Plant Operation and Control within Smart Grid Concept: Indian Approach

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***Abstract*—With smart grid typically characterized by attributes like, reliable and secure, efficient and economic, environment friendly and safe to the extreme extent as feasible, it calls for quality transmission and distribution operation backed by generation with optimum utilization of assets considering expected level of commitment from all stakeholders. Latter encompass investors, owners, traders, service providers, operators, and consumers of different categories. Such being the concept plant operation and control assumes an important, but difficult task at every instant of time to go. With Indian grid still growing to meet demand along with expansion of network whether from new generation or strengthening intermediate power systems, stabilization of the process would definitely take some more years. But aspiration of consumers nevertheless is not going to stop from the point of view of quality, besides quantitative adequacy at every instant of time. This calls for on the one hand smart grid to adjust with generation and its possible storage with availability whenever and wherever called for, self-healing mechanism in the face of disturbance, optimum utilization of assets achieving high level of efficiency in operation, while at the other hand consumer getting quality electricity as per quantitative requirement, through successfully enabled provision of services, products marketed, etc. Extensive usage of digital technology in terms of communication and information technology on real-time basis is an essential feature for achieving success in the matter considering the demand-supply scenario accurately at every instant. Depending upon the same means of automatic or intelligent operation and control within smart grid concept has been deliberated in the paper.**

***Index Terms*—Condition-monitoring, EMS, environment friendly, extra high voltage transmission, information and communication technology, MBC, optimum utilization of assets, PDC, PMU, reliable, safe, SCADA, secure, self-healing mechanism, smart grid, STPS, ULDC, WAMS.**

I. Introduction

INDIA starting from a meager generation capacity of 1,360 MW or so [1] has reached to a level of 167 GW by October 2010 [2]. During the journey from a scenario of concentrated generation in and around urban agglomeration with almost no transmission and then successively going through development of river-valley projects for both irrigation and power, forming state grids, regional grids, it stands at present with four out of five regional grids synchronously integrated and having the remaining southern grid connected asynchronously through long distance HVDC bulk power supply system at $\pm$500 kV. Side by side unit size, particularly on thermal side moved from few MW to 660 MW along with transmission voltage going upwards from 132 kV to 765 kV with in between levels of 220 kV and 400 kV. Today all-India peak demand and annual electrical energy demand are respectively at the level of 121 GW and 800 Billion Units. Though by the end of current five-year plan in March 2012 it was envisaged to provide electricity for all, according to an optimistic estimate it may take still few years more to be successful in this endeavor. Amidst this scenario too, India is taking step in moving towards intelligent operation and control envisaged under smart grid concept. It has become all the more necessary for wide-spread connectivity of four regions of Northern, Western, Eastern and North-Eastern part of the country.

Accordingly with the power system starting from generation, and then comprising of extra high voltage transmission and high or medium voltage sub-transmission, followed by low voltage distribution, and finally culminating in utilization of electricity by industrial, agricultural, commercial, and domestic sectors, at every stage operation and control has become important for such a large system. With the advent of communication and information technology, utilizing the concerned benefits attempts are being made to achieve the desired characteristics of smart grid [3]. Measures are aimed at having reliable, secure, efficient, economic, environment friendly, and safe system as a whole in the process of meeting demand of electricity. Spelling out the requirement in details, some of them have been described through the text of this paper.

II. Smart Grid And Expectations

As it has been rightly defined, smart grid [3] is a form of electricity network to deliver electricity from suppliers to consumers using two-way digital communications to control appliances at consumers' homes, thus saving energy, reducing costs and increasing reliability and transparency by virtue of overlaying the usual electrical grid with information and smart metering system basically to address issues of energy independence, global warming, and emergency resilience. This in turn calls for use of sensors for measurement and control with two-way communications for all forms of electricity generation, transmission, distribution, and

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utilization parts of the power grid that communicate information about grid condition to system users, operators and automated devices, enabling to dynamically respond to changes in grid condition at every instant of time.

So a smart grid has intelligent and automatic monitoring system effecting virtual operation and control of usual electrical grid. The activity covers both supply and consumption. Therefore, active participation of all stake holders from production, then transmission and distribution, to utilization of electricity is required. The expectation from the smart grid is in terms of reliable, secure, safe, efficient, economic, and environment friendly operation with in-built self-healing mechanism in delivering quality electricity for consumption. The term electricity, however, in real sense refers to both, instantaneous power and energy over a period of time. Anyway for the survival of such a system it definitely calls for smart measurements, recording, and pricing. Efficient and economic operation is expected to lead to affordable power & energy pricing. MBC (Metering, Billing, & Collection) process may continue with either post consumption payment, or with pre-paid arrangement through advanced purchase.

III. Measures Adopted In the Supply System

SCADA (Supervisory Control & Data Acquisition) system is in vogue with Indian power grids since eighties when out of five regions three were equipped with the same for data transmission to area level (in some cases), then state level, and then to regional level Load Dispatching Centers. By late nineties and early this decade all the five regions got Unified Load Dispatch & Communication (ULDC) systems in a big way to facilitate grid control and operation. With four out of five regions synchronously connected by that time, security of the system emerged as a big challenge. Decades of experience of working with SCADA and EMS (Energy Management System) lead to proper operation and control of grid through accurate insight into the monitoring process. However, quite a significant amount of disturbances, minor and major in the regions could not be avoided. Even restoration time too was unexpectedly much after small sub-systems islanded and survived and / or in case black-start had to be resorted consequent to wide-spread disturbance, as in the case of a major disturbance. Thus for the security of large grid, it is inevitable to install a number of Phasor Measurement Unit (PMU) at strategic locations as a part of Wide Area Monitoring System (WAMS). Action towards this has been the first step for moving towards achieving smart grid.

In order to get signature of the entire Northern Regional grid, as pilot project [4] few PMUs along with GPS have been installed at strategic locations based on the criteria of locating them near large generation complex or load center or pooling points, but apart from each other with the availability of fast communication mode to Regional Load Dispatch Center. Locations selected in this context are Vindhyachal HVDC Back-to-Back (near to major thermal generation complex), 400 kV Substaion at Kanpur (major transmission pooling point), 400 kV Dadri (load center), and 400KV Substation at Moga (major hydro generation pooling point). Fig. 1 shows placement of PMUs in the Northern Regional grid.

Fig. 1. System visualization.

Since April-May this year data are available through Phasor Data Concentrator (PDC) to the SCADA system. Though elsewhere as known from available literature, PMUs with high sampling rate are in use in power plants to measure rotor angle of the generator, excitation voltage and current, valve position, output of the power system stabilizer (PSS), etc., in the instant case load angle between different pockets of the grid is available more accurately with updating time in the range of few m-sec. With the data so collected continuously and hence trend known, it is expected to help operators to analyze system performance subsequent to any grid incident and arrive at a conclusion to take remedial action in future. Even under normal circumstances data would provide, besides means of wide area measurements, protection and control, an insight into inter-area oscillations, system inertia constant and frequency response characteristic in terms of stiffness, early detection of fault, demand response, power quality, etc.

Already efficacy of installation of such devices has been proved due to availability of accurate data giving complete picture of system in terms of variables consequent to incidents, like, loss of major generation due to tripping of generating units in Rihand Super Thermal Power Station (STPS) Stage I & II of National Thermal Power Corporation on June 01 and loss of generation due to outage of units at Panipat Thermal Power Station in Haryana on July 12 this year. Fig. 2 and 3 show respectively the voltage & frequency profile at Rihand, and angle difference between Vindhyachal and Dadri. Further with various regions connected synchronously and fast means of communication available, in future it may be possible to track dynamic response of other interconnected regions as well and visualize its impact on each other possibly to safeguard the interest of regions and avoid cascade failure for a fault in neighboring region.

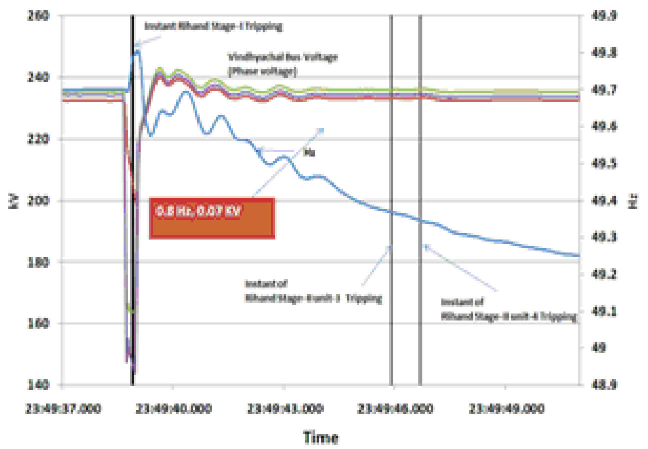

Fig. 2. Variation in frequency & voltage when units tripped at Rihand STPS as captured by PMU at Vindhyachal and transmitted to NRLDC.

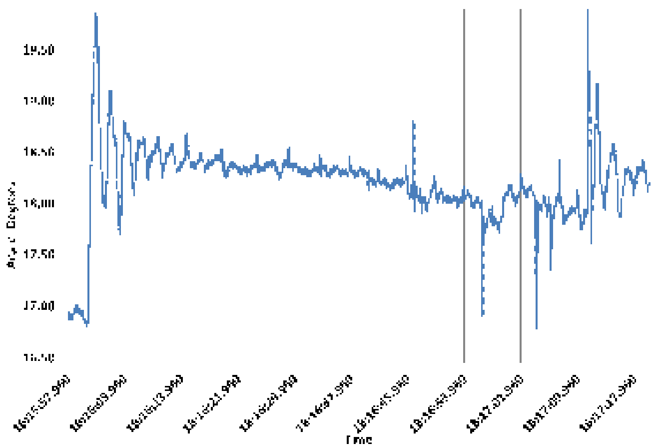

Fig. 3. Angle difference between Vindhyachal and Dadri when units tripped at Panipat TPS measured by PMUs at Vindhyachal and Dadri.

While reliability is an important feature of smart grid, towards meeting that up to a very high level it is essential that various equipment and devices constituting the grid individually too are reliable. Utilizing the advances in information and communication technology, therefore, online health monitoring of major components is a basic requirement. In India while central power utilities have taken the lead, some of the progressive state utilities too are now going in a big way for adopting such measures at the instance of Central Electricity Authority [5]. Condition based maintenance, refurbishing or replacement in time, based on trend analysis of deterioration in conducting, insulating, and other parts are the result of such activity that not only reduces cost of operation, but also enables optimum utilization of assets with complete data available for the life cycle of equipment and devices.

IV. Measures Adopted At The Consumption Side

With the enactment of Energy Conservation Act, 2001, India took a bold step towards energy savings in equipment and appliances that consume electrical energy. In fact with the encouragement given to the manufacturers through star-rating of products and consumers gaining benefits out of it, in this part it is a praiseworthy initiative towards smart grid. Following of best practices sector-wise, namely, in industrial, agricultural, commercial and residential sectors is resulting in significant conservation of energy [6]. Of course it may be termed as a static measure only. For a developing country like India it is still not dynamic in nature with automatic or remote control of load when not in use. But with economic growth resulting in more and more consumption of electrical energy, being a clean form and for easiness in handling concerned appliances there is possibility of sea-change in consumption pattern and consequent wastage. Therefore, it may not be far to establish two-way communications taking advantage of convergence of technologies to control the situation by minimizing the wastage, thus leading to success in consumption front of smart grid.

V. Conclusion

In the context of India, a developing country with all-round progress going on in building infrastructure including power sector, due attention is being paid on operation and control within smart grid concept. Though achievement everywhere may not be comparable to the developed countries of the world, at least at the supply end there is significant promise for achievement. While attempt is being made to have reliability, security, efficiency, economy, environmental friendliness along with safety, the essential characteristics of a typical smart grid, in so far as utilization is concerned in fact very little has been targeted or achieved. Energy saving measures while consuming electricity through usage of quality product and adopting best practices only are being advocated at present. But with economic growth future may see scope in savings through application of more of intelligent and / or automatic control during operation.

VI. Acknowledgment

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VII. References

[1] Subrata Mukhopadhyay, "Towards Electricity for All," *IEEE Power & Energy Magazine*, vol. 3, pp. 71-78, Sep-Oct. 2007.

[2] http://cea.nic.in/power_sec_reports/Executive_Summary/index_Executive_Summary.html.

[3] Available in Wikipedia: http://en.wikipedia.org/wiki/Smart_grid

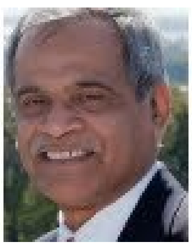
[4] S. K. Soonee, S. R. Narasimhan, R. K. Porwal, S. Kumer, R. Kumar, and V.Kumar, "Application of phase angle measurement for real time security monitoring of Indian Electric Power System- An Experience", CIGRE Session , Paris, France, 2008.

[5] Subrata Mukhopadhyay, and S. K. Ray Mohapatra, "Risk and Asset Management of Transmission System in a Reformed Power Sector", in *Proc. 2006 IEEE Power India Conference, New Delhi, India,* paper no. 252.

[6] Subrata Mukhopadhyay, and Ashok Rajput, "Demand Side Management and Load Control - An Indian Experience", in *Proc. 2010 IEEE PES General Meeting, Minneapolis, MN,* paper no. 795.

VIII. Biographies

Subrata Mukhopadhyay (S'70, M'70, SM'80) graduated in Electrical Engineering from Jadavpur University, Calcutta in 1968 and had his Master's and Doctorate Degrees from Indian Institute of Technology, Kharagpur and Roorkee in 1970 and 1979 respectively. His employment experience of about four decades includes teaching and research in Roorkee, IILM Academy (as Director and Professor in EE), and Lingaya's University (as Acting Vice Chancellor), and power system planning, design and operation with the Central Electricity Authority of Government of India. He had been Director of HVPNL, the TRANSCO of the state of Haryana, also. Currently he is with the Lingaya's University. He has authored two books and thirty-five papers, won IEEE Third Millennium Medal in 2000, IEEE PES Delhi Chapter Outstanding Engineer Award and IEEE PES Asia-Pacific Regional Outstanding Engineer Award for 2001, IEEE Regional Activities Board Leadership & Achievement Awards in 2002 and 2004 respectively. He is a Senior Member of IEEE, Fellow of the Institution of Engineers (India) as well as Institution of Electronics and Telecommunication Engineers, India, and Member of ASME. He is associated with the Technical Activities Board of IEEE, and Power & Energy Society of the latter in various capacities.



Sushil K Soonee (M'99, SM'01) born in 1956, had his graduation in Electrical Engineering from the Indian Institute of Technology (IIT), Kharagpur, India in 1977. After a brief stint in private sector joined Central Electricity Authority and worked extensively in integration of State Grid to form a Regional Grid in Eastern and North-Eastern Region, carried out Research and Literature Survey in Power System Operation and Control at IIT Kharagpur in 1981, traveled extensively Europe, USA and SAARC countries. He had first hand experience of Power System Operation of Eastern, Southern and Northern Grids, and also on Commercial Settlement, Restoration and entire gamut of Power Pooling and System. Frequency maintenance within permissible limits, voltage control, etc. achieved to a great extent during his tenure in Southern Region. Persuaded constituents to rejuvenate Inter-State Transmission lines, hitherto dormant. Worked for implementation of Availability Based Tariff (ABT) and on implementation, the scheme is recognized not only in India but worldwide. Responsible for implementing the Intra-State ABT scheme also, and Free Governor Mode of Operation. Streamlined Open Access in Inter-State Transmission System. Authored quite a good number of technical articles and presented in various forums, chaired many technical sessions in seminars / workshops, acted as Member of various committees for Regional Power System on disturbance and restoration. Currently he is CEO of Power System Operation Corporation Ltd. He is a Fellow of the Institution of Engineers (India), Member of CIGRE C2, VLPGO (Very Large Power Grid Operator) and TSO comparison group also.

Ravindra Joshi (M'06, SM'07) graduated in Electrical Engineering from Indian Institute of Technology Roorkee in 1978 and received Master's degree in Business Administration in General Management from Lancaster University, UK subsequently. Having 32 years of business success on national and international levels with enormous experience including Project Management, Process development and improvement, he is presently with North Delhi Power Limited, a Joint Venture of Tata Power and Govt. of Delhi, and working there as Assistant General Manager-EHV Projects. He is associated with IEEE Delhi Section, its PES-IAS Chapter, and chairs Human Technology Challenge Group.