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A Note on Recent Research Developments in Power Systems and Power Electronics Area

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About three decades ago, the oil and air-line industries were making lot of profits in U.S., after they were freed from strict regulations. Power system engineers did not like to be left behind; they introduced the concept of deregulating the system operation with complete privatization after breaking the monopolistic operation. It is well known that competition brings in efficiency and effectiveness. Deregulation became necessary for another reason as well; a utility, as a single entity, could not increase the power transfer nor could it go for large substations and hence the privatization became handy. Deregulation brought many people into action, each trying to make as much profit as possible. Profit became important parameter, not the system reliability, its resilience nor the power quality. In the year 2003, there were a large number of power breakdowns in USA and in Western Europe. IEEE constituted a committee to study the problem. They came out with a research paper in IEEE proceedings which suggested that deregulation must not be done without understanding it.

One of the important problems being studied under Deregulation even today is pricing of electricity. It contains three components: price of energy, price of losses caused by the customer and price for any congestion caused by taking extra power; these are known as Locational Marginal Prices (LMPs) which can be computed, as per the current state-of-art, by an A.C. optimal power flow or by an iterative D.C. Optimal Power flow. Under deregulation you no longer work on system pool basis but under bi-lateral and multi-lateral basis which mean that the consumers can directly enter into agreement with utility given their bids for purchase or for selling the energy.

From deregulation, the power engineers wanted to utilize the available modern technologies for system operation and control; this brought the Smart Grid into being. Smart distribution networks and Micro-grids consisting of distributed generation like solar, wind and diesel power are under the focus. This distributed generation (DGs) makes good use of power electronic devices. The DGs not only control the pollution from coal but also mitigate to a large extent the harmonic pollution in power networks. Under the Smart Grid operation, the customer is participating in the system operations in helping the system to reduce the power mismatches during the peak load periods. The utilities motivate the customers, giving them proper incentives, to cut down their loads going through an agreement with the customer. So, the customer helps in what can be called as 'shave the peak and fill the valley' of load curve. This is what we call as demand response which is monitored by the smart meter located at the customers' place. The smart meter has the freedom to dictate to the load controllers as to when a particular load in a residential or commercial place can be switched on or off with minimum discomfort to the customer. The smart meters located in a given load centre operate in a co-ordinated way to minimize supply-load mismatch and also to minimize the electrical losses. A smart meter also takes the responsibility of 24-hour load fore-casting to help the utility to fix the energy price for the next day; it is a bi-directional communication source between the utility and the customer. It is an important device in the distributed and co-ordinated control of Micro-grid.

Along a distribution network, there can be a large number of Micro-grids, all connected to the Mega-grid. When the mega-grid fails and the grid breaker opens, the micro-grid voltage is available at the breaker and this can lead to physical security of the working personnel who get on to the line seeing the breaker which is off. So, a micro-grid and its islanding can also damage the system hardware through asynchronous synchronization when the auto-reclosing breaker closes after a specified period (usually 500ms). Presently, work is in progress on the detection of islanding and anti-islanding measures; they are known as passive, active and communication-based methods.

For decades, the system monitoring is being done through SCADA (supervisory Control and Data Acquisition) which is not accurate and also slow. For monitoring and control of Wide Area Systems, PMUs (Phasor Measurement Units) which provide time-synchronized measurements at a very fast rate ensuring accurate system control in real time. As of now, the PMUs are expensive for installation and therefore there is a need to minimize the number of PMUs that can be installed while keeping the entire system observable. This problem of minimum PMUs is easily solvable with Integer Linear Programming methods. With the provision of a set of units, is every node of the network observable or not, is problem solved with the use of matrix algebra and matrix LDU factorization. Thus, the system Observability, PMU placements, detection of any bad data in the measurements are all needed to solve state estimator. Thanks to the PMUs, the state estimator problem becomes linear for accurate solution in real-time.

The system engineers have been solving the Economic Dispatch problem off-line, so far, along with the Automatic Generation Control. This off-line solution can lead to inaccuracies in real time implementation and result in frequency regulation problems. The researchers are now busy to find real-time implementation of Economic Dispatch even in a modest way. The other problems under attack now are frequency and voltage regulation of micro-grids and their sustainability after islanding. With the introduction of microgrids, the power electronic devices needed to be sophisticated and thus the power and power electronic engineers are working together towards the solution of all these problems.