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15. Application of Information and Communication Technologies (ICT) at SLDC

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Abstract—*Widely spreading grid has increased the complexity towards monitoring and control of such large grid. The excessive penetration of renewable generation due its unpredictability, variability and intermittency is also posing challenges in operation of the grid. Under such complexities, carrying out security assessment on real time basis and responding to contingencies are critical for maintaining reliability and stability of the grid. The real time power system management is accomplished efficiently & reliably with the Supervisory Control and Data Acquisition (SCADA) systems but the advancement of new measurement & analytic technologies has produced a range of new options. In particular, technologies like URTDSM, ADMS & establishment of Renewable Energy Management Centre (REMC) have come to the fore as a means to address the immediate reliability concerns. This paper covers the existing & proposed information & communication technologies that are in use or being implemented at SLDC, Madhya Pradesh.*

1. INTRODUCTION

Indian Power Sector has the fifth largest installed capacity in the world having installed capacity of 329.23 GW & per capita power consumption in India is 1010 kWh. For the integrated & reliable operation of such a large power system, the region wise demarcation of the country was done with Regional Load Despatch Centre (RLDC) being the apex body at the regional level & State Load Despatch Centre (SLDC) being the apex body at the state level for ensuring integrated operation of the power system in accordance with prevailing grid codes and standards.

The State Load Despatch Centre is an apex body to ensure integrated operation of the power system in a State. The functions of State Load Despatch Centre are optimum scheduling and despatch of electricity within a state, monitoring grid operations, keeping account of the quantity of electricity transmitted through the State grid, supervision and control over the intra-state transmission system and carrying out real time operations for grid control and dispatch of electricity within the State through secure and economic operation of the State grid in accordance with the Grid Standards and the State Grid Code.

The State Load Despatch Centre at Jabalpur started functioning in 1969 in very limited way equipped with only express point to point power line carrier communication (PLCC) and analog frequency meter as a total means of monitoring and control of MP power system. Upto 1983, generation availability and demand calculations were done with the manual data obtained telephonically.

2. STATE LOAD DESPATCH CENTRE

Hierarchy of Load Despatch Centre

In order to have smooth and reliable management of the regional grid the computerized SCADA system was introduced in 1983. The Western Region was the first REB to implement hierarchical computerized SCADA system in the country which was subsequently augmented and replaced time to time with the state of the art systems in 1999, 2007 and 2016. The existing SCADA/EMS system is installed and commissioned by M/s Alstom T&D India Ltd (now GE T&D India Ltd) under joint replacement project for complete WR states.

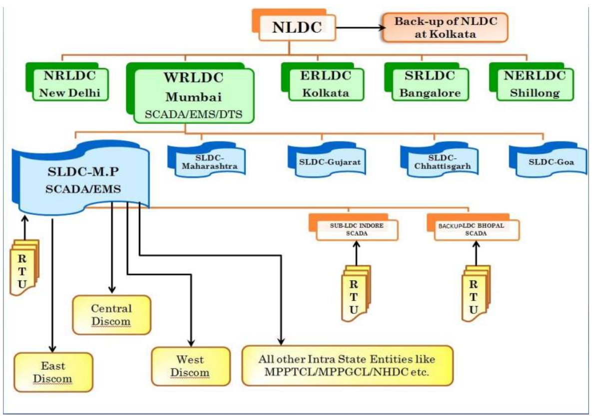

Figure 1. Various Applications of ICT in SLDC MP

Supervisory Control and Data Acquisition (SCADA) system

SCADA is a centralized system which monitors and controls an entire site for real-time operation. Under this system, information can be automatically or manually exchanged between remote facilities and the centralized Control Centers. Data acquisition begins at the Remote Terminal Unit (RTU) which exchanges data with connected field devices or sensors. The control center, in turn, exchanges data with RTUs via Communication Networks.

The SCADA/EMS system is acquiring Analog parameters (Active Power & Reactive power of all transmission elements, bus voltage and frequency) and Digital parameters (Circuit breaker/isolator status and Sequence of events (SOE)). The Analog parameters are acquired cyclically while status signals are acquired on change basis (Report by exception). The various type and makes of Remote Terminal Units (RTUs) installed and commissioned at field locations are configured for reporting to multiple masters (simultaneously reporting to SLDC Main and backup control centres, TRANSCO SCADA Control Centre, Local data management system (LDMS).

Architecture of SLDC SCADA System

In MP, the SLDC is having main SCADA control centre at Jabalpur while its Area load dispatch centre is functioning at Indore and Bhopal. As a disaster recovery measure, the backup SLDC is also established at Bhopal. The basic system architecture of SCADA/EMS system is indicated below:

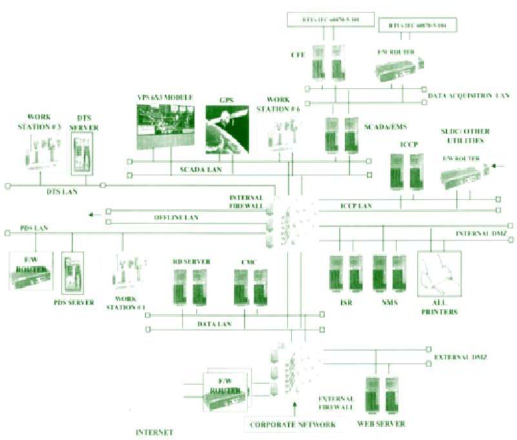

Figure 2. Configuration of SLDC SCADA System

3. SUB-SYSTEM DETAILS

SCADA/EMS Subsystem (Data Server):- The SCADA/EMS subsystem is the heart of the system. It hosts the SCADA & EMS databases, carries out the SCADA processing and EMS calculations, feeds the historical information server and sends data to the operator consoles (amongst other functions). It will support the functions of SCADA and real time dispatching.

Front End Processor:- The Communication Front End (CFE) drives the communication and pre-processing between RTUs (on both IEC 60870-5-101 and IEC 60870-5-104 protocol) and SCADA/EMS servers. It passes the RTU data up to the SCADA/EMS servers on a "report by exception" basis. The FE functions are considered as critical functions and hence supported with dual redundant FE servers.

Inter Control Center Communication (ICCP):- The Inter Control Center Communication system handles communications with external systems and the neighboring utilities of control centers. The SCADA/EMS system acquires real-time data like analog, status, calculated and manually entered data from connected control centers over ICCP protocol. The ICCP links are established between SLDC to Sub-LDC, SLDC to RLDC, backup SLDC to backup RLDC and SLDC to TRANSCO SCADA system.

HIS & Archive Subsystem(ISR) :- The Archive/Report subsystem (based on e-terraarchive), stores any user-defined data and events into the SQL Server based historic database; In particular, the Archive system will store real time database snapshot, historical Information, SOE data etc. The system is designed for storage of historical information up to 5 year period. To support huge data storage for long period time series data analysis based software tool i.e. eDNA tool is utilized in the system. Further, to support the same redundant Storage Area Network (SAN) with capacity of 18 TB is available at main and backup control centres.

User Interface (UI) Subsystem :- The User Interface (UI) subsystem is composed of multiple workstation consoles. All of the consoles are equivalent from a hardware perspective (dispatcher, engineer, trainees, instructor, etc.). The privileges assigned to a user depend upon the user account type (dispatcher, maintenance, administrator, etc.) and the console's IP address.

Development Subsystem :- The role of the development system is to maintain a central repository for all software development tools and environment, data models and displays representing the network. It also acts as test bench for the integration of new RTU/DCU integration into the system and Control Centre integration to the existing hierarchy through ICCP with main/backup SCADA/EMS system before putting them online in real time environment.

GPS Subsystem :- The role of the GPS subsystem is to accumulate the real data through GPS antenna and synchronize the time & date to servers, workstations and networking equipment, using the standard Network Time Protocol (NTP). Simultaneously the GPS system is transmitting the time, Day & Frequency data to respective display units. The CFE whose clock is getting time synchronized through GPS, in turn helps in synchronizing the RTU time through IEC 60870-5-101/104 protocol.

LAN & WAN Subsystem :- The role of the Local Area Network (LAN) subsystem is to assume the inter-connection of all the servers, workstations, and peripherals. The role of the Wide Area Network (WAN) subsystem is to communicate with external system (Remote Control center, IP Based RTU and the corporate Network

Video Projection System :- The system is equipped with huge Video display system consisting of 3*5 display array (total 15 screens) of 70" screens for display of system control and supervisory operations.

Cyber Security System : The system is equipped with two different layers of firewall i.e. External & Internal Firewall to protect the network from Intrusion and Detection system to meet the cyber security requirements. The system is equipped with separate patch management system, to continuously update the system. Periodic penetration test and vulnerability analysis is conducted to avoid any cyber security threat.

Applications of SCADA

- Automatic data logging and generation of reports
- Effective Control & Operation of all EHV substations through the real time information.
- Event sequence recording at EHV substations.
- Reduction of Transmission losses by control of voltages & circulating MVAR through the centralized information.
- Saving in running cost by optimizing operation & maintenance cost & reducing risk of failure of sub-station equipments.
- Identify potential risks to take preventive action in advance.
- Overcoming shortage of man power by automatic data logging and generation of all system reports.
- Preparation of precise MIS & Performance Standards of Transmission System for State Regulatory Commission
- Quality Monitoring of Power Transformers, CT, PT, Circuit Breakers, Multi Function Meters etc.
- Accurate centralized information help in quality monitoring of power supply. Improved services to customer.

For providing data input to various Energy Management System (EMS) applications like state estimation, Load flow studies, Contingencies analysis etc.

Achievements of SCADA Project

Integration of around 218 RTUs (EHV Sub stations, generating stations, IPPS) has been done successfully which helps in better & efficient system operation & monitoring. Apart from this system is also getting data of all 400KV Sub stations of central sector stations/ other states EHV sub stations falling under Western region through WRLDC.

Integration of about 60 RTUs of Renewable Energy Power Plants has been done which helps in maintaining the load-generation balance as the generation of Renewable Energy is quite dynamic & keeps changing frequently. In addition, the observability of RE telemetry is more than 98% which is quite significant & has been appraised at the regional level.

The integration of data channel of RTUs is done using Power Line Carrier Communication (PLCC), OPGW based fiber Optical communication back bone, V-SAT, Leased Line obtained through various Service providers like BSNL, Reliance, PGCIL, Idea etc. In several cases, data channel using combination of these various modes of communication is also utilized.

The MPPTCL is having its own OPGW based optical fibre network. Presently OPGW is available on 800 km EHV lines and OPGW laying on around 700 km EHV lines is under progress. MPPTCL is presently having 13 Wideband nodes & establishment of 24 wideband nodes is under progress. Presently around 45 % data channel of RTU & voice channel of RTU Stations are using wideband network. After completion of master telecom project around 70% data channel of RTU & voice channel of RTU Stations shall be utilizing wideband communication.

Integration of Restricted Governor Mode of Operation (RGMO) & Free Governor Mode of Operation (FGMO) of thermal & Hydel generating units in SCADA has been done which helps in ensuring grid security.

The SCADA/EMS system is communicating to RTUs through IEC 60870-5-101 protocol, IEC 60870-5-104 protocol. In some substations the RTU is reporting through both protocols which ensures dual redundancy.

All RTUS are planned with dual communication channel. The first communication channel is reporting to main/ back up control centre depending on the area in which RTU substation is located while alternate channel is reporting to backup/main control centre which ensures complete redundancy of data channel as well as control centre.

The in-house development of interface for providing real time SCADA data on website as well as mobiles is successfully achieved by SLDC. Presently, the real time SCADA data related with generation, transmission lines, transformer loads, EHV substation voltage, deviation parameters etc along with current day trend for MP, DISCOM demand and Solar and Wind generation is available on SLDC website in URL sldcmpindia.com.

Limitations of SCADA

The existing SCADA/EMS provides only the steady state view of the power system. These systems take few seconds to deliver a snap shot of a system whose characteristic are changing very fast.

The SCADA/EMS system does not provide the phase angle of the system which is very important for studying the oscillations in the grid.

In existing SCADA/EMS system, the field data is obtained from RTUs. As the RTUs are scattered in large geographical Area, the data from a cluster of RTUs are concentrated at Sub-LDC level and sent to SLDC and then to RLDC by wide band communication. Thus the data updation time at the main control centre is having a latency of few seconds ranging from 10 to 30 seconds. Due to slow rate of data update at times, the fluctuations are observed in the network through SCADA system due to fault/power swing/ loss of generation/load but the operators find it difficult to accurately pin point the cause and location of problems. Thus the SCADA is suitable only for steady state analysis.

Unified Real Time Dynamic State Measurement(URTDSM) / Wide Area Management System (WAMS)

WAMS (Wide Area Monitoring Systems) using Phasor measurement unit (PMUs) is advanced measurement system that provides synchronized measurements at sub second rate. The WAMS technology provides phasor measurements in terms of amplitude and phase angle of voltage and current over a widely spread grid. It’s a collective technology to monitor power system dynamics in real time, identify system stability related weakness and helps to design and implement counter measures & improve the performance, reliability and security of power systems.

It is based on Phasor measurement units (PMUs) that measures electrical parameters in power systems such as voltages, currents, and frequency. It uses Global Positioning Satellite (GPS) to provide globally synchronized power system measurements. The precise synchronization using GPS is the key to WAMS performance.

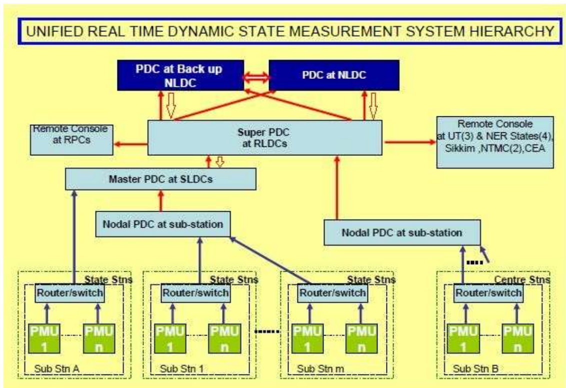

Figure 3. Hierarchy of URTDSM System

Components of URTDSM

Phasor Measurement Unit (PMU) :- The Phasor Measurement Unit (PMU) is a Power System device capable of measuring the synchronized voltage and current Phasor in a Power System. Each phasor measurement recorded by PMU devices is time-stamped based on universal standard time, such that phasors measured by different PMUs installed in different locations can be synchronized by aligning time stamps. Presently PMUS are being planned to be installed at all 400KV Sub Stations and Generating Power Stations of voltage level of 220KV or above.

Phasor Data Concentrator (PDC) :- The electrical parameters measured by a number of PMUs are to be collected by some device either locally or remotely, this function is performed by Phasor Data Concentrator (PDC). A PDC forms a node in a system where phasor data from a number of PMUs is collected, correlated and fed as a single stream to other applications. In a hierarchical set up the PDCs can also be used to collect the data from other PDCs.

Global Positioning System (GPS for Time Synchronization of the phasor) :- Synchronicity among Phasor Measurement Units (PMUs) is achieved by same-time sampling of voltage and current waveforms using a common synchronizing signal from the global positioning satellite (GPS).

Visualization & Analysis Tools

The user interface application software is required to visualize and analyze the real time phasor data. User interface is provided for the configuration, monitoring and analysis of multiple synchronized phasor data on single and multiple displays. Some typical visualization parameters are as follows:

- Deviation of frequency from nominal
- Rate-of-change of frequency exceeding a set value
- Voltage magnitude outside upper or lower boundaries
- Active or reactive power exceeding limits
- Voltage angle difference between selected points exceeding limits
- Visualization displays rapidly detect abnormal power flow or sudden change in power flow across the line, voltage violation areas etc.

Table 1: Advantages of URTDSM over SCADA

Features	SCADA/ EMS	WAMS	Advantages
Data Periodicity & Measurement	4-10 seconds Unsynchronized	40 millisecond Synchronized	Accurate System representation for pin pointed problems detection
Angle Measurement	Not Possible	Possible	Improved Power Flow for maintaining automatic Load/ Generation balance
Oscillation Monitoring	Not Possible	Possible	Power system oscillations damping by improved tuning to achieve greater Grid stability
Post fault analysis	Not in Real Time	Possible in Real Time	Accurate & Fast Fault Analysis for suitable remedial actions
Dynamic Behavior of the system	Not Possible	Possible	Corrective Measures possible to achieve greater Grid Stability

Unique Applications of URTDSM

Phase Angle Monitoring- Provides operator real time information about voltage phase angle deviation, Improve voltage control, improve system stability, security and reliability, and operate safety carrying components closer to their limit.

Voltage Stability Monitoring-Provides early warning against voltage collapses, immediate stop of cascading effects, and Protection against uprising voltage instabilities.

Power Oscillation Monitoring- Detection of oscillation, assessment of power system damping, Increase power transfer at defined security, and early warning to avoid power system collapse.

Information about auto reclosure of transmission lines can be indirectly inferred from the plots of df/dt. Such information is very useful in better situational awareness and operational planning in the real time.

Oscillations observed through PMU is found to be very useful in validating the transfer capability, tuning the SPS settings, identifying the need for PSS tuning.

Information obtained through PMUs has been found to be very helpful in monitoring the performance of protection system in the grid. Some of the discrepancies in overvoltage settings and unnecessary overvoltage tripping could be detected through the PMU.

PMU measurement has also been found to be very useful in validating the real time online SCADA network model and offline network models.

- Vulnerability test on relay characteristics.
- Instrument transformer measurement validation.
- Dynamic State Measurements - Wide Area measurement and control in regional transmission networks-Linear State Estimation.
- Supervised Zone-3 protection scheme to prevent unwanted tripping of distance relays.
- Schemes for controlling angular instability (i.e., out of step protection and smart islanding).
- Emergency control schemes for controlling frequency and voltage instabilities.
- Increase the reliability of the power grid by detecting faults early, preventing local events allowing for isolation of operative system, and the prevention of power outages.
- Improved transmission corridor capability.
- Adaptive islanding.
- Network transient stability model validation.

Load shedding and other load control techniques such as demand response mechanisms to manage a power system

4. AUTOMATIC DEMAND MANAGEMENT SYSTEM (ADMS)

The Automatic Demand Management System is a tool for automatic load disconnection from the distribution network under overdrawal conditions on crossing the defined frequency limits & further automatic load normalization on relief from overdrawal conditions.

Architecture of ADMS

The ADMS scheme in MP is based on two heterogeneous SCADA/EMS systems, MP SLDC SCADA/EMS system & MPPTCL SCADA (Transco SCADA) system along with the field RTUs. Both the SCADA systems exchange data through ICCP link. The SLDC SCADA provides the real time data of frequency, drawal deviation at regional periphery, DISCOM drawal deviations at State periphery and based on the logics the TRANSCO SCADA issues commands to SCADA Control Centres at Jabalpur, Bhopal & Indore which in turn processes data and issues commands to activate control commands for load disconnection to selected field RTUs. The ADMS scheme is unique as not only it sheds the loads under overdrawal conditions but also restores the load when overdrawal conditions are relieved. The logics have been developed by grouping load feeders (33KV) of each DISCOMS into about 30 groups. The group for which AUFLS is set on a particular weekday gets excluded from ADMS operation on that day so that the same is available for AUFLS operation.

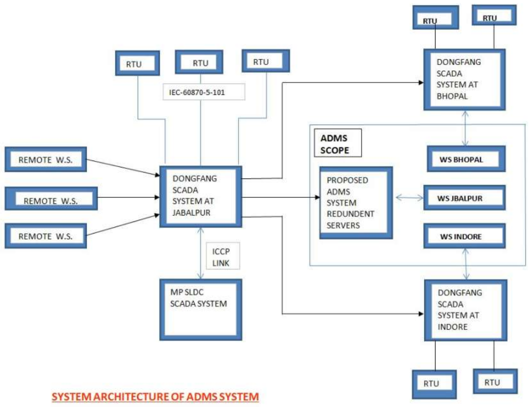

Figure 1. System Architecture ADM System

The ADMS system is having separate software module which works out quantum of load restoration, as well as group wise load shed/ restoration separately for each DISCOM and transfer this information to the respective SCADA Control Centre for issue of command. The other important features of ADMS system are provision for cyclic rotational load shedding/load restoration based on real time telemetry, user friendly GUI based interface for maintenance of ADMS database/user management. The group if continuously under ADMS outage is automatically normalized after 1 hour of operation and simultaneously next group shall operate to compensate for overdrawal. The system is having unique feature of alarm at Substation level for identification of normal tripping from ADMS tripping/restoration. This is the only ADMS scheme in India which is completely based on SCADA/EMS system and has provision for load shed as well as for load restoration.

5. FUTURE PLANS

Establishment of Renewable Energy Management Centre (REMC)

Variability of RE generation in a high penetration scenario is a critical challenge for system operator to manage power system balance. This calls for establishment of Renewable Energy Management Centre (REMC) as dedicated RE management system to facilitate adequate grid operation equipped with advanced Forecasting tools, Smart Dispatching solutions, & Real Time Monitoring of RE generation for safe, secure and optimal operations of the overall grid.

Upgradation of ABT, OA & MIS System

Scheduling of power, energy accounting & settlement, computation of DSM charges, reactive energy accounting, computation of transmission loss, outage management of transmission elements, computation of transmission availability is a quite cumbersome process. A dedicated tool for automized computation & processing is a need of the hour. Therefore an integrated system for ABT, OA & MIS system which will interact with SCADA/EMS system, AMR system, WRLDC, REMC system is under commissioning stage.

Integration of Automatic Under Frequency Load Shedding (AUFLS) in SCADA

In case of any major event/disturbance in the grid, there is a significant drop in the frequency of grid. Automatic under frequency load shedding in such an event helps to restore the frequency towards its operating range & thus improves the system security & reliability. Thus integration of telemetry of under frequency & df/dt relays in RTUs, integration of telemetry of all feeders/load covered under AUFLS & development of software to provide details regarding load relief on operation of df/ dt & under frequency relay is under progress.

Data Voice & Protection through Optical Fibre Communication

At present data & voice communication is utilized using the optical fibre communication technology. The expansion of optical fibre network upto 33 KV level is under planning. After implementation of in house backbone wideband communication network for various application like data, voice, protection, video conferencing, MIS, VOIP shall be available. This shall be a forward step towards achieving the implementation of Smart Grid.

6. CONCLUSION

The application of ICT at SLDC is directed towards ensuring & enhancing the grid security & reliability and thus provide better quality of power supply to the citizens of our country. Establishment of REMC will provide wings to achieve the ambitious target of deploying 175 GW of Renewable Energy by 2022. With the implementation of these technologies the company is expected to improve its operational efficiency manifolds setting an example for other State Transmission Utilities.

REFERENCES:

Required