of the maximum rated generation capability of the unit. By doing this the State Estimator will consider the unit behavior in the following manner –

Case	Sign of analog mapped on Load as received from SCADA	Estimated value *(If Maximum Generation MW parameter is P and Minimum is 0)*	Estimated value *(If Maximum Generation MW parameter is P and Minimum is –P)*
Unit in	Magnitude: *P*	P	P

generation mode	Sign: *Positive*		
Unit in pumping mode	Magnitude: *P* Sign: *Negative*	0 *(will not go beyond the minimum rated limit)*	-P

Table 16: Modeling of pump units

9.4 FSC/TCSC Modeling

The easiest way to model an FSC is by modeling a line in form of line segments (facility provided by most vendors) and the assigning negative Reactance value to the line segment corresponding to FSC component as shown below –

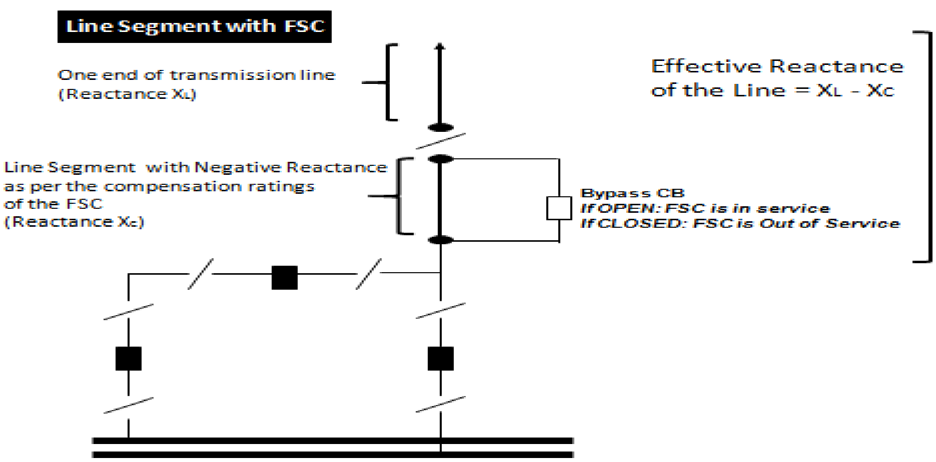


Figure 50: Modeling of FSC as a line segment in series with the line

9.5 HVDC Modeling

The easiest way to handle HVDC lines in Network applications is by truncating it, modeling a Load/Injection at its place and mapping the real-time power flow data on the convertor transformers on it. The AC filter banks can be modeled as Capacitors with ratings as per the Engineering design specifications. The MVAR data of AC filter bank is not taken into account by the SE. It only checks the connectivity of the capacitor and injects corresponding MVARs into the bus as per its ratings. However each vendor of EMS may provide different mechanisms to model HVDC systems, which need to be considered while modeling these systems.

Some of the examples taken from modeling of HVDC in NLDC SCADA system (M/s Alstom project) are as follows –

Example 1: Mundra(Adani)-Mahendragarh HVDC Bi-pole link is a major link connecting high generation Mundra complex of Gujarat with high load complex of Northern region. It is one of the important inter-regional connectivity between Western and Northern region.

Modeling of Mundra–Mahendragarh HVDC Bipole line is done by modeling two loads at Mundra for Pole 1 and Pole 2 respectively and the same is done at Mahendragarh end also (as shown in ***fig.51***).

The real-time Analog data of the Poles is mapped to these loads. In case the power is flowing from Mundra to Mahendragarh then the Analogs received at Mundra end are positive and Mahendragrh end are negative. So, Loads at Mundra consume power and Loads (act as injection in this case) at Mahendragarh inject power into the bus.

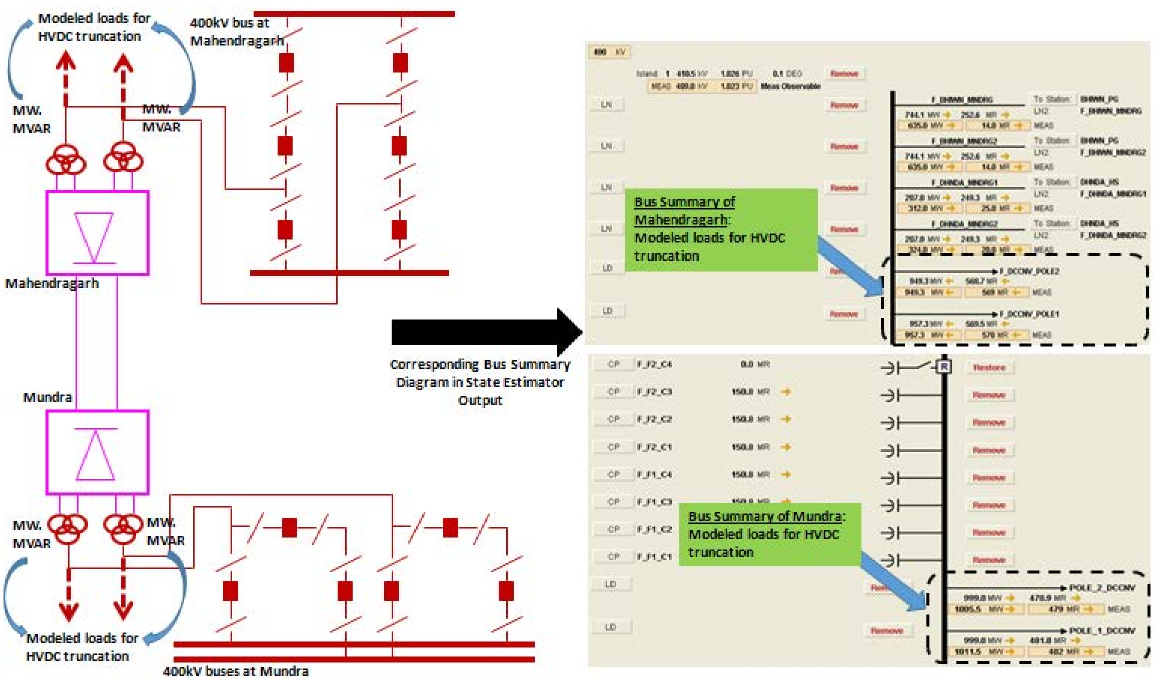


Figure 51: Modeling at NLDC for Mundra-Mahendragarh HVDC Bi-pole

Example 2: Vindhyachal B/B HVDC is a station connected by short feeders to Singrauli and Vindhyachal AC stations. It is one of the major connectivity link between Northern Region and Western Region.

Modeling of Vindhyachal B/B is done by modeling two loads at Singrauli station and two loads at Vindhyachal station (as shown in ***fig.52***).

The mapping of data at the loads is done as follows –

a) Singrauli end MW and MVAR data of 400kV Singrauli-Vindhyachal HVDC D/C feeders mapped at modeled loads at Singrauli station.

b) Vindhyachal AC end MW and MVAR of 400kV Vindhyachal AC-Vindhyachal HVDC D/C feeders mapped on modeled loads at Vindhyachal AC station.

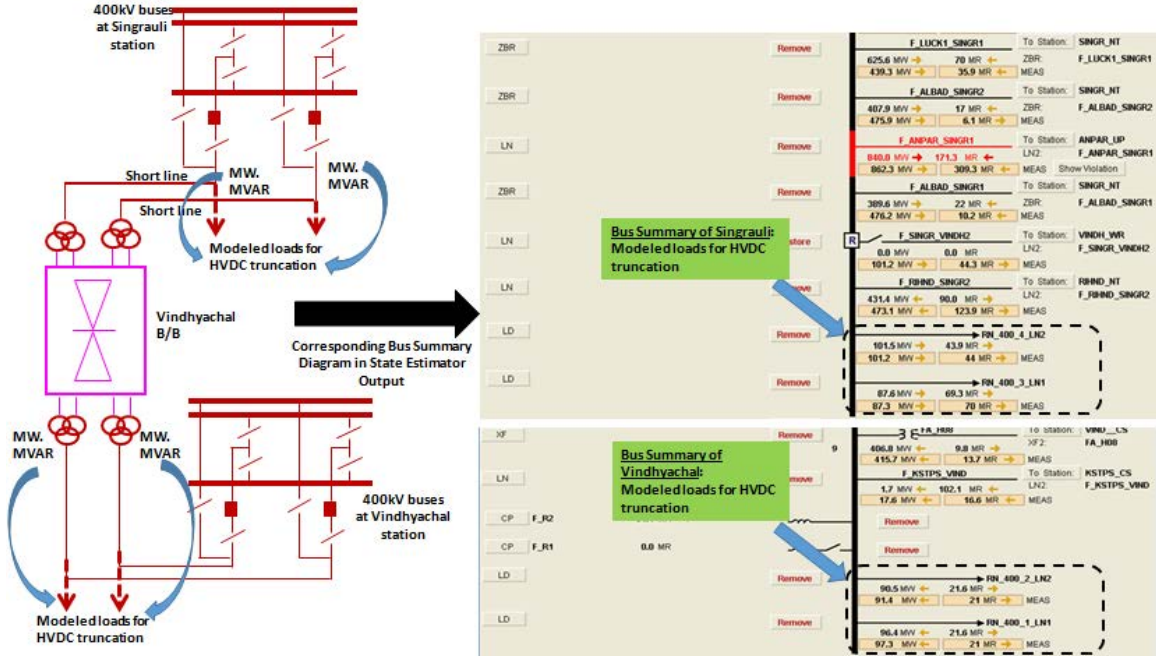


Figure 52: Modeling at NLDC for Vindhyachal HVDC B/B

Example 3: Sasaram B/B HVDC (also called Pusauli HVDC) is a station with a single block of HVDC with 500MW rated capacity and it is one of the major links of power exchange between Eastern Region with Northern Region. Its Eastern Bus is connected to AC buses of Sasaram station and its Northern bus is connected to Allahabad and Varanasi stations through AC lines (as shown in ***fig.53***).

For modeling of HVDC, the Eastern and Northern nodes of HVDC B/B are short-circuited and two loads are modeled after the Line Isolators of Allahabad and Varanasi lines. One load each is modeled at Allahabad and Varanasi end also at the terminating points of the lines with Sasaram (as shown in ***fig.53***).

The mapping of data at the loads is done as follows –

a) Sasaram end MW and MVAR data of 400kV Sasaram-Allahabad and 400kV Sasaram-Varanasi line is mapped on respective modeled load at Sasaram station.
b) Allahabad end MW and MVAR data of 400kV Allahabad-Sasaram is mapped on the modeled load at Allahabad station.
c) Varanasi end MW and MVAR data of 400kV Varanasi-Sasaram is mapped on the modeled load at Varanasi station.

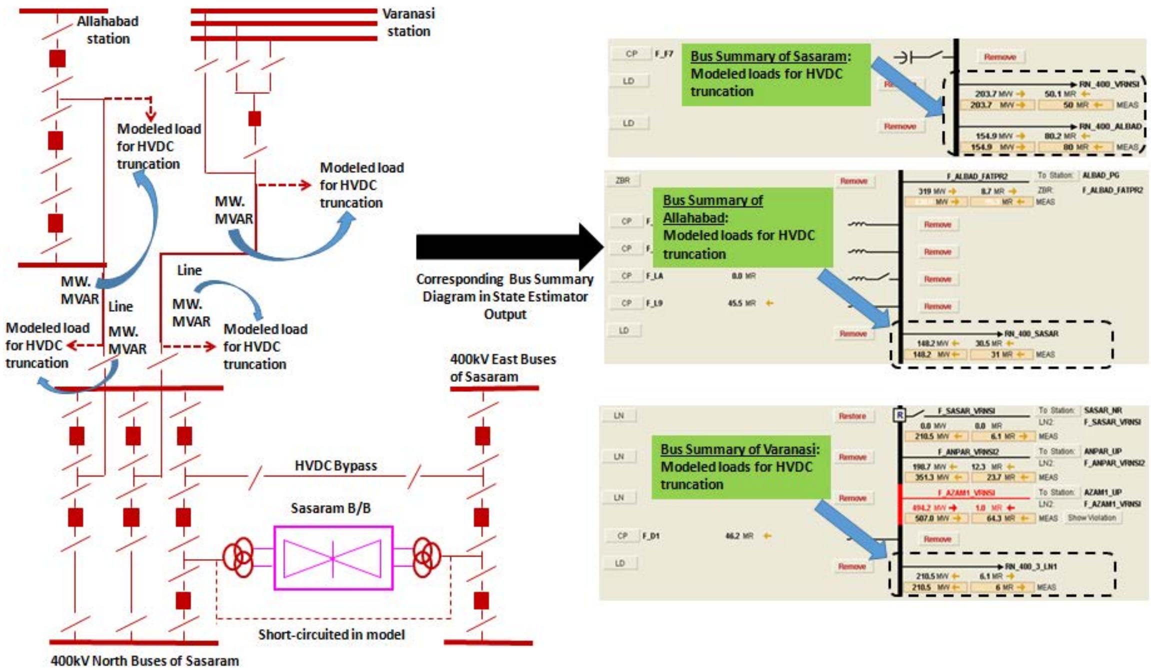


Figure 53: Modeling at NLDC for Sasaram HVDC B/B

9.6 Tuning tools

Various tuning tools and online editing displays (as described in the ***section 5***) can be used to get a better State Estimator output.

Application/Display helpful in Tuning	Purpose	Section for reference
Topology correction	To correct the topology of the network	***6.1***
Parameters verification	To check and online edit the equipment parameters	***6.3***
Residual check of measurements	To identify the measurement causing problem in SE	***6.4***
Iterations check for buses	Check in an iterative manner to find out the bus leading to non-convergence	***6.5***
Bus Measurement Mismatch	To check the bus with maximum mismatch in SE output	***6.7***

Table 17: Use of tuning tools

9.7 Load Scheduling for Pseudo Measurements

In order to get some significant Pseudo Load measurements in case of unavailability of Load data it is required to maintain and update the Load Scheduling data frequently. Refer to ***Section 5.2*** for details.

9.8 State Estimator validation tools

Various state estimator validating tools such as Dead Equipment's details, equipments residuals and cost summary should be traced in order to gain confidence on the SE results. Proper convergence parameters should be used to get good state estimator results. Each vendor may provide ways to look at different SE performance indices to judge the quality of the results. EMS vendors should be able to provide Daily performance reports of SE for the management level monitoring.

In ERCOT a State Estimator Performance Monitoring Dashboard is used to monitor the various performance related parameters of State Estimation in SCADA/EMS (provided by Alstom). It is known as ERCOT State Estimator Assessment Tool [13] and is shown in ***fig.54*** below.

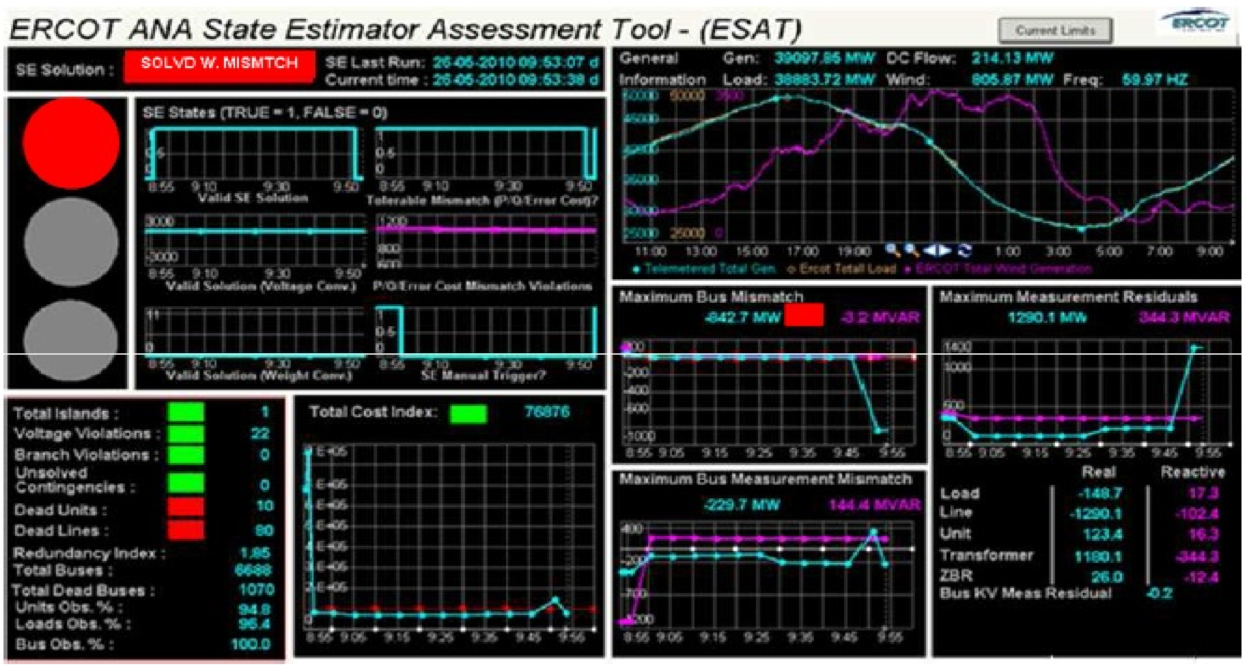


Figure 54: ERCOT State Estimator Assessment Tool

10. COMMON MYTHS

There are a number of myths in the mind of the operator working on State Estimator applications. Some of the myths are discussed in the sections below.

[13] Murali Boddeti, Thinesh Devadhas Mohandas, Sarma (NDR) Nuthalapati, Subhadarshi Sarkar, "SE Performance Requirements for the ERCOT Nodal Market", AREVA User Group Conference Technical Symposium on 'State Estimator Quality/Performance Metrics', 6-10 June 2010, Bellevue, USA.

10.1 SE is not a Load-flow algorithm

State Estimator is based on Weighted Least Square Algorithm and not the conventional loadflow techniques.

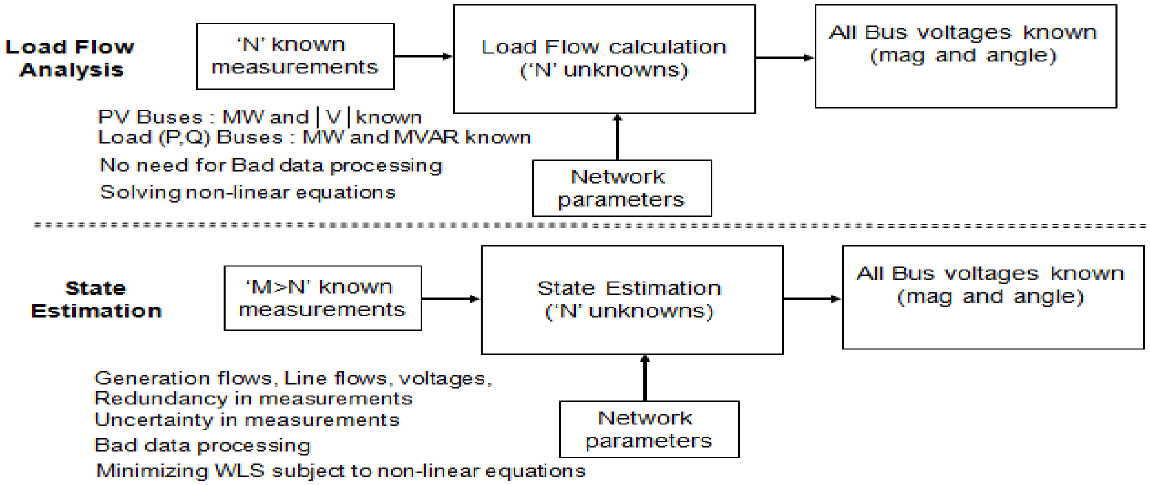


Figure 55: Comparison of State Estimator and Load-Flow

10.2 SE does not use frequency data

State Estimator is a single frequency model and hence does not use the Frequency measurements in SCADA. Refer to ***Section 2*** for details.

10.3 SE does not estimate branch flows directly

State Estimator algorithm estimates voltage and angle at each bus and then calculates the branch flows based on it. Refer to ***Section 2*** for details.

10.4 No RTU/SAS data does not mean that SE will not run

Unavailability of data from RTU/SAS may sometimes lead to un-observability of the network. Because of the redundancy of measurements, SE will be able to estimate the state even if some RTU/SAS data is not available.

11. PROPOSED ACTION ITEMS

In order to improve the usage of State Estimation at all load dispatch centers in India, based on the initial study, the following action items are suggested:

a) Initially the RTU/SAS connectivity analysis should be done to establish if sufficient measurements are available (system is observable) to perform state estimation. This should be accomplishing within three months (after the release of this report). If the study indicates that there are no sufficient measurements then steps are to be taken to enhance the measurement set by adding more RTU/SAS to make the system observable. This study would also help to identify new location for placement of RTU/SAS. This is to be treated as very crucial for running state estimation and essential for establishing the current operating state of the system.

b) Daily status reports of RTU/SAS to be uploaded in the website in appending mode so that its performance could be monitored and action will be taken by RLDCS/NLDC. Monthly reports on status of RTU/SAS should be published and circulated with concerned authorities for immediate action.

c) A formal process of chasing the telemetry issues should be drafted, approved and followed. This is crucial in handling telemetry issues in timely manner.

d) Monthly reports on SE results should be published and circulated with concerned authorities for immediate action. Reports shall include hourly, daily convergence details, residuals for line/unit/transformer/load details, etc. These reports shall also include the details of manual overrides of data done to get correct SE results. If required, the State Estimation Tool should be enhanced to have the capability of providing the summary of its performance such as hourly/daily convergence details, residuals for line/unit/transformer/load details, etc.

e) The correction process should be started from down side i.e. State Load Dispatch Centre, so that real-time data/databases can be rectified with the local inputs and process can be established to run the state estimation without hurdles of data responsibilities.

f) A user group on State Estimation should be formed in order to develop team-building among the people working in this specialized field. Bi-monthly conference call shall be organized for this group.

g) Review of staff requirements should be done in order to provide adequate man-power for EMS. Appropriate training shall be provided to all engineers.

h) The matter regarding non-satisfactory output of State Estimator to be put up to CERC and corresponding enforcement of regulation to be done on priority basis as non-functioning of SE could lead to poor Visualization and Situational Awareness which could hamper operator actions during emergencies.

i) Regulation corresponding to clause (g) above should be issued by SERCs too.

j) The availability of digital data and analog data is also important while considering synchrophasor measurements which are a part of Unified Real Time Dynamic State Measurement (URTDSM) project under execution by POWERGRID. Linear State Estimator being developed as an application would be useful only if the digital status and analog data from the Phasor Measurement Units (PMUs) is available. This would also serve as a back-up for the conventional State Estimation in the EMS System.

Appendix 1

Summary of Discussions of Meetings at Different RLDCs during December 2014 – January 2015

Gist of Discussion on 14-12-2014 at NLDC - visit of Dr. NDR Sarma (of ERCOT, USA) regarding State Estimator functioning of RLDCs/NLDC

Mr.S.K. Soonee, CEO (POSOCO) welcomed Dr NDR Sarma and expressed his concern over various issues hampering the smooth functioning of EMS applications in POSOCO. He emphasized on the importance of running of State Estimator and its benefits in real-time grid operation. He also advised that a email discussion group should be formed on which executives can post queries, experiences and learning related to state estimators applications and further discussions.

1. Importance and necessity of State Estimation

Some of the participants raised an issue questioning the relevance and importance of SE in Load Despatch Centers. Dr NDR Sarma demonstrated the various roles of SE which clarified the doubts of all participants regarding this matter.

2. Literature available on State Estimator.

CEO (POSOCO) stated that a number of papers has been published on SE but some of the classic papers by Fred Schweppe (3 parts) are a good literature to begin with. Dr NDR Sarma told that Power System Analysis book by Stevenson & Grainger also contains a chapter well-written on SE.

3. Load Flow Vs State Estimation

Dr NDR Sarma explained the difference between Load Flow algorithms and State Estimator's Weighted Least Square Algorithm.

4. Role of SE in determining whether the system is (n-1) secure or not.

A list of contingencies is defined in the RTCA database which is evaluated on the base case taken from the output of SE in real-time. It gives a result whether any violation would occur if a contingency occurs. It will give operator warning and sufficient time to take remedial action. Dr NDR Sarma also emphasized that there are Non-Correctable contingencies also which if occurs in a scenario of "All Loads getting supplied" then a Load Shedding action has to be taken. At ERCOT, shift engineer in the control center, does studies and may come out with some mitigation plans for some contingency violations that may occur due to some forced outages.

5. Un-observable network due to inadequate telemetry.

Dr NDR Sarma told that to maintain observability of the network Pseudo Measurements are used which could be either the last known good quality data of some data taken from the scheduled/modeled/archived values. He also emphasized the importance of redundant measurements in this scenario.

6. Rejection of bad-data from SE algorithm.

Dr NDR Sarma explained that the SE takes the good quality telemetered data and creates subsequent SE equations for the same as per WLS method. It compares the Estimated value with SCADA data and the difference is treated as Residuals. It also uses Chi-square criterion which specifies if there is some bad-data in the measurement sets. If it indicates bad-data then the measurement with maximum Residual is dumped out or assigned less weight in the next iterations. He also mentioned that different vendors of State Estimation may have different ways of handling bad data.

7. Confidence factor in violation shown by output of Real-time Contingency Analysis (RTCA).

Dr Sarma stated that if a violation is shown in the output of RTCA then operator compares the pre-contingent value with the corresponding real-time value in SCADA. If it matches then the operator considers it to be correct depiction of violation and takes necessary action.

8. Handling of missing data from stations due to non-installation of RTUs or other reasons.

Dr NDR Sarma explained that all such missing data is flagged as “Un-initialized” and such data is first checked and compared with the Outage Scheduler list and if not matched then it is manually replaced by the grid operator.

9. Accuracy classes defined for measurements.

Dr Sarma told that the a number of Accuracy classes are defined in ERCOT EMS system based on the measurement types such as Unit measurements, Load measurements, Branch Measurements, etc.

10. State Estimator performance monitoring tools.

ERCOT has developed a software tool named SESTATS to check the various parameters of SE and focusing on the areas affecting solution of SE. Dr. Sarma suggested that if SESTATS is not there as a part of EMS System, one can easily write a program to compute the residuals for every SE run. This can be used to chase discrepancies between SE value and SCADA value. Sometimes this is also useful to correct model errors.

11. Frequency of Model update in ERCOT.

Dr NDR Sarma told that model update in ERCOT is done on weekly basis. All utilities need to tell in advance about commissioning of elements to the ERCOT ISO.

12. Tuning of State Estimator.

Dr NDR Sarma demonstrated various factors affecting the convergence of State Estimator on the real-time SE system of NLDC. He demonstrated on how to handle situation when SE is giving an INVALID solution in ALSTOM EMS. He explained on how to look to non-convergence due to tap estimation issues. He also explained how to look for Cost of SE solution, Topology Estimation, depicting islands and Violations in the SE output, etc.

13. State Estimator at NLDC

State Estimator running at NLDC on All India Network of 400kV and above Voltage Level was demonstrated to Dr NDR Sarma. He tried hands-on tuning of State Estimator on NLDC EMS. He pointed various points to put under consideration while running EMS applications.

Gist of Discussion on 15-12-2014 at NRLDC - visit of Dr. NDR Sarma & Prof. S.C. Srivastava regarding State Estimator functioning of RLDCs/NLDC

CEO (POSOCO), ED (NLDC) & GM (NRLDC) welcomed Dr NDR Sarma and expressed their concern over various issues hampering the smooth functioning of EMS applications in POSOCO. CEO (POSOCO) emphasized on the importance of running of State Estimator and its benefits in real-time grid operation. He also advised that a team comprising of members from NRLDC and corresponding SLDCs should be formed in order to discuss and improve the State Estimator output.

1. Importance and necessity of State Estimation

Dr NDR Sarma gave a brief presentation to demonstrate the various roles of State Estimator which would help he operator in real-time decision making.

2. Literature available on State Estimator.

CEO (POSOCO) stated that a number of papers has been published on SE but some of the classic papers by Fred Schweppe (3 parts) are a good literature to begin with. He also told that the various papers written by Dr NDR Sarma can be referred to get a more practical idea of State Estimator related problems and tuning. Dr NDR Sarma told that Power System Analysis book by Stevenson & Grainger also contains a chapter well-written on SE numericals.

3. Load Flow Vs State Estimation

Dr NDR Sarma explained the difference between Load Flow algorithms and State Estimator's Weighted Least Square Algorithm.

4. Role of SE in determining whether the system is (n-1) secure or not.

A list of contingencies is defined in the RTCA database which is evaluated on the base case taken from the output of SE in real-time. It gives a result whether any violation would occur if a contingency occurs. It will give operator warning and sufficient time to take remedial action. He told that Load Shedding is the last option used by the Grid Operators in ERCOT to maintain Grid Security.

5. Un-observable network due to inadequate telemetry.

Dr NDR Sarma told that to maintain observability of the network Pseudo Measurements are used which could be either the last known good quality data of some data taken from the scheduled/modeled/archived values. He also emphasized that if sufficient redundant measurements are available in the system then the Solution would be better.

6. Rejection of bad-data from SE algorithm.

Dr NDR Sarma explained that the SE takes the good quality telemetered data and creates subsequent SE equations for the same as per WLS method. It compares the estimated value with SCADA data and the difference is treated as Residuals. It also uses Chi-square criterion which specifies if there is some bad-data in the measurement sets. If it indicates bad-data then the measurement with maximum Residual is dumped out or assigned less weight in the next iterations. He also mentioned that different vendors of State Estimation may have different ways of handling bad data.

7. Confidence factor in violation shown by output of Real-time Contingency Analysis (RTCA).
Dr Sarma stated that if a violation is shown in the output of RTCA then operator compares the pre-contingent value with the corresponding real-time value in SCADA before taking necessary action for the same.

8. Accuracy classes defined for measurements.
Dr Sarma told that the a number of Accuracy classes are defined in ERCOT EMS system based on the measurement types such as Unit measurements, Load measurements, Branch Measurements, etc.

9. State Estimator performance monitoring tools.
ERCOT has developed a software tool named SESTATS to check the various parameters of SE. He suggested that if SESTATS is not there as a part of EMS System, one can easily write a program to compute the residuals for every SE run. This can be used to chase discrepancies between SE value and SCADA value. Sometimes this is also useful to correct model errors.

10. Frequency of Model update in ERCOT.
Dr NDR Sarma told that model update in ERCOT is done on weekly basis. All utilities need to tell in advance about commissioning of elements to the ERCOT ISO.

11. State Estimator at NRLDC.
State Estimator running at NRLDC on a truncated network was demonstrated to Dr NDR Sarma. Various displays available in the Siemens system related to EMS applications were shown. He pointed various points to put under consideration while running EMS applications.

12. Topology correction in Siemens EMS system.
Siemens executive demonstrated that the EMS system delivered to NR constituents has a secure of Topology correction in which the Analog Data is compared with the status of corresponding switching devices and if an anomaly is found then it changes the status of the switching device to OPEN/CLOSED depending upon the scenario. Dr NDR Sarma suggested that there should be different flags to enable this feature for CBs and Isolators respectively.

13. Training on EMS features of Siemens system.
Dr NDR Sarma suggested that training at NRLDC should be organized before the beginning of SAT for all respective SLDCs in order to familiarize themselves with the various features of Siemens EMS system. As Uttarakhand SLDC has a EMS system of Alstom so it may coordinate with NLDC for the same.

Gist of Discussion on 21-12-2014 at NERLDC - visit of Dr. NDR Sarma
Regarding State Estimator functioning of NERLDC

Mr. S.C. De Chief Manager (NERLDC) welcomed Dr NDR Sarma and other members from NERLDC, ERLDC, WRLDC, NLDC and Alstom representatives located at NERLDC.

1. Importance and necessity of State Estimation

Dr NDR Sarma gave a brief presentation to demonstrate the various roles of State Estimator which would help the operator in real-time decision making. He also referred to the classic papers by Fred Schweppe (3 parts). He explained that NLDC have already uploaded these papers and some other papers written by ERCOT which can be referred to get a more practical idea of State Estimator related problems and tuning. Dr NDR Sarma told that Power System Analysis book by Stevenson & Grainger also contains a chapter well-written on SE.

2. Load Flow Vs State Estimation

Dr NDR Sarma explained the difference between Load Flow algorithms and State Estimator's Weighted Least Square Algorithm.

3. Role of SE in determining whether the system is (n-1) secure or not.

A list of contingencies is defined in the RTCA database which is evaluated on the base case taken from the output of SE in real-time. It gives a result whether any violation would occur if a contingency occurs. It will give operator warning and sufficient time to take remedial action. He told that Load Shedding is the last option used by the Grid Operators in ERCOT to maintain Grid Security. He explained about Remedial Action Schemes (RAS) and Remedial Action Plans (RAPs).

4. Un-observable network due to inadequate telemetry.

Dr NDR Sarma told that to maintain observability of the network Pseudo Measurements are used which could be either the last known good quality data of some data taken from the scheduled/modeled/archived values. He also emphasized that if sufficient redundant measurements are available in the system then the Solution would be better. Concept of observability was discussed. Issue of large amount of non-availability of data from RTUs was also discussed. Dr. Sarma told Alstom people to have displays indicating the status of Communication links.

5. Rejection of bad-data from SE algorithm.

Dr NDR Sarma explained that the SE has the capability of detected bad data in the measurements. It compares the estimated value with SCADA data and the difference is treated as Residuals. It also uses Chi-square criterion which specifies if there is some bad-data in the measurement sets. If it indicates bad-data then the measurement with maximum Residual is dumped out or assigned less weight in the next iterations. He also mentioned that different vendors of State Estimation may have different ways of handling bad data.

6. Accuracy classes defined for measurements.

Dr Sarma told that the a number of Accuracy classes are defined in ERCOT EMS system based on the measurement types such as Unit measurements, Load measurements, Branch Measurements, etc.

7. State Estimator performance monitoring tools.

ERCOT has developed a software tool named SESTATS to check the various parameters of SE. He explained that it is good to have such tools. He suggested that if SESTATS is not there as a part of EMS System, one can easily write a program to compute the residuals for every SE run. This can be used to chase discrepancies between SE value and SCADA value. Sometimes this is also useful to correct model errors.

8. Frequency of Model update in ERCOT.

Dr NDR Sarma told that model update in ERCOT is done on weekly basis. All utilities need to tell in advance about commissioning of elements to the ERCOT ISO.

9. State Estimator at NERLDC.

State Estimator running at NERLDC on a full network (400 kV to 66kV levels) It is running on a regular basis and getting good solutions most of times. RTCA is also running along with SE. Demonstration of SE and RTCA was given to Dr. Sarma. Dr. Sarma explaniend on how to chase invalid solutions and 'Solved with Excessive mismatch' situations. Dr. Sarma suggested that it may be a good idea to truncate the system upto 132kV level at NERLDC in view of issues of getting good updated models at the distribution level. Dr. Sarma explained that at ERCOT they model 345 kV, 138 kV and 69 kV levels. Dr. Sarma explained that in ERCOT tie lines are modeled as DC tie lines. It will be modeled either as a generator or load based on the direction of power flow. HVDC lines can be modeled in the same way in NERLDC.

Gist of Discussion on 22-12-2014 at NERLDC - visit of Dr. NDR Sarma
Regarding State Estimator functioning of NERLDC and SLDCs of ASSAM,MEGHALAYA & TRIPURA

Mr.T.S. Singh, GM (NERLDC) welcomed Dr NDR Sarma and other members from NLDC, WRLDC, ERLDC at NERLDC. He advised all to use this opportunity for understanding EMS (SE/RTCA) operation and run it successfully.

1. Importance and necessity of State Estimation.

Dr. Sarma explained the different level of security in power system with simple example. Dr NDR Sarma gave a brief presentation to demonstrate the various roles of State Estimator which would help the operator in real-time decision making. He also referred to the classic papers by Fred Schweppe (3 parts). He explained that NLDC have already uploaded these papers and some other papers written by ERCOT which can be referred to get a more practical idea of State Estimator related problems and tuning. Dr NDR Sarma told that Power System Analysis book by Stevenson & Grainger also contains a chapter well-written on SE.

2. Load Flow Vs State Estimation.

Dr NDR Sarma explained the difference between Load Flow algorithms and State Estimator's Weighted Least Square Algorithm. He also explained how wrong telemetry data can be corrected through WLS method.

3. Role of SE in determining whether the system is (n-1) secure or not.

A list of contingencies is defined in the RTCA database which is evaluated on the base case taken from the output of SE in real-time. It gives a result whether any violation would occur if a contingency occurs. It will give operator warning and sufficient time to take remedial action. He told that Load Shedding is the last option used by the Grid Operators in ERCOT to maintain Grid Security. He explained about Remedial Action Schemes(RAS) which is also known as SPS in INDIA and Remedial Action Plans (RAPs).

4. Un-observable network due to inadequate telemetry.

Observability issue was discussed at length. Dr NDR Sarma told that to maintain observability of the network Pseudo Measurements are used which could be either the last known good quality data of some data taken from the scheduled/modeled/archived values. He also emphasized that if sufficient redundant measurements are available in the system then the Solution would be better. Concept of observability was discussed. Issue of large amount of non-availability of data from RTUs was also discussed. Dr. Sarma told Alstom people to have displays indicating the status of Communication links.

5. Rejection of bad-data from SE algorithm.

Dr NDR Sarma explained that the SE has the capability of detected bad data in the measurements. It compares the estimated value with SCADA data and the difference is treated as Residuals. It also uses Chi-square criterion which specifies if there is some bad-data in the measurement sets. If it indicates bad-data then the measurement with maximum Residual is dumped out or assigned less weight in the next iterations. He also mentioned that different vendors of State Estimation may have different ways of handling bad data.

6. Accuracy classes defined for measurements.

Dr Sarma told that the a number of Accuracy classes are defined in ERCOT EMS system based on the measurement types such as Unit measurements, Load measurements, Branch Measurements, etc. Based on the accuracy, we can give weightage on various data for SE.

7. State Estimator performance monitoring tools.

ERCOT has developed a software tool named SE-STATS to check the various parameters of SE. He explained that it is good to have such tools. He suggested that if SE-STATS is not there as a part of EMS System, one can easily write a program to compute the residuals for every SE run. This can be used to chase discrepancies between SE value and SCADA value. Sometimes this is also useful to correct model errors.

8. State Estimator at SLDCs on NER.

Dr. NDR Sarma discussed the State Estimator running status at SLDcs of Assam and Meghalaya. Representative of Assam intimated that % telemetry (data/status) availability at SLDC, Kahilipara is very low mainly due to communication link related .No of RTUs are connected through PLCC link. So they are not utilizing SE/RTCA.

In Meghalaya telemetry condition is better but they are also not running SE.

Dr. Sarma requested all constituents to rectify all telemetry and start running Se/RTCA which is very much helpful tool for Grid operators.

9. Manpower requirement

All SLDCs /RLDC representatives opined that manpower shortage is the major hurdle in SLDCs/RLDC. It is very difficult to fill the gap due to which different activities including SCADA/EMS are getting affected.

10. Needs more hands on training

NERLDC/SLDC representative opined that some more in depth training is required for successful operation of SE/RTCA in SLDCs/RLDC. In this respect realtime EMS operation hands on is necessary apart from presentation. All requested Dr. Sarma to give more support and share expertise in solving SE/RTCA related issues. Dr. Sarma also agreed to visit all SLDCs to solve the EMS related problem in future.

Gist of Discussion on 23-12-2014 at ERLDC - visit of Dr. NDR Sarma
Regarding State Estimator functioning of ERLDC

Mr.U.K. Verma (General Manager, ERLDC) welcomed Dr NDR Sarma and other members from ERLDC, WRLDC, NRLDC, NLDC, SRLDC, BSEB, DVC, GRIDCO and Alstom representatives located at ERLDC.

1. Importance and necessity of State Estimation

Dr NDR Sarma gave a brief presentation to demonstrate the various roles of State Estimator which would help the operator in real-time decision making. He also referred to the classic papers by Fred Schweppe (3 parts). He explained that NLDC have already uploaded these papers and some other papers written by ERCOT which can be referred to get a more practical idea of State Estimator related problems and tuning. Dr NDR Sarma told that Power System Analysis book by Stevenson & Grainger also contains a chapter well-written on SE.

2. Load Flow Vs State Estimation

Dr NDR Sarma explained the difference between Load Flow algorithms and State Estimator's Weighted Least Square Algorithm.

3. Role of SE in determining whether the system is (n-1) secure or not.

A list of contingencies is defined in the RTCA database which is evaluated on the base case taken from the output of SE in real-time. It gives a result whether any violation would occur if a contingency occurs. It will give operator warning and sufficient time to take remedial action. He told that Load Shedding is the last option used by the Grid Operators in ERCOT to maintain Grid Security. He explained about Remedial Action Schemes(RAS) and Remedial Action Plans (RAPs).

4. Un-observable network due to inadequate telemetry.

Dr NDR Sarma told that to maintain observability of the network Pseudo Measurements are used which could be either the last known good quality data of some data taken from the scheduled/modeled/archived values. He also emphasized that if sufficient redundant measurements are available in the system then the Solution would be better. Concept of observability was discussed. Issue of large amount of non-availability of data from RTUs was also discussed.

5. Rejection of bad-data from SE algorithm.

Dr NDR Sarma explained that the SE has the capability of detected bad data in the measurements. It compares the estimated value with SCADA data and the difference is treated as Residuals. It also uses Chi-square criterion which specifies if there is some bad-data in the measurement sets. If it indicates bad-data then the measurement with maximum Residual is dumped out or assigned less weight in the next iterations. He also mentioned that different vendors of State Estimation may have different ways of handling bad data.

6. Accuracy classes defined for measurements.

Dr Sarma told that the a number of Accuracy classes are defined in ERCOT EMS system based on the measurement types such as Unit measurements, Load measurements, Branch Measurements, etc.

7. State Estimator performance monitoring tools.
ERCOT has developed a software tool named SESTATS to check the various parameters of SE. He explained that it is good to have such tools. He suggested that if SESTATS is not there as a part of EMS System, one can easily write a program to compute the residuals for every SE run. This can be used to chase discrepancies between SE value and SCADA value. Sometimes this is also useful to correct model errors.

8. Frequency of Model update in ERCOT.
Dr NDR Sarma told that model update in ERCOT is done on weekly basis. All utilities need to tell in advance about commissioning of elements to the ERCOT ISO.

. State Estimator at ERLDC.
State Estimator running at ERLDC on truncated network of 765 kV to 220 kV. It is running on a regular basis and getting good solutions most of times. Dr. Sarma explained on how to chase invalid solutions and 'Solved with Excessive mismatch' situations. Dr. Sarma explained that at ERCOT they model 345 kV, 138 kV and 69 kV levels. Dr. Sarma explained that in ERCOT tie lines are modeled as DC tie lines. It will be modeled either as a generator or load based on the direction of power flow. Since there are interconnections with other RLDCs there is need to do external model of other RLDCs. Dr. Sarma informed that he will get additional information about external modeling done at other ISOs in US. While debugged, some model issues were identified (Example: Unit Max MW being less that the SCADA values). With some effort we could get good valid solutions with bus mismatch tolerance of 50 MW, 50 MVAR and voltage convergence of 0.01.

The following aspects were discussed:

1. Dr. Sarma mentioned about GT (EX:GMR GT mapping) mapping issues, GMR GT mapping was wrong in ERLDC system.

2. Dr Sarma asked to develop the Residues, List of measurements which are dropped in State estimation, List of anomalous measurements, List of measurements whose values are replaced, List of measurements and status which are manually marked and SLD Network connectivity with SCADA and Estimator data displays.

3. Dr Sarma suggested to model the inter-regional stations as load and generator with in the region instead of modeling the same in other region.

4. BSEB and DVC told that they will try to run the state estimator and RTCA.

5. GRIDCO told that at present they are migrating from ALSTOM system to Chemtrol system, with-in three months they are able to run estimator and RTCA.

6. Dr Sarma suggested ERLDC to visit all the SLDCs and provide hands on training to constituents towards successful operation of EMS system. Representatives of various constituents present in the workshop also requested to GM, ERLDC to extend help in this regard. GM, ERLDC accepted the same and assured full cooperation from ERLDC side.

Summary of Discussions on 4th and 5th January, 2015 at SRLDC - visit of Dr. NDR Sarma Regarding State Estimator functioning of SRLDC

Mr. Rakesh (Manager, SRLDC) welcomed Dr. NDR Sarma and other members from NLDC, SRLDC, ERLDC, WRLDC, APSLDC, KSEB, KPTCL & TNEB. The session started with presentation by Dr. NDR Sarma on various aspects of State Estimation. Following topics were discussed:

1. Importance and necessity of State Estimation

The various roles of State Estimator which would help the operator in real-time decision making were covered. Dr. Sarma also referred to the classic papers by Fred Schweppe (3 parts). He explained that NLDC have already uploaded these papers and some other papers written by ERCOT which can be referred to get a more practical idea of State Estimator related problems and tuning. Dr NDR Sarma told that Power System Analysis book by Stevenson & Grainger also contains a chapter well-written on SE.

2. Load Flow Vs State Estimation

Dr NDR Sarma explained the difference between Load Flow algorithms and State Estimator's Weighted Least Square Algorithm.

3. Role of SE in determining whether the system is (n-1) secure or not.

A list of contingencies is defined in the RTCA database which is evaluated on the base case taken from the output of SE in real-time. It gives a result whether any violation would occur if a contingency occurs. It will give operator warning and sufficient time to take remedial action. He told that Load Shedding is the last option used by the Grid Operators in ERCOT to maintain Grid Security. He explained about Remedial Action Schemes(RAS) and Remedial Action Plans (RAPs), Operational Plans. He explained that at ERCOT, contingency violations that show up before RAP actions are implemented are shown to the operators at ERCOT. There was discussion about usefulness of showing violations before RAS actions are implemented.

4. Un-observable network due to inadequate telemetry.

Dr NDR Sarma told that to maintain observability of the network Pseudo Measurements are used which could be either the last known good quality data of some data taken from the scheduled/modeled/archived values. He also emphasized that if sufficient redundant measurements are available in the system then the Solution would be better. Concept of observability was discussed. Issue of large amount of non-availability of data from RTUs was also discussed.

5. Rejection of bad-data from SE algorithm.

Dr NDR Sarma explained that the SE has the capability of detected bad data in the measurements. It compares the estimated value with SCADA data and the difference is treated as Residuals. It also uses Chi-square criterion which specifies if there is some bad-data in the measurement sets. If it indicates bad-data then the measurement with maximum Residual is dumped out or assigned less weight in the next iterations. He also mentioned that different vendors of State Estimation may have different ways of handling bad data.

6. Accuracy classes defined for measurements.

Dr Sarma told that the a number of Accuracy classes are defined in ERCOT EMS system based on the measurement types such as Unit measurements, Load measurements, Branch Measurements, etc.

7. State Estimator performance monitoring tools.

ERCOT has developed a software tool named SESTATS to check the various parameters of SE. He explained that it is good to have such tools. He suggested that if SESTATS is not there as a part of EMS System, one can easily write a program to compute the residuals for every SE run. This can be used to chase discrepancies between SE value and SCADA value. Sometimes this is also useful to correct model errors in State Estimation as well.

8. Frequency of Model update in ERCOT.

Dr NDR Sarma told that model update in ERCOT is done on weekly basis. All utilities need to tell in advance about commissioning of elements to the ERCOT ISO.

9. State Estimator at SRLDC.

SRLDC Engineers demonstrated the usage of State Estimator at SRLDC. They explained the reports that are being generated based on State Estimation results on a daily basis. Dr. Sarma appreciated these reports. He also suggested that large residuals needs to resolved for each State Estimation execution. A case of large residual was taken and was resolved by correcting the status of an isolator which was wrongly coming as open. A case where an analog telemetry was wrongly coming in SCADA was also discussed. Dr. Sarma suggested that it may be good to disable such wrong analog telemetry until it is corrected. A process for correcting wrong telemetry need to be established and strictly followed. This exercise was very useful and demonstrated the feasibility of running State Estimator on a regular basis.

10. Status of State Estimator at other constituents

Other constituents also discussed about the status of their EMS Systems. KSEB demonstrated the working of state estimation in their new SCADA system from ALSTOM. It was observed that state estimation was converging with excessive mismatch warnings. Dr. Sarma guided for the proper tuning of configuration and tolerance parameters. He also suggested to check with the vendor for updating state estimation displays with links to RTNET and SCADA displays.

Telangana representatives expressed their views on usefulness of running state estimator at control centres. They informed that post bifurcation of Andhra Pradesh, the network model is still to be updated by ALSTOM.

Representatives from TNEB informed that the EMS package in existing GE scada is not being used by them. They further informed that they are in the process of migrating to ALSTOM scada system and will ensure running of state estimation in the new system.

KPTCL representatives demonstrated their ABB Network Manager EMS package. They informed that the EMS network has been modeled for 220 KV and higher voltage buses. Dr. Sarma appreciated the efforts and suggested for further tuning of parameters.

11. Clarification session

Dr. NDR Sarma provided clarifications on doubts raised by SRLDC representatives on SE modeling techniques. On doubts on usage of ZBR in EMS modeling, he confirmed that he will revert back on the usage of ZBR in ERCOT network model. On questions on modeling for FSC lines, Pump mode operation & condenser mode operation of generators he informed that he will revert back with further insights of modeling these devices in ALSTOM network.

The workshop ended with a vote of Thanks from ED, SRLDC.

Summary of Discussions on 7th January, 2015 at WRLDC - visit of Dr. N. D. R. Sarma Regarding State Estimator functioning of WRLDC

Sh.P. Mukhopadhyay (General Manager, WRLDC) formally welcomed Dr. N. D. R. Sarma from ERCOT, Texas and members from NLDC, ERLDC and SRLDC for training cum discussion session on State Estimation in Power Systems. Executives from all departments of WRLDC were present for this discussion.

1. Importance and necessity of State Estimation

Following the introduction of the participants, the session started with a brief presentation by Dr. N. D. R. Sarma explaining the need and necessity of State Estimator which can be used by the operator in real-time decision making. He explained state estimation forms the basis for other advanced applications like contingency analysis which operators may use to see the effects of a contingency on the system in real time. He also explained how it helps in correcting telemetry inaccuracies. However, he insisted on ensuring the correction of inaccurate telemetry and integration of non-available telemetry since it is essential for running state estimation itself. He referred to three classic papers by Fred Schweppe have already been shared with members of POSOCO. He also suggested some papers written by ERCOT executives which can be referred to get a more practical idea of State Estimation related problems and its solutions. He also suggested a book authored by Grainger and Stevenson on Power System Analysis which has a complete chapter on State Estimation.

2. Load Flow Vs State Estimation

Dr. N. D. R. Sarma explained the difference between Load Flow and State Estimation program. Since State Estimation has more number of known variables than the number of equations, the algorithm has multiple checks for validity of data and hence gives an acceptable solution. He discussed the algorithm of Weighted Least Squares in detail.

3. Relation between N-1 criteria and SPS

Dr. N. D. R. Sarma explained that N-1 criteria is system specific and SPS is component specific. N-1 security criteria is to be maintained all the time, however if certain component gets overloaded due to ambient conditions SPS must save the system. SPS is not related to the state of the system.

4. Role of SE in determining whether the system is (n-1) secure or not.

SE solution gives the snapshot of the system which is further used for contingency analysis. A list of contingencies can defined in the RTCA database which is evaluated on the base case taken from the output of SE in real-time. Generally N-1 contingency is considered. In ERCOT the multiple outage contingencies like outage of Double circuit tower is also considered as N-1 contingency however it is categorized as a double contingency. Contingency analysis gives whether any violation would occur if the system goes in N-1 state suddenly. It will enable the operator to take preventive actions to bring the system in secure state if at all the contingency occurs. He told that Load Shedding should be used as the last option as people are dependent on it. He explained about Remedial Action Schemes (RAS/SPS), Remedial Action Plans (RAPs) and Operational Plans (OpPlans) done in ERCOT. He explained that RAS/SPS and RAP are done on yearly basis where as OpPlans are done as and when required on a temporary basis. These plans are drawn out from study environment of state estimation. He also mentioned about a software called D-RAP which would draw plans for securing the system during contingencies in real time.

5. States of Power System.

Dr. N. D. R. Sarma explained that an operator must know the state of the power system. Sometimes it may be required to operate the system in a less economical but more secure state. The Correctively Secure state is more economical than a secure state. State estimation would provide the operator an idea about the state of the system. He also explained the importance of the reserves in the system and sometimes load shedding may be required for maintaining the reserves in the system for a large credible contingency.

6. Un-observable network due to inadequate telemetry.

Dr. N. D. R. Sarma told that to maintain observability of the network state estimation uses Pseudo Measurements which could be either the last known good quality data or some data taken from the scheduled/modeled/archived values. He explained a simple spanning tree technique to determine the observability of the system. He also emphasized that if sufficient redundant measurements are available in the system then the Solution would be better. Issue of large amount of non-availability of data from RTUs or ICCP was also discussed.

7. Rejection of bad-data from SE algorithm.

Dr. N. D. R. Sarma explained that the SE has the capability of detecting bad data in the measurements based on the residue value. It compares the estimated value with SCADA data and the difference is treated as Residual. It also uses Chi-square criterion which specifies if there is some bad-data present in the measurement set. If Chi-square test indicates presence of bad data then the measurement with maximum Residual is dumped out or assigned less weight in the next iterations. He also mentioned that different vendors of State Estimation may have different ways of handling the bad data. Residuals can also sometimes point out the parameter or structural errors in modelling the system. He mentioned categories may be formed for assigning the weights like high weighting for Generator data than the line flows, etc.

8. Accuracy classes defined for measurements.

Dr. Sarma told that a number of Accuracy classes are defined in ERCOT EMS system based on the measurement types such as Unit measurements, Load measurements, Branch Measurements, etc.

9. State Estimator performance monitoring tools.

ERCOT has developed a software tool named SESTATS to check the various parameters of SE. He explained that using this tool quality of state estimation results can be assessed and can be easily chased. Further tools of such type may be made internally even if SESTATS is not available. This can be used to chase discrepancies between SE value and SCADA value. Sometimes this is also useful to correct model errors in State Estimation as well.

10. List of displays

Dr. Sarma explained the important displays to be seen while chasing the discrepancies in state estimation. The main display of iteration summary would give the bus with maximum mismatch. This can be a good starting point for chasing the problem. Further the violation can be in bus mismatch or residue or cost. Displays like dead equipment with significant data values are required to correct the status of the element. List of residues is also an important display for correcting the telemetry. He explained that sometimes the SCADA value may be correct and there may be an issue with SE model (parameter error). Dr. Sarma, explained how to navigate displays on the WRLDC's new Alstom EMS system. Since the system is still in the process of building we could not get valid SE solution in the new Alstom's EMS system.

11. Frequency of Model update in ERCOT.

Dr. N. D. R. Sarma told that model update in ERCOT is done on weekly basis. All utilities need to tell in advance about commissioning of elements to the ERCOT ISO.

Summary of Discussions on 8th January, 2015 at WRLDC - visit of Dr. N. D. R. Sarma Regarding State Estimator functioning of WRLDC (Participation of SLDCs)

Sh. P. Mukhopadhyay (General Manager, WRLDC) formally welcomed Dr. N. D. R. Sarma, Chief Engineer & officers from Gujarat SLDC, Chief Engineer & officers from Madhya Pradesh SLDC and officers from Chhattisgarh SLDC for familiarization cum discussion session on State Estimation in Power Systems. Also Officers from MP SLDC and Chhattisgarh SLDC joined over video conference. Officers from WRLDC, SRLDC, NLDC and ERLDC were also present for this discussion. The session commenced at 10:30 AM.

1. CE SLDC Gujarat mentioned that the new SCADA system was under development and the database models were thoroughly checked during FAT. In the current system of SCADA, the State estimation converges and is used regularly. He also suggested that guidance from Dr. N. D. R. Sarma will be taken from time to time regarding state estimation. He further stated that the time was apt for training of state estimation as the new SCADA system is in process.

2. CE SLDC MP stated that PNA is currently not used on daily basis however young engineers have been identified for running the EMS functionalities in the new SCADA system. Further he also said that the transmission network of MP is strong with less constraints but still state estimation will be used for further strengthening the grid.

3. GM, WRLDC suggested that an internal session may be held for SLDCs who could not participate during this discussion.

4. Presentation by Dr. N. D. R. Sarma on state estimation –

a) Importance and necessity of State Estimation
Following the introduction of the participants, the session started with a brief presentation by Dr. N. D. R. Sarma explaining the need and necessity of State Estimator which can be used by the operator in real-time decision making. . He suggested three classic papers by Fred Schweppe which will be shared on the state estimator group. He also suggested a book authored by Grainger and Stevenson on Power System Analysis which has a complete chapter on State Estimation. He mentioned state estimation should be used to detect and avoid overloading on the lines.

b) Limits used in state estimation
Dr. N. D. R. Sarma explained the limits put on the analog values as normal, emergency and load shedding limits. The limits were based on thermal rating was confirmed after a question was raised. Further he also stated that in ERCOT, dynamic ratings is also imposed to maximize the use of the line. Further there are other limits such as stability limits which are also calculated using other applications. An operator must take the lowest of the different types of limits to keep the system safe and secure.

c) N-1 condition simulations
Dr. N. D. R. Sarma mentioned that the state estimation forms the basis for contingency analysis. Contingency analysis takes the solution of state estimation and simulate all the contingencies and show the top credible contingencies. He also mentioned that in ERCOT, outage of multiple

elements like outage of Double circuit tower is also considered as N-1 contingency and categorized as Double contingency. An operator must look for limit violations in contingency analysis.

d) Man power requirement
Dr. N. D. R. Sarma also discussed the structure of man power in ERCOT. A dedicated person is available and responsible for maintaining the state estimation valid.

e) SPS/RAS and RAP schemes
Dr. N. D. R. Sarma explained about Remedial Action Schemes (RAS/SPS), Remedial Action Plans (RAPs) and Operational Plans (OpPlans) done in ERCOT. He explained that RAS/SPS and RAP are done on yearly basis whereas OpPlans are done as and when required on a temporary basis. These plans are drawn out from study environment of state estimation.

f) States of Power system
Dr. N. D. R. Sarma explained that an operator must know the state of the power system. Sometimes it may be required to operate the system in a less economical but more secure state. The Correctively Secure state is more economical than a secure state. State estimation would provide the operator an idea about the state of the system. He also explained the importance of the reserves in the system and sometimes load shedding may be required for maintaining the reserves in the system for a large credible contingency. He further stated that ERCOT has the full authority to bring the reserve units online.

g) Observability of the system
Dr. N. D. R. Sarma explained a simple technique used for checking the observability of the system. A spanning tree may be formed connecting the two nodes having at least one telemetry on either side and if all the nodes get connected the system can be considered as observable. He also emphasized that if the spread of telemetry is proper then even the states of stations with no RTU can be estimated.

h) Gross and Net measurement in generators
It was discussed that when gross and net measurement is available, a simple load is to be modeled as auxiliary loads on the generator bus to take care of the state estimation contingency.

i) Archiving philosophy
Dr. N. D. R. Sarma explained that in ERCOT the model of state estimation case is saved regularly and pulled back in the system as and when required. The save cases are preserved and there is a fixed periodicity of saving SE models and data. He also explained that at ERCOT all the SCADA data is also archived using OSI’s PI system. It is required to archive last 7 years data at ERCOT. He also explained that all the models are updated in EMS system every week. All the old models are also archived in the form of save cases.

5. **Demonstration of State estimation at WRLDC**
On the current GE SCADA system, a demonstration on running the state estimation was performed on WRLDC network. WRLDC network is modeled upto 400kV level. It was demonstrated that by manually correcting the wrong status information from field, the

convergence of State estimation can be further improved. Further the mismatches on voltages and angles were also checked in iteration summary. Due to modeling differences the mismatches on the lines were observed in bad measurement summary. The importance of voltage and angle tolerances was explained by Dr. N. D. R. Sarma.

6. **Status of state estimation at SLDCs**

a) Chhattisgarh SLDC

The state estimation database model consists of 400kV, 220 kV and some important 132 kV stations. However Dr. N. D. R. Sarma suggested that if the network below a certain voltage level is radial, the lower network can be simply modelled as loads. With the current system the state estimation does not converge regularly. However the aspects of state estimation are well understood and will be taken care of during the SAT of the new SCADA EMS system.

b) Madhya Pradesh SLDC

The state estimation model database consists of 400kV and 220kV network. They will go upto 132kV network once data from all 132kV network is available. The state estimation is not run regularly, however young engineers are identified for making the state estimation work in the new SCADA system.

c) Gujarat SLDC

The state estimation model consists of 400kV, 220kV and 132kV network. The state estimation is run on regular basis. The advantage with Gujarat is the engineers from SLDC Gujarat themselves fix the problems in telemetry. So the RTU observability and hence the telemetry is quite strong.

The session was concluded with Dr. N. D. R. Sarma mentioning that the consistent representation of the system is to be maintained to keep the system secure.

<u>Wrapping –up discussions of the state estimation awareness exercise</u>
<u>Date: 08/01/2014</u>

1. A wrap up session on the state estimation exercise mentioned below, was held on a video conference between WRLDC and NLDC on 8th Jan 2015 A/N. Officers from NLDC, ERLDC, SRLDC, and WRLDC were present at WRLDC, CEO, ED & other officers from NLDC were present on Video conference.

    - NRLDC/NLDC, Delhi : 13-14 Dec 2014
    - NERLDC, Shillong : 21-22 Dec 2014
    - ERLDC, Kolkata : 23-24 Dec 2014
    - SRLDC, Bengaluru : 4-5 Jan 2015
    - WRLDC, Mumbai : 7-8 Jan 2015

2. A draft table of content for state estimation in India, experience, issues and action plans was discussed by Dr. N. D. R. Sarma. He narrated his experience and thoughts on state estimation in each region and was confident of having built an effective state estimation team through this endeavor.

3. Following the discussion on contents of the report by Dr. Sarma, CEO (POSOCO) was highly impressed on the work of Dr. Sarma and shared his thoughts and vision for taking the state estimation level to a higher level. He suggested that the report be made public so that it can be viewed as a reference material by the practicing engineers and academia. The report may also be used as a feedback to regulatory commission.

4. He also suggested that a draft report is to be prepared by 22nd Jan. 2015 and may be included as an agenda item during the FOLD meeting.

5. It was also discussed that since there are no standards for state estimation, regular discussions need to be held to streamline and innovate the state estimation process.

6. CEO, POSOCO also suggested that a group of practicing engineers be formed consisting of engineers dealing with state estimation so that a platform for discussion is available.

7. CEO also suggested that at National Power Systems Conferences, presentations and panel sessions regarding experiences of State Estimation should be organized. He also suggested that POSOCO can organize a world conference on State Estimation inviting world leaders which will provide opportunity for young engineers to meet with ICONs and gurus of State Estimation across the world. He suggested that it can be organized under CIGRE or IEEE. Dr. Sarma appreciated this idea and suggested that it can be planned to have it in 1-2 years.

8. Since state estimation is of utmost importance for maintaining the system secure, the students in engineering must be taught about state estimation in detail. Considering this a change in course material may be suggested in the educational institutes. He also suggested that POSOSCO can allocate some R&D fund so that Academia can work on some practical problems related to State Estimation. Practical data can also be provided for the research work. Some Power System POSOCO awards can also be given.

9. Further he also suggested that the SLDCs must be actively involved in this process and RLDCs may coordinate with them to run the state estimation.

10. Opinions from members who visited other RLDCs was taken and the issues of telemetry strengthening and model updating were discussed.

11. Executive Director suggested that we can explore the possibility of having MOU between ERCOT and POSOCO so that engineers and visit ERCOT and understand the usage of EMS systems.

12. Mr. Narasimhan suggested that RLDCs could have weekly sessions on usage of State Estimation.

13. The discussion ended with a vote of thanks from General Manager WRLDC on behalf of POSOCO and SLDCs to Dr. N. D. R. Sarma. Standing ovation was given to Dr. Sarma for his efforts in improving the usage of State Estimation in India.

Appendix 2

List of participants

Visit at NLDC on 14th December 2014

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*** Chhattisgarh and Madhya Pradesh SLDCs joined through Video Conferencing**

Appendix 3

List of RTUs at each RLDCs and NLDC

Summary of all regions

S. No.	Region	Utility	Total No. of RTUs	Number of RTUs continuously reporting	Number of RTUs intermittently reporting	Number of RTUs not reporting
1	NR	Central Sector	17	5	7	5
2		BBMB	18	10	8	0
3		Delhi	36	14	14	8
4		Haryana	45	12	16	17
5		Himachal Pradesh	10	5	4	1
6		Jammu & Kashmir	6	0	3	3
7		Punjab	66	19	31	16
8		Rajasthan	105	55	32	18
9		Uttar Pradesh & Uttarakhand	85	32	30	23
		Total	**388**	**152**	**145**	**91**
10	ER	Central Sector	47	46	0	1
11		IPPs	69	39	0	30
12		DVC	30	18	0	12
13		Jharkhand	15	6	0	9
14		Odisha	55	44	0	11
15		West Bengal	59	30	0	29
		Total	**275**	**183**	**0**	**92**
16	WR	Central Sector	42	42	0	0
17		IPPs	24	24	0	0
18		Chhattisgarh	17	13	0	4
19		Daman & Diu	1	0	0	1
20		Dadra & Nagar Haveli	2	0	0	2
21		Goa	7	0	0	7
22		Gujarat	73	71	0	2
23		Madhya Pradesh	62	59	0	3
24		Maharashtra	155	105	0	50
		Total	**383**	**314**	**0**	**69**
25	SR	Central Sector	61	61	0	0

S. No.	Region	Utility	Total No. of RTUs	Number of RTUs continuously reporting	Number of RTUs intermittently reporting	Number of RTUs not reporting
26		Andhra Pradesh & Telangana	169	169	0	0
27		Karnataka	130	130	0	0
28		Kerala	34	34	0	0
29		Puducherry	17	17	0	0
30		Tamil Nadu	133	133	0	0
		Total	**544**	**544**	**0**	**0**
31	NER	Central Sector	21	21	0	0
32		Assam	52	37	0	15
33		Manipur	7	0	0	7
34		Meghalaya	16	12	0	4
35		Mizaram	1	0	0	1
36		Tripura	15	12	0	3
		Total	**112**	**82**	**0**	**30**
All India Total			**1702**	***1275***	***145***	***282***

List of RTUs in Northern Region

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
1	Salal	NHPC	400	Reporting
2	Sambha	Powergrid	400	Intermittent
3	Sewa2_NH	NHPC	400	Not Reporting
4	Shree Cement	IPP	400	Intermittent
5	Sikar_PG	Powergrid	400	Intermittent
6	Singrauli	NTPC	400	Reporting
7	Sitarganj	Powergrid	400	Reporting
8	Sohewal	Powergrid	400	Reporting
9	Sonepat	Powergrid	400	Not Reporting
10	Tanakpur	NHPC	400	Intermittent
11	Tehri	THDC	400	Reporting
12	Unchahar	NTPC	400	Not Reporting
13	Uri	NHPC	400	Intermittent
14	Uri_2_NH	NHPC	400	Not Reporting
15	VINDH_WR	NHPC	400	Intermittent

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
16	Wagoora	Powergrid	400	Intermittent
17	Wanpo	Powergrid	400	Not Reporting
18	BHAKR_BB	BBMB	--NA--	Reporting
19	BHIWN_BB	BBMB	--NA--	Reporting
20	BLBGH_BB	BBMB	--NA--	Reporting
21	DADRI_BB	BBMB	--NA--	Reporting
22	DEHAR_BB	BBMB	--NA--	Reporting
23	DELHI_BB	BBMB	--NA--	Intermittent
24	DHULK_BB	BBMB	--NA--	Intermittent
25	GANGL_BB	BBMB	--NA--	Reporting
26	HISAR_BB	BBMB	--NA--	Reporting
27	JAMAL_BB	BBMB	--NA--	Intermittent
28	JGDRI_BB	BBMB	--NA--	Intermittent
29	JLNDR_BB	BBMB	--NA--	Intermittent
30	NRELA_BB	BBMB	--NA--	Intermittent
31	PANPT_BB	BBMB	--NA--	Reporting
32	PIPLI_BB	BBMB	--NA--	Intermittent
33	PONG__BB	BBMB	--NA--	Reporting
34	SMYUR_BB	BBMB	--NA--	Reporting
35	SNGRU_BB	BBMB	--NA--	Intermittent
36	BAMNL_DV	Delhi	--NA--	Intermittent
37	BWANA_DV	Delhi	--NA--	Intermittent
38	CCGTB_DV	Delhi	--NA--	Intermittent
39	DAIL__DV	Delhi	--NA--	Not Reporting
40	DSIDC_DV	Delhi	--NA--	Intermittent
41	DWRK1_DV	Delhi	--NA--	Not Reporting
42	DWRK2_DV	Delhi	--NA--	Intermittent
43	GAZIR_DV	Delhi	--NA--	Reporting
44	GEETA_DV	Delhi	--NA--	Reporting
45	GOPAL_DV	Delhi	--NA--	Intermittent
46	HARSH_DV	Delhi	--NA--	Intermittent
47	HCMLA_DV	Delhi	--NA--	Not Reporting
48	IPPOS_DV	Delhi	--NA--	Reporting
49	K_GAT_DV	Delhi	--NA--	Intermittent
50	KANJW_DV	Delhi	--NA--	Reporting
51	MBAGH_DV	Delhi	--NA--	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
52	MEHRU_DV	Delhi	--NA--	Reporting
53	MSJID_DV	Delhi	--NA--	Not Reporting
54	MUNDK_DV	Delhi	--NA--	Reporting
55	NAJAG_DV	Delhi	--NA--	Intermittent
56	NAREL_DV	Delhi	--NA--	Reporting
57	NRINA_DV	Delhi	--NA--	Not Reporting
58	OKHLA_DV	Delhi	--NA--	Reporting
59	PARKS_DV	Delhi	--NA--	Reporting
60	PATPR_DV	Delhi	--NA--	Intermittent
61	PRGTI_DV	Delhi	--NA--	Reporting
62	RIDGE_DV	Delhi	--NA--	Not Reporting
63	ROHN2_DV	Delhi	--NA--	Intermittent
64	ROHNI_DV	Delhi	--NA--	Intermittent
65	SARIV_DV	Delhi	--NA--	Reporting
66	SHALI_DV	Delhi	--NA--	Intermittent
67	SUBZI_DV	Delhi	--NA--	Intermittent
68	TRUMA_DV	Delhi	--NA--	Not Reporting
69	VSANT_DV	Delhi	--NA--	Reporting
70	WAZID_DV	Delhi	--NA--	Reporting
71	WAZIR_DV	Delhi	--NA--	Not Reporting
72	BADSH_HS	Haryana	--NA--	Not Reporting
73	BATTA_HS	Haryana	--NA--	Not Reporting
74	BHIWN_HS	Haryana	--NA--	Not Reporting
75	BSTRA_HS	Haryana	--NA--	Not Reporting
76	CHJPR_HS	Haryana	--NA--	Not Reporting
77	CHRMR_HS	Haryana	--NA--	Not Reporting
78	DCRTP_HS	Haryana	--NA--	Intermittent
79	DHNDA_HS	Haryana	--NA--	Reporting
80	DLTBD_HS	Haryana	--NA--	Intermittent
81	DPLPR_HS	Haryana	--NA--	Not Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
82	FTEBD_HS	Haryana	--NA--	Intermittent
83	HISAR_HS	Haryana	--NA--	Reporting
84	JINDN_HS	Haryana	--NA--	Reporting
85	KBLPR_HS	Haryana	--NA--	Intermittent
86	KRNAL_HS	Haryana	--NA--	Intermittent
87	KRORI_HS	Haryana	--NA--	Not Reporting
88	KTHAL_HS	Haryana	--NA--	Reporting
89	LLAHR_HS	Haryana	--NA--	Reporting
90	MAJRA_HS	Haryana	--NA--	Reporting
91	MASDP_HS	Haryana	--NA--	Not Reporting
92	MAU___HS	Haryana	--NA--	Not Reporting
93	MGTPS_HS	Haryana	--NA--	Intermittent
94	MHANA_HS	Haryana	--NA--	Not Reporting
95	MHIND_HS	Haryana	--NA--	Reporting
96	NARWN_HS	Haryana	--NA--	Intermittent
97	NISNG_HS	Haryana	--NA--	Reporting
98	NRNUL_HS	Haryana	--NA--	Reporting
99	NWADA_HS	Haryana	--NA--	Intermittent
100	NYWAL_HS	Haryana	--NA--	Intermittent
101	PALLA_HS	Haryana	--NA--	Intermittent
102	PANCH_HS	Haryana	--NA--	Intermittent
103	PANTH_HS	Haryana	--NA--	Intermittent
104	PHOWA_HS	Haryana	--NA--	Reporting
105	PLWAL_HS	Haryana	--NA--	Not Reporting
106	RAWLI_HS	Haryana	--NA--	Not Reporting
107	RGTPS_HS	Haryana	--NA--	Intermittent
108	ROTAK_HS	Haryana	--NA--	Intermittent
109	RWARI_HS	Haryana	--NA--	Not Reporting
110	SAGWN_HS	Haryana	--NA--	Not Reporting
111	SALEM_HS	Haryana	--NA--	Reporting
112	SEC72_HS	Haryana	--NA--	Not Reporting
113	SFDON_HS	Haryana	--NA--	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
114	SHBAD_HS	Haryana	--NA--	Intermittent
115	SIRSA_HS	Haryana	--NA--	Intermittent
116	SONEP_HS	Haryana	--NA--	Not Reporting
117	BADDI_HP	Himachal Pradesh	--NA--	Intermittent
118	BASPA_HP	Himachal Pradesh	--NA--	Reporting
119	BHABA_HP	Himachal Pradesh	--NA--	Intermittent
120	GIRI__HP	Himachal Pradesh	--NA--	Intermittent
121	HAM2P_HP	Himachal Pradesh	--NA--	Reporting
122	JASOR_HP	Himachal Pradesh	--NA--	Reporting
123	JEORI_HP	Himachal Pradesh	--NA--	Intermittent
124	KANGO_HP	Himachal Pradesh	--NA--	Reporting
125	KUNIH_HP	Himachal Pradesh	--NA--	Reporting
126	UPNGL_HP	Himachal Pradesh	--NA--	Not Reporting
127	BGLHR_JK	Jammu and Kashmir	--NA--	Intermittent
128	GLDNI_JK	Jammu and Kashmir	--NA--	Intermittent
129	HRNGR_JK	Jammu and Kashmir	--NA--	Not Reporting
130	PAMPO_JK	Jammu and Kashmir	--NA--	Not Reporting
131	UDHAM_JK	Jammu and Kashmir	--NA--	Intermittent
132	ZNKOT_JK	Jammu and Kashmir	--NA--	Not Reporting
133	ABLWL_PS	Punjab	--NA--	Intermittent
134	BAGHA_PS	Punjab	--NA--	Not Reporting
135	BAJAK_PS	Punjab	--NA--	Intermittent
136	BARNL_PS	Punjab	--NA--	Reporting
137	BGARH_PS	Punjab	--NA--	Reporting
138	BOTIA_PS	Punjab	--NA--	Not Reporting
139	BUTRI_PS	Punjab	--NA--	Intermittent
140	CLASR_PS	Punjab	--NA--	Reporting
141	DASYA_PS	Punjab	--NA--	Reporting
142	DERAB_PS	Punjab	--NA--	Intermittent
143	DHNDR_PS	Punjab	--NA--	Intermittent
144	DHUR4_PS	Punjab	--NA--	Intermittent
145	DHURI_PS	Punjab	--NA--	Not Reporting
146	FATEH_PS	Punjab	--NA--	Intermittent

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
147	FIROZ_PS	Punjab	--NA--	Not Reporting
148	FRLDH_PS	Punjab	--NA--	Intermittent
149	GGSTP_PS	Punjab	--NA--	Reporting
150	GHTP__PS	Punjab	--NA--	Reporting
151	GNDTP_PS	Punjab	--NA--	Reporting
152	GOBIN_PS	Punjab	--NA--	Intermittent
153	GOBIN_PS	Punjab	--NA--	Intermittent
154	GOBIO_PS	Punjab	--NA--	Intermittent
155	GORAY_PS	Punjab	--NA--	Intermittent
156	GUBYA_PS	Punjab	--NA--	Intermittent
157	GWLTP_PS	Punjab	--NA--	Not Reporting
158	HIMAT_PS	Punjab	--NA--	Intermittent
159	HMBRA_PS	Punjab	--NA--	Intermittent
160	JGRAO_PS	Punjab	--NA--	Reporting
161	JHUNR_PS	Punjab	--NA--	Not Reporting
162	JMSHR_PS	Punjab	--NA--	Not Reporting
163	KANJL_PS	Punjab	--NA--	Not Reporting
164	KARTA_PS	Punjab	--NA--	Not Reporting
165	KJNGA_PS	Punjab	--NA--	Not Reporting
166	KSURT_PS	Punjab	--NA--	Intermittent
167	LALRU_PS	Punjab	--NA--	Intermittent
168	LALTN_PS	Punjab	--NA--	Intermittent
169	MAKHU_PS	Punjab	--NA--	Intermittent
170	MALER_PS	Punjab	--NA--	Reporting
171	MASTE_PS	Punjab	--NA--	Intermittent
172	MHLPR_PS	Punjab	--NA--	Reporting
173	MKTS2_PS	Punjab	--NA--	Reporting
174	MKTS4_PS	Punjab	--NA--	Not Reporting
175	MLOT2_PS	Punjab	--NA--	Reporting
176	MNSA2_PS	Punjab	--NA--	Not Reporting
177	MOGA4_PS	Punjab	--NA--	Intermittent
178	MOGAN_PS	Punjab	--NA--	Intermittent

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
179	MOHL2_PS	Punjab	--NA--	Intermittent
180	MOHLI_PS	Punjab	--NA--	Reporting
181	NABHA_PS	Punjab	--NA--	Intermittent
182	NKDR4_PS	Punjab	--NA--	Intermittent
183	PATRA_PS	Punjab	--NA--	Reporting
184	PATTI_PS	Punjab	--NA--	Intermittent
185	PKHWL_PS	Punjab	--NA--	Not Reporting
186	RAJLA_PS	Punjab	--NA--	Not Reporting
187	RAJPR_PS	Punjab	--NA--	Intermittent
188	RJPR4_PS	Punjab	--NA--	Intermittent
189	RJPTS_PS	Punjab	--NA--	Reporting
190	RSDPH_PS	Punjab	--NA--	Intermittent
191	SADQ2_PS	Punjab	--NA--	Reporting
192	SAHNE_PS	Punjab	--NA--	Reporting
193	SARNA_PS	Punjab	--NA--	Reporting
194	SULTN_PS	Punjab	--NA--	Not Reporting
195	SUNAM_PS	Punjab	--NA--	Intermittent
196	TLDTP_PS	Punjab	--NA--	Not Reporting
197	VERPL_PS	Punjab	--NA--	Reporting
198	WDALA_PS	Punjab	--NA--	Intermittent
199	ADANI_RS	Rajasthan	--NA--	Reporting
200	AJMER_RS	Rajasthan	--NA--	Reporting
201	AKAL4_RS	Rajasthan	--NA--	Intermittent
202	ALMIA_RS	Rajasthan	--NA--	Reporting
203	ALWAR_RS	Rajasthan	--NA--	Reporting
204	ALWR4_RS	Rajasthan	--NA--	Not Reporting
205	AMSGR_RS	Rajasthan	--NA--	Reporting
206	BAGRU_RS	Rajasthan	--NA--	Intermittent
207	BALI__RS	Rajasthan	--NA--	Intermittent
208	BARAN_RS	Rajasthan	--NA--	Reporting
209	BARMR_RS	Rajasthan	--NA--	Reporting
210	BARSR_RS	Rajasthan	--NA--	Not Reporting
211	BEWAR_RS	Rajasthan	--NA--	Intermittent
212	BHART_RS	Rajasthan	--NA--	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
213	BHDRA_RS	Rajasthan	--NA--	Intermittent
214	BHIL4_RS	Rajasthan	--NA--	Reporting
215	BHIWR_RS	Rajasthan	--NA--	Not Reporting
216	BHNML_RS	Rajasthan	--NA--	Reporting
217	BILRA_RS	Rajasthan	--NA--	Reporting
218	BKNER_RS	Rajasthan	--NA--	Intermittent
219	BKNR4_RS	Rajasthan	--NA--	Intermittent
220	BLOTR_RS	Rajasthan	--NA--	Intermittent
221	BNSWR_RS	Rajasthan	--NA--	Reporting
222	BORND_RS	Rajasthan	--NA--	Not Reporting
223	BPGRH_RS	Rajasthan	--NA--	Not Reporting
224	CHIRW_RS	Rajasthan	--NA--	Reporting
225	CHITO_RS	Rajasthan	--NA--	Reporting
226	CHOMU_RS	Rajasthan	--NA--	Reporting
227	CHTPS_RS	Rajasthan	--NA--	Intermittent
228	DAUSA_RS	Rajasthan	--NA--	Intermittent
229	DCCPP_RS	Rajasthan	--NA--	Reporting
230	DEBAR_RS	Rajasthan	--NA--	Reporting
231	DECHU_RS	Rajasthan	--NA--	Reporting
232	DEED4_RS	Rajasthan	--NA--	Intermittent
233	DHOD__RS	Rajasthan	--NA--	Intermittent
234	DLPUR_RS	Rajasthan	--NA--	Intermittent
235	DRMNA_RS	Rajasthan	--NA--	Not Reporting
236	DUNI__RS	Rajasthan	--NA--	Intermittent
237	DYRA__RS	Rajasthan	--NA--	Reporting
238	FLODI_RS	Rajasthan	--NA--	Not Reporting
239	GAJNR_RS	Rajasthan	--NA--	Not Reporting
240	GIRAL_RS	Rajasthan	--NA--	Intermittent
241	GULPR_RS	Rajasthan	--NA--	Reporting
242	HANUM_RS	Rajasthan	--NA--	Reporting
243	HEERP_RS	Rajasthan	--NA--	Reporting
244	HEERP_RS	Rajasthan	--NA--	Reporting
245	HERP2_RS	Rajasthan	--NA--	Reporting
246	HIND4_RS	Rajasthan	--NA--	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
247	HNDUN_RS	Rajasthan	--NA--	Not Reporting
248	IGNGR_RS	Rajasthan	--NA--	Reporting
249	JALOR_RS	Rajasthan	--NA--	Intermittent
250	JDHPR_RS	Rajasthan	--NA--	Reporting
251	JHALR_RS	Rajasthan	--NA--	Reporting
252	JHUNJ_RS	Rajasthan	--NA--	Intermittent
253	JODH4_RS	Rajasthan	--NA--	Reporting
254	KATPP_RS	Rajasthan	--NA--	Intermittent
255	KGBAS_RS	Rajasthan	--NA--	Reporting
256	KHIWR_RS	Rajasthan	--NA--	Not Reporting
257	KHTRI_RS	Rajasthan	--NA--	Reporting
258	KHUSH_RS	Rajasthan	--NA--	Reporting
259	KMCTY_RS	Rajasthan	--NA--	Not Reporting
260	KNGRH_RS	Rajasthan	--NA--	Not Reporting
261	KNKRL_RS	Rajasthan	--NA--	Intermittent
262	KOTAS_RS	Rajasthan	--NA--	Reporting
263	KOTPL_RS	Rajasthan	--NA--	Reporting
264	KTPS__RS	Rajasthan	--NA--	Reporting
265	KUKAS_RS	Rajasthan	--NA--	Reporting
266	LALST_RS	Rajasthan	--NA--	Not Reporting
267	MERTA_RS	Rajasthan	--NA--	Intermittent
268	MKRNA_RS	Rajasthan	--NA--	Reporting
269	MNDWR_RS	Rajasthan	--NA--	Reporting
270	MORAK_RS	Rajasthan	--NA--	Reporting
271	NAGUR_RS	Rajasthan	--NA--	Intermittent
272	NDBAI_RS	Rajasthan	--NA--	Not Reporting
273	NIMBH_RS	Rajasthan	--NA--	Not Reporting
274	NMRNA_RS	Rajasthan	--NA--	Intermittent
275	NOKHA_RS	Rajasthan	--NA--	Reporting
276	PADAM_RS	Rajasthan	--NA--	Not Reporting
277	PALI__RS	Rajasthan	--NA--	Reporting
278	PHULR_RS	Rajasthan	--NA--	Reporting
279	PINDW_RS	Rajasthan	--NA--	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
280	RAJWT_RS	Rajasthan	--NA--	Reporting
281	RAS___RS	Rajasthan	--NA--	Reporting
282	RATAN_RS	Rajasthan	--NA--	Reporting
283	RATN4_RS	Rajasthan	--NA--	Intermittent
284	RATN4_RS	Rajasthan	--NA--	Intermittent
285	REENG_RS	Rajasthan	--NA--	Intermittent
286	RENWL_RS	Rajasthan	--NA--	Intermittent
287	RJWND_RS	Rajasthan	--NA--	Reporting
288	SAWA__RS	Rajasthan	--NA--	Not Reporting
289	SDUNG_RS	Rajasthan	--NA--	Intermittent
290	SEZ_1_RS	Rajasthan	--NA--	Intermittent
291	SGNER_RS	Rajasthan	--NA--	Reporting
292	SGNGR_RS	Rajasthan	--NA--	Reporting
293	SIKAR_RS	Rajasthan	--NA--	Intermittent
294	SNCHR_RS	Rajasthan	--NA--	Intermittent
295	SROHI_RS	Rajasthan	--NA--	Reporting
296	SUJAN_RS	Rajasthan	--NA--	Intermittent
297	SURAT_RS	Rajasthan	--NA--	Reporting
298	SURTP_RS	Rajasthan	--NA--	Reporting
299	SURTP_RS	Rajasthan	--NA--	Reporting
300	SWAIM_RS	Rajasthan	--NA--	Intermittent
301	TINWR_RS	Rajasthan	--NA--	Reporting
302	VKIA__RS	Rajasthan	--NA--	Reporting
303	VSLP__RS	Rajasthan	--NA--	Not Reporting
304	AGRA2_UP	Uttar Pradesh	--NA--	Intermittent
305	ALHA2_UP	Uttar Pradesh	--NA--	Reporting
306	ALHAC_UP	Uttar Pradesh	--NA--	Reporting
307	ATRLI_UP	Uttar Pradesh	--NA--	Intermittent
308	AZAM2_UP	Uttar Pradesh	--NA--	Reporting
309	BADUN_UP	Uttar Pradesh	--NA--	Not Reporting
310	BANDA_UP	Uttar Pradesh	--NA--	Intermittent
311	BARUT_UP	Uttar Pradesh	--NA--	Not Reporting
312	BASTI_UP	Uttar Pradesh	--NA--	Not Reporting
313	BEHAT_UP	Uttar Pradesh	--NA--	Not Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
314	BHLPR_UP	Uttar Pradesh	--NA--	Not Reporting
315	BHRTN_UP	Uttar Pradesh	--NA--	Reporting
316	BTHOR_UP	Uttar Pradesh	--NA--	Reporting
317	CBGA2_UP	Uttar Pradesh	--NA--	Reporting
318	CHIBM_UP	Uttar Pradesh	--NA--	Intermittent
319	CHINT_UP	Uttar Pradesh	--NA--	Reporting
320	CHRLA_UP	Uttar Pradesh	--NA--	Reporting
321	DADRI_UP	Uttar Pradesh	--NA--	Intermittent
322	DOHNA_UP	Uttar Pradesh	--NA--	Reporting
323	DORIA_UP	Uttar Pradesh	--NA--	Not Reporting
324	ETAH__UP	Uttar Pradesh	--NA--	Reporting
325	FARID_UP	Uttar Pradesh	--NA--	Not Reporting
326	FRZBD_UP	Uttar Pradesh	--NA--	Intermittent
327	FTEPR_UP	Uttar Pradesh	--NA--	Intermittent
328	GJOKR_UP	Uttar Pradesh	--NA--	Not Reporting
329	GJRLA_UP	Uttar Pradesh	--NA--	Reporting
330	GOKUL_UP	Uttar Pradesh	--NA--	Not Reporting
331	GOMTI_UP	Uttar Pradesh	--NA--	Reporting
332	GONDA_UP	Uttar Pradesh	--NA--	Intermittent
333	GRK_2_UP	Uttar Pradesh	--NA--	Not Reporting
334	GRK2N_UP	Uttar Pradesh	--NA--	Not Reporting
335	GZIPR_UP	Uttar Pradesh	--NA--	Intermittent
336	HAROD_UP	Uttar Pradesh	--NA--	Not Reporting
337	HATRS_UP	Uttar Pradesh	--NA--	Not Reporting
338	HLDWN_UP	Uttar Pradesh	--NA--	Not Reporting
339	HRDNJ_UP	Uttar Pradesh	--NA--	Reporting
340	HRDOI_UP	Uttar Pradesh	--NA--	Intermittent
341	JAYPE_UP	Uttar Pradesh	--NA--	Reporting
342	JHASI_UP	Uttar Pradesh	--NA--	Not Reporting
343	JHNGR_UP	Uttar Pradesh	--NA--	Intermittent

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
344	JHUSI_UP	Uttar Pradesh	--NA--	Intermittent
345	JUNPR_UP	Uttar Pradesh	--NA--	Intermittent
346	KANPR_UP	Uttar Pradesh	--NA--	Reporting
347	KANPS_UP	Uttar Pradesh	--NA--	Reporting
348	KHARA_UP	Uttar Pradesh	--NA--	Reporting
349	KHODR_UP	Uttar Pradesh	--NA--	Not Reporting
350	KHURJ_UP	Uttar Pradesh	--NA--	Reporting
351	LONI__UP	Uttar Pradesh	--NA--	Intermittent
352	LUCK2_UP	Uttar Pradesh	--NA--	Reporting
353	MAINP_UP	Uttar Pradesh	--NA--	Reporting
354	MEUPT_UP	Uttar Pradesh	--NA--	Intermittent
355	MORA2_UP	Uttar Pradesh	--NA--	Intermittent
356	MUR2N_UP	Uttar Pradesh	--NA--	Reporting
357	MUZA2_UP	Uttar Pradesh	--NA--	Intermittent
358	NANAU_UP	Uttar Pradesh	--NA--	Intermittent
359	NETHR_UP	Uttar Pradesh	--NA--	Reporting
360	NOIDA_UP	Uttar Pradesh	--NA--	Intermittent
361	OBRAA_UP	Uttar Pradesh	--NA--	Reporting
362	ORAI__UP	Uttar Pradesh	--NA--	Not Reporting
363	PANK2_UP	Uttar Pradesh	--NA--	Reporting
364	PANKT_UP	Uttar Pradesh	--NA--	Reporting
365	PHLPR_UP	Uttar Pradesh	--NA--	Intermittent
366	PRINC_UP	Uttar Pradesh	--NA--	Not Reporting
367	RAIBR_UP	Uttar Pradesh	--NA--	Not Reporting
368	RAMPR_UP	Uttar Pradesh	--NA--	Not Reporting
369	RASRA_UP	Uttar Pradesh	--NA--	Not Reporting
370	RCGRN_UP	Uttar Pradesh	--NA--	Intermittent
371	RPH_2_UP	Uttar Pradesh	--NA--	Reporting
372	SAFAI_UP	Uttar Pradesh	--NA--	Not Reporting
373	SAHUP_UP	Uttar Pradesh	--NA--	Reporting
374	SAMBH_UP	Uttar Pradesh	--NA--	Intermittent
375	SBHLI_UP	Uttar Pradesh	--NA--	Reporting
376	SC129_UP	Uttar Pradesh	--NA--	Intermittent

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
377	SEC62_UP	Uttar Pradesh	--NA--	Intermittent
378	SHARN_UP	Uttar Pradesh	--NA--	Intermittent
379	SHATB_UP	Uttar Pradesh	--NA--	Intermittent
380	SHIBD_UP	Uttar Pradesh	--NA--	Reporting
381	SHJHA_UP	Uttar Pradesh	--NA--	Intermittent
382	SHMBD_UP	Uttar Pradesh	--NA--	Not Reporting
383	SHMLI_UP	Uttar Pradesh	--NA--	Reporting
384	SHWL__UP	Uttar Pradesh	--NA--	Intermittent
385	SITPR_UP	Uttar Pradesh	--NA--	Intermittent
386	SKNBD_UP	Uttar Pradesh	--NA--	Intermittent
387	SULT2_UP	Uttar Pradesh	--NA--	Reporting
388	TANDA_UP	Uttar Pradesh	--NA--	Reporting

List of RTUs in Eastern Region

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
1	Angul	Powergrid	765/400/220	Reporting
2	Arrah	Powergrid	220/132	Not Reporting
3	Banka	Powergrid	400/220	Reporting
4	Barh	NTPC	400	Reporting
5	Berhampur	Powergrid	400	Reporting
6	Bheramera	Powergrid	400	Reporting
7	Biharsariff	Powergrid	400/220	Reporting
8	Birpara	Powergrid	220/132	Reporting
9	Bolangir	Powergrid	400	Reporting
10	Chaibasa	Powergrid	400/220	Reporting
11	Dalkhola	Powergrid	220/132	Reporting
12	Durgapur	Powergrid	400/220	Reporting
13	Farakka	Powergrid	400/220	Reporting
14	Gangtak	Powergrid	132	Reporting
15	Gaya 765KV S/S	Powergrid	765/400/220	Reporting
16	Indravati	Powergrid	400	Reporting
17	Jamshedpur	Powergrid	400/220	Reporting
18	Jeypore	Powergrid	400/220	Reporting
19	Jharsuguda	Powergrid	765/400	Reporting
20	Kalabadia	Powergrid	400/220/132	Reporting
21	Keonjhar	Powergrid	400	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
22	KhSTPP	Powergrid	400/132	Reporting
23	Lakshisarai	Powergrid	400/220	Reporting
24	Lalmatia	Powergrid	220/132	Reporting
25	Maithon	Powergrid	400/220	Reporting
26	Maldah	Powergrid	400/132	Reporting
27	Melli	Powergrid	132	Reporting
28	Muzaffarpur	Powergrid	400/220	Reporting
29	Nabinagar	Powergrid	400	Reporting
30	New Farakka	NTPC	400	Reporting
31	New Ranchi	Powergrid	765/400	Reporting
32	New sasaram	Powergrid	765/400	Reporting
33	Patna	Powergrid	400	Reporting
34	Purnea	Powergrid	220/132	Reporting
35	Purnea New	Powergrid	400/220	Reporting
36	Ranchi	Powergrid	400/220	Reporting
37	Rangit	Powergrid	132	Reporting
38	Rangpo	Powergrid	400/220/132	Reporting
39	Rengali	Powergrid	400/220	Reporting
40	Rourkela	Powergrid	400/220	Reporting
41	Sasaram	Powergrid	400/220	Reporting
42	Siliguri 220	Powergrid	220/132	Reporting
43	Siliguri 400	Powergrid	400/220	Reporting
44	Subhasgram	Powergrid	400/220	Reporting
45	Teesta	Powergrid	400	Reporting
46	THVDC	Powergrid	400	Reporting
47	TSTPP	Powergrid	400/220	Reporting
48	ACTION ISPAT	ACTION ISPAT	132	Reporting
49	ADITY ALLUMINIUM	ADITY ALLUMINIUM	220	Reporting
50	AISCL	AISCL	132	Reporting
51	APNRL	APNRL	400	Reporting
52	ARATI STEELS	ARATI STEELS	132	Not Reporting
53	BEGUSARAI	BSPTCL	220/132	Reporting
54	BHUSAN THELKOI	BHUSAN THELKOI	132	Reporting
55	BIHARSHARIF	BSPTCL	220/132	Reporting
56	BODHGAYA	BSPTCL	220/132	Reporting
57	BRPL	BRPL	132	Not Reporting
58	BSL___GR	BSL	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
59	CHANDAUTI	BSPTCL	132	Reporting
60	Chuzachen	Chuzachen	132	Reporting
61	CONCAST IRON	CONCAST IRON	220	Not Reporting
62	DARBHANGA	BSPTCL	132	Not Reporting
63	DEHRI	BSPTCL	220/132	Reporting
64	DUMRAON	BSPTCL	220/132	Not Reporting
65	EMAMI	EMAMI	132	Not Reporting
66	FATHWA	BSPTCL	132	Reporting
67	GMR	GMR	400	Reporting
68	HAJIPUR	BSPTCL	132	Reporting
69	HALCP	HALCP	132	Not Reporting
70	HATHIDAH	BSPTCL	132	Not Reporting
71	HAZIPUR NEW	BSPTCL	220/132	Not Reporting
72	HINDALCO	HINDALCO	132	Reporting
73	IB TPS	IB TPS	400/220	Reporting
74	ICCL	ICCL	132	Not Reporting
75	IMFAA	IMFAA	132	Reporting
76	Indbarath	Indbarath	400	Reporting
77	JAKKANPUR	BSPTCL	132	Not Reporting
78	JAYSHREECHEMICALS	JAYSHREECHEMICALS	132	Not Reporting
79	JITPL	JITPL	400	Reporting
80	JK PAPER	JK PAPER	132	Reporting
81	JSL	JSL	220	Reporting
82	JSPL	JSPL	220	Reporting
83	JSPLA	JSPLA	400/220	Reporting
84	KARMANSHA	BSPTCL	132	Not Reporting
85	KHAGAUL	BSPTCL	220/132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
86	KOSHI	BSPTCL	132	Not Reporting
87	LAKHISARAI	BSPTCL	220/132	Not Reporting
88	MIL	MIL	220	Not Reporting
89	MINAKHI	MINAKHI	132	Not Reporting
90	MOTIHARI	BSPTCL	132	Not Reporting
91	MPL	MPL	400	Reporting
92	MSP JHARSUGUDA	MSP JHARSUGUDA	132	Reporting
93	MUZAFARPUR	BSPTCL	220/132	Not Reporting
94	NBVL	NBVL	132	Reporting
95	OCL_RAJGA	OCL_RAJGA	132	Not Reporting
96	PARADEEP PHOSPHATE	PARADEEP PHOSPHATE	132	Reporting
97	PURNEA	BSPTCL	132	Not Reporting
98	RAJGIR	BSPTCL	132	Not Reporting
99	RAMDAYALU GRID	BSPTCL	132	Not Reporting
100	ROHIT FERO	ROHIT FERO	220	Not Reporting
101	RSP_ROURK	RSP_ROURK	132	Reporting
102	SABOUR	BSPTCL	132	Reporting
103	SAMASTIPUR	BSPTCL	132	Not Reporting
104	SEL	STERLITE	400	Reporting
105	SHYAM DRI	SHYAM DRI	132	Reporting
106	SIPARA	BSPTCL	220/132	Not Reporting
107	SITAMARHI	BSPTCL	132	Not Reporting
108	SMC , JHARSUGUDA	SMC , JHARSUGUDA	132	Not Reporting
109	SONE NAGAR	BSPTCL	132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
110	SULTANGANJ	BSPTCL	132	Not Reporting
111	TISCO	TISCO	400	Reporting
112	TSIL	TSIL	220	Reporting
113	TTPS	TTPS	220/132	Reporting
114	VEDANTA	VEDANTA	220	Reporting
115	VEDANTA ALLUMI	VEDANTA ALLUMI	132	Reporting
116	VISA STEEL	VISA STEEL	132	Not Reporting
117	ASP	Damodar Valley Corporation	132	Reporting
118	BARHI HPS	Damodar Valley Corporation	132	Reporting
119	BARJO_DVRA	Damodar Valley Corporation	220	Reporting
120	BOKARA A	Damodar Valley Corporation	400/220	Not Reporting
121	BOKARA B	Damodar Valley Corporation	220/132	Reporting
122	BURDWAN	Damodar Valley Corporation	132	Not Reporting
123	CTPS 132	Damodar Valley Corporation	132	Reporting
124	CTPS 220	Damodar Valley Corporation	220	Reporting
125	CTPS B	Damodar Valley Corporation	220	Reporting
126	DSTPS	Damodar Valley Corporation	400	Reporting
127	DURGAPUR	Damodar Valley Corporation	220	Not Reporting
128	HOWRAH	Damodar Valley Corporation	132	Not Reporting
129	JAMSHEDPR	Damodar Valley Corporation	220/132	Not Reporting
130	KALIPAHARI	Damodar Valley Corporation	132	Not Reporting
131	KALYANESWARI	Damodar Valley Corporation	220/132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
132	KODARMA	Damodar Valley Corporation	400/220	Reporting
133	KOLAGHAT	Damodar Valley Corporation	132	Not Reporting
134	KUMARDUBRI	Damodar Valley Corporation	132	Reporting
135	MAITHON	Damodar Valley Corporation	132	Reporting
136	MEJIA	Damodar Valley Corporation	220	Reporting
137	MEJIA B	Damodar Valley Corporation	400	Reporting
138	MOSABANI	Damodar Valley Corporation	132	Not Reporting
139	PANCHAT	Damodar Valley Corporation	132	Reporting
140	PARULIA	Damodar Valley Corporation	220	Reporting
141	PATHERDIH	Damodar Valley Corporation	132	Not Reporting
142	PATRATU	Damodar Valley Corporation	132	Not Reporting
143	PUTKI	Damodar Valley Corporation	132	Not Reporting
144	RAGHUNATHPUR	Damodar Valley Corporation	400/220	Reporting
145	RAMGARH	Damodar Valley Corporation	132	Not Reporting
146	WARIA	Damodar Valley Corporation	220/132	Reporting
147	CHANDIL	Jharkhand	220/132	Reporting
148	DEOGHAR	Jharkhand	132	Not Reporting
149	GARHWA	Jharkhand	132	Not Reporting
150	GOELKERA	Jharkhand	132	Not Reporting
151	HATIA	Jharkhand	132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
152	HATIA NEW	Jharkhand	220/132	Not Reporting
153	JADUGODA	Jharkhand	132	Not Reporting
154	JAMTARA	Jharkhand	132	Not Reporting
155	KENDPOSI	Jharkhand	132	Not Reporting
156	LALMATIA	Jharkhand	132	Reporting
157	PATRATU	Jharkhand	220/132	Reporting
158	RAJKHASRAWAN	Jharkhand	132	Not Reporting
159	RAMC'RAPUR	Jharkhand	220/132	Not Reporting
160	SUBARNA REKHA	Jharkhand	132	Reporting
161	TENUGHAT	Jharkhand	220	Reporting
162	ROURKELA	Odisha	132	Reporting
163	AKUSINGHA	Odisha	132	Reporting
164	ANGUL	Odisha	132	Reporting
165	ASKA	Odisha	132	Not Reporting
166	BALASORE	Odisha	220/132	Reporting
167	BALIMELA	Odisha	220	Reporting
168	BARGARH	Odisha	132	Reporting
169	BARIPADA	Odisha	132	Reporting
170	BARKOT	Odisha	220	Reporting
171	BERAHAMPUR	Odisha	132	Not Reporting
172	BHADRAK	Odisha	220/132	Reporting
173	BHANJNAGAR	Odisha	220/132	Reporting
174	BHUBANESWAR	Odisha	132	Not Reporting
175	BIDANASI	Odisha	220/132	Reporting
176	BOINDA	Odisha	132	Reporting
177	BOLANGIR(NEW)	Odisha	220/132	Not Reporting
178	BOLANGIR(OLD)	Odisha	132	Not Reporting
179	BUDHIPADAR	Odisha	220/132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
180	BURLA	Odisha	220/132	Reporting
181	BURLA HPS	Odisha	132	Reporting
182	CHAINPAL	Odisha	132	Reporting
183	CHANDAKA	Odisha	220/132	Reporting
184	CHATRAPUR	Odisha	132	Not Reporting
185	CHIPLIMA HPS	Odisha	132	Reporting
186	CHOUDWAR	Odisha	132	Reporting
187	CUTTAK	Odisha	132	Reporting
188	DHENKNAL	Odisha	132	Reporting
189	DUBRINEW	Odisha	220	Reporting
190	DUBRIOLD	Odisha	220/132	Reporting
191	INDRAVATI	Odisha	400/220	Reporting
192	JAJPUR ROAD	Odisha	132	Reporting
193	JAYANAGAR	Odisha	220/132	Reporting
194	JODA	Odisha	220/132	Reporting
195	KAMAKSHYANAGAR	Odisha	132	Not Reporting
196	KENDRAPADA	Odisha	132	Reporting
197	KESINGA	Odisha	132	Reporting
198	KHURDA	Odisha	132	Reporting
199	MACHKUND	Odisha	132	Reporting
200	MENDHASAL	Odisha	400/220	Reporting
201	MERAMUNDALI	Odisha	400/220/132	Reporting
202	NARENDRAPUR	Odisha	220/132	Not Reporting
203	NAYAGARH	Odisha	220	Reporting
204	PARADEEP	Odisha	220/132	Not Reporting
205	PURI	Odisha	132	Reporting
206	RAIRANGAPUR	Odisha	132	Not Reporting
207	RAJGANGPUR	Odisha	132	Not Reporting
208	RAYAGADA	Odisha	132	Reporting
209	RENGALI S/S	Odisha	220	Reporting
210	RENGALI(PH)	Odisha	220	Reporting
211	SAMBALPUR	Odisha	132	Reporting
212	SIJUA	Odisha	132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
213	SUNABEDA	Odisha	132	Reporting
214	TARKERA	Odisha	220/132	Reporting
215	THERUVALI	Odisha	220/132	Reporting
216	UPPER KOLKAB	Odisha	220	Reporting
217	ADISASAPTAGRAM	West Bengal	132	Not Reporting
218	ALIDWAR	West Bengal	132	Not Reporting
219	ARAMBAGH	West Bengal	400/220/132	Reporting
220	ASANSOLE	West Bengal	220/132	Not Reporting
221	ASHOK NAGAR	West Bengal	132	Reporting
222	BAKRESWAR	West Bengal	400/220	Reporting
223	BANTALA	West Bengal	220/132/33	Reporting
224	BARASAT	West Bengal	132	Not Reporting
225	BARJR	West Bengal	132/33	Not Reporting
226	BGHTI	West Bengal	132/33	Not Reporting
227	BIRPARA	West Bengal	132/66	Not Reporting
228	BISHNUPUR	West Bengal	132	Not Reporting
229	BONGAON	West Bengal	132	Reporting
230	BTPS	West Bengal	132	Reporting
231	CHALSA	West Bengal	132/66	Not Reporting
232	DEBOGRAM	West Bengal	132	Not Reporting
233	DHARAMPUR	West Bengal	132	Reporting
234	DOMJUR	West Bengal	220/132	Not Reporting
235	DPL	West Bengal	220/132	Not Reporting
236	DURGAPUR	West Bengal	220/132	Not Reporting
237	DURGAPUR(400KV)	West Bengal	400/220	Not Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
238	GANGARAMPUR	West Bengal	132	Not Reporting
239	GOKARNA	West Bengal	220/132/66	Not Reporting
240	HALDIA NEW	West Bengal	220/132	Reporting
241	HALDIA OLD	West Bengal	132	Reporting
242	HOWRAH	West Bengal	220/132	Reporting
243	JEERAT	West Bengal	400/220/132	Reporting
244	JOKA	West Bengal	132	Not Reporting
245	KASBA	West Bengal	220/132	Reporting
246	KHARAGPUR	West Bengal	132	Reporting
247	KHARAGPUR(400KV)	West Bengal	400/220/132	Not Reporting
248	KOLAGHAT	West Bengal	132	Reporting
249	KOLGHAT TP	West Bengal	400/220/132	Reporting
250	KRISHNA NAGAR	West Bengal	220/132/33	Not Reporting
251	LAKSHMIKANTPUR	West Bengal	220/132	Reporting
252	LILUA	West Bengal	132	Reporting
253	MALDA	West Bengal	132	Reporting
254	MIDNAPORE	West Bengal	220/132	Reporting
255	NBU	West Bengal	132	Reporting
256	NEW BISHNUPUR	West Bengal	220/132/33	Reporting
257	NJP	West Bengal	220/132	Reporting
258	PPSP	West Bengal	400	Reporting
259	PURULIA	West Bengal	132	Not Reporting
260	RAIGANJ	West Bengal	132	Not Reporting
261	RAJARHUT	West Bengal	220/132/33	Reporting
262	RAMAM	West Bengal	132	Reporting
263	RISHRA	West Bengal	220/132	Reporting
264	SAGARDIGHI	West Bengal	400/220	Not Reporting
265	SAGARDIGHI(400)	West Bengal	400/220	Not Reporting
266	SALTLAKE	West Bengal	132	Reporting
267	SANTHALDHI	West Bengal	220/132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
268	SATGACHIYA	West Bengal	220/132	Not Reporting
269	SIANT	West Bengal	132	Not Reporting
270	SUBHASGRAM	West Bengal	220/132/33	Reporting
271	TARAKESWAR	West Bengal	132	Reporting
272	TEESTA ST-1	West Bengal	132	Not Reporting
273	TEESTA ST-2	West Bengal	132	Not Reporting
274	TEESTA ST-3	West Bengal	132	Not Reporting
275	TITAGARH	West Bengal	132	Not Reporting

List of RTUs in Western Region

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
1	Aurangabad PG	PGCIL	765/400/220	Reporting
2	Bachau	PGCIL	400/220	Reporting
3	Bhadrawati	PGCIL	400/220	Reporting
4	Bhatapara	PGCIL	400/220	Reporting
5	Bina PG	PGCIL	765/400/220	Reporting
6	Boisar	PGCIL	400/220	Reporting
7	Daman	PGCIL	400/220	Reporting
8	Damoh	PGCIL	400/220	Reporting
9	Dehgam	PGCIL	400/220	Reporting
10	Dharamjaygarh	PGCIL	765/400	Reporting
11	Essar Vadinar	PGCIL	400	Reporting
12	Gandhar	NTPC	400/220	Reporting
13	Gwalior	PGCIL	765/400/220	Reporting
14	Itarsi	PGCIL	400/220	Reporting
15	Jabalpur Pooling	PGCIL	765/400	Reporting
16	Kakrapar	NPCIL	220	Reporting
17	Kala	PGCIL	400/220	Reporting
18	Kawas	NTPC	220	Reporting
19	Khandwa	PGCIL	400/220	Reporting
20	Korba	NTPC	400/220	Reporting
21	Mapusa	PGCIL	400/220	Reporting
22	Mauda	NTPC	400	Reporting
23	Navsari	PGCIL	400/220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
24	Parli PG	PGCIL	400/220	Reporting
25	Pirana	PGCIL	400/220	Reporting
26	Pune	PGCIL	400/220	Reporting
27	Raigarh	PGCIL	400/220	Reporting
28	Raigarh 765	PGCIL	765/400	Reporting
29	Raigarh 765	PGCIL	765/400	Reporting
30	Raipur	PGCIL	400/220	Reporting
31	Raipur Durg	PGCIL	765/400	Reporting
32	Rajgarh	PGCIL	400/220	Reporting
33	Sasan	NTPC	765/400	Reporting
34	Satna	PGCIL	765/400/220	Reporting
35	Seoni	PGCIL	765/400/220	Reporting
36	Sipat	NTPC	765/400	Reporting
37	Solapur PG	PGCIL	765/400/220	Reporting
38	Sujalpur	PGCIL	400/220	Reporting
39	Tarapur	NPCIL	400/220	Reporting
40	Vapi	PGCIL	400/220	Reporting
41	Vindhyachal	NTPC	765/400/	Reporting
42	Wardha	PGCIL	765/400/220	Reporting
43	ACBIL	ACBIL	400/132	Reporting
44	BALCO	BALCO	400/220	Reporting
45	BDTCL Bhopal	BDTCL	765/400	Reporting
46	BDTCL Dhule	BDTCL	765/400	Reporting
47	CGPL	CGPL	400	Reporting
48	DB Power	Diligent Power	400	Reporting
49	Dgen	Torrent	400/220	Reporting
50	Dhariwal PG	Dhariwal	400	Reporting
51	Essar Hazira	Essar	400/220	Reporting
52	Essar Mahan	Essar	400/220	Reporting
53	GMR EMCO	GMR	400	Reporting
54	GMR Raipur	GMR	400	Reporting
55	Jindal	JPL	400	Reporting
56	Jindal Tamnar	JPL	400	Reporting
57	JP Nigri	Jaypee	400	Reporting
58	KSK	KSK	400	Reporting
59	KWPCL	KWPCL	400/220	Reporting
60	LANCO	LANCO	400	Reporting
61	MB Power	Moser Baer	400	Reporting
62	MCPL	MCPL	400	Reporting
63	RGPPL	RGPPL	400	Reporting
64	RKM	RKM	400	Reporting
65	Sugen	Torrent	400	Reporting
66	Vandana Vidyut	VVNL	400	Reporting
67	BARSOOR	Chhattisgarh	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
68	BHATAPARA	Chhattisgarh	220	Reporting
69	BHILAI	Chhattisgarh	400/220	Reporting
70	BILASPUR	Chhattisgarh	220	Reporting
71	CHHURRI	Chhattisgarh	220	Not Reporting
72	DHAMDHA	Chhattisgarh	132	Not Reporting
73	DONGARGARH	Chhattisgarh	132	Reporting
74	HASDEO BANGO	Chhattisgarh	132	Reporting
75	KORBA EAST	Chhattisgarh	220/132	Reporting
76	KORBA WEST	Chhattisgarh	400	Reporting
77	KORBA WEST EXT	Chhattisgarh	400	Reporting
78	MARWA TPS	Chhattisgarh	400	Reporting
79	PENDRA	Chhattisgarh	220	Not Reporting
80	RAIGARH	Chhattisgarh	220	Reporting
81	RAITA	Chhattisgarh	400/220	Not Reporting
82	SARAIPALLI	Chhattisgarh	220	Reporting
83	URLA	Chhattisgarh	220	Reporting
84	MAGARWADA	DD	220	Not Reporting
85	KHADOLI	DNH	220	Not Reporting
86	KHARADPADA	DNH	220	Not Reporting
87	AMONA	Goa	220	Not Reporting
88	CUNCOLIM	Goa	220	Not Reporting
89	KADAMBA	Goa	110	Not Reporting
90	PONDA	Goa	220	Not Reporting
91	TIVIM	Goa	220	Not Reporting
92	VERNA	Goa	110	Not Reporting
93	XELDAM	Goa	220	Not Reporting
94	ACHCHHALIA	Gujarat	220	Reporting
95	ADANI	Gujarat	400/220	Reporting
96	AKRIMOTA	Gujarat	220	Reporting
97	AMRELI	Gujarat	400/220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
98	ANJAR	Gujarat	220	Reporting
99	ASOJ	Gujarat	400/220	Reporting
100	BHAT	Gujarat	220	Reporting
101	BHATIA	Gujarat	220	Not Reporting
102	BHILAD	Gujarat	220	Reporting
103	CHANDRAPURA	Gujarat	220	Reporting
104	CHHATRAL	Gujarat	220	Reporting
105	CHITROD	Gujarat	220	Reporting
106	CHORANIA	Gujarat	400/220	Reporting
107	DEODAR	Gujarat	220	Reporting
108	DHANGADHRA	Gujarat	220	Reporting
109	DHANSURA	Gujarat	220	Reporting
110	ESSAR POWER	Gujarat	400/220	Reporting
111	GANDHINAGAR	Gujarat	220	Reporting
112	GAVASAD	Gujarat	220	Reporting
113	GODHARA	Gujarat	220	Reporting
114	GONDAL	Gujarat	220	Reporting
115	GPEC	Gujarat	220	Reporting
116	GSEG HAZIRA	Gujarat	220	Reporting
117	HADALA	Gujarat	400/220	Reporting
118	HALDARVA	Gujarat	220	Reporting
119	ICHCHHAPUR	Gujarat	220	Reporting
120	JAGHADIA	Gujarat	220	Reporting
121	JAMANVAD	Gujarat	220	Reporting
122	JAMBUVA	Gujarat	220	Reporting
123	JAMLA	Gujarat	220	Reporting
124	JAMNAGAR	Gujarat	220	Reporting
125	JETPUR	Gujarat	400/220	Reporting
126	KADANA	Gujarat	220	Reporting
127	KANSARI	Gujarat	400/220	Reporting
128	KAPADWANJ	Gujarat	220	Reporting
129	KARAMSAD	Gujarat	220	Reporting
130	KASOR	Gujarat	400/220	Reporting
131	KESHOD	Gujarat	220	Reporting
132	KHANPUR	Gujarat	220	Reporting
133	KIM	Gujarat	220	Reporting
134	KOSAMBA	Gujarat	400/220	Reporting
135	LIMBDI	Gujarat	220	Reporting
136	MANSAR	Gujarat	400/220	Reporting
137	MEHSANA	Gujarat	220	Reporting
138	MOKHA	Gujarat	220	Not Reporting
139	MORBI	Gujarat	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
140	NAKHATRANA	Gujarat	220	Reporting
141	NANO	Gujarat	220	Reporting
142	NAVSARI	Gujarat	220	Reporting
143	OTHA	Gujarat	220	Reporting
144	PANADHR	Gujarat	220	Reporting
145	RAJKOT	Gujarat	220	Reporting
146	RANASAN	Gujarat	220	Reporting
147	RANAVAV	Gujarat	220	Reporting
148	RANCHODPURA	Gujarat	400	Reporting
149	SACHIN	Gujarat	220	Reporting
150	SALEJADA	Gujarat	220	Reporting
151	SAMI	Gujarat	400	Reporting
152	SANKHARI	Gujarat	220	Reporting
153	SARDAR SAROVAR	Gujarat	400/220	Reporting
154	SAVARKUNDLA	Gujarat	220	Reporting
155	SLPP	Gujarat	220	Reporting
156	SOJA	Gujarat	400/220	Reporting
157	TIMBDI	Gujarat	220	Reporting
158	UKAI(THERMAL)	Gujarat	400/220	Reporting
159	UTRAN	Gujarat	220	Reporting
160	VAPI	Gujarat	220	Reporting
161	VARSANA	Gujarat	400	Reporting
162	VARTEJ	Gujarat	220	Reporting
163	VAV	Gujarat	220	Reporting
164	VIJAPUR	Gujarat	220	Reporting
165	VIRAMGAM	Gujarat	220	Reporting
166	WANAKBORI	Gujarat	400/220	Reporting
167	AMARKANTAK	Madhya Pradesh	220	Reporting
168	ANUPUR	Madhya Pradesh	220	Reporting
169	ASTHA	Madhya Pradesh	132	Reporting
170	BADOD	Madhya Pradesh	220	Reporting
171	BAIRAGARH	Madhya Pradesh	220	Reporting
172	BALAGHAT	Madhya Pradesh	132	Reporting
173	BANMORE	Madhya Pradesh	132	Reporting
174	BANSAGAR-	Madhya Pradesh	220/132	Reporting
175	BANSAGAR II	Madhya	132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
		Pradesh		
176	BARGI	Madhya Pradesh	132	Reporting
177	BARWAHA	Madhya Pradesh	220	Reporting
178	BHOPAL	Madhya Pradesh	400/220	Reporting
179	BINA	Madhya Pradesh	400/220	Reporting
180	BORGAON	Madhya Pradesh	132	Reporting
181	CHHEGAON	Madhya Pradesh	400/220	Reporting
182	CHICHLI	Madhya Pradesh	220	Not Reporting
183	CHINDWARA	Madhya Pradesh	132	Reporting
184	DALODA	Madhya Pradesh	220	Reporting
185	DAMOH	Madhya Pradesh	220	Reporting
186	DEWAS	Madhya Pradesh	220/132	Reporting
187	DHAR	Madhya Pradesh	220	Not Reporting
188	GANDHISAGAR	Madhya Pradesh	132	Reporting
189	GUNA	Madhya Pradesh	220	Reporting
190	GWALIOR	Madhya Pradesh	220	Reporting
191	HANDIA	Madhya Pradesh	220	Reporting
192	INDORE	Madhya Pradesh	400	Reporting
193	INDORE(CHL)	Madhya Pradesh	132	Reporting
194	INDOREEAST	Madhya Pradesh	220	Reporting
195	INDORENZ	Madhya Pradesh	220	Reporting
196	ISP	Madhya Pradesh	400	Reporting
197	ITARSI	Madhya	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
		Pradesh		
198	JABALPUR	Madhya Pradesh	400/220	Reporting
199	JULWANIA	Madhya Pradesh	400/220	Reporting
200	KATNI	Madhya Pradesh	400/220	Reporting
201	MALANPUR	Madhya Pradesh	220	Reporting
202	MARIKHEDA HPS	Madhya Pradesh	132	Reporting
203	MEHGAON	Madhya Pradesh	220	Reporting
204	MORWA	Madhya Pradesh	132	Reporting
205	NAGDA	Madhya Pradesh	400/220	Reporting
206	NARSINGPUR	Madhya Pradesh	132	Reporting
207	NEEMUCH	Madhya Pradesh	220	Reporting
208	NEPANAGAR	Madhya Pradesh	220	Reporting
209	OMKARESHWAR	Madhya Pradesh	220	Reporting
210	PANAGAR	Madhya Pradesh	220	Not Reporting
211	PANDURNA	Madhya Pradesh	220	Reporting
212	PENCH	Madhya Pradesh	132	Reporting
213	PIPARIYA	Madhya Pradesh	132	Reporting
214	PITAMPURA	Madhya Pradesh	400/220	Reporting
215	RAJGARH	Madhya Pradesh	220	Reporting
216	RAJGARH(BEORA)	Madhya Pradesh	220	Reporting
217	RAJGHAT HPS	Madhya Pradesh	132	Reporting
218	RATLAM	Madhya Pradesh	220	Reporting
219	SARNI	Madhya	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
		Pradesh		
220	SATNA	Madhya Pradesh	220/132	Reporting
221	SATPURA	Madhya Pradesh	400	Reporting
222	SEONI	Madhya Pradesh	132	Reporting
223	SGTPS	Madhya Pradesh	220	Reporting
224	SHAJAPUR	Madhya Pradesh	132	Reporting
225	SHUJALPUR	Madhya Pradesh	220	Reporting
226	SINGHAJI	Madhya Pradesh	400	Reporting
227	TIKAMGARH	Madhya Pradesh	220	Reporting
228	UJJAIN	Madhya Pradesh	220	Reporting
229	AAREY	Maharashtra	220	Reporting
230	AHMEDNAGAR	Maharashtra	220	Reporting
231	AKOLA	Maharashtra	400	Reporting
232	AKOLA ADANI	Maharashtra	765	Reporting
233	AKOLA1	Maharashtra	220	Reporting
234	AKOLA2	Maharashtra	765	Reporting
235	ALEPHENTA	Maharashtra	220	Reporting
236	AMALNER	Maharashtra	220	Reporting
237	AMBAZARY	Maharashtra	220	Reporting
238	AMRAVATI	Maharashtra	220	Reporting
239	APTA	Maharashtra	220	Not Reporting
240	AURANGABAD	Maharashtra	400/220	Reporting
241	AURANGABAD3	Maharashtra	220	Reporting
242	BABLESHWAR2	Maharashtra	400	Reporting
243	BACKBAY	Maharashtra	220	Reporting
244	BADNERA	Maharashtra	220	Reporting
245	BARAMATI	Maharashtra	220	Reporting
246	BEED	Maharashtra	220	Reporting
247	BHANDARDARA	Maharashtra	132	Reporting
248	BHANDARDARA	Maharashtra	220	Reporting
249	BHIRA TAILRACE	Maharashtra	220	Not Reporting
250	BHUGAON	Maharashtra	220	Reporting
251	BHUSAWAL1	Maharashtra	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
252	BHUSAWAL2	Maharashtra	132	Reporting
253	BHUSAWAL3	Maharashtra	400/220	Reporting
254	BOISAR	Maharashtra	220	Reporting
255	BOMBAYDYENIG	Maharashtra	220	Not Reporting
256	BORIVLI	Maharashtra	220	Reporting
257	BOSARY	Maharashtra	220	Reporting
258	BUTIBORI	Maharashtra	220	Not Reporting
259	CARNAC	Maharashtra	220	Reporting
260	CHAKAN	Maharashtra	400	Reporting
261	CHALISGAON	Maharashtra	220	Reporting
262	CHANDRAPUR	Maharashtra	220	Reporting
263	CHIKHALI	Maharashtra	220	Reporting
264	CHITEGAON	Maharashtra	220	Reporting
265	COLORCHEM	Maharashtra	220	Not Reporting
266	DABHOL	Maharashtra	220	Reporting
267	DAHANU	Maharashtra	220	Reporting
268	DEEPNAGAR	Maharashtra	400	Not Reporting
269	DHAMANGAON	Maharashtra	220	Reporting
270	DHARAVI	Maharashtra	220	Reporting
271	DHARIWAL	Maharashtra	400	Not Reporting
272	DHULE	Maharashtra	400/220	Reporting
273	Dhule1	Maharashtra	220	Reporting
274	Dombivali	Maharashtra	220	Reporting
275	Dondaicha	Maharashtra	220	Not Reporting
276	Gadchandur	Maharashtra	220	Reporting
277	Ghatghar	Maharashtra	220	Not Reporting
278	Ghatnandre	Maharashtra	220	Not Reporting
279	GHODBUNDER	Maharashtra	220	Reporting
280	Halkarni	Maharashtra	220	Not Reporting
281	Harangul	Maharashtra	220	Not Reporting
282	Harsool	Maharashtra	132	Not Reporting
283	Hinjewadi	Maharashtra	220	Reporting
284	IB AMRAWATI	Maharashtra	400	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
285	IB NASHIK	Maharashtra	400	Not Reporting
286	Ichalkaranji	Maharashtra	220	Reporting
287	JAIGAD	Maharashtra	400	Reporting
288	Jalana	Maharashtra	220	Not Reporting
289	Jamde	Maharashtra	220	Not Reporting
290	JEJURI	Maharashtra	400	Not Reporting
291	Jejuri1	Maharashtra	220	Reporting
292	JEJURY	Maharashtra	220	Reporting
293	Jeur	Maharashtra	220	Reporting
294	KALAMSAR	Maharashtra	220	Not Reporting
295	KALWA1	Maharashtra	220	Not Reporting
296	KALWA2	Maharashtra	400/220	Reporting
297	KALWA2	Maharashtra	220	Reporting
298	Kamba	Maharashtra	220	Reporting
299	KANHAN	Maharashtra	220	Reporting
300	KARAD1	Maharashtra	220	Reporting
301	KARGAR	Maharashtra	400	Reporting
302	Kawalewada	Maharashtra	220	Not Reporting
303	KDPH	Maharashtra	220	Reporting
304	KHAPARKHEDA2	Maharashtra	400/220	Not Reporting
305	Kharepatan	Maharashtra	220	Reporting
306	KOLHAPUR2	Maharashtra	400	Reporting
307	KOLHAPUR3	Maharashtra	220	Reporting
308	Kolshet	Maharashtra	220	Not Reporting
309	KORADI	Maharashtra	400	Reporting
310	KORADI ADANI	Maharashtra	765	Reporting
311	KORADY	Maharashtra	220	Reporting
312	KOYN1N2	Maharashtra	400	Not Reporting
313	KOYNA	Maharashtra	220	Reporting
314	KOYNA3	Maharashtra	400	Not Reporting
315	KOYNAN	Maharashtra	220	Reporting
316	KUNDALGAON	Maharashtra	220	Not Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
317	Kurkumbh	Maharashtra	220	Reporting
318	Latur	Maharashtra	132	Not Reporting
319	LONIKHAND	Maharashtra	400	Reporting
320	LONIKHAND2	Maharashtra	400	Not Reporting
321	Mahad	Maharashtra	220	Not Reporting
322	Mahape	Maharashtra	220	Reporting
323	Malegaon	Maharashtra	220	Reporting
324	Malharpeth	Maharashtra	220	Not Reporting
325	Malinagar	Maharashtra	220	Reporting
326	Malkapur	Maharashtra	132	Reporting
327	Manmad	Maharashtra	132	Not Reporting
328	MIRAJ	Maharashtra	220	Reporting
329	MULUND	Maharashtra	220	Reporting
330	Mumewadi	Maharashtra	220	Not Reporting
331	Murud	Maharashtra	220	Reporting
332	NAGOTHANE	Maharashtra	400	Not Reporting
333	NANDED	Maharashtra	220	Reporting
334	Nandurbar	Maharashtra	132	Not Reporting
335	NASIK	Maharashtra	220	Not Reporting
336	NERUL	Maharashtra	220	Reporting
337	Osmanabad	Maharashtra	220	Reporting
338	Pachora	Maharashtra	132	Reporting
339	PADGHE	Maharashtra	400	Reporting
340	PADGHE	Maharashtra	220	Reporting
341	Paithan	Maharashtra	132	Not Reporting
342	Pandharpur	Maharashtra	220	Reporting
343	PARAS	Maharashtra	220	Not Reporting
344	Paras Extn	Maharashtra	220	Reporting
345	PARBHANI	Maharashtra	132	Reporting
346	PARLY1	Maharashtra	220	Reporting
347	PARLY2	Maharashtra	400/220	Reporting
348	Parvati	Maharashtra	220	Reporting
349	Pathardi	Maharashtra	132	Not

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
				Reporting
350	Peth	Maharashtra	220	Reporting
351	Phursungi	Maharashtra	220	Reporting
352	Purti	Maharashtra	220	Not Reporting
353	PUSAD	Maharashtra	220	Not Reporting
354	Ranjangaon	Maharashtra	220	Reporting
355	Raymonds	Maharashtra	220	Reporting
356	Sahada	Maharashtra	220	Not Reporting
357	Sakari	Maharashtra	132	Reporting
358	SALSET	Maharashtra	220	Reporting
359	Satana	Maharashtra	220	Reporting
360	SATARA	Maharashtra	220	Reporting
361	Sawantwadi	Maharashtra	220	Not Reporting
362	SOLAPUR	Maharashtra	400/220	Reporting
363	SOLAPUR3	Maharashtra	220	Reporting
364	Supa	Maharashtra	132	Reporting
365	Taloja	Maharashtra	220	Not Reporting
366	TAPTITANDA	Maharashtra	400	Reporting
367	Temghar	Maharashtra	220	Not Reporting
368	THEUR	Maharashtra	220	Reporting
369	TILLARY	Maharashtra	220	Not Reporting
370	TIRODA	Maharashtra	765/400	Reporting
371	TROMBAY	Maharashtra	220	Reporting
372	TROMBAY	Maharashtra	220	Reporting
373	URAN	Maharashtra	220	Reporting
374	Urse	Maharashtra	220	Reporting
375	VAITARNA	Maharashtra	220	Not Reporting
376	Valve	Maharashtra	220	Not Reporting
377	Vankuswadi	Maharashtra	220	Not Reporting
378	VERSOVA	Maharashtra	220	Reporting
379	VITA	Maharashtra	220	Not Reporting
380	Wada	Maharashtra	220	Reporting
381	WARDHA	Maharashtra	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
382	WARORA	Maharashtra	400	Not Reporting
383	Yeldari	Maharashtra	132	Not Reporting

List of RTUs in Southern Region

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
1	Arasur 400	Central Sector	400	Reporting
2	Bhadrawati 400 (WR Station)	Central Sector	400	Reporting
3	BIDADI SAS	Central Sector	400	Reporting
4	Chinakampally 400	Central Sector	400	Reporting
5	Coastal Energy	Central Sector	400	Reporting
6	Gazuwaka 400	Central Sector	400	Reporting
7	Ghanapur 400	Central Sector	400	Reporting
8	Gooty 400	Central Sector	400	Reporting
9	Hassan 400	Central Sector	400	Reporting
10	Hiriyur 400	Central Sector	400	Reporting
11	Hosur 400	Central Sector	400	Reporting
12	IL&FS generating station	Central Sector	400	Reporting
13	Kaiga APP 220	Central Sector	220	Reporting
14	Kalivantapattu 400	Central Sector	400	Reporting
15	Kalpakkam 230	Central Sector	230	Reporting
16	Karaikudi	Central Sector	400	Reporting
17	Kayamkulam 220	Central Sector	220	Reporting
18	Khammam 400	Central Sector	400	Reporting
19	Kochi	Central Sector	400	Reporting
20	Kolar AC Station	Central Sector	400	Reporting
21	Kolar HVDC RCI	Central Sector	400	Reporting
22	Kudankulam 400	Central Sector	400	Reporting
23	Kurnool765	Central Sector	765	Reporting
24	Lanco IPP	Central Sector	400	Reporting
25	Madurai 400	Central Sector	400	Reporting
26	Meenakshi Genr. Stn.	Central Sector	400	Reporting
27	Munirabad 400	Central Sector	400	Reporting
28	Mysore 400 RCI	Central Sector	400	Reporting
29	Narendra 400	Central Sector	400	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
30	Nellore 400	Central Sector	400	Reporting
31	Nellore Pooling Station	Central Sector	400	Reporting
32	Nellore SAS	Central Sector	400	Reporting
33	Nelmangala	Central Sector	400	Reporting
34	Neyveli TS2 Exp	Central Sector	400	Reporting
35	Neyveli TS-I Extn.	Central Sector	400	Reporting
36	Neyveli TS-II	Central Sector	400	Reporting
37	NTPL	Central Sector	400	Reporting
38	Palakkad 400	Central Sector	400	Reporting
39	Puducherry 400 S/s	Central Sector	400	Reporting
40	Pugalur	Central Sector	400	Reporting
41	Raichur765	Central Sector	765	Reporting
42	Ramagundam 400	Central Sector	400	Reporting
43	Salem 400	Central Sector	400	Reporting
44	Simhadri Stg 2	Central Sector	400	Reporting
45	Simhapuri genr. Stn.	Central Sector	400	Reporting
46	Somanahalli 400	Central Sector	400	Reporting
47	Sriperumbudur 400	Central Sector	400	Reporting
48	Talcher HVDC RCI	Central Sector	400	Reporting
49	Tallapally 400	Central Sector	400	Reporting
50	Thermal PowerTech (TPCIL)	Central Sector	400	Reporting
51	Thiruvalam 765	Central Sector	765	Reporting
52	Tirunelveli 400	Central Sector	400	Reporting
53	Trichur North 400	Central Sector	400	Reporting
54	Trichy 400	Central Sector	400	Reporting
55	Trivandrum 400	Central Sector	400	Reporting
56	Tutikorin Pooling Station	Central Sector	400	Reporting
57	Udumalpet 400	Central Sector	400	Reporting
58	Vallur generating station	Central Sector	400	Reporting
59	Vijayawada 400	Central Sector	400	Reporting
60	Warangal	Central Sector	400	Reporting
61	Yelankha 400 S/s	Central Sector	400	Reporting
62	A.P. Carbides	Andhra Pradesh	220	Reporting
63	Ananthapur	Andhra Pradesh	220	Reporting
64	Anrak	Andhra Pradesh	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
65	Bandlaguda 132	Andhra Pradesh	132	Reporting
66	Bhimadole	Andhra Pradesh	220	Reporting
67	Bhimgal	Andhra Pradesh	220	Reporting
68	Bhongir	Andhra Pradesh	220	Reporting
69	Bilakalabudur	Andhra Pradesh	220	Reporting
70	Bommur	Andhra Pradesh	220	Reporting
71	BSES	Andhra Pradesh	220	Reporting
72	BSES	Andhra Pradesh	220	Reporting
73	CH Gutta	Andhra Pradesh	220	Reporting
74	Chellakurthy	Andhra Pradesh	220	Reporting
75	Chilakallu	Andhra Pradesh	220	Reporting
76	Chinakampalli	Andhra Pradesh	220	Reporting
77	Chitoor 220	Andhra Pradesh	220	Reporting
78	Chittoor 400	Andhra Pradesh	400	Reporting
79	Cuddapah 220	Andhra Pradesh	220	Reporting
80	Dairy Farm 220	Andhra Pradesh	220	Reporting
81	Dhone SWS	Andhra Pradesh	220	Reporting
82	Dichpally 220	Andhra Pradesh	220	Reporting
83	Ditchpalli 400	Andhra Pradesh	400	Reporting
84	Durshed	Andhra Pradesh	220	Reporting
85	Emul	Andhra Pradesh	220	Reporting
86	Erragada	Andhra Pradesh	132	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
87	Gachibowli	Andhra Pradesh	220	Reporting
88	Gajwel	Andhra Pradesh	400	Reporting
89	Gandikota 132kV	Andhra Pradesh	132	Reporting
90	Garividi	Andhra Pradesh	200	Reporting
91	Gazuwaka	Andhra Pradesh	220	Reporting
92	Ghanapur	Andhra Pradesh	220	Reporting
93	Girija 220kV	Andhra Pradesh	220	Reporting
94	GMR	Andhra Pradesh	400	Reporting
95	GMR Barge	Andhra Pradesh	220	Reporting
96	Gooty 220	Andhra Pradesh	220	Reporting
97	Gooty SWS	Andhra Pradesh	220	Reporting
98	GOUTAMI	Andhra Pradesh	400	Reporting
99	Gowtami	Andhra Pradesh	400	Reporting
100	GUDIWADA	Andhra Pradesh	220	Reporting
101	Gudiwada	Andhra Pradesh	220	Reporting
102	Gunadala	Andhra Pradesh	220	Reporting
103	Gunrock 132	Andhra Pradesh	132	Reporting
104	GVK400	Andhra Pradesh	400	Reporting
105	GVK-II	Andhra Pradesh	400	Reporting
106	Hampi PH	Andhra Pradesh	132	Reporting
107	Hetero 132kV	Andhra Pradesh	132	Reporting
108	HIAL	Andhra Pradesh	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
109	Hindupur	Andhra Pradesh	220	Reporting
110	Jagitial	Andhra Pradesh	220	Reporting
111	Jagityal	Andhra Pradesh	220	Reporting
112	Jeegurupadu PH	Andhra Pradesh	220	Reporting
113	JP Cements 132kV	Andhra Pradesh	132	Reporting
114	Jubilee Hills	Andhra Pradesh	132	Reporting
115	Jurala 220	Andhra Pradesh	220	Reporting
116	K.Kota	Andhra Pradesh	220	Reporting
117	Kakatiya Thermal	Andhra Pradesh	400	Reporting
118	Kakinada SS	Andhra Pradesh	220	Reporting
119	Kalapakka	Andhra Pradesh	400	Reporting
120	Kalikiri	Andhra Pradesh	220	Reporting
121	Kalwakurthy	Andhra Pradesh	220	Reporting
122	Kalwakurthy SWS	Andhra Pradesh	220	Reporting
123	Kalyandurg 220	Andhra Pradesh	220	Reporting
124	Kandi 132	Andhra Pradesh	132	Reporting
125	Khammam - B	Andhra Pradesh	220	Reporting
126	KMPally	Andhra Pradesh	220	Reporting
127	Kodur 220	Andhra Pradesh	220	Reporting
128	Konasema	Andhra Pradesh	400	Reporting
129	KONASEMA	Andhra Pradesh	400	Reporting
130	Kondapalli	Andhra Pradesh	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
131	Kottur 132	Andhra Pradesh	132	Reporting
132	Krishnapatnam 400kV	Andhra Pradesh	400	Reporting
133	KTPS	Andhra Pradesh	220	Reporting
134	KTPS VI	Andhra Pradesh	400	Reporting
135	KTPS Vth stage	Andhra Pradesh	220	Reporting
136	KTPS-V	Andhra Pradesh	400	Reporting
137	Kurnool	Andhra Pradesh	400	Reporting
138	LANCO	Andhra Pradesh	220	Reporting
139	Local RTU	Andhra Pradesh	--NA--	Reporting
140	Lower Sileru	Andhra Pradesh	220	Reporting
141	Machkund	Andhra Pradesh	132	Reporting
142	Mahaboob Nagar	Andhra Pradesh	220	Reporting
143	Mahaboobnagar 400 RCI (Vellatoor)	Andhra Pradesh	400	Reporting
144	Malkaram	Andhra Pradesh	220	Reporting
145	Malkaram 400	Andhra Pradesh	400	Reporting
146	Mamidapally 400	Andhra Pradesh	400	Reporting
147	Manugur	Andhra Pradesh	220	Reporting
148	Marakapur	Andhra Pradesh	220	Reporting
149	Markapur	Andhra Pradesh	220	Reporting
150	Medchal	Andhra Pradesh	132	Reporting
151	Minpur	Andhra Pradesh	220	Reporting
152	Miryalaguda	Andhra Pradesh	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
153	Moulali	Andhra Pradesh	220	Reporting
154	My Home Power Plant 132kV	Andhra Pradesh	132	Reporting
155	Mydukur	Andhra Pradesh	220	Reporting
156	N' Sagar LCPH	Andhra Pradesh	132	Reporting
157	N' Sagar PH	Andhra Pradesh	220	Reporting
158	N' Sagar RCPH	Andhra Pradesh	132	Reporting
159	Nandyal	Andhra Pradesh	220	Reporting
160	Narasaraopeta	Andhra Pradesh	220	Reporting
161	Narketpalli	Andhra Pradesh	220	Reporting
162	Navabharat 220kV	Andhra Pradesh	220	Reporting
163	Nelloor 400	Andhra Pradesh	400	Reporting
164	Nellore 220	Andhra Pradesh	220	Reporting
165	Nidadhavolu 132	Andhra Pradesh	132	Reporting
166	Nidadhavolu 220KV SS	Andhra Pradesh	220	Reporting
167	Nirmal	Andhra Pradesh	220	Reporting
168	NTS (presently shifted to Shamshabad under Mamidipally SLDC - under integration)	Andhra Pradesh	--NA--	Reporting
169	Ongole	Andhra Pradesh	220	Reporting
170	Orient Cements 132kV	Andhra Pradesh	132	Reporting
171	Palamner 220	Andhra Pradesh	220	Reporting
172	Paruchiri 220	Andhra Pradesh	220	Reporting
173	PARWAD	Andhra Pradesh	220	Reporting
174	Peddapuram	Andhra	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
		Pradesh		
175	Pendurthy	Andhra Pradesh	220	Reporting
176	Podili	Andhra Pradesh	220	Reporting
177	Pratapnagar 132kV	Andhra Pradesh	132	Reporting
178	Pulivendala	Andhra Pradesh	220	Reporting
179	R.C.Puram	Andhra Pradesh	132	Reporting
180	Rachagunneri 220kV	Andhra Pradesh	220	Reporting
181	Raghunathpally	Andhra Pradesh	132	Reporting
182	Rajampet	Andhra Pradesh	220	Reporting
183	Ramagiri 220/33	Andhra Pradesh	220	Reporting
184	Ramagundam(Malayalapally)	Andhra Pradesh	220	Reporting
185	Rampachodavaram	Andhra Pradesh	220	Reporting
186	Rayala Wind Power 220kV	Andhra Pradesh	220	Reporting
187	RCI wind power 220kV	Andhra Pradesh	220	Reporting
188	Renigunta	Andhra Pradesh	220	Reporting
189	Rentachintala	Andhra Pradesh	220	Reporting
190	RTPP	Andhra Pradesh	220	Reporting
191	RTS - B	Andhra Pradesh	132	Reporting
192	RTU_CMC St	Andhra Pradesh	220	Reporting
193	RTU_MED220	Andhra Pradesh	220	Reporting
194	Samarlakota	Andhra Pradesh	220	Reporting
195	sarda	Andhra Pradesh	220	Reporting
196	Sattenapally 400kV	Andhra	400	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
		Pradesh		
197	ShadNagar	Andhra Pradesh	220	Reporting
198	Shamshabad	Andhra Pradesh	220	Reporting
199	Shankarpally	Andhra Pradesh	400	Reporting
200	Shapuram	Andhra Pradesh	220	Reporting
201	Shapurnagar	Andhra Pradesh	220	Reporting
202	ShivaramPalli	Andhra Pradesh	220	Reporting
203	Siddipet	Andhra Pradesh	220	Reporting
204	Simhadhri	Andhra Pradesh	400	Reporting
205	Sitarampatnam	Andhra Pradesh	220	Reporting
206	Somayajulapalli	Andhra Pradesh	220	Reporting
207	Spectrum	Andhra Pradesh	220	Reporting
208	Srisailam LBPH	Andhra Pradesh	400	Reporting
209	Srisailam PH	Andhra Pradesh	220	Reporting
210	Sullurpet	Andhra Pradesh	220	Reporting
211	Tadikonda 220KV	Andhra Pradesh	220	Reporting
212	Tadipatri 220	Andhra Pradesh	220	Reporting
213	Tadipet	Andhra Pradesh	--NA--	Reporting
214	Tallapally	Andhra Pradesh	220	Reporting
215	Tandur 220 KV	Andhra Pradesh	220	Reporting
216	Tekkali	Andhra Pradesh	220	Reporting
217	Undi (Bheemavaram)	Andhra Pradesh	220	Reporting
218	Upper Sileru	Andhra	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
		Pradesh		
219	Vemagiri 400	Andhra Pradesh	400	Reporting
220	Vijaywada	Andhra Pradesh	220	Reporting
221	Vijjeswaram	Andhra Pradesh	220	Reporting
222	Visakhapatanam SWS	Andhra Pradesh	220	Reporting
223	VTPS	Andhra Pradesh	220	Reporting
224	VTPS400	Andhra Pradesh	400	Reporting
225	VVB	Andhra Pradesh	220	Reporting
226	Wadekothapally	Andhra Pradesh	220	Reporting
227	Wanaparthy	Andhra Pradesh	220	Reporting
228	Warangal	Andhra Pradesh	220	Reporting
229	Yeddumailaram	Andhra Pradesh	220	Reporting
230	Yerraguntla	Andhra Pradesh	220	Reporting
231	Alipur (Bellary)	Karnataka	220	Reporting
232	Almatti Generating Station	Karnataka	220	Reporting
233	Almatty 220	Karnataka	220	Reporting
234	Ambewadi	Karnataka	220	Reporting
235	Anchepalya 220	Karnataka	220	Reporting
236	Antharasanahalli	Karnataka	220	Reporting
237	Athani	Karnataka	220	Reporting
238	Bagalkot 220	Karnataka	220	Reporting
239	BANAVIKAL 66 KV	Karnataka	66	Reporting
240	Basavana Bagewadi	Karnataka	220	Reporting
241	Begur	Karnataka	220	Reporting
242	Belgam 220 KV	Karnataka	220	Reporting
243	Bhadra	Karnataka	66	Reporting
244	Bidadi	Karnataka	220	Reporting
245	Bijapur	Karnataka	220	Reporting
246	BMMISPAT	Karnataka	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
247	Bng.Metro East Division	Karnataka	220	Reporting
248	Bng.Metro Naganathpura	Karnataka	220	Reporting
249	Bng.Metro Sarjapura	Karnataka	220	Reporting
250	BTPS 220 kV	Karnataka	220	Reporting
251	BTPS 400 kV	Karnataka	400	Reporting
252	Chamrajnagar 220	Karnataka	220	Reporting
253	CHIKAMANGALORE	Karnataka	220	Reporting
254	CHIKKAGANGANAWADI 66KV	Karnataka	66	Reporting
255	Chikkamangalur 220	Karnataka	220	Reporting
256	Chikkodi	Karnataka	220	Reporting
257	Chinthamani 220	Karnataka	220	Reporting
258	Chitradurga 220	Karnataka	220	Reporting
259	CHORNUR 66 KV	Karnataka	66	Reporting
260	CR Patnnam	Karnataka	220	Reporting
261	D. G. Plant (Yelahanka)	Karnataka	66	Reporting
262	Dabuspet	Karnataka	220	Reporting
263	Davangere 220 KV	Karnataka	220	Reporting
264	Devanahalli 220	Karnataka	220	Reporting
265	DHRUVDESH	Karnataka	220	Reporting
266	Doddaballapur	Karnataka	220	Reporting
267	EPIP	Karnataka	220	Reporting
268	Gadag	Karnataka	220	Reporting
269	Ghatprabha	Karnataka	110	Reporting
270	GHATPRABHA	Karnataka	220	Reporting
271	Gopalpura	Karnataka	220	Reporting
272	Gowribidanur 220 KV	Karnataka	220	Reporting
273	Guttur (Davangere)	Karnataka	220	Reporting
274	HAL	Karnataka	220	Reporting
275	HALBURGA	Karnataka	220	Reporting
276	HANUMANTHANAGAR 66 KV	Karnataka	66	Reporting
277	HARTI	Karnataka	220	Reporting
278	Hassan	Karnataka	220	Reporting
279	Haveri 220 KV	Karnataka	220	Reporting
280	Hebbal	Karnataka	220	Reporting
281	Hiriyur 220 KV	Karnataka	220	Reporting
282	Honnali	Karnataka	220	Reporting
283	Hoody 220/400 KV	Karnataka	400	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
284	Hootagalli (Mysore) 220 KV	Karnataka	220	Reporting
285	Hoskote	Karnataka	220	Reporting
286	HSR Layout	Karnataka	220	Reporting
287	Hubli 220 KV	Karnataka	220	Reporting
288	Humnabad	Karnataka	220	Reporting
289	HUNASENAHALLI 66KV	Karnataka	66	Reporting
290	Indi	Karnataka	220	Reporting
291	Itagi (Hagari Bommanahalli)	Karnataka	220	Reporting
292	Jindal IPP	Karnataka	220	Reporting
293	Jog GS (MGHE)	Karnataka	110	Reporting
294	Kadakola	Karnataka	220	Reporting
295	Kadra	Karnataka	220	Reporting
296	Kadur	Karnataka	220	Reporting
297	KAIDB	Karnataka	220	Reporting
298	Kanakpura	Karnataka	220	Reporting
299	Kapnur	Karnataka	220	Reporting
300	Karwar	Karnataka	220	Reporting
301	Kavoor 220 KV	Karnataka	220	Reporting
302	KEMAR 220	Karnataka	220	Reporting
303	Kibbanahalli Cross	Karnataka	220	Reporting
304	Kodasalli	Karnataka	220	Reporting
305	Kolar 220	Karnataka	220	Reporting
306	Kollegal	Karnataka	220	Reporting
307	KRPET	Karnataka	220	Reporting
308	Kuduchi	Karnataka	220	Reporting
309	Kushtagi	Karnataka	220	Reporting
310	Linganamakki LPH	Karnataka	110	Reporting
311	Lingapur 220	Karnataka	220	Reporting
312	Lingasugur	Karnataka	220	Reporting
313	M.K.Hubli 220	Karnataka	220	Reporting
314	Madhunahalli 220	Karnataka	220	Reporting
315	Madugiri	Karnataka	220	Reporting
316	Mahalingapur	Karnataka	220	Reporting
317	Malur 220	Karnataka	220	Reporting
318	Mangalore	Karnataka	220	Reporting
319	MKHUBLI	Karnataka	220	Reporting
320	Munirabad GS	Karnataka	110	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
321	N.R.S. (Bangalore)	Karnataka	220	Reporting
322	Nagjhari	Karnataka	220	Reporting
323	Narendra 220	Karnataka	220	Reporting
324	NEELGUNDA	Karnataka	220	Reporting
325	Nelamangala 400	Karnataka	400	Reporting
326	NELLGUNDA	Karnataka	220	Reporting
327	NIMHANS	Karnataka	220	Reporting
328	Nittur 220	Karnataka	220	Reporting
329	Peenya 220	Karnataka	220	Reporting
330	Puttur	Karnataka	220	Reporting
331	Raichur 220	Karnataka	220	Reporting
332	Ranibennur 220	Karnataka	220	Reporting
333	Rayalseema IPP	Karnataka	110	Reporting
334	RTPS	Karnataka	400	Reporting
335	Sahapur	Karnataka	220	Reporting
336	Sedam	Karnataka	220	Reporting
337	Shahabad 220	Karnataka	220	Reporting
338	Sharavathy	Karnataka	220	Reporting
339	Shimoga 220	Karnataka	220	Reporting
340	Shiralkoppa	Karnataka	220	Reporting
341	Shivashamudram	Karnataka	66	Reporting
342	Sindhnaur	Karnataka	220	Reporting
343	Somanahalli 220	Karnataka	220	Reporting
344	Soundatti	Karnataka	220	Reporting
345	STRP	Karnataka	220	Reporting
346	Subramanyapura 220 KV	Karnataka	220	Reporting
347	Supa GS	Karnataka	110	Reporting
348	T.K. Halli	Karnataka	220	Reporting
349	Talaguppa 400	Karnataka	400	Reporting
350	Tallak	Karnataka	220	Reporting
351	Tata Power House IPP	Karnataka	110	Reporting
352	THIMMASANDRA 66 KV	Karnataka	66	Reporting
353	THYAMAGONDLU 66 KV	Karnataka	66	Reporting
354	Tubinkere	Karnataka	220	Reporting
355	UPCl	Karnataka	220	Reporting
356	Vajamangala 220	Karnataka	220	Reporting
357	Vajramati	Karnataka	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
358	Varahi	Karnataka	220	Reporting
359	Vrishbhavti(V. valley)	Karnataka	220	Reporting
360	Yerandahalli 220	Karnataka	220	Reporting
361	Arikode 220	Kerala	220	Reporting
362	Brahmapuram 220	Kerala	220	Reporting
363	BSES IPP	Kerala	220	Reporting
364	Chalakudy 110	Kerala	110	Reporting
365	Edamon 220	Kerala	220	Reporting
366	Edappon 220	Kerala	220	Reporting
367	Idamalayar 110	Kerala	110	Reporting
368	Idukki 220	Kerala	220	Reporting
369	Kakkad 110	Kerala	110	Reporting
370	Kalamassery 220	Kerala	220	Reporting
371	Kanhirode 220	Kerala	220	Reporting
372	Kaniampetta 220	Kerala	220	Reporting
373	Kanjikode 220	Kerala	220	Reporting
374	Kozhikode 220	Kerala	220	Reporting
375	Kundara 220	Kerala	220	Reporting
376	Kuttiady 110	Kerala	110	Reporting
377	Lower Periyar 220	Kerala	220	Reporting
378	Madakkathara 400/220	Kerala	400	Reporting
379	Malaparamba 220	Kerala	220	Reporting
380	Manjeswaram 110	Kerala	110	Reporting
381	MLPB	Kerala	220	Reporting
382	Mylatty 220	Kerala	220	Reporting
383	Neriamangalam 110	Kerala	110	Reporting
384	Pallivasal 66	Kerala	66	Reporting
385	Pallom 220	Kerala	220	Reporting
386	Parasala 110	Kerala	110	Reporting
387	Poringalkuttu 110	Kerala	110	Reporting
388	Pothencode 220	Kerala	220	Reporting
389	Punnapra 220	Kerala	220	Reporting
390	Sabarigiri 220	Kerala	220	Reporting
391	Sengulam 110	Kerala	110	Reporting
392	Sholayar 110	Kerala	110	Reporting
393	Shornur 220	Kerala	220	Reporting
394	Thaliparamba 220 KV	Kerala	220	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
395	Bahour 110/22 KV	Puducherry	110	Reporting
396	Bahour 230 KV	Puducherry	230	Reporting
397	Eripakkam 110/22 KV	Puducherry	110	Reporting
398	Kalapet 110/22 KV	Puducherry	110	Reporting
399	Karaikal 110/11 KV	Puducherry	110	Reporting
400	Korkadu 110/22 KV	Puducherry	110	Reporting
401	Kurumbapet 110/22 KV	Puducherry	110	Reporting
402	Mahe 110/11 KV	Puducherry	110	Reporting
403	Marapallam 110 /22/11 KV	Puducherry	110	Reporting
404	Pillaitheruvasal 110/11KV	Puducherry	110	Reporting
405	Sedarapet	Puducherry	110	Reporting
406	T.R.Pattanam 110/11 KV	Puducherry	110	Reporting
407	Thethampakkam 110/22 KV	Puducherry	110	Reporting
408	Thirubhuvani 110 KV	Puducherry	110	Reporting
409	Thondattham	Puducherry	230	Reporting
410	Vallianur 230/110 KV	Puducherry	230	Reporting
411	Yanam 132/11 KV	Puducherry	132	Reporting
412	Aanikadavu 230	Tamil Nadu	230	Reporting
413	Aban	Tamil Nadu	110	Reporting
414	Acharapakkam	Tamil Nadu	230	Reporting
415	Alamathy	Tamil Nadu	400	Reporting
416	Aliyar PH	Tamil Nadu	110	Reporting
417	Aliyar230	Tamil Nadu	230	Reporting
418	Amudhapuram 230	Tamil Nadu	230	Reporting
419	Arasur	Tamil Nadu	230	Reporting
420	Arkay CPP	Tamil Nadu	110	Reporting
421	Arkay IPP (Penna)	Tamil Nadu	110	Reporting
422	Arni	Tamil Nadu	230	Reporting
423	ATHIPATTU	Tamil Nadu	230	Reporting
424	Athur 230 (Deviakurchi)	Tamil Nadu	230	Reporting
425	Aurobindo IPP	Tamil Nadu	110	Reporting
426	Basin Bridge	Tamil Nadu	110	Reporting
427	Basin Bridge 230	Tamil Nadu	230	Reporting
428	BSR Micro	Tamil Nadu	110	Reporting
429	Coramandal CPP	Tamil Nadu	110	Reporting
430	Cuddalore	Tamil Nadu	230	Reporting
431	Echangodu	Tamil Nadu	230	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
432	Ennore TPS	Tamil Nadu	230	Reporting
433	EPVN CPP	Tamil Nadu	230	Reporting
434	Erode	Tamil Nadu	110	Reporting
435	GMR PCL IPP	Tamil Nadu	230	Reporting
436	Gobichettypalayam	Tamil Nadu	230	Reporting
437	Gumidipoondi	Tamil Nadu	230	Reporting
438	Hosur	Tamil Nadu	230	Reporting
439	Ingur	Tamil Nadu	230	Reporting
440	Kadamparai PH	Tamil Nadu	230	Reporting
441	Kadaperi	Tamil Nadu	230	Reporting
442	Karaikudi	Tamil Nadu	230	Reporting
443	Karamadi 230/110KV SS	Tamil Nadu	230	Reporting
444	KaramBayam	Tamil Nadu	230	Reporting
445	Kauvery CPP	Tamil Nadu	110	Reporting
446	Kavanoor	Tamil Nadu	--NA--	Reporting
447	Kayathar	Tamil Nadu	230	Reporting
448	Kilpaunk	Tamil Nadu	230	Reporting
449	Kmngalam	Tamil Nadu	230	Reporting
450	Kodaiyar PH2	Tamil Nadu	110	Reporting
451	Kodikurchi	Tamil Nadu	230	Reporting
452	Koratur	Tamil Nadu	230	Reporting
453	Kovilkalappal	Tamil Nadu	110	Reporting
454	Koyambedu	Tamil Nadu	230	Reporting
455	Koyambedu	Tamil Nadu	230	Reporting
456	Kundah PH 1	Tamil Nadu	110	Reporting
457	Kundah PH 2	Tamil Nadu	230	Reporting
458	Kundah PH 3	Tamil Nadu	230	Reporting
459	Kundah PH 4	Tamil Nadu	230	Reporting
460	Kuttalam	Tamil Nadu	110	Reporting
461	Lower Mettur PH3	Tamil Nadu	110	Reporting
462	Madurai 230	Tamil Nadu	230	Reporting
463	Madurai 400	Tamil Nadu	400	Reporting
464	Madurai North (Alagarkoil)	Tamil Nadu	230	Reporting
465	Manali	Tamil Nadu	230	Reporting
466	Mettur Auto SS	Tamil Nadu	230	Reporting
467	Mettur Dam PH	Tamil Nadu	110	Reporting
468	Mettur TPS	Tamil Nadu	230	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
469	Mettur Tunnel PH	Tamil Nadu	230	Reporting
470	Mosur	Tamil Nadu	230	Reporting
471	Moyar	Tamil Nadu	110	Reporting
472	MPCL IPP	Tamil Nadu	110	Reporting
473	MTPS Statge-3	Tamil Nadu	400	Reporting
474	MTPS Stg3	Tamil Nadu	230	Reporting
475	MVTN	Tamil Nadu	230	Reporting
476	Myladuthurai	Tamil Nadu	230	Reporting
477	Mylapore	Tamil Nadu	230	Reporting
478	Mylapore	Tamil Nadu	230	Reporting
479	Nallamannayaickanpatti 230/110KV SS	Tamil Nadu	230	Reporting
480	NCTPS STG2	Tamil Nadu	400	Reporting
481	NCTPS_STG2	Tamil Nadu	400	Reporting
482	Neyveli TS I	Tamil Nadu	230	Reporting
483	NMTPS	Tamil Nadu	230	Reporting
484	OKMBAM	Tamil Nadu	230	Reporting
485	Orgadam	Tamil Nadu	230	Reporting
486	P Chandai	Tamil Nadu	230	Reporting
487	Palladom	Tamil Nadu	230	Reporting
488	Paramkudi	Tamil Nadu	230	Reporting
489	Parsons' Valley	Tamil Nadu	230	Reporting
490	Penna Electrcity IPP	Tamil Nadu	230	Reporting
491	Perambulur	Tamil Nadu	230	Reporting
492	Periyar PH	Tamil Nadu	110	Reporting
493	Ponnapuram	Tamil Nadu	230	Reporting
494	PP Nallur IPP	Tamil Nadu	230	Reporting
495	PSQ	Tamil Nadu	230	Reporting
496	Pudukottai	Tamil Nadu	230	Reporting
497	Pugalur	Tamil Nadu	230	Reporting
498	Pushep	Tamil Nadu	230	Reporting
499	Pykara PH	Tamil Nadu	110	Reporting
500	Regnathpuram	Tamil Nadu	230	Reporting
501	S.R.Pudur	Tamil Nadu	230	Reporting
502	Sadayanpallayam 230	Tamil Nadu	230	Reporting
503	Sai_Regency CPP	Tamil Nadu	100	Reporting
504	Salem 230	Tamil Nadu	230	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
505	Salem 400	Tamil Nadu	400	Reporting
506	Samayapuram	Tamil Nadu	230	Reporting
507	Sanganeri	Tamil Nadu	230	Reporting
508	Sathur (Anuppankulam)	Tamil Nadu	230	Reporting
509	Sembatty	Tamil Nadu	230	Reporting
510	Sembiyam 110 KV	Tamil Nadu	110	Reporting
511	Shoazanganallur230	Tamil Nadu	230	Reporting
512	Sholayar PH 1	Tamil Nadu	110	Reporting
513	Singarapet	Tamil Nadu	230	Reporting
514	SIPCOT	Tamil Nadu	230	Reporting
515	Siruseri 230	Tamil Nadu	230	Reporting
516	SP Koil	Tamil Nadu	230	Reporting
517	SPCL IPP	Tamil Nadu	230	Reporting
518	Sriperumbudur	Tamil Nadu	400	Reporting
519	STCMS IPP	Tamil Nadu	230	Reporting
520	Sterlite CPP	Tamil Nadu	230	Reporting
521	Sungavarchatram 400	Tamil Nadu	400	Reporting
522	Taramani	Tamil Nadu	230	Reporting
523	TCPL IPP	Tamil Nadu	110	Reporting
524	Thanjore	Tamil Nadu	230	Reporting
525	Theni	Tamil Nadu	230	Reporting
526	Thiruchengode	Tamil Nadu	230	Reporting
527	Thiruvalam	Tamil Nadu	230	Reporting
528	Thiruvarur	Tamil Nadu	230	Reporting
529	Thudiyalur	Tamil Nadu	230	Reporting
530	Tondiarpet	Tamil Nadu	230	Reporting
531	Trichy 230	Tamil Nadu	230	Reporting
532	Trichy 400	Tamil Nadu	400	Reporting
533	Tuticorin Auto	Tamil Nadu	230	Reporting
534	Tuticorin TPS	Tamil Nadu	230	Reporting
535	TV Malai	Tamil Nadu	230	Reporting
536	Udaythoor	Tamil Nadu	230	Reporting
537	Udumalpet 230	Tamil Nadu	230	Reporting
538	Udumalpet 400	Tamil Nadu	400	Reporting
539	UNJI	Tamil Nadu	230	Reporting
540	Vazhuthur	Tamil Nadu	110	Reporting
541	Veerapuram	Tamil Nadu	230	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
542	Villupuram 230	Tamil Nadu	230	Reporting
543	Vinnamangalam	Tamil Nadu	230	Reporting
544	Vyasarpadi 110 KV	Tamil Nadu	110	Reporting

List of RTUs in North-Eastern Region

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
1	AIZAWL	Powergrid	--NA--	Reporting
2	BADARPUR	Powergrid	--NA--	Reporting
3	BALIPARA	Powergrid	--NA--	Reporting
4	BONGAIGAON	Powergrid	--NA--	Reporting
5	BYRNIHAT	Powergrid	--NA--	Reporting
6	DIMAPUR	Powergrid	--NA--	Reporting
7	HAFLONG	Powergrid	--NA--	Reporting
8	IMPHAL/ NIRJULI	Powergrid	--NA--	Reporting
9	ITANAGAR	Powergrid	--NA--	Reporting
10	JIRIBAM	Powergrid	--NA--	Reporting
11	KHLEIHRIAT	Powergrid	--NA--	Reporting
12	KOLASIB	Powergrid	--NA--	Reporting
13	KUMARGHAT	Powergrid	--NA--	Reporting
14	LOCAL RTU	Powergrid	--NA--	Reporting
15	LOKTAK	NHPC	--NA--	Reporting
16	MARIANI	Powergrid	--NA--	Reporting
17	MISA	Powergrid	--NA--	Reporting
18	PALATANA	Central Sector	--NA--	Reporting
19	SALAKATI	Powergrid	--NA--	Reporting
20	SILCHAR	Powergrid	--NA--	Reporting
21	ZIRO	Powergrid	--NA--	Reporting
22	AGARTALA GAS/RC NAGAR	NEEPCO	--NA--	Reporting
23	DOYANG	NEEPCO	--NA--	Reporting
24	KATHALGURI	NEEPCO	--NA--	Reporting
25	KHANDONG	NEEPCO	--NA--	Reporting
26	KOPILI	NEEPCO	--NA--	Reporting
27	KOPILI EXT	NEEPCO	--NA--	Reporting
28	RANGANADI	NEEPCO	--NA--	Reporting
29	AGIA	Assam	--NA--	Not Reporting
30	APM (JOGIGHOPA)	Assam	--NA--	Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
31	B. CHARIALI	Assam	--NA--	Reporting
32	BOKAJAN	Assam	--NA--	Reporting
33	BOKAKHAT	Assam	--NA--	Reporting
34	BOKO	Assam	--NA--	Not Reporting
35	BONGAIGAON (BTPS)	Assam	--NA--	Not Reporting
36	BORNAGAR	Assam	--NA--	Reporting
37	CHANDRAPUR	Assam	--NA--	Reporting
38	DEPOTA (TEZPUR)	Assam	--NA--	Not Reporting
39	DHALIGAON	Assam	--NA--	Reporting
40	DHEMAJI	Assam	--NA--	Reporting
41	DIBRUGARH	Assam	--NA--	Not Reporting
42	DIPHU	Assam	--NA--	Reporting
43	DISPUR	Assam	--NA--	Reporting
44	DOOMDOOMA (RUPAI)	Assam	--NA--	Reporting
45	DULLAVCHERA	Assam	--NA--	Not Reporting
46	GAURIPUR	Assam	--NA--	Reporting
47	GOHPUR	Assam	--NA--	Reporting
48	GOLAGHAT NEW	Assam	--NA--	Reporting
49	GOLAGHAT OLD	Assam	--NA--	Reporting
50	GOSSAIGAON	Assam	--NA--	Reporting
51	HAFLONG	Assam	--NA--	Reporting
52	JAGIROAD (BAGHJAP)	Assam	--NA--	Reporting
53	JAWHR NAGAR	Assam	--NA--	Not Reporting
54	JORHAT (GARMUR)	Assam	--NA--	Reporting
55	KAHELIPARA	Assam	--NA--	Reporting
56	KAHELIPARA LOC	Assam	--NA--	Reporting
57	KARBI LONGPI	Assam	--NA--	Not Reporting
58	LAKWA (LTPS)	Assam	--NA--	Not Reporting
59	LANKA (SANKARDEVNAGAR)	Assam	--NA--	Reporting
60	MAJULI	Assam	--NA--	Reporting
61	MARGHERITA	Assam	--NA--	Reporting
62	MARIANI	Assam	--NA--	Not Reporting

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
63	MORAN	Assam	--NA--	Reporting
64	NALBARI	Assam	--NA--	Reporting
65	NAMRUP PS	Assam	--NA--	Not Reporting
66	NARANGI	Assam	--NA--	Reporting
67	NAZIRA	Assam	--NA--	Reporting
68	NORTH LAKHIMPUR	Assam	--NA--	Reporting
69	PAILAPOOL	Assam	--NA--	Reporting
70	PANCHGRAM (BADARPUR)	Assam	--NA--	Reporting
71	PANCHGRAM OLD	Assam	--NA--	Reporting
72	RANGIA	Assam	--NA--	Not Reporting
73	ROWTA	Assam	--NA--	Reporting
74	SAMAGURI	Assam	--NA--	Not Reporting
75	SARUSAJAI	Assam	--NA--	Not Reporting
76	SIBSAGAR	Assam	--NA--	Reporting
77	SILCHAR (SRIKONA)	Assam	--NA--	Reporting
78	SIPAJHAR	Assam	--NA--	Reporting
79	SISHUGRAM (AMINGAON)	Assam	--NA--	Reporting
80	TINSUKIA	Assam	--NA--	Not Reporting
81	Dimapur, Nagaland	Manipur	--NA--	Not Reporting
82	Imphal	Manipur	--NA--	Not Reporting
83	Kakching	Manipur	--NA--	Not Reporting
84	Karong	Manipur	--NA--	Not Reporting
85	Kohima, Nagaland	Manipur	--NA--	Not Reporting
86	Mokokchung, Nagaland	Manipur	--NA--	Not Reporting
87	Ningthoukong	Manipur	--NA--	Not Reporting
88	EPIP-1	Meghalaya	--NA--	Reporting
89	EPIP-2	Meghalaya	--NA--	Reporting
90	KHLEIHRIAT	Meghalaya	--NA--	Not Reporting
91	KILLING	Meghalaya	--NA--	Not

S. No.	Name/Code of RTU or SAS	Ownership	Voltage level	Status
				Reporting
92	LESKA_ME	Meghalaya	--NA--	Not Reporting
93	LUMSHNONG	Meghalaya	--NA--	Reporting
94	MAPHILONG	Meghalaya	--NA--	Reporting
95	MAWLAI	Meghalaya	--NA--	Reporting
96	NEHU	Meghalaya	--NA--	Reporting
97	NEIGRIHMS	Meghalaya	--NA--	Reporting
98	UMIAM	Meghalaya	--NA--	Reporting
99	UMIAM I	Meghalaya	--NA--	Reporting
100	UMIAM II	Meghalaya	--NA--	Not Reporting
101	UMIAM III	Meghalaya	--NA--	Reporting
102	UMIAM IV	Meghalaya	--NA--	Reporting
103	UMTRU	Meghalaya	--NA--	Reporting
104	AIZAWL	Mizoram	--NA--	Not Reporting
105	AGARTALA	Tripura	--NA--	Reporting
106	AMBASA	Tripura	--NA--	Reporting
107	BADHARGHAT	Tripura	--NA--	Reporting
108	BARAMURA	Tripura	--NA--	Reporting
109	BUDHJUNGNAGAR	Tripura	--NA--	Reporting
110	DHALABILL	Tripura	--NA--	Reporting
111	DHARMANAGAR	Tripura	--NA--	Not Reporting
112	GAMAITILA	Tripura	--NA--	Reporting
113	GOURNAGAR	Tripura	--NA--	Reporting
114	GUMTI	Tripura	--NA--	Not Reporting
115	JIRANIA	Tripura	--NA--	Reporting
116	KAMALPUR	Tripura	--NA--	Reporting
117	PKBARI	Tripura	--NA--	Not Reporting
118	ROKHIA	Tripura	--NA--	Reporting
119	UDAIPUR	Tripura	--NA--	Reporting

Appendix 4

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