Experience of Integrated Operation of SCADA/EMS System at National Level – *A Case Study*

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Abstract — **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 multilevel integrated SCADA/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 lower 32 state control center.**

National control center was established in 2009. Purpose of national control center is to watch 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. SCADA/EMS system of NLDC and regional control centers has different manufacturers. Integrated operation of SCADA system of NLDC has been a unique experience and has imparted many learning to the system operator and SCADA engineers at NLDC. This paper is an attempt to consolidate these experiences and learning.

Keywords- Supervisory Control and Data Aquitision (SCADA), Energy Management System (EMS), Communication System. National Load Despatch Centre (NLDC), Regional Load Despatch Centre (RLDC).

I. INTRODUCTION

Indian power system is third largest power system in the world. Its transmission network is dispersed all over India and has many cross border connections with Bhutan, Nepal, Bangladesh, etc. Indian power grid is distributed into five regional grids as North, West, South, East and Northeast. It covers diverse geographical, environmental & demographic area. All Five regional grids are connected synchronously.[*]

The challenges in operations of Indian power system are multiplying manifold day by day due to increasing system size; brisk pace of capacity addition; long distance haulage of power. Integration of multiple players' electricity market; increasing competition; emphasis on pan India optimization; climate change; large scale integration of renewable energy sources and increasing customer expectations have even added more challenges. The ability of the system operators to take decisions in real-time is dependent on their 'situational awareness' derived from the data/information available with them in real-time. In present scenario, system operators at different control centers are managing the grid with the information derived from real-time data and visualization provided by the SCADA/EMS system in that region.

Regional SCADA/EMS systems in India were installed under Unified Load Dispatch and Communication (ULDC) Schemes. Under ULDC project SCADA/EMS systems were established in three hierarchical levels with five Regional Load Despatch centers (RLDCs) at regional levels and many State Load Despatch Centers (SLDCs) and Sub Load Despatch Centers (Sub-LDCs) at state levels. Establishment of NLDC was not envisaged under ULDC scheme.

Geographical regions of India have diversity in peak demand time and have variations in seasons and generating resources. To take advantages of the diversity and variations, National Load Despatch Center (NLDC) was established in 2009. The task of operation coordination between different regions as well as with adjoining countries was entrusted to NLDC. SCADA/EMS system of NLDC was commissioned on 1st May' 2009.

NLDC SCADA system acquires its real-time power system data from SCADA systems of regional control centers. A number of challenges were faced during commissioning as well as keeping real time data updated and system models current during operation of NLDC SCADA system as NLDC SCADA integrates SCADA systems supplied by multiple vendors.

Rest of the paper gives the experiences in integrated operation of NLDC SCADA system. It also details out the challenges faced and how NLDC could over come these challenges during its years of operation.

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II. REGIONAL SCADA/EMS PROJECTS

In late eighties, Central Electricity Authority took initiative to create telemetry, communication and control center infrastructure in India under a single integrated project; Unified Load Dispatch and Communication Scheme. POWERGRID implemented the Unified Load Dispatch and Communication (ULDC) project. ULDC project involved implementation of SCADA/EMS Systems and dedicated communication links in all the regions of India. The ULDC project established a hierarchical telemetry/SCADA/EMS system which includes Regional Load Despatch centers (RLDCs) at regional level and State Load Despatch Centers (SLDCs) and Sub Load Despatch Centers (Sub-LDCs) at state level.

Different vendors supplied SCADA/EMS systems under ULDC scheme. Out of five SCADA/EMS systems, three were supplied by one vendor while other two regions by two different vendors as indicated in **Figure-1**.

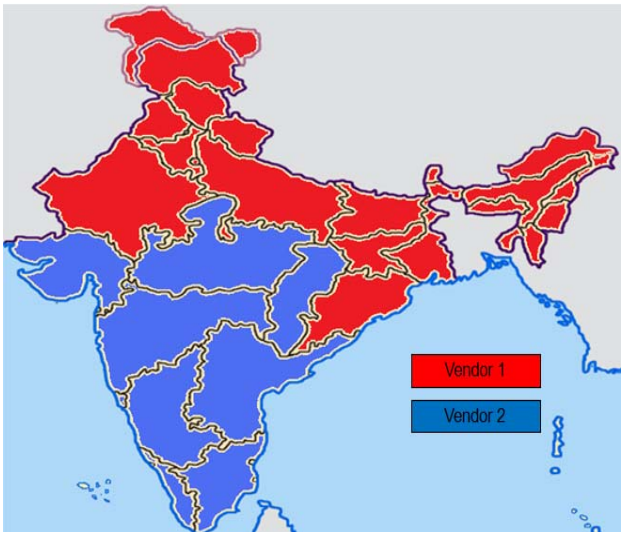

Figure 1 – Vendor distribution of SCADA systems Commissioned under ULDC scheme.

SCADA/EMS and communication systems under ULDC scheme were based on the latest technologies available at that time i.e. 2002. Since then, many technological developments took place in IT and communication arena. The emergence of SOA and industry standards like Common Information Model (CIM) is testimony of the same. The development in Information and Communication Technology coupled with the scorching pace of expansion in power system pushed the existing SCADA/EMS systems towards the obsolescence. Keeping this in view, the Government and Regulators in India gave the renewed thrust to the investment in Modernization of Control centers through Policy decisions and Regulations. At governance level, the Pradhan Committee and Satnam Singh committee recommended a life span of 5 to 7 years (which was originally 15 years) for the system in operation and 3 years for normal IT systems. In line with these recommendations, regulators recommended continuous upgrade in terms of ICT CAPEX [2].

Subsequent to above enabling decisions, 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. **Figure-2** shows the vendors and the regions in which they are executing the up-gradation projects.

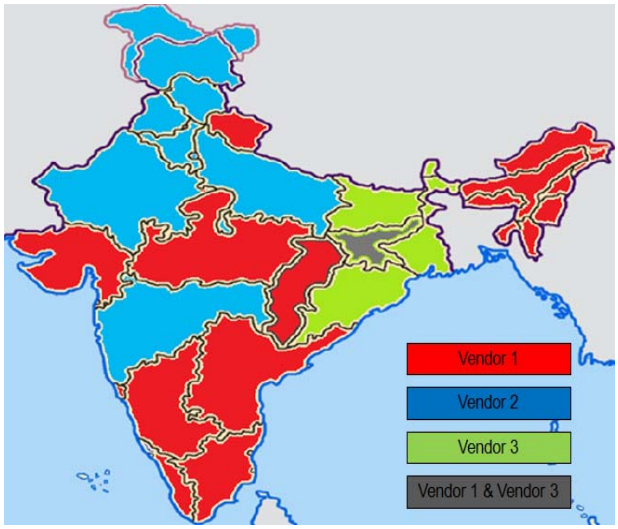

Figure 2 - Vendor distribution of SCADA systems after up-gradation project.

III. INTEGRATION AT NATIONAL LEVEL

At the time of establishment of ULDC projects, establishment of NLDC was not envisaged. In India, there is diversity in load as well as power system resources like coal, water etc. Eastern region has high coal resources whereas more water is available in South and North. Further to this, there is time diversity between different regions resulting different time of peak power. To take full advantages of these diversities, India started integrating regional grids synchronously to allow free exchange of power between the regions. In addition to this, certain cross border connections were also established with neighboring countries facilitating import of power from surplus countries. This necessitated the establishment of National control center. In 2009, India proactively established a National control center known as National Load Despatch Center (NLDC). In order to coordinate and manage inter-regional and international connections, SCADA/EMS system was also implemented at NLDC which was commissioned on 1st May' 2009.

NLDC SCADA/EMS acquires data by integrating all regional SCADA/EMS systems through high speed communication links on Inter-Control Center Protocol (ICCP). A backup national control center was also established to facilitate operational continuity in case of any contingency. Each RLDC

independently communicates with both main as well as back-up NLDC through individual communication channels as shown in **Figure-3**. Main and back-up NLDC control centers are also synchronized with each other.

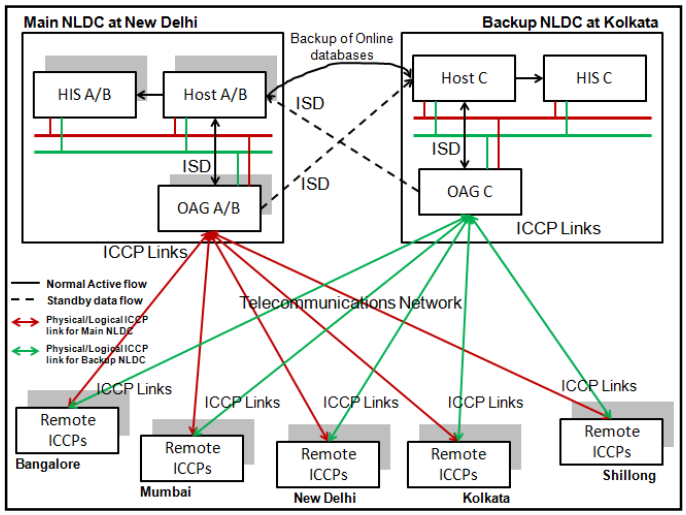

Figure 3 – Integrated SCADA System architecture at NLDC

The most challenging part of establishment of NLDC was to stabilize the interfaces with the existing RLDCs which had SCADA systems supplied by two different vendors and also of different vintage. **Figure 4** shows the SCADA/EMS systems of RLDCs and NLDC at the time of establishment of NLDC.

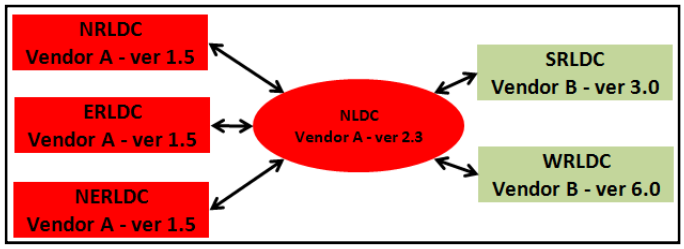

Figure 4 – Different version of SCADA system of ULDC Scheme

Fortunately, the vendor who supplied the SCADA systems of three regions i.e. North, East and North-East regions also won the tender of supply of SCADA/EMS system of NLDC. But both the systems were of different vintage.

Since, SCADA/EMS system was established in 2009, up-gradation of this system was not taken up with the up-gradation of regional SCADA/EMS systems. It is being taken up separately and expected to complete by 2016.

IV. CHALLANGES FACED DURING INTEGRATED OPERATION OF NLDC SCADA/EMS SYSTEM

Many challenges were faced during commissioning and last many years since commissioning. These challenges and experiences of NLDC in overcoming them have been described in following paragraphs.

A. Different naming conventions

As regional SCADA/EMS systems are from two different vendors, their database structure and data tags naming conventions are different. However, SCADA/EMS system of NLDC was supplied by one of the regional vendor, in the case of three of the regions naming conventions for data tags were same and integration was quite easy. Same tags of regional SCADA systems could be used at NLDC as it is. However in case of other two regions, SCADA system naming conventions were different since they are highly dependent upon the design of individual SCADA database of particular vendor.

In such cases a mapping tables were created at NLDC, which maps the data tag names of regional SCADA system to data tag names of national SCADA system. Typically, CSV formatted files were used for these mapping tables. **Figure-5** shows the one of such mapping table. During the on-lining process, ICCP names at NLDC get converted to the ICCP names of other control centre for exchanging the data.

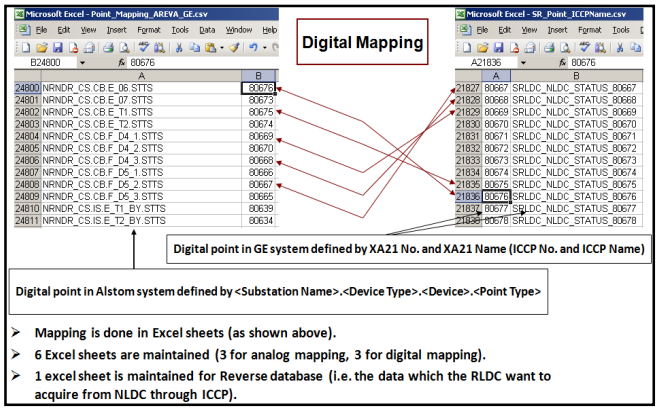

Figure 5 – SCADA tags mapping table

NLDC also wheels the data of one regional control center to the other regional control center by providing the data on reverse ICCP links. Due to different naming conventions, in this case also reverse mapping tables are used at NLDC.

Though, the mapping tables in CSV formatted files are being used at NLDC since its commissioning, but maintenance and updating of these mapping table is tedious and time consuming. Many a time it introduces error due to large number of tags.

To overcome such issues, a standard naming convention will be created at NLDC level and tag aliasing facility existing in the regional SCADA database system will be used. Alias based on standard naming convention will required to be created only once at the time of defining any new tag at regional SCADA systems. In this case no mapping table will be required to be maintained at NLDC.

B. Support of partial data exchange

In order to provide real time data of one region to other region, data received at NLDC is transferred from NLDC to RLDC on reverse ICCP links as reversed data flow. As the SCADA/EMS systems of regional control centers were installed about 10 years before they are of very old version. ICCP servers of three SCADA systems do not support the transfer of partial dataset. In this case any mismatch in any ICCP ID causes the failure of entire data at remote sites. The mismatch of ICCP ID generally results of different time of on lining of SCADA database. Since, RLDCs acquire data from states, they have to match their on-lining schedule with states. Any change in data at any side causes this type of issue. To solve such issue, NLDC is required to do on-lining frequently.

In order to take care of this problem support of partial data transfer and addition/deletion/change of tags directly in online system is being incorporated in technical specifications of next upgrading of NLDC SCADA.

C. SCADA Modeling

Any addition of new power system element is first required to be modeled in SCADA database for incorporating the real-time data of the same. At NLDC this task is carried out by a vendor supplied data-modeling tool. In case of integrated system addition of any grid element is first required to be done by the lowest control center and than to be replicated at other upper level control centers based on the information supplied by lower level control centers. This is a repetitive task and in case if SCADA systems are of different make, modeling is required to be carried out from scratch. This is time consuming and error prone process.

To overcome these difficulties efforts for implementation of Common Information Model is being done. CIM will facilitate exchange of network model even in case of different vendors' SCADA system.

D. Status points

SCADA system acquires two types of data from the Remote Terminal Units (RTUs); analog data like line flows, generations, bus voltage, system frequency etc. and status data like open/close positions of circuit breakers (CBs) and isolators. As per philosophy followed, isolator position is transferred by single bit while CB position by two bits. Single bit provide 2 states (open/close). Double bits provide four states; open, close, between and invalid. Accordingly, in general all RTUSs follow these conventions and send single bit for isolator position and double bit for circuit breaker position. However, some new RTUs and sub station automation systems use double bits for sending positions of isolators also.

Furthermore, RTUs/Substation automation does not use position of two bits for providing different states uniformly as shown in **table 1**.

Table 1-Possible States by two bits Status

Bits		States	States	States
0	0	Invalid	Open	Between
0	1	Close	Open	Between
1	0	Open	Close	Between
1	1	Between	Invalid	Close

In such situations, at least four different tables have to be defined and individually mapped to station level. Since, this work is to be done manually, many a times wrong table mapping results in wrong status of CB or isolators.

The long term solution for this problem is defining the standard convention at national level.

E. Data updation from Back-up Control Centre

NLDC SCADA system has a backup SCADA system located at Kolkata as a disaster time control center. In order to ensure uninterrupted data to back-up SCADA system during any disaster at main NLDC control center, data at backup SCADA system is acquired directly from all five RLDC's which are reporting parallel to both Main and Back-up NLDC simultaneously. In addition, both main and backup SCADA systems are also connected with each other and communicating with each other for keeping both systems synchronized. **Table 2** shows the data sources at both control centers.

Table 2- Data sources for NLDC and Backup NLDC

Control Centre	Primary Source	Secondary Source
Main NLDC	RLDCs	Backup NLDC
Backup NLDC	Main NLDC	RLDCs

SCADA system at NLDC can receive data from RLDCs as well as from backup NLDC. Accordingly, each SCADA tag has two sources for a data value; one is defined as primary from which data is updated normally and other is secondary source for providing data in case of failure of primary source.

Philosophy used for both sources are as follows:

a. Data has either 'good' or 'suspect' quality: Both Main NLDC and back-up NLDC will use primary source as mentioned in table-2.
b. Data has different quality at both sources: System would take the data which has the 'good' quality flag from any of the source.

In many cases it is found that values are updating with suspect quality, in such case system would prefer to take data from primary source only. Generally such type of cases arises in case of calculated data, where many points are used to perform the calculation and if anyone data in this calculation has suspect quality, output result of this calculation would have suspect quality.

This type of situation may confuse the operators due to partial updated data. For change over decision from one data source to other data source in addition to quality flag other status may also be checked like change in value, status of ICCP association with region etc.

F. Telemetry availability of status

A valid state estimator output is a fundamental requirement for successful running of any EMS application. For this, successful running i.e. successful convergence of this state estimator is a must which depends on the overall availability of real-time telemetry status of the circuit breakers and isolators in the network. Correct status of CBs and isolators enables the correct output from topology processor module of state estimator. National level network being very large and complicated, there is a high probability of wrong status for many of the isolators and few of circuit breakers. In such case probability of non-convergence of state estimator as well as wrong output is high.

Status telemetry of CBs and isolators is, in general, provided through Contact Multiplying Relays (CMR) at site. Outage of CMR many-a-times does not provide correct status. This generally happens in case of status of isolators and wrong status of isolators effects the output of topology processor and hence that of state estimator. This problem could be solved to a great extent by closing all isolators provided on both side of any CB i.e. except special purpose isolator like line isolator, pole isolator etc.

G. Data availability monitoring

National control center (NLDC) maintain database of complete Indian grid and hence required to maintain about 75,000-80,000 data tags. More tags are continuously being added every day due to fast growth of the Indian power sector. Monitoring of data availability, intermittency, duration of outage etc. for these large number of tags is generally not possible manually. At present, SCADA system does not have any such self-monitoring tool.

For this, a tool was developed in MS Excel. SCADA data is transferred to an Excel sheet every minute. Excel sheet compares the value with previous value and if both values are same it flag that time for data outage. The comparison is done on frequency value, since frequency changes very frequently. However, this is a crude method and many-a-times report incorrect flag.

Self-diagnosis and monitoring features are being incorporated in new SCADA system to solve above challenge.

H. Data change other than reporting control center are not getting reflected at upper control centers

The data of all SLDCs are shared among themselves and the corresponding Regional Load Despatch Centre. Any changes made in the Analog or Digital measurement by its reporting control center (owner of the data) is getting reflected to other control centers with which data is being shared. However, if any changes has been made other than its reporting control center (SLDC) and data is exchanged by this control center (RLDC) to upper control center (NLDC) than these changes would not be reflected. At NLDC it has been observed that for state's data RLDCs replaces the value and the same is not reflected at NLDC. In case of Eastern Region, CPCC is at other location than ERLDC and as per philosophy all central sector data is reporting to CPCC. It has been observed many times that changes made at RLDC are not getting reflected at NLDC. Some coordination amongst the control center operators for information sharing and respective tools are required to sort-out this type of issues. Otherwise operators at different control centers would have different parameters for visualization and subsequently decision based on the data.

I. Communication Issues

Communication used between regional control centers to National control center is Optical Fiber. Dual communication channel between control centers has been taken in order to provide the path redundancy. However, many times it has been observed that fiber cut at a particular location causes data loss to either main or back-up NLDC. It has been investigated and found that physical path redundancy has not been taken into consideration and both main and back-up link has been configured through same fiber.

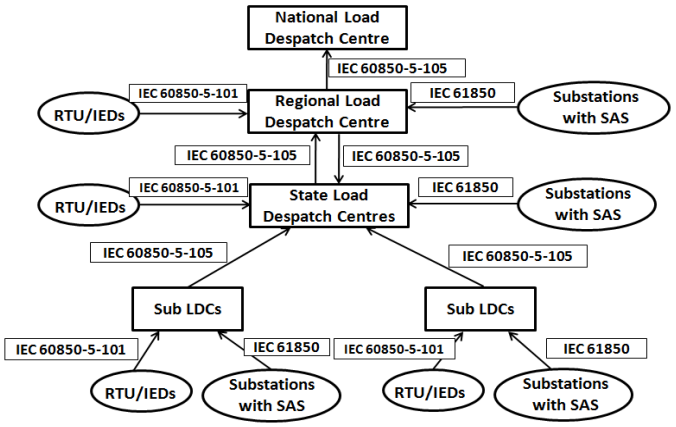

Figure 6 – Different protocols in practice for data transfer

Sometimes data is found to be not available at both main and back-up NLDC due to fiber cut in nearby regional telecom control center. This type of non-availability of data affects the real-time grid operation at control centers and also affects the running of State Estimators due to non-availability of entire regional data. **Figure 6** shows the communication protocols used right from station level to NLDC for data transfer. Any failure in communication (depending on the location of occurrence) causes the loss of partial or entire State/region data to the operator at National Control center.

J. SoE integration

Sequence of Events (SoE) is a very important part of SCADA system and used for post-event analysis extensively. SoE are time stamped data captured at RTU/Sub-station level. This data is used whenever some fault occurs in the system and helps in determining the sequence of event taken place in the system. As SoE is generated at RTU level, it is immediately available at the control center where RTUs are directly connected. However, NLDC does not have any direct reporting RTU and

hence National level SOE data is fetched by using FTP on daily basis. This delay of availability of SoE data at NLDC causes delay in analysis of events. Hence, it is desirable to have facility in each SCADA system to instantly get SoE data from RTU and transfer to other control centers as soon as it is generated at RTU level.

K. Latency Due to Long Haulage of Data

Data transfer between control centers is accompanied with expected delay between the destinations.

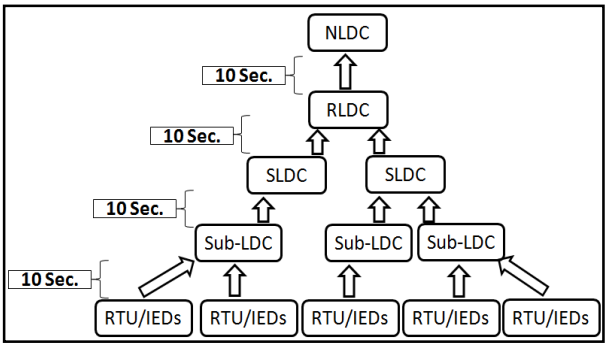

Figure 7 – Latency of data between control centres

In real-time connected station data displayed for the operators at control centers have different value as the time of their receipt at control centers are different.

V. CHALLANGES AFTER UP-GRADATION OF REGIONAL SCADA / EMS SYSTEM

Since, existing SCADA systems at regions and states was commissioned about 10 years ago. These are now been upgraded except SCADA system of NLDC which was installed only in 2009. With the experience of last 10 years in SCADA/EMS installation and operation many improvements are being incorporated in new SCADA/EMS system. One major change is the philosophy of maintenance of SCADA network model. Previous system follows a philosophy of single database system for the entire region and extraction of control center wise database from this. This was more rigid system of database and requires very close coordination among all stakeholders of a region. In new SCADA system each control center will be maintaining its database individually in decentralized way. This may throw some new challenges. Additionally, implementation of backup control centers for each regional control center and establishment of National/Regional Transmission Asset Monitoring Centers (NTAMC/RTAMCs) and sharing of real-time data between all these centers may throw new and different type of challenges.

Up-gradation of SCADA/EMS system of all five RLDCs is under implementation and within 1-2 years new system would be operational at all control centres and old system would be dismantled. Under up-gradation project, three regions (SR, WR & NER) have been awarded to one vendor and other two regions (NR & ER) have been awarded to two different vendors. As already mentioned mapping table has been defined at NLDC for SR & WR due to different naming convention. Now in new system vendor location, except in NER, has been changed and naming convention adopted at these locations are different from the same at NLDC. In this case ICCP mapping need to be changed either at RLDCs or at NLDC. Similarly, vendor at NR & ER have also been changed and for ICCP association mapping tables need to be defined either side. In near future, SCADA system of NLDC will also be upgraded by some new vendor who may have different database architecture. It will again involve the same mapping process to be done again.

VI. CONCLUSION

Integration of Regional control centers at National level brought the unified visibility of system as well as increased observability of Indian power grid. This also facilitates the availability of real-time data of one region to other region and helped the grid operators in many ways in day to day operation by visualizing data of neighboring regions along with their own region. Since the geographically spread of the area is large in size and data has to travel through many hops of different types of communication media, frequent interruptions of data acquisition takes place. This affects the grid operation as well as running of EMS applications. Some tool may be readily available to identify these types of intermittent non-availability of data in order to take corrective action at the earliest and to avoid the data loss. Data available for visualization is in huge volume and some advance tool is required like geographically spread map equipped with various type of alarming for the operators. There are immense possibilities and scope in providing better displays for visualization.

Also as discussed, due to the multi-vendor scenario some standard regarding the naming convention needs to be adopted in PAN India and also explore the possibility of data transfer through CIM.

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