Challenges and Learnings during Integration of Phasor Measurement Unit Data with Supervisory Control and Data Acquisition System – An Indian Experience

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Abstract. With gradual expansion of the grid, the conventional SCADA (Supervisory Control and Data Acquisition) required additional visualisation tools to operate the grid in more efficient manner. Due to low situational awareness, it became difficult for the operator to control the grid in safe and secure manner. This also resulted in isolated blackouts in the grid. In order to enhance the situational awareness PMUs (Phasor Measurement Units) were installed initially at critical locations identified on the basis of system studies. Upon installation of PMUs, the resolution of data increased from 2-4 (SCADA) to 40-60 samples/cycle (PMU). India being geographically diverse and large, the number of PMUs requirement was very high. This large scale integration of PMUs with existing SCADA posed many technological, geographical, financial and adaptability problems (electricity being Concurrent subject of State and Centre). This paper elaborates all such integration issues and challenges faced during integration of SCADA-PMU pan India.

Keywords. ICCP, PMU, PDC, RTUs, SCADA, Situational awareness, URTDSM, WAMS.

1. Introduction

SCADA (Supervisory Control and Data Acquisition) system facilitates smooth grid operation in real time by the system operator. Data updation is the key requirement in the SCADA system for operator to take suitable action in real time. Over the period of time, it was observed that despite taking all measures to get uninterrupted and accurate data in SCADA, few data (Analog, Status etc.) became erratic/non reporting at times due to various reasons. Non-reporting of data may be on account of communication failures, RTU failures, errors in conversions, transducer errors etc. Since resolution of these issues take some time and non-availability of real time data during this period may result in various operational and commercial issues. To overcome such issues, Synchro-phasors were envisaged and commissioned that helped in providing redundancy of data in case of SCADA failure and that too at a higher speed. URTDSM (Unified Real Time Dynamic State Measurements) scheme by POWERGRID (Central Transmission Utility of India) involved in installation of PMUs to establish WAMS (Wide Area Measurement System) in Indian power system.

1(a) SCADA System at Load Despatch Centres

Primary functions of Load Despatch Centres is to ensure the integrated operation of the power system in the respective region, monitoring of system parameters and system security along with many other allied functions. India is being demarcated into five Regions, viz., Western, Eastern, Southern, Northern and North-Eastern. These Regions control the States coming under their jurisdiction through SLDCs (State Load Despatch Centres). For performing these functions, the state of art SCADA systems were implemented at all control centres. SCADA is also called Eyes and Ears of the operator, as without SCADA it becomes very difficult to comprehend the state of the power system which is absolutely necessary for the system operator in real time. Load dispatch & Communication facilities are available at State Load Despatch Centres (SLDCs), Regional Load Despatch Centres (RLDCs), National Load Despatch Centres (NLDC). ULDC scheme has been established in the hierarchical order which includes Regional Load Despatch Centre at the apex level and the Remote Terminal Units (RTUs)/Substation Automation Systems (SAS) at Power Station/Sub-station at the lowest level as shown in Figure 1. In between there State Load Despatch Centres (SLDC). The RTU/SAS acquire and forward parameters like voltage, frequency, MW, MVAR, Breaker and Isolator Positions etc. to SLDC/RLDC in real time. The Central Sector data is directly transmitted to RLDC and the state sector data is transmitted to SLDC in the respective state. For data exchange between Control Centres, ICCP protocol has been used.

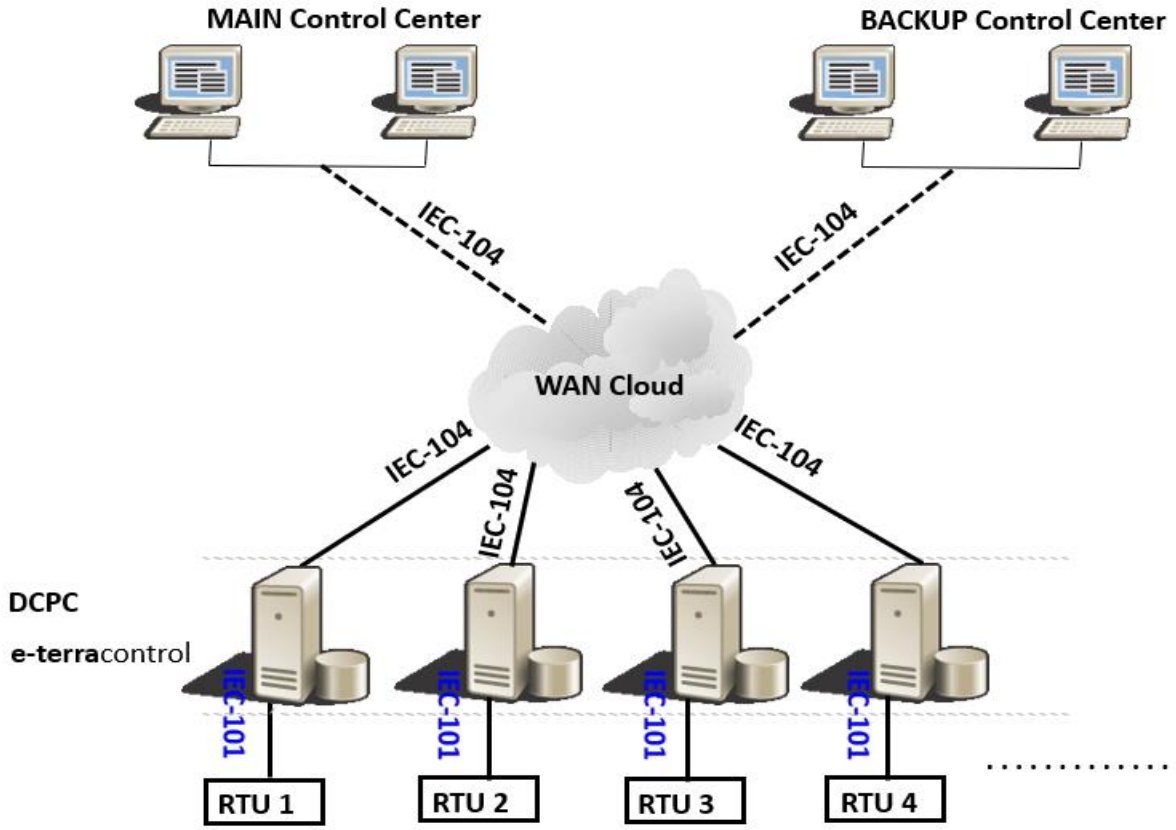

Fig. 1. RTU Reporting to Control Centre

Subsequently, all SCADA system at RLDCs (Regional Load Despatch Centres) are reporting to SCADA system of main NLDC (National Load Despatch Centre), whereas back up SCADA system of RLDCs reports to SCADA system of back up NLDC (Fig. 2).

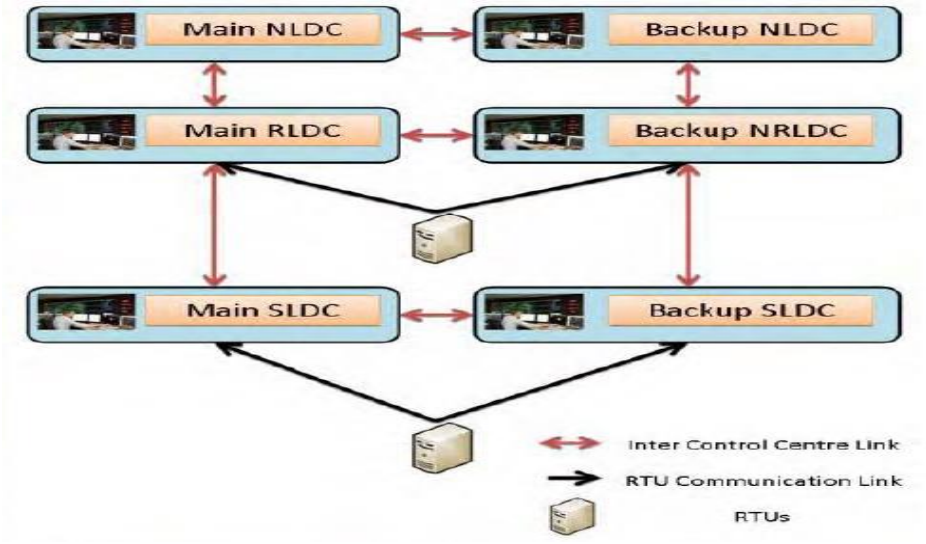

Fig. 2. Data reporting to Main and Back up Control Centre

Further data from SCADA system of all the state load despatch centre reports to SCADA system of Regional Load despatch centre. All the SCADA system of Regional Load Despatch Centre reports data to SCADA system of NLDC through ICCP Protocol (Fig 3).

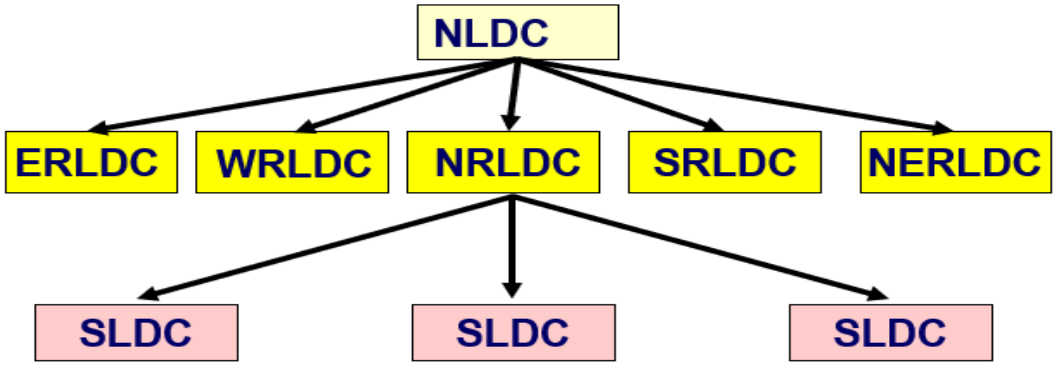

Fig. 3. Hierarchical set Up of Data Reporting

1 (b) WAMS at Load Despatch Centres

WAMS is based on the new data acquisition technology of phasor measurement. Recognizing the need of Wide area monitoring systems application in Indian Power System, PMUs have been installed on substations at 400kV level and above in the State & Central grids, all generating stations at 220kV level and above, HVDC (High Voltage Direct Current) terminals, important inter-regional connection points, inter-national connection points etc., provision of PDC (Phasor Data Concentrators) at all SLDCs, RLDCs and NLDC along with visualization aids in the first phase. This has been done as part of URTDSM project towards improved system operation. Architecture of URTDSM is as given below (Fig. 4).

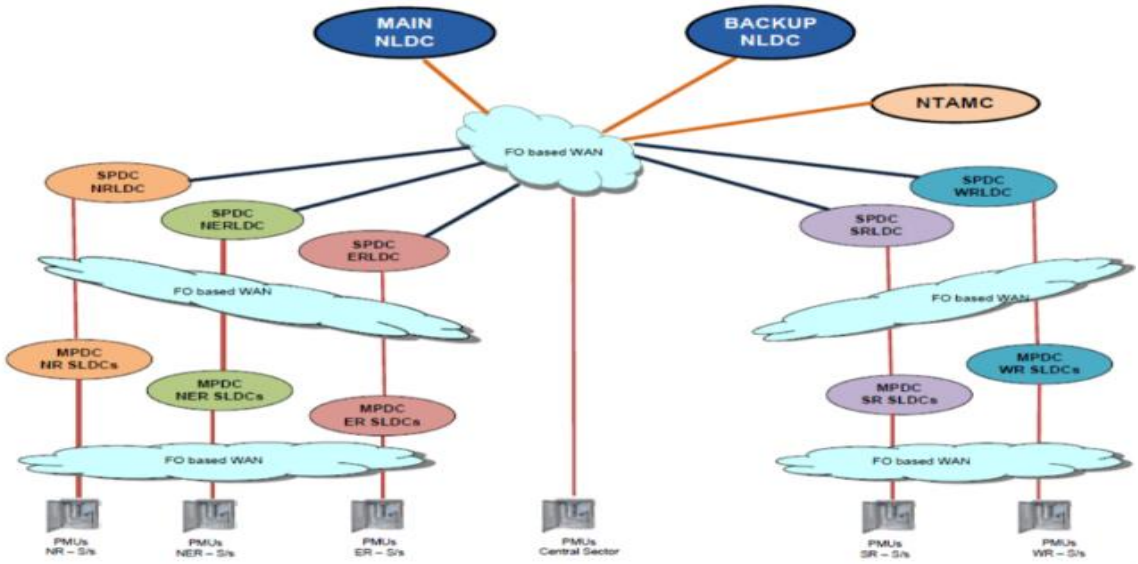

Fig. 4. Architecture of URTDSM System

Normally, the basic data i.e. voltage, MW, MVAR, connection status of elements of power system, etc. which is required for real time grid operation is available in SCADA at control centre. With implementation of URTDSM project, lot of data is available from many substations where PMU has been installed. Although data available from URTDSM is subset of data available from SCADA in terms of geographic spread, it is very important as a redundant data source. Additionally, data available from PMUs are more accurate with high refresh rate. With implementation of URTDSM, data redundancy has been increased as the data is available from multiple sources and from diverse communication channels. After integration of PMU data with the SCADA system, data availability from PMU can be used for operation, in case data from RTU is not reporting or faulty, thereby improving the real time data availability.

2. Need of Integration of PMU Data in SCADA

2.1 Angular Difference Between Different Buses

The Phase angle difference of voltage across different nodes (buses) is an indication of stress across the grid and needs to be monitored with respect to the stability limit for secure grid operation.SCADA being asynchronous measurement, angular difference cannot be measured. Angular difference between two buses in interconnected system is very important from real time operation point of view. In WAMS, Phase angle of each bus can be computed with respect to reference bus. This has been integrated in GRID display helping real time operator to get angular data of each bus and hence determine angular separation (Fig 5).

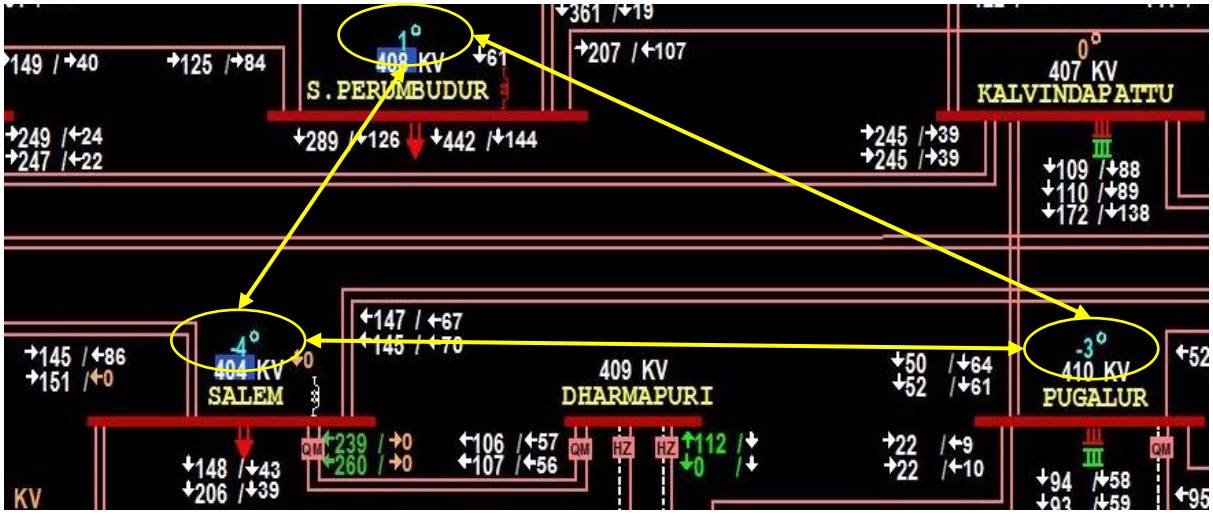

Fig. 5. Displaying angular separation in Grid Display

2.2 Real Time Drawl Computation of State from the Grid (Central Sector)

Real time drawl computation is a key calculation used to find out drawl from central sector for each state /control centre in real time. It is always desirable to have drawl equal to schedule for the state. For a state, schedule remains same for at least 15 minutes (1 block), whereas drawl keeps on changing. Accurate computation of drawl can be ensured with the availability of telemetry of all interface points.

In case any one interface telemetry is not available, drawl calculation becomes erroneous. resulting in operational and commercial issue. In this type of problem of erratic interface, telemetry data can be obtained from WAMS. Calculation using PMU data for drawl computation has been shown below (Fig 6).

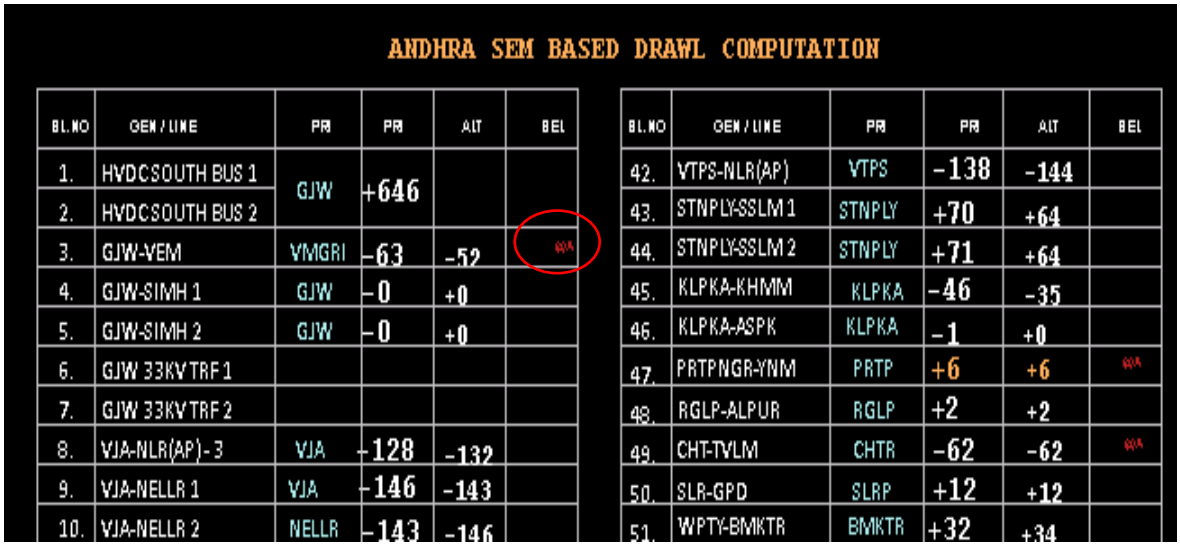

Fig. 6. Real time drawl computation using PMU data

It appears with an **@ A** (shown in red circle in Figure 6 above) symbol against the source in display. When the value of a particular telemetry is not updating or has wrong value due to Transducer issues or RTU errors, PMU data serves as ideal replacement.

2.3 Availability of All Type of Data from PMU

Several points from PMU report to SCADA from the URTDSM PMUs. Some of them are:

- Voltage Magnitude (+ve seq)
- Voltage Angle (+ve seq)
- Frequency
- MW
- MVAR

2.4 State Estimation

Usage of PMU data in State Estimation gives better and consistent results. It has been observed that cost factor (Index used for quality of State Estimation) reduces when PMU data is used in State Estimation. While configuring data base, higher weightage can be given to telemetered data with WAMS as source.

3. Integration Philosophy of WAMS (URTDSM) to SCADA System at Regional Control Centre- Indian Perspective

As mentioned, WAMS has been deployed pan India under URTDSM WAMS. The selected real time data is being exchanged from URTDSM WAMS to existing SCADA/EMS (Energy Management System) of respective control centre in each Region over IEC-60870-5-104 Protocol at all RLDCs/SLDCs respectively. Architecture of same is shown below (Fig 7 & Fig 8).

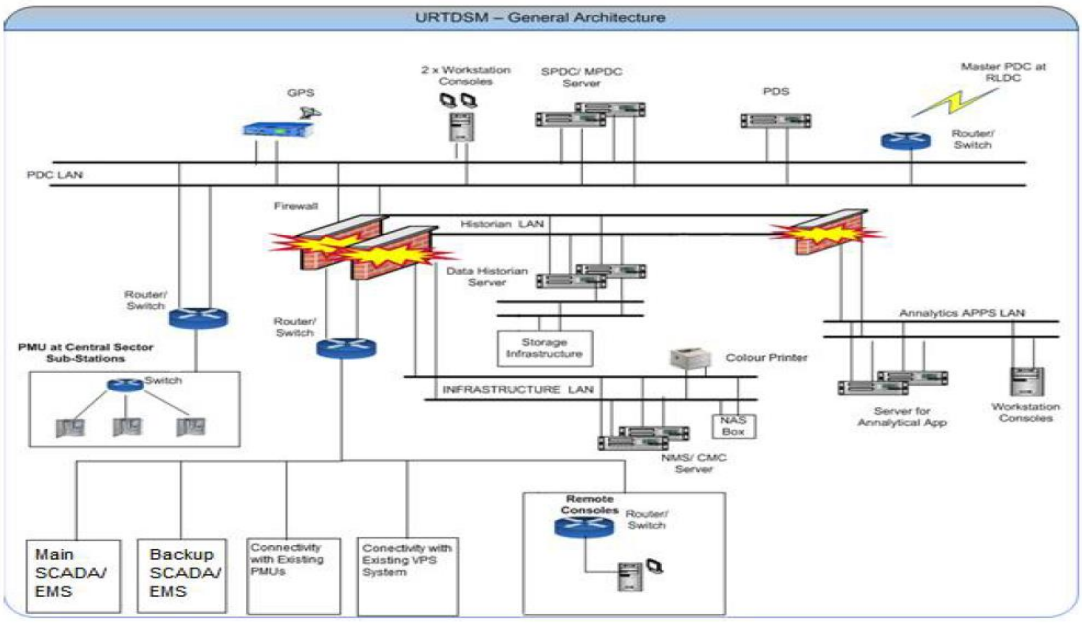

Fig. 7. URTDSM WAMS Integration with Existing SCADA / EMS at RLDCs, and SLDCs

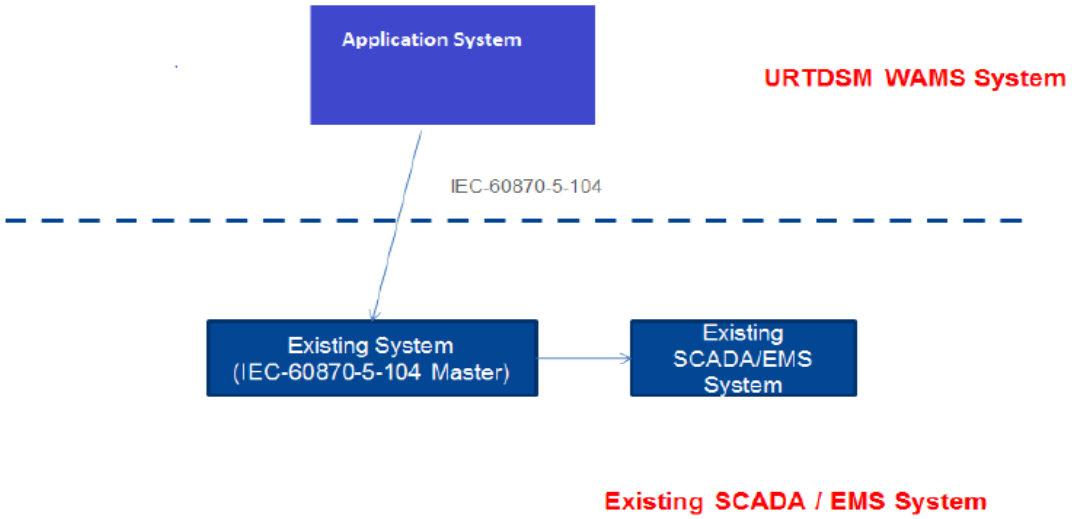

Fig. 8. URTDSM WAMS Integration with Existing SCADA / EMS at RLDCs, and SLDCs

4. Challenges and Mitigation in Integration of PMU Data to SCADA

Following are the key challenges and its solutions adopted for integration of PMU data to SCADA system:

4.1 Protocol Compatibility Issue

PMU data reports to Phasor Data Concentrator (PDC) which can be integrated to SCADA. This integration can be done on 60870-5-104 protocol. Some SCADA systems did not support integration of data on 60870-5-104 protocol.

To resolve this problem, a protocol converter was used for conversion of 60870-5-101 to 60870-5-104 between WAMS and SCADA. Following screen shot shows integration of WAMS with SCADA system using protocol converter (Fig 9 & Fig 10).

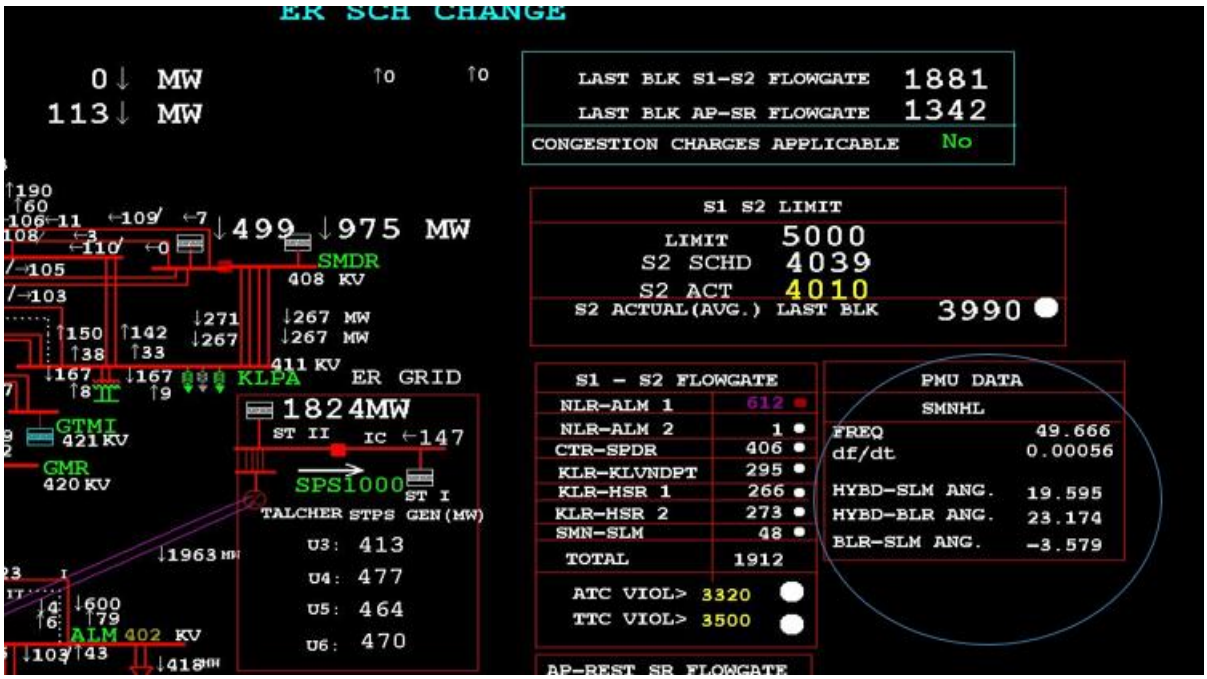

Fig. 9. Integration of PDC to SCADA system using protocol converter

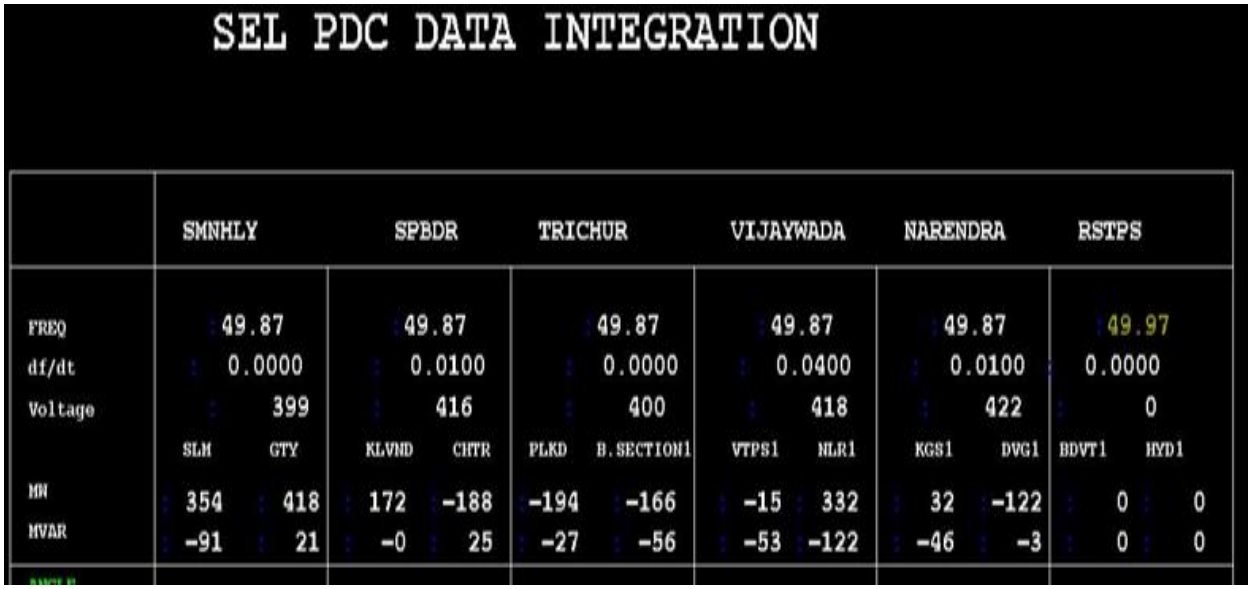

Fig. 10. Integration of PDC to SCADA system using protocol converter

4.2 Data Acquisition Rate -

Refresh rate of data in case of WAMS is very high as compared to SCADA system. Sampling rate in WAMS may be in the range of 10 to 50 samples per second. Considering average sampling rate to be 25 cycles per sec, in terms of time scale, it comes out to one sample of data at an interval of 40 millisecond. Whereas in case of SCADA normally, for Analog data generally periodic scan is in the range of 2 to 10 second. Due to this many samples may be missed while transferring PMU data to SCADA.

This problem was solved to a large extent by configuring lowest periodic scan in the available SCADA system. Data very critical from operation point of view was configured at higher scan rate, whereas other less critical data was configured to scan rate similar to data available from RTUs.

4.3 High Volume of Data

Due to very high sampling rate, volume of data was huge in case of WAMS system. After integration of PMU data to SCADA system this data is available in SCADA system also. SCADA system is designed to have its own archival system to store data. In case data volume increases in SCADA system because of PMU integration, it may result into scarcity of resources in historian of SCADA system in terms of storage space and performance.

To mitigate this problem, proper design of SCADA archival system was done envisaging volume of PMU data to be integrated with SCADA. Alternatively, data archival from WAMS was configured selectively.

4.3.1 Data Base Size

Generally, SCADA data base sizing is designed considering the number of sub stations reporting through RTU or ICCP. Due to integration of PMU Data to SCADA, additional data points (tags) were required to be configured in SCADA. This may create problem in terms of data base sizing beyond the limit of designed data base.

For resolution of this issue and to have smooth integration of PMU data, the SCADA database size needs to be considered at design stage itself. In the Indian context , the existing PMU data was integrated smoothly as the design of existing data was sufficient. However, for upcoming advancement of SCADA system and PMUs, the data base size was not sufficient. So, in all upcoming SCADA systems, enhanced data base size specifications were incorporated.

4.4 Data Base Related Issues

Data which is being integrated in to SCADA is already available from RTUs. In SCADA data base design, provision should be there to integrate data with multiple sources. For example, Bus voltage of a substation may be reporting in SCADA from RTU. In SCADA feature should be available to integrate same data as a separate tag or data base point. There should be 'Alternate Data Source' (ADS) feature in SCADA system for optimal use of PMU data.

This problem was resolved by designing the data base in such a fashion that was able to take data from multiple input sources automatically.

4.5 Hardware Issues

For integration of WAMS data to SCADA system, additional hardware may be required, which are not part of Implemented SCADA and WAMS system. This may include Switches, Protocol converter, Routers etc. It has been observed that many times these hardware devices creates problem in smooth integration of WAMS system to SCADA because of nonstandard design, difference in data transfer rate, unavailability of proper interface etc.

To avoid this problem, detail engineering needs to be done after study of both the WAMS & SCADA system. All technical aspects such as design, speed, and configuration etc. of additional hardware devices should be clearly defined to avoid any issue during integration. Additionally it will ensure stable data transfer between WAMS and SCADA system, post integration

5. Conclusion and Way Ahead

SCADA & WAMS are the enabling technologies currently available for power system operation and analysis. However, applications developed on SCADA systems are much more matured than those developed for PMUs. Present phase is witnessing a gradual transition from traditional SCADA systems to the high-resolution data technology based WAMS. Future SCADA systems will surely be based on PMUs as de-facto system for data acquisition for Load Despatch Centres. In the intervening period, integration of WAMS data with SCADA systems offers lot of advantages. Further, this will pave the way for development of SCADA application with most of the data acquired through PMUs. Indian grid being larger in size and geographically diverse posed many challenges and the same were resolved by meticulous planning and real time adaptations. The lessons learnt during said integration might be useful to other grids across the globe to design their SCADA and PMU system in a smooth and economical manner.

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