Modernization of Multi Location Live SCADA system–A case Study

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Abstract— **SCADA system has come a long way over the past three decades and now the same are not an isolated system serving only the system operators for operational safety. Presently, the SCADA system needs to support a wide variety of user requirements starting from system operators to different market participants, regulators, data analysts, and requirement for interconnection between SCADA and IT system is felt. Further, working with legacy systems can present a number of problems that ranges from higher maintenance cost, sluggish performance, non-availability of support service, availability of modern facilities in State of the art SCADA systems, interconnection facility with heterogeneous systems and operational efficiency of the new technology.**

With rapid expansion of the power system in India and evolution of markets through establishment of power exchanges, system operation has become more and more complex with interaction with huge number of market participants. Advanced visualization is of utmost importance to the system operators to ensure reliability of the system. Further, the requirement of interconnection of IT system with SCADA was felt to support the various MIS and data analysis requirement. With a view to use the present technology for better system efficiency and to support the present day need of the system operators and the customers, it was decided that the legacy SCADA is upgraded at all the State, Regional and National Control Centre in India..

Keywords – Supervisory Control and Data Aquitision (SCADA), Energy Management System (EMS), Communication System. Regional Load Despatch Centre (RLDC), State Load Despatch Centre (SLDC), National Load Despatch Centre (NLDC), Technical Specification (TS).

I. INTRODUCTION

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 projects 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. Subsequently, National Load Despatch Centre has been established by integrating RLDCs at National level, through a dedicated project executed by POWERGRID.

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 Service Oriented Architecture (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. Also in current scenario SCADA/EMS system needs to support a wide variety of user requirements staring from system operators to different market participants, regulators, data analyzers, and sharing of data to support the various MIS requirement. Further, legacy systems can present a number of problems that ranges from higher maintenance cost, low scalability, degraded performance, non-availability of support services etc. compared to facilities available in modern SCADA systems.

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 upgradation in terms of REPEX. As a result of these enabling decisions, SCADA/EMS systems are upgraded in all the five regions. Different vendors are involved in implementation of projects; three regions are being executed by one vendor while other two regions by other two different vendors leading to another heterogeneous implementation of SCADA/EMS system in India**.**

Replacement/Up-gradation of SCADA system first took place in Northern Region. This paper shares experience of migrating from old legacy SCADA system to new SCADA system of different vendor. Paper will describe all the process involved, right from planning to execution of project, and challenges faced in ensuring the un-interrupted real-time data to the operators, a critical requirement for grid management.

II. ACTIVITIES INVOLVED

Once the decision is taken to modernize / upgrade the running SCADA system, it is of utmost importance to plan various steps to implement the new system and also migrate from old to new system without disturbing the system operation, keeping in mind the data exchange requirement with downward (SLDC) and upward control centre (NLDC). Earlier back-up of Regional and State Control Centres were not envisaged, however, in replacement/up-gradation project, back-up of Regional and State Control Centres were also considered, which lead to requirement of strong communication system for the establishment of the new SCADA system architecture. The various process/activities involved for successful execution of project may be classified as:

1. **Planning, Design and Award–** Finalization of technical specification, Communication Planning, tendering process and evaluation and award of project.
2. **Engineering and Execution** - Finalization of Technical documents, database structure, database creation, validation of database w.r.t. old existing system, integration with different system as envisaged, creation of displays. Performing various tests as per Technical Specification.
3. **Migration and Operation** - Migration from old to new SCADA system, gaining confidence of Operators in using new system, training the operators and transition to the new system.

III. PLANNING, DESIGN AND AWARD

1. ***Finalisation of Technical Specification***

The most important part in modernization of SCADA in control centre is to prepare the technical specification of the future system which should meet the current as well as future requirement of the grid operation and also equip the system operators with the latest tools available in the market. This necessitates the knowledge of the SCADA system available in the market or is up-coming with latest design and future requirements. To meet this requirement, a conclave was organized wherein various leading SCADA vendors and companies dealing with application packages, Relational databases, Historian and visualization software participated. Special emphasis was given on the cyber security aspect to ensure protection from the cyber threat to ensure reliable performance of the new SCADA system (old system was operational in isolation mode hence there was threat to security). Based on the knowledge gathered, new SCADA system architecture was finalized after several rounds of discussions with the prospective vendors for the new system and keeping in mind the vision of the company and users' requirements.

Further, while designing the new system, transition from old system to new system was to be planned properly so that seamless migration could be achieved. This requirement was ensured though implementation of listening mode technology which ensured available of data in IEC 101 initially in listening mode to the new system and gradually the new system was changed to Master mode for one by one station. Since ICCP was planned with separate communication channel, requirement of listening mode for ICCP was not felt necessary.

2. ***Scope of the project***

The existing system did not have the back-up control centre. The architecture of the present hierarchy is shown in the **figure-1** below. While planning the new architecture, it was decided to have back-up CC as a disaster Management system. Further, Back-up Control centres were envisaged for all of the control centre at State and the Regional level. Two types of Back-up control centres were planned:

a. Dedicated back-up control centre: In this configuration, both Control Centres are capable of controlling the entire power system. Both are directly connected to the power system's RTUs. The centre configured to control the power system operates as the main control centre.

b. Each control centre will be Back-up of the other control centre for optimization of cost. In this configuration pre-defined main control centre will operate as Backup of other CC. At any time, an operator at the Backup CC can initiate a control centre failover which causes the two centres to change operational responsibilities.

The implemented architecture is shown in **Figure 2a** and **2b** respectively below.

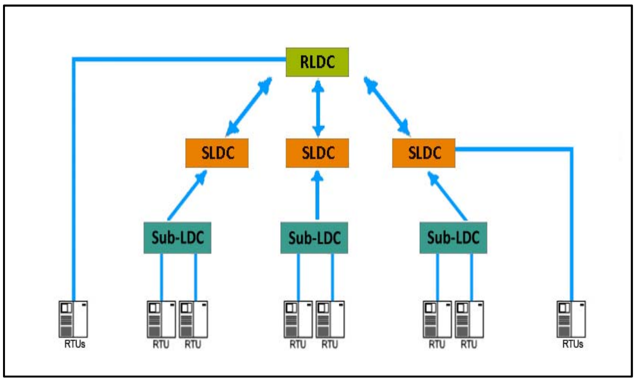

Figure 1: Existing Control centre connectivity

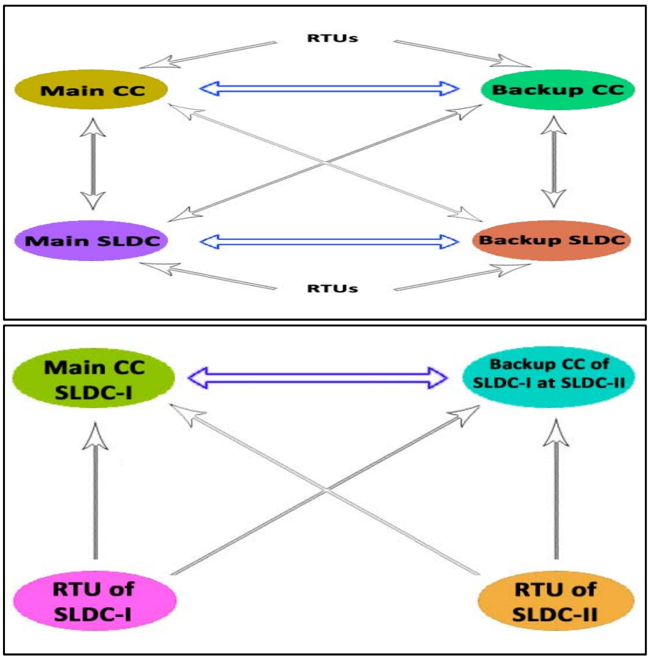

Figure 2a & 2b : New Main CC connectivity with Back-up CC

New proposed SCADA/EMS control centre planned for compatibility to standards IEC 60870-5-101 and IEC 60870-5-104 protocol for RTU data acquisition. The Main & Backup Control Centres exchange real-time data through dedicated link as well as on ICCP with SLDCs. Main & Backup Control System will have identical database for all RTUs and communicating to RTUs with separate communication links. Scope of Supply included implementation of 12 Nos. SCADA/EMS CC with SCADA, EMS, OTS, Transmission network applications with HVDC/FACTs, Data Historian for MIS, integration of Existing 1000+ RTUs.

3. *Communication planning*

Implementation of SCADA system required detailed communication planning and the success of the SCADA system totally depends on the reliability and robustness of the communication provided to the SCADA system. A detailed communication network was planned on fiber to support the new SCADA system. Following major steps were planned:

a. Direct high bandwidth communication between Man CC and Backup CC.
b. Redundant VLAN between the Control Centres (between RLDC to SLDC, Main to Back-up Control Centre).
c. The channel level planning was carried to find out the detail requirement of the ports at SDH level.
d. The bandwidth requirement for each path and accordingly the logical data flow diagram was prepared for implementation. **Figure 3b shows** below, the logical data flow diagram which was prepared for implementation.
e. Separate communication nodes the routing the RTU/SAS on the communication ring to avoid single point failure of data acquisition.

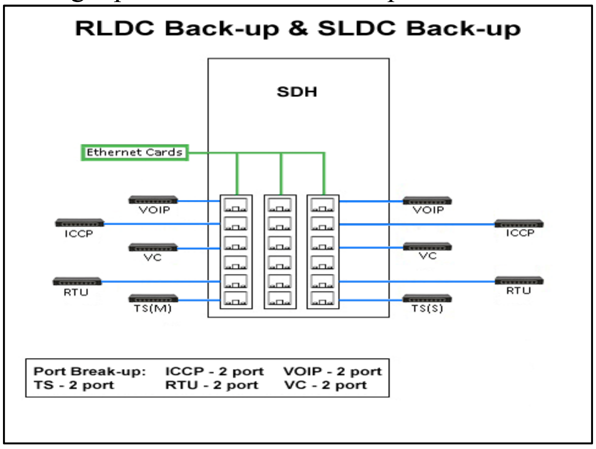

Figure 3a: RLDC and SLDC Back-up

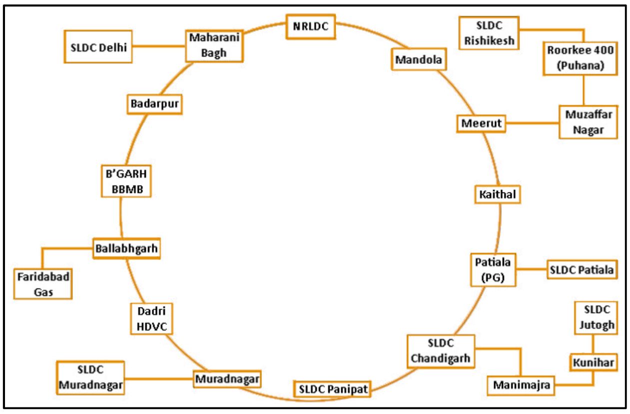

Figure 3b: Logical data flow diagram

IV. ENGINEERING AND EXECUTION

1. *Database preparation*

Porting of database from the existing database to the new system needs to be done to maintain continuity of the operation. Further, since both the systems were to operate in parallel, the address mapping had to be ensured to maintain proper data integrity. As database of new system should be CIM compatible, accordingly hierarchy was decided so that it should be CIM compatible. As Existing system followed a logical pattern, it helped in porting of existing database of old system to new system through scripting porting tool prepared to support the logic. Effort was made to keep the same id in new system wherever possible to facilitate the system operator to identify the equipment without any major hassles. However, while porting data, the substation Id was kept same while the equipment Id was converted keeping in view restriction of the character with a view to keep the bay no. of the equipment with the equipment Id. Database which do not follow the standard logic could not be ported through script and made manually.

Final hierarchy adopted in new system is shown in the **figure- 4** below. The Complete Instance for each type of data (Analog / Status Measurements) is as follows, where the <Network/Company> is the container of the database:-

- /Network/Companies/<Geographical Region (6 char)> . <Sub-Geographical Region (4 char) > . <Substation Id (8 char)>.<voltage level (8 char)> . <Equipment Id (8char)> . <Signal/Measurement> . <MvMoment / Status>.

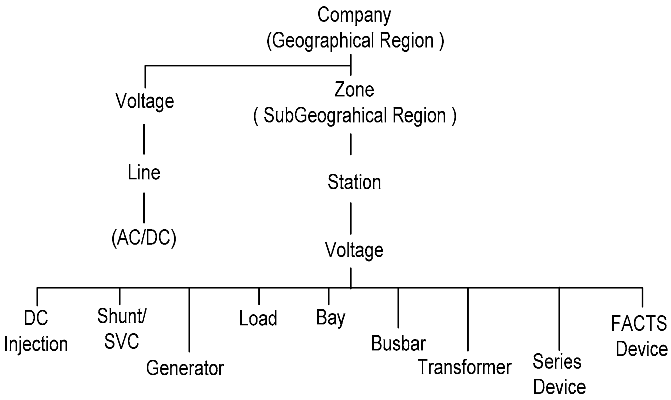

Figure 4: Database Hierarchy

2. ***Database cleaning***

The database model needs to be cleaned before porting, so as to port only the required part of the database. It was necessary because always some points accumulate in database during operation and becomes irrelevant with the passage of time and need to be removed in time. This is caused mainly by network restructuring and incorporation of different user's requirement.

3. ***Data validation Activity***

The real time data available in the new system requires detailed validation so that system operation should not suffer due to bad data. All analog & digital data, station-wise, was validated along with the connectivity of each of the equipment. Validation of network connectivity was also done as result of State Estimator depends on the correct network connectivity and quality data. Validation of all the required calculations has also been done with respect to existing system. Database validation activity was carried out separately in all the Control Centres to avoid any mismatch between existing and new system. Generally data validation has been done using displays of both systems.

4. ***Displays Standardization***

Porting of displays from existing system to new system was not possible, also it was preferred to build it from scratch. Accordingly, standardization of display has been made so that uniformity in display amongst the control centres in the region could be maintained. While creating the displays effort was made to maintain the same look and feel and the same navigation across the displays so that the system operators can start using the new system without much trouble. The visual alarms are also made similar so that the system operators are alerted in the same manner as the existing system. Displays for quick access of important and critical displays have also been made by using the "Basic Signaling Window" feature available in new system.

5. ***Integration of RTUs***

As per the requirements, both existing and new system has to run in parallel for a specified period. As Grid Operation was being performed from the old system and to start the data from the field device to new system, listening mode features have been used. All hardwares were prepared and tested for listening mode operation. The communication parameters and other IEC parameters were checked before the RTUs/ SASs was connected to the front end system. The existing hardware cable connecting the communication channel to the existing SCADA system was replaced gradually to facilitate the listening mode communication with the new system.

6. ***ICCP integration with SLDCs***

ICCP association was tested and established between new systems of SLDCs. ICCP mapping of desired points of all the SLDCs was done at RLDC. Mapping of ICCP points was required due to the adaptation of decentralized database maintenance philosophy. Decentralized database maintenance philosophy was adopted so that each control centers can maintain their network and can perform State Estimator of their network. Displays can be exchanged amongst the control centers based on the requirement of the individual centre.

7. ***ICCP integration with CC with heterogeneous vendor***

ICCP integration within a region with same vendor is implemented in secure mode. However, Control centres that are not supporting secure mode were also integrated. Following steps have been performed to integrate with NLDC system:

a. Initially ICCP integration testing with NLDC was performed on spare server of NLDC in standalone mode in order to avoid data interruption to NLDC as it was required to restart the application many times. ICCP and network setting of NLDC side was kept unchanged and necessary changes have been made in new system side.

b. Initial test was performed with two datasets (one for analog and other for digital) with limited number of data items.
c. After successful integration of ICCP with NLDC Spare ICCP server, testing with real-time was planned with back-up NLDC. Necessary changes have been done on network devices for new configuration.
d. Bulk mapping of ICCP data points at RLDC end as new system was required to map each and every point in their ICCP. Hence it was better to perform mapping at RLDC end without any changes in database at NLDC.
e. For data validation main system was kept connected with old SCADA system and back-up NLDC was connected with new SCADA system. Both main and back-up NLDC system kept disconnected so that data exchange with these two should not take place. By using two monitor system and also Excel sheet, data in old and new system was validated.
f. Shifting of both main and back-up NLDC system to new system of NRLDC.
g. Failover test of ICCP have been performed in order to ensure the data flow with main and standby servers.
h. After establishment of synchronization of Main and Back-up NRLDC system, back-up NLDC will be shifted to back-up NRLDC system.
i. Database synchronization across the integrated control centres

On achieving the connectivity through ICCP, database synchronization was performed to maintain the database integrity across the control centres. Incremental database maintenance philosophy was implemented which was available in the new system. The exchange of change log for the new changes was started by the users to maintain the database integrity. Once the change log was been implemented, integrity check was started through a synchronization script which detects any discrepancies in the database across the control centre and changes are incorporated. It is proposed to perform the database integrity check on fortnightly basis. The displays are also exchanged on change basis across the control centres.

8. ***Implementation of Back-up*** Control Centre

The implementation of Back-up Control Centre was started after the implementation of the main control centre. The database sync was done through high speed dedicated link between main and Back-up centres. Gradually the dedicated link was established from the terminal Servers to the Back-up CC to test the real time data availability from the RTUs to Back-up CC and implementation of ICCP link was done from SLDCs to Back-up CC.

9. ***Report generation from new System***

After the migration to new system from old system, all reports which were being generated from the old system are being generated from the new system. Shifting of reports generation from old to new system was done in a planned manner. This required thorough checking of each and every report with proper validation of data from new system to give the confidence to the operators. After detailed validation gradually it had been shifted to new system from old.

10. ***Preparation for State Estimator and correcting the model***

Once the data is received properly from all control centers, tuning of estimator model was started. The parameter was tuned along with the network model to achieve the initial convergence. The updation of network model was started with each changes in the physical changes in the network after proper checking of the network parameters. Once the acceptable estimated result was achieved, the other network application was tested.

11. ***Cyber security and Audit***

MIS is an important activity in today's SCADA implementation and connectivity between IT application and SCADA application. Presently the SCADA is also connected to web for access to the SCADA information. Hence, implementation of Cyber Security is a must. As indicated in the general architecture, two firewall systems, one internal and one external firewall were implemented. Apart from the SCADA side security, the connectivity was implemented through interconnection to DMZ zones of the IT and SCADA systems to ensure protection from public network. The rules are defined to give restricted access to the SCADA system whereas to prevent access to the unwanted intrusions in the system. Security Audit was carried out through third party and recommendations were implemented to ensure proper security of the SCADA system before launching the same to the web on permanent basis.

V. MIGRATION AND OPERATION

1. ***Parallel Operation and Migration***

The Operator consoles from both the systems (old and new SCADA system) were provided to the operator for familiarization with the new system and building their confidence. Displays were put on VPS screen also for better visualization of the new system in parallel to the existing system. Initially the operation was carried with the existing system (Old) and validating the action from the New System. Once the confidence is achieved on the new system, it was decided to migrate the operation to the new system. The RTUs / SASs were gradually put to Master mode and operation was shifted to the new system. The activity was implemented in the SLDC level first and then at the RLDC level to ensure smooth migration.

2. ***System tuning on Master Mode***

With the RTUs/SASs put on master mode on the new system, the front end system was loaded and system was observed for proper operation resolving the minor teething problems in communication, specially hardware in command direction, which could not be tested earlier. The channel failover of the RTUs/SASs were tested to ensure reliability of real time data. ICCP failover was also tested for failure of communication between regional CC to Main CC. Failover testing was carried out with main CC and Back-up CC and fail over of RTYs / SASs to the Back-up CC to test the various functionality of the redundant system.

3. ***System Availability and acceptance***

The system availability test and the performance test were carried out as per agreed norms / the agreed documents for the performance criteria. During the performance test, various applications were tuned, tuning of false alarm was carried out to reduce the additional load on the system. The oracle supporting the historical database was tuned for faster access of the historical data by the users.

VI. CONCLUSION

Successful implementation and migration to the new system depends on what details the existing system is analyzed and migration is planned. Lack of proper planning may affect proper implementation of the SCADA system and will lead to dissatisfaction of the system operator and user of the new system. Assessing vendor capability for timely implementation of the SCADA system plays major role. One of the options which can be explored is to have a new system which is already implemented elsewhere and better to avoid being the pioneer for any upgrade of the vendor's software. The vendor will learn from the first few implementations and make their system reliable which could be implemented in a faster manner otherwise implementation may be delayed to continuous up-gradation process/bug fixing by the vendors due to their first-hand experience on the latest upgrade put to real time operation.

Seamless migration from old to new system also depends on the ability to judge the new system capability and making quick assessment in respect of non-availability of the critical functions which operators are using on the old system and take necessary action during implementation period. This may require contingency fund requirement and amendment of award so that the necessary development could be done and implemented at the time when the system is made available to the system operator / Dispatchers.

Training should be well defined and also imparted at a regular interval to familiarize the system users till the building up of confidence on new system. With the change in technology in IT, the architecture, as well as the operating system gets changed, apart from the SCADA features and various implementations of the power application packages. Un-learning of the existing system is very difficult which makes the new implementation very difficult. Further, maintenance of the system, being a totally different architecture and content, it is better to have fresh engineer trained with open mind other than to train existing engineers for quick learning and adaptation of the new system and better maintenance of the system.

The chance of success will be greater if all involved in the chain understand the magnitude and difficulty of the task at hand and synchronise their activities with the migration process. The synchronization may be affected by the availability of communication, availability of skilled manpower at appropriate locations, diversion of critical manpower to less critical activities and finally the acceptability of the users to accept the new system.

ACKNOWLEDGEMENT

The authors are thankful to their Management for publication of this paper. The views expressed in this paper are of authors only, Power System Operation Corporation does not subscribed the same in any way.

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