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Experience of Upscaling and Integration of Regional Level Synchrophasors Pilot Projects to a National Level project

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1 SUMMARY

Synchrophasors data and applications are valuable tools for ensuring security and reliability of any power grid. Synchrophasors data provide unprecedented insight into the minuscule happening in the grid at very high resolution to the grid operators. Synchrophasors data provide dynamic visibility of power system of a wide area and helps the grid operators in understanding early evidence of emerging grid problems and to diagnose, evaluate and implement remedial action towards system reliability.

In most parts of the world, synchrophasors technology deployment is in its initial stage and generally being taken up as pilot projects to experiment with operational capabilities of the technology. In India, Power System Operation Corporation Ltd. (POSOCO) started experimenting with this technology by implementing a pilot project in 2010 in Northern Region (NR). The project was implemented initially with 4 phasor measurement units (PMUs) and a phasor data concentrator (PDC). Later, more PMUs were added and PDC was upgraded.

After the inexorable use of data obtained from NR synchrophasors pilot project, similar projects were taken up by POSOCO in other regions i.e. Western Region (WR) with 8 PMUs, Southern Region (SR) having 6 PMUs, Eastern Region (ER) with 8 PMUs and North Eastern Region (NER) with 6 PMUs. Meanwhile some Independent Power Producers (IPP's) like Karcham Wangtoo Hydro Electric Project Ltd and Mundra Adani Power Ltd have also installed the PMUs in their premises and integrated the same with Phasor Data Concentrator (PDC) of Northern Region pilot project. Pilot projects in SR, WR and NER are already commissioned. Project in Eastern Region is under commissioning.

Phasor Data Concentrators of all pilot projects acquire data from PMUs installed in respective regions only. Accordingly, visualisation of synchrophasors data are available at regional control centers only. Hence, all India data was not available at single place. Thus, a national level pilot project was planned in order to get and visualise all India synchrophasors data at a central place by integrating PDCs of all the pilot projects. Installation of 18 nos additional PMUs were also planned in this project across all the regions. This paper describes the experiences of up-scaling and integration of regional level pilot projects to the national level project. It also detailed out the challenges faced during the execution of project.

2 KEYWORDS

Angle Measurement, Phasors, Phasor Data Concentrator, Phasor Measurement Unit, Synchrophasors, WAMS.

3 INTRODUCTION

Existence of voltage and current phasor quantities are as old as the alternating current technology of electricity production. However, measurement of these phasor quantities could be possible only in year 1981 when the first prototype phasor measurement unit (PMU) was developed at Virginia Tech University. But its commercial usage could become possible only after advancement of information and communication technology. Before this, only RMS (root mean square) values of voltage and current parameters of the grid were available to the grid operators. Advent of PMU and advancement of information and communication technology made the measurement of rms values as well as phasor angle of voltages and currents possible. It provided the dynamic visibility of the grid in comparison to static visibility provided by conventional SCADA system. Deployment of PMUs started in US after the black out of 1995. PMU data was used in the event analysis of 2003 US blackout. World-wide, it has been established that synchrophasors technology can dramatically improve the visualization of the grid as well insight of any happening in the grid.

The challenges in power system operation in India are increasing manifold day by day as a result of enlarged system size; brisk pace of capacity addition; long distance power flows; multiple players; increasing competition in the electricity market; emphasis on pan India optimization; climate change; large scale integration of renewable energy sources in certain pockets; and increasing customer expectations. 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. The network of phasor measurement units is called wide area measurement system (WAMS)

WAMS allows the acquisition of high-speed, real-time, time-synchronized grid parameters across an entire system or interconnection. This data provide wide-area visibility across the bulk power system in ways that let grid operators understand real-time conditions, see early evidence of emerging grid problems, and better diagnose, implement and evaluate remedial actions to protect system reliability [1].

In order to gain first hand experience of this WAMS technology, the first pilot project was implemented in Northern Region of India. Subsequently other pilot projects were also taken up in other regions of India. Since, all these pilot projects were individually located in respective regions, they were isolated and real time data available from these projects were available at respective regional control centres only. Consequently, a National level pilot project was planned for integrating all regional pilot projects and some additional PMUs in each region.

Rest of the paper will give the details about how this emerging technology was introduced through smaller pilot projects in Indian power sector and then scaled up to the national pilot project. First the over view of the WAMS architecture at regional and National level has been given than challenged faced during these period have been discussed.

4 REGIONAL PILOT PROJECTS

Very first WAM project was implemented in India in year 2009. Since, there was no previous experience of the technology, the project was kept simple and technical requirements were

prepared by specifying the specifications of readily available products and to enable the participation of maximum number of vendors. The project was located in Northern Region. In this pilot project, four Phasor measurement units (PMUs) each with a GPS were installed at strategically selected locations and one phasor data concentrator (PDC) was installed at Northern Regional Load Despatch (NRLDC) Center, Delhi, a regional control center managing the northern power grid in India. Synchrophasor visualization software as well as data archiving / historian software were also installed along with PDC. Project became operational in 2010. **Figure-1** shows the architecture of WAMS system in Northern Region.

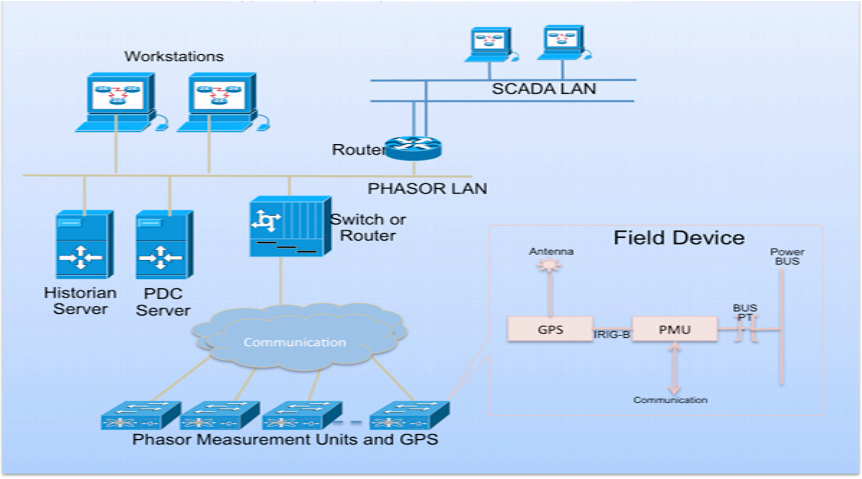

Figure 1 - Architecture of first Indian pilot project on synchrophasors.

Subsequently, 5 more PMUs were added to NR project. The PMUs get time reference from the GPS clock installed with it and measures the voltage phasors, current phasors, frequency and rate of change of frequency for each location. The Phasor Data Concentrator (PDC) and associated equipment's installed at NRLDC, time aligns the time stamp data sent by PMUs and display it on the operator console. The inputs that have been given to the PMU at the chosen substations are three phase voltage of the 400kV buses and three phase currents of the feeders at the chosen substations [3].

In 2011, an Indian origin vendor came up with indigenously designed PDC and installed a demo project in Southern region with four PMUs. In this PDC, an oscillation monitoring application was also installed providing small signals modal analysis of the grid on real time basis. Subsequently, one more demo project was commissioned in western region by using open PDC and two nos PMUs.

Having experiencing the utility of synchrophasors data in managing and improving the performance of the grid, similar pilot projects were taken up in other regions. Some of them are already operational and others are under commissioning. Followings are the details of these pilot projects:-

- Southern Region - PDC located at Southern Regional Load Despatch Center, Banglore and 6 PMUs located in southern region. Project is operational.
- Western Region - PDC located at Western Regional Load Despatch Center, Mumbai and 10 PMUs located in western region. Project is already commissioned and operational.
- Eastern Region - PDC located at Eastern Regional Load Despatch Center, Kolkata and 8 PMUs located in eastern region. Project is under implementation.

- North Eastern Region - PDC located at North Eastern Regional Load Despatch Center, Shillong and 6 PMUs located in southern region. Project is already commissioned and operational.

5 INTEGRATION AT NATIONAL LEVEL

Subsequent to commissioning of regional pilot projects, real time synchrophasors data became available to all the regional control centres. Under regional synchrophasors project, data was available to regional control centers only. As regional grids are operating synchronously (except SR grid), need of a unified availability and visualization of synchrophasors data from all the PMUs was felt. Consequently, a National level pilot project was planned for integration of the regional pilot projects along with installation of additional PMUs to improve the observability.

In national pilot project, a PDC is installed at National Load Despatch Center and all regional pilot project's PDCs are integrated with this. At present data from about 42 PMUs located all over India is available at National PDC and is expected to scale up to 59 nos (56 PMUs under pilot projects plus 3 PMUs installed by IPP's) by end of year 2013. The architecture of national pilot project and locations of PMUs integrated with this pilot project are shown in **figure 2.**

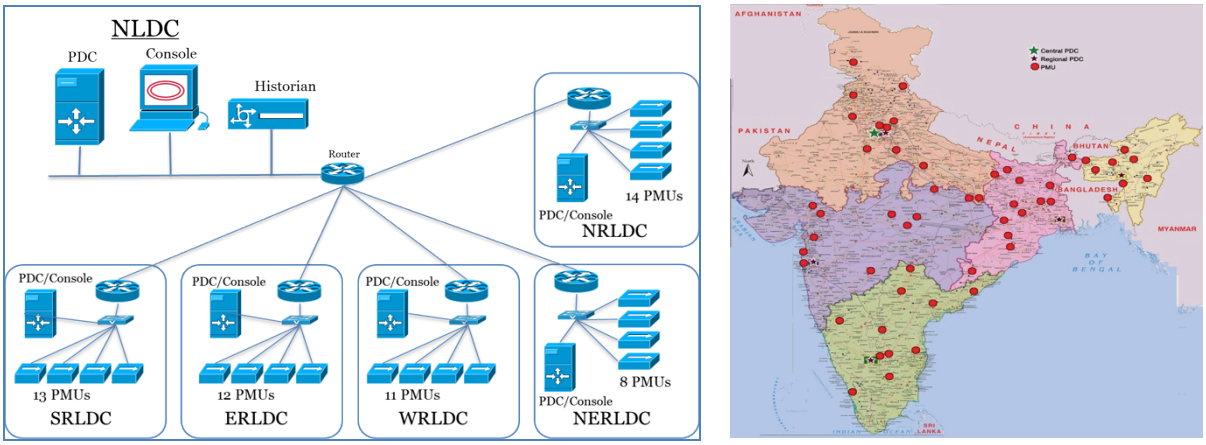

Figure 2 - National Level Pilot project architecture and PMU locations,

Region wise details of all the PMU locations (other then installed under demo projects) from which real time data is available or would be available to national PDC are given in Table 1:-

SN	Northern Region	Southern Region	Western Region	Eastern Region	North Eastern Region
1	Agra	Gajuwaka	Asoj	Biharshariff	Agratala
2	Bassi	Gooty	Bhadravati	Binaguri	Badarpur
3	Dadri HVDC	Kolar	Bina (MP)	Durgapur	Balipara
4	Hissar	Narendra	Boisar	Farakka	Bongoigaon
5	Kanpur	Ramagundam	Dehgam	Jamshedpur	Imphal
6	Moga	Somanhalli	Itarsi	Jeypore	Misa
7	HVDC Vindhychal,	Sriperumbdur	Jabalpur	Patna	Nehu
8	Kishenpur	Thrissur	Kalwa	Ranchi	Sarusajai
9	Meerut	Tirunelveli	Korba	Rengali	
10	Balia	Vijaywada	Raipur	Rourkela	
11	Rihand		Rgppl	Sasaram	
12	Bawana		Satna	Talcher	
13	Karcham Wangtoo HEP		Solapur		
14	Mahendragarh		Vindhyachal (WR)		
15			Mundra APL		

Before the integration and up-scaling of regional projects to National level it was not possible to analyse the impact of an event occurred in one region on the far situated substations located in other regions. After the availability of all regional PMUs data at National Control Center it became possible to visualise the grid wide impact of any grid event.

6 MATURING FUCTIONALITY

With experience of many pilot project and its visualization software provided by different vendor, maturity of WAMS functionality has been achieved to some extent in India. For example, visualization tools and data historian provided with national pilot project have many improved features as compared to provided in earlier projects. These improvements came out after the improvement of project specification based on the experience gained and problem faced during the operation of earlier projects. Model analysis of selected parameters and configuration of alarms of selected parameters are now also possible in national PDC.

7 CHALLENGES FACED DURING IMPLEMENTATIONS

The regional pilot projects have been implemented by different manufactures and hence their PDCs and PMUs are of different make. These regional PDCs are integrated to national PDC in order to capture data at NLDC from a wide foot print covering the whole of country. During integration and commissioning of PMUs and PDC's many challenges were faced which have been described below:-

7.1 **Communication channels**: Limited communication links/channels between PMU locations and regional control centers and between regional control centers to National Control center was the biggest challenge. Due to this, location of some of the PMUs have to be shifted. Data updation rate adopted for all the project is 25 samples per second (40 msec per sample). For such high rate of reporting, in general, dedicated fibre channel are required for reliability of real time data. However, at some locations, implementation of fibre optic network is still going on. Hence, PMUs at such locations have to be relocated to the sub stations where fibre optic communication is already available.

7.2 **Constraint in suitable space for installation of GPS antenna**: In order to get good strength signals, a location with clear view of sky is required for installation of GPS antenna. These were constraint at some places due to limitation of cable length of GPS antenna. Due to unavailability of clearest possible view of the sky, the GPS sometimes goes 'out of sync' in bad weather conditions.

7.3 **Non availability of signals form protection core**: Since, PMUs needs accurate measurement of current and voltage signals as input, ideally input should be provided from protection core of the current transformer (CT). However, non-availability of protection core or restriction of burden on protection core, the inputs to PMUs have to be provided from CT's metering core. If it would have been possible to get the measurements from the protection core of CT's the values/data from PMUs might have been more accurate. However, as presently PUM data is not being used for any control action, the present accuracy is quite acceptable.

7.4 **Issues with substations with automation system**: At substations having substation automation installed, issue of providing CT/PT connections to PMUs came up. In substation with automatic control, the physical connection from CT/PT are available only in bay control units (BCU) installed in switch yard area. Furthermore, all bays have

separate BCUs. Since, PMU requires main input from bus PT, they were installed in BCU having bus signals. But CTs for feeders were available in different BCUs. Hence, at such places line current could not be wired to PMUs.

7.5 **Communication connectors**: Challenges were faced while interfacing PMUs with communication equipment in the field due to mismatch between different types of connectors used for termination of communication cables. The issue of the use of different types of connectors-due to difference of rating/resistance/make and communication equipment of different technologies was a tedious task to resolve. Present communication system was installed under ULDC scheme in year 2000. In year 2000, PDH technology was used for communication equipment. In PDH, channels are separated by using hardware which uses G703 interface. But present equipment used for networking system uses Ethernet interface. To solve these mismatch in interfaces, converters from G.703 to Ethernet were used. These converters require external power supply. Due to this, though the converters could solve the issue of different interfaces but became a week point due to need of external power supply. Probably, availability of self powered converters might have solved this issue completely.

7.6 **Storage of data at Regional PDC vs at National PDC:** Since in national project, number of PMUs were large, increased data storage capacity have to be provided in order to store data form all PMUs. The solution of storing of data at regional PDC might have solved this challenge, but in order to fast retrieval of data, all the data was to be stored at NLDC. In this scenario, using of internal hard drives of servers for data storage was not feasible. Hence, storage area network (SAN) system has been used for providing the high capacity of hard disk capacity required for the data historian. SAN also provided the scalability of storage capacity required in future.

7.7 **Configuration of parameters**: Parameters matching of regional PDC with that of national PDC were the tedious task. Since, regional PDCs are of different make, they were having OEM supplied configuration utilities, matching of their configuration parameters were not straight forward task. However, use of open source PMU connection tester was used for establishing the communication availability than parameters were easy to match.

7.8 **Integration with SCADA**: Integration of PMU data with the data of existing SCADA system is still to be worked on. The integration of PMU data with the existing SCADA system through the conventional IEC 60870-5-104 protocol is a challenge due to the update rate of one sample per 4 to 5 seconds in SCADA as compared to the 20 samples per sec. Even a middle-ware software (currently excel) is not able to handle the high sampling rate of the PMU data which in turn results in a mismatch.

8 CONCLUSION

Integration of Regional PDC in to National PDC brought the unified visibility of system with increased observability of Indian power grid. This has helped the grid operators in many ways in day to day operation. Occurrence of minor to minor event in the system left its signature on the real time trend of voltage, frequency and angle measurement. A big signature warns the operator of happening of some significant happening. However frequent interruption has been observed due to communication and some tool may be readily available to identify these types of issues in order to avoid the data loss. There are immense possibilities and scope for better displays for visualization.

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