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CONSEIL INTERNATIONAL DES GRANDS RESEAUX ELECTRIQUES
INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS

STUDY COMMITTEE D2
INFORMATION SYSTEMS AND TELECOMMUNICATION

2013 Colloquium
November 13-15, 2013
Mysore – KARNATAKA - INDIA

D2-02_01

FUTURE CONTROL CENTER WITH ADVENT OF SMARTGRID

By

N.S.Sodha, Kumud Wadhwa, Manoj kumar Tripathi, Ankur Jain

Power Grid Corporation of India Limited

(IN)

SUMMARY

Electricity growth in fast growing Indian economy needs to match the pace of economic growth for sustained developmental efforts. Peak demand is expected to increase more than 170 GW by 2013 which requires installed capacity of about 275 GW as against present installed capacity of 210 GW. Further, to meet the growth rate of Indian Economy, installed capacity of Power Generation shall be about 600 GW by 2025. The distinct feature of power system development after Independence has been continuous growth of Interconnections giving rise to complex and integrated Electric Power Systems in States, Regions and Country as a whole. Traditional control center operations comprises of mainly monitoring and limited control. The technology advance in communication, computing and power system algorithms has made it possible to rethink the way to perform real time monitoring and control.

Future control center, shall be more automated, and based on wide-area measurement, Grid Security Expert System (GSES) and system protection scheme. From control center perspective there is a need to support new generation sensors and devices as well as the new Smart Grid eco system, comprising of distributed generation, electric vehicles, energy storage devices etc. With all these new breed of devices, technologies and systems, the overall utility will see a change in the way power is managed and delivered. Smart Grid development will require a new concept of Smart Grid control center which will use the new infrastructure that integrates Information Technology (IT), Operation technology (OT) and other support systems in the utility to maximize business value and deliver high reliability. This integration will facilitate the Smart Grid control center operator to carry out efficient, reliable and flexible operation of entire Smart Grid eco system.

This paper attempts to describe next generation application monitoring, assessment and integrated (OT, IT and support system integration) control functions in a future control center for having a self-healing power system leading to secure operation of the electricity grids in the country. The architectural changes in the Data & Information system exchange, Control Centre hierarchy, Creation of Back up Control Centres and Integration of WAMS by adopting Service Oriented Architecture (SOA), Common Information Model (CIM), Cyber Security features for

"Saudamini" Plot No. 2, Sector-29,

Gurgaon-122001, Haryana, India

Fax: +91 124 2571981, E- Mail : tripat_m@powergridindia.com

delivering a cost effective system. This paper also outlines a migration strategy for data acquisition at Main and Backup Control Centres from RTUs and among Control Centres, parallel operation of existing and new systems and integration issues while minimising downtime and proprietary work in existing systems. In addition the need for emerging IT networking techniques like platform independence and seamless integration of older systems of Load Dispatch and Communication are also highlighted.

KEYWORDS

CENTRAL ELECTRICITY REGULATORY COMMISSION (CERC), GSES, WAMS, RAS, SPS, PMU

1. BACKGROUND

In view of the recent Grid disturbances, failure of self-defense mechanism system like Under Frequency relays, df/dt relays, free governor operation it is the need of the hour that a Grid Security Expert System (GSES) is implemented to automatically disconnect the loads or the generation depending upon the criticality of Grid based upon Real Time information. Under this proposal Generation disconnection has invariably been used for the backing down of the Generators or Tripping of the Units similar to SPS implemented in the Indian power System.

This development in Information and Communication Technology coupled with the scorching pace of expansion in power system and regulatory changes is leading to existing system obsolescence.

The Present technology in Power system operation such as state estimation and contingency analysis was initially developed. The technology advance in communication, computing and power system algorithms has made it possible to rethink the way to perform real time monitoring and control. The typical present technology of monitoring and control may be briefly summarized as follows:

- The monitoring system is based on the output from the state estimation, which is subject to a considerable delay at the scale of tens of seconds to minutes.

- The security assessment is based on contingency screening, which is mainly a steady-state power flow analysis.

- The protection and control system is mostly based on local information.

- Operation of defense mechanisms like load shedding based on under frequency relays (UFRs) and Rate of change of frequency (df/dt) relays have been adopted. Similarly, increasing number of Special Protection Schemes is being employed to save system in case of contingencies. However, the experience of the recent grid disturbances reveals that desired load relief from these schemes was not achieved.

To eliminate these limitations, the future control centres are expected to utilize wide-area information for online, measurement and decentralized control strategy. Hence, the system will be more hybrid, integrated, coordinated, supervisory and hierarchical. This vision for future control centres, also referred to as smart control centres, can be a critical part to implement the overall framework of the future smart grid.

The functions of future smart control centres can be classified as monitoring functions, Dynamic security assessment and linear state estimation functions, Operation of Defense Mechanism and Primary Response from Generators

2. TECHNOLOGICAL TRENDS POST ULDC PROJECT

The design criteria adopted for ULDC scheme was in consonance with the available technology and organizational set up prevailing at that time. Due to organizational and regulatory changes in the Indian Power Sector the functional requirements of the operations have also undergone changes. Now, with the availability of advanced cost effective technological products we are in a better position to meet these requirements.

The changes in the IT industry towards compact hardware, portability of software and application platforms, emergence of Service Oriented Architecture, emerging browser based universal access tool has brought many changes in SCADA systems. The technological changes which are having an impact on upgrade are as follows.

- CIM
- Cyber Security
- Storage & retrieval (Historian)
- SOA
- Virtualization
- Disaster Management

3. FUTURE CONTROL CENTRES IN INDIA

3.1. Load Dispatch Centres in Transmission Sector

The RLDCs were installed progressively between 2000 and 2005 under ULDC project. The system at RLDCs has grown obsolete in terms of hardware and application versions. The regulatory environment has also changed after implementation of Electricity Act 2003 and Decentralized Scheduling, Availability based Tariff (ABT).

In view of above, a large scale Regional SCADA/EMS upgrades for Indian Power Sector is under progress. In all, around 70 Control Centres including associated backups are expected to be installed/ upgraded under these projects in next three years. The highlights of these upgrade projects are as follows:

- New SCADA/EMS System
- Use of Secure ICCP Protocol
- Graphical web based User Interface
- Provision of Applications for integration of Scheduling application, ABT Metering and Open Access with SCADA/EMS System.
- Provision of exchange of data using web services.
- Installation of Back up Control Centre
- Hybrid Estimator for integrating PMU data with SCADA values for improved state estimation.
- Parallel Operation for 3 Months before dismantling of old systems.
- Maintenance Contract of 7 years (Life Cycle cost)

One of the significant risk factors in such large-scale SCADA system projects is the performance and stability testing of the newly integrated system. The ultimate challenge is to keep the downtime of system as minimum as possible and minimize proprietary work in the system. Many issues which are foreseen during the implementation are as follows:

- RTU Migration: The existing RTUs established in ULDC Project were based on 101 Protocol. The dual channels of these RTUs need to be hardwired tapped at the nearest Wideband location and fed to the new system in "listen mode" till the new system is declared fully operation after parallel operation.

- Issues for support services and auxiliary: Foreseen issues are as follows:

  - Availability of Spare Load in Auxiliary Power Supply system at existing location to operate satisfactorily during parallel operation period.

  - Air-conditioning and other logistics in additional space.

  - Space for Cabling for New System and multiple communication Channels in existing Raceways.

  - Multiple changes in the same time frame at SLDC and RLDCs can run into resource issue and affect the planning considerations.

3.2. Load Dispatch Centres for Renewable Energy

India has been bestowed with huge Renewable Energy potential; however it is not distributed uniformly across the country. Solar, wind, biomass and small hydro are the major RE sources in India. As on December 2011, India has an installed capacity of 20,162 MW (10.9 % of total generating capacity) of Renewable energy and plans are in place for further expansion of 41,500 MW by 2017. Further, Wind based generation capacity constitutes about 80% of the total renewable energy based installed generation capacity in the country. Wind energy potential is mainly concentrated in the western and southern part of the country due to regular wind pattern in the coastal areas. At Governance level, the regulator has granted special status to the Renewable energy sources under the Indian Electricity Grid Code (IEGC-2010) as

"All renewable energy power plants, except for biomass power plants and non-fossil fuel based cogeneration plants whose tariff is determined by the CERC shall be treated as 'MUST RUN' power plants and shall not be subjected to 'merit order despatch' principles."*

*- CERC: Central Electricity Regulatory Commission

3.3. SYNCHROPHASOR TECHNOLOGY

Emerging technologies like Wide Area Measurement Systems (WAMS) using Phasor measurement Unit (PMU) provide advanced measurement system that will utilize synchronized measurements from geographically distant locations and increase the situational awareness of power system status every cycle of power frequency. The Synchrophasor technology is now considered as a major breakthrough in providing time synchronized and dynamic visibility of the power system. Though basic technology existed earlier than 2000, but the development in ICT especially readiness for handling terabytes of data and fibre communication at acceptable cost unlocked potential for proliferation of these devices into the Grid Control Centers.

Indian Power System and System Operators have had the first-hand experience of the benefits of phase angle measurement [4]. Later on, PMUs were infused for better monitoring and control of Indian Grid through pilot project wherein PMUs were commissioned at nine critical locations of Northern Grid and the phasor data was made available at one of the Regional control centres through Optical Fibre communication [4]. The objective of the pilot project was to gain a quick first-hand experience of Synchrophasors based Wide Area Monitoring Systems

(WAMS) before its large scale deployment in India. Similar projects in other regional grids are in various stages of execution [5].

The experience so far has been rewarding and some of the applications envisaged using PMU data are as following:

- Angular separation analysis and alarming
- Monitoring of long-duration, low frequency, inter-area sustained oscillations
- Monitoring and control of voltage stability
- System Model Validation and Fine Tuning of Parameters
- System Protection Scheme to Wide Area Protection Schemes (SPS to WAPS)
- CT/CVT Calibration

3.3.1. Monitoring Functions

A. From Separate system Model to one unified system model

The present system models for planning and operations are different even within a control area or region. In the figure, it will be highly beneficial to have one unified model for both planning and operation purpose. An interface function is needed to seamlessly transfer the EMS real time data to/from planning model. This will reduce the discrepancy between planning studies and real-time operations. Although the actual data used or the way to utilize the data by planning and operation will be still different, the unified system model will significantly eliminate the data maintenance and synchronization that must be repeated regularly.

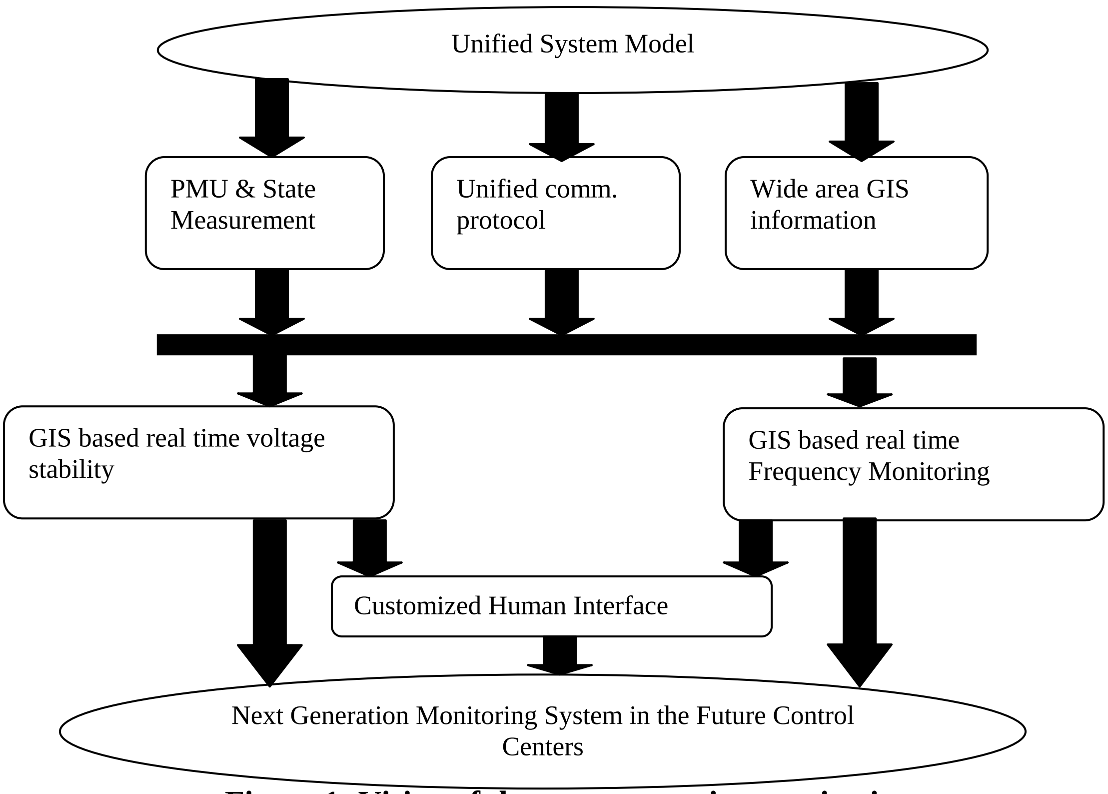

Figure 1: Vision of the next generation monitoring system

B. From state estimation to state measurement

The present monitoring system in a control centre depends on state estimator, which is based on data collected via SCADA and remote terminal units. In the future control centre, the system level information will be obtained from the state measurement module based on Phasor Measurement Unit (PMU). The PMU based state measurement is more efficient than the present state estimation since synchronized phasor signals give the state variables, in particular voltage angles.

C. From one line diagram to wide-area GIS

The present technology displays the system configuration with one line diagrams that can show which buses are connected with specific bus. However, it is not exactly matched to the geographical location. In the future, the results from state measurement shall be combined with a wide area geographical information system (GIS), The wide area GIS shall cover a broad region including the control centres own service territory as well as all interconnected areas. This will increase the situational awareness across a very broad scope

D. From limited stability margin monitoring to true stability margin monitoring

With the state variables obtained from state measurement, it is more feasible to display the true system stability measures in real time. The present technology typically displays the voltage magnitude, which presents limited information of voltage stability margin. As the system is more stressed and voltage collapse is a recurring threat, the voltage magnitude is no longer a good indicator of voltage stability. Hence, a true indicator of voltage stability margin is needed for better monitoring.

E. From Mixed communication system to dedicated communication system

Since the future visualization and monitoring technology will cover a much broader scope, better information exchange is needed. The present technology for inter-area communication includes a mix of traditional and new technologies, such as telephone lines, wireless, fibre optics, etc. In the future, the communication channel is expected to be more dedicated such as employing a fibre optic network for communication with Quality of Service (QoS) implemented.

F. From Limited customization to more flexibility

Another technology that is usually overlooked is the monitoring and visualization system. The present monitoring technology in control centres does not offer much flexibility in customisation for better human-machine interface. The future control centre should offer easy customization capability and be more users friendly such that the monitoring system can be configured to match the focus and to address specific concerns at different control centers.

3.3.2. Assessment Function

A. From Alarm Management to Intelligent Alarm Advancement

Alarm system shall have advance alarm management features. Minimum features of the advance alarm management function shall include following:

i. Minimization of nuisance alarm messages (e.g., repetitive alarms for the same alarm condition)

ii. Highlighting of the most urgent messages

iii. Display of Alarms Substation wise

iv. Sort, filter of alarms by users by node, element, type, date & time.

v. Intelligent Alarm processing (Alarm based on logic of alarms) - to assist operator in quickly finding the root cause of disturbance.

vi. Voice guided alarm shall be able to read static alphanumeric text (User entered message) & dynamic alphanumeric text (e.g. alarm message given by the applications). Each alarm and alarm priority level shall be assignable for voice guidance also.

B. From steady state security assessment to dynamic security assessment

The present on-line analysis in control centres typically performs steady-state contingency analysis. In future control centres, it is expected that online time domain based analysis such as voltage stability and transient angular stability can be carried out in real time. Also, online small signal stability analysis is expected**.**

C. From deterministic approach to probabilistic approach

The present technology applies N-1 contingency in a deterministic approach. In the future control centres, N-x or cascading failure should be considered with probabilistic risk analysis.

3.3.3. Control Functions

A. From local control actions to globally coordinated control actions

The present technology lacks the coordination of protection and control systems. Each component takes actions based on its own decision. Sometime this uncoordinated control may lead to overreaction under contingency. Hence, future control centre shall have the capability to coordinate many control devices distributed in the system such that the optimal coordination can be achieved for better controllability.

B. From offline-based parameter settings to online reconfigured parameter settings

Presently, the protection and control setting are configured as fixed values based on offline studies. In the future, these settings should be configured in real time in a proactive and adaptive way such that it will better utilize the generation and transmission asset.

C. From offline-based control strategy to online restorative plan

In the present control centres, the ultimate control action like separation is taken based on offline studies. In the future, the system separation will be performed in real time to better utilize the dynamic system condition. Similarly, the present restoration plan based on offline studies should be replaced with online restorative plans.

3.4. SYSTEM PROTECTION SCHEMES (SPS)

System protection schemes (SPS) (also called remedial action schemes, RAS) [3] are designed to detect abnormal system conditions, typically contingency-related, and initiate pre-planned, corrective action to mitigate the consequence of the abnormal condition and provide acceptable system performance. SPS actions include, among others, changes in load, generation, or system configuration to maintain system stability, acceptable voltages or power flows.

3.4.1. Relationship between SPS and Synchrophasor Technology

Synchrophasor technology provides system status at a much faster rate, compared to SCADA and other traditional state estimators. A Synchrophasor based vector processor (SVP) [3], which collects synchronous phasor measurements from the system, processes them and detects any unstable conditions within local as well as large areas.

3.4.2. Wide Area Monitoring, Protection and Control

After the advent of Phasor Measurement Units (PMUs), in 1988 Bonneville Power Administration (BPA) [3] was the first to use PMUs. Then inspired by its many advantages such as to record information useful for crucial system analysis, which were not earlier possible using SCADA or IED data, many utilities have started deploying PMUs. Figure 2 shows a typical data exchange using PMU and PDCs, which provide the ability to monitor system security and limits over a wide-area, and take necessary control actions over a wide-area of the power network.

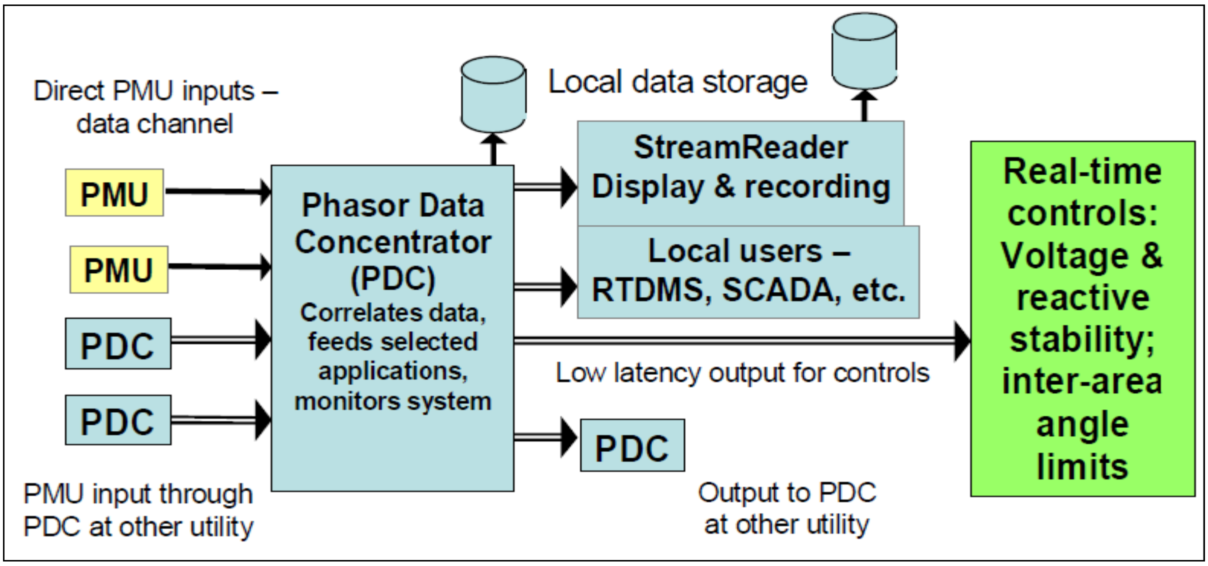

Figure 2: Typical PMU Data Flow [3]

Wide-area monitoring system (WAMS) based on PMUs is real time monitoring application of electric power grid performing various tasks such as monitoring phase angle, line loading, voltage stability, power oscillations, frequency stability, and event archiving. WAMS has gained a lot of importance in the electric power grid applications since there has been incessant load growth, aggressive renewable generation expansion and, also frequent blackout threat. WAMS are also used in implementing Wide-area protection schemes (WAPS), which are used to stop widespread blackout.

3.5. GRID SECURITY EXPERT SYSTEM (GSES)

In view of the recent Grid disturbances, self-defense mechanism system like Under Frequency relays, df/dt relays, free governor operation were unable to save the system. A Grid Security Expert System (GSES) based on WAMS should be there to automatically disconnect the loads or the generation depending upon the criticality of Grid based upon Real Time information. The loads shall be in the Groups which will be operated in order of priority and cyclic manner such that the same area may not always be affected.

The scheme for disconnection shall be implemented in well defined conditions e.g. overloading, overdrawl, etc. These conditions shall be dynamically verified through a suitable logic based upon various simulation studies. A tripping shall be initiated for pre identified feeders/ load of the constituent / agency who is responsible for such cause. For example, a constituent draws more than schedule (with suitable margins) and it is unsafe, the load/ pre identified feeder shall be cut off automatically to that extent (approx.). Similarly, some generators are injecting more than the schedule (with suitable margins) & it is unsafe, the same shall be automatically cut off to that extent (approx.). The provision shall be made to check the integrity / healthiness of the entire circuit so that availability of the intelligent system is ensured to the extent possible. Further the GSES system shall have well defined logic by monitoring the followings before actuating the actual operation:-

- Real-time flow of the load and generator to be disconnected
- Status of Numerical Relays, Programmable Logic Controller, and Digital tele-protection Coupler used for load /generation disconnection etc.

4. CONCLUSIONS

This Paper presents the vision of future control centres for real time operation. Comparison of the present technology and the future vision is discussed. Infrastructure and technology gaps, as well as the roadmap towards the propose vision, are discussed. Future work may lie in research and demonstration of the feasibility of the proposed concept of future smart control centres, including the monitoring functions, the assessment functions and controllability through deployment of WAMS system

Though, the first round of upgrade of Grid control centers in India takes care of multiple challenges and will incorporate answers to challenges of redundancy as well as integration of varied interfaces. The upgrade team is also conscious of promising new solutions in terms of CIM, Cyber security, Virtualization and SOA however some technologies are not matured. Accordingly, the upgrades are a mix bag in terms of technology but state of art for answering the emerging organizational need of the Power sector of India.

ACKNOWLEDGEMENT

The authors are thankful to their Management for publication of this paper. The views expressed in this paper are of authors and not necessarily the views of the institutions to which they represent.

BIBLIOGRAPHY

[1] Fangxing Li, Senior Member, IEEE, Pei Zhang, Senior Member, IEEE, Navin Bhatt, Senior Member IEEE, “Next Generation Monitoring and Control Functions for Future Control Centers”

[2] Meeting taken by Secretary (POWER) on 6th August 2012 with chief Scretaries of Northern Region states and adoption of 12 point resolution with subject “Automated Defence Plans for the All India electricity Grids”.

[3] “System Protection Schemes: Limitations, Risks, and Management” Final Project Report, Project Team:- James McCalley (Project Leader), Olatujoye Oluwaseyi, Venkat Krishnan, Renchang Dai, Iowa State University, PSERC Publication 10-19, December 2010.

[4] Soonee S. K, et al, “Application of phase angle measurement for real time security monitoring of Indian Electric Power System- An Experience”, CIGRE, 2008.

[5] V.K.Agrawal, P.K.Agarwal and Rajesh Kumar, “Experience of commissioning of PMUs Pilot Project in the Northern Region of India.”, IEEE-NPSC-2010.