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Smart Grid: Advanced Metering Infrastructure (AMI) & Distribution Management Systems (DMS)

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***Abstract*— in this we have touched upon features and various implementation challenges of deploying of Electrical Smart Grid. Though the Electrical Smart Grid Architecture involves wide and exhaustive combination of Elements, we have limited the discussions to a simple Smart Architecture involving Distribution Management Systems (DMS) and Advanced Metering Infrastructure (AMI). There are various implementation challenges both technical and commercial such as interoperability, standardisation, cost implementations, process integrations etc. and the need of the hour is to explore the best solution to present power supply scenario.**

***Keywords*—** DMS, AMI,SCADA

I. INTRODUCTION

The present Grid system is under pressure to cater the increasing demand for power. Further stable and sustainable supply of electricity is also key challenge. Thus, there is need to think about deploying smart and intelligent elements to existing overloaded grid rather than only Enhancing & Augmenting electrical distribution systems. A smart grid is a system which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources [1]. Some of the important features of post Smart Grid implementation are:

a. Reliability: Fault Detection, Isolation followed by self-healing mode of restoration ensures reliable power supply.
b. Flexibility in network topology: This ensures Import and Export concept of electricity, thereby allowing Bi-Directional flow of Energy & distributed energy generation [2] in the Grid System making it more flexible.
c. Efficiency: Using Smart Grid Technologies the overall efficiency of the energy can be improved since it includes Demand Side Management (DSM) [3], AMI systems to improve Outage Management [4], Optimum power supply generation to decrease the average price of power purchase by distribution utilities thereby making electricity cheap for general public.
d. *Load Reduction: Smart Grid using intelligent algorithms can broadcast messages for load reduction indicating the equipment's to be shut off and thereby reducing the Grid Load by analyzing the power available in the grid.*
e. Sustainability & Integration of large-scale renewable energy systems: The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as solar power and wind power, even without the addition of energy storage.

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II. COMPONENTS & CHARATERITICS OF SMART GRID

Smart Grid components can be combined to form a simple architecture as shown in Figure 1 which is spread across Generation, Distribution and Transmission processes.

At level of Generation the Smart Grid Technologies is used for Grid Automation to effectively monitor the Generation parameters such as temperature, pressure, water injection speed, turbine throughput etc depending upon source of generation. Apart from this various factors such as Availability factor Capacity factor, Demand factor, Diversity factor, Utilization factor (UF) and Plant Load Factors (PLF) are automatically calculated to increase the production thereby reducing cost of billing charges for consumers.

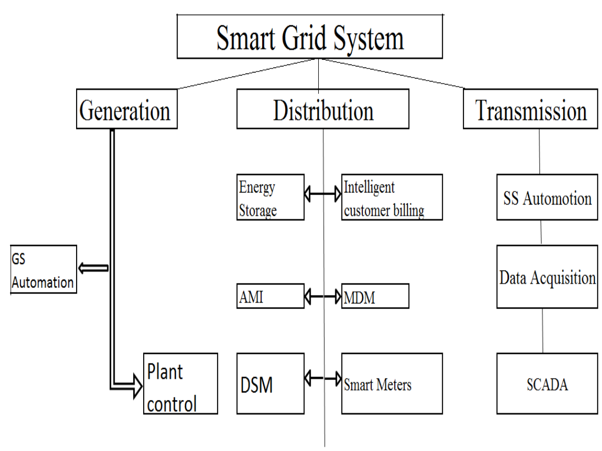

Figure 1: Smart Grid Components

Similarly at transmission level the Sub-Stations are automated by incorporating the Supervisory Control and Data Acquisition (SCADA) systems to convert analog power components to digital and communicating the real time data from Sub Stations to BCC/ MCC units.

At Distribution Level, Smart Grid plays major role to implement DSM, MDM [5], AMI, Smart Metering, intelligent billing systems etc. to facilitate consumers thereby increasing reliable & quality power supply

III. ADVANCED METERING INFRASTRUCTURE

Advanced metering infrastructure (AMI) is an architecture for automated, two-way communication between a smart utility meter with an IP address and a utility company [6]. AMI facility provides the real time data to distribution utilities and bills consumers using parameters viz., Dynamic Pricing, Critical Peak Pricing, Real Time Pricing, and Emergency Demand Response / Economic Demand Response[7] . AMI is not a standalone technology but it is a configured infrastructure which is built up by integrating smart meters, communication networks at different levels, Meter Data Management Systems (MDMS), & also importantly the bi-directional data transfer channel to integrate the received data into applications & Interfaces.

The simple AMI Architecture involves three operative zones namely Customer Zone, Distributive Utility Zone & Communication Zone as seen in Figure 2.

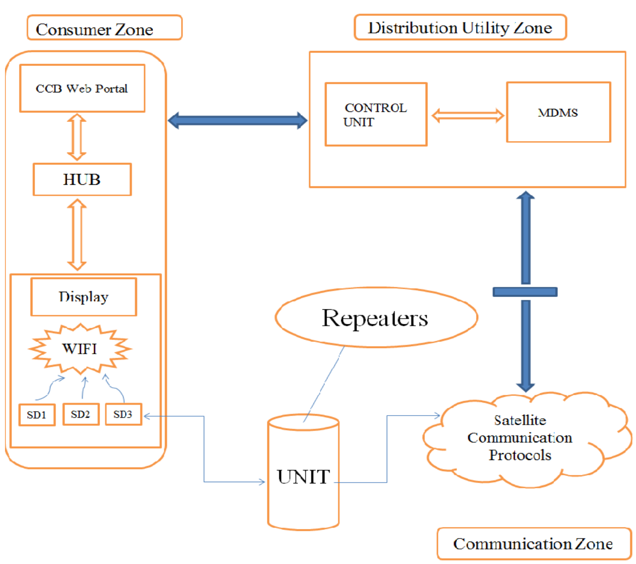

Figure 2: Simple AMI Architecture

In Consumer zone of AMI system, the consumer console is kept update about the Grid status and thereby alerting consumer to shift the load to off peak using intelligent heuristic algorithms. The loads have bi-directional communications and collation of all devices are communicated to hub using Wi-Fi which in turn exchange the data to Distribution utility zones. Many such smaller units are interconnected through HAN [8].

In Distribution Utility Zone there are two important components namely Control Unit & Master Data Management System (MDMS). The Control Unit will interact with the Communication Zone elements & MDMS performs long term data storage and management for the vast quantities of data delivered by smart metering systems. This data consists primarily of usage data and events that are imported from the head end servers that manage the data collection in Advanced metering infrastructure (AMI) or Automatic meter reading (AMR) systems [9].

*Communication Zone h*andles all the network/communication elements responsible for bi-directional data exchanges. The media may be Satellite, Fiber optics depending upon the architectural solutions.

A. *Benefits of AMI*:

- Benefits can be viewed from two perspectives viz., Distribution utilities & Smart Grid Consumers. From Distribution utilities view number of meter reads are reduced and thus accuracy is I ncreased due to higher degree of automation, detection of theft in the system, effective load staggering policies, effective load management etc.
- Customer Service benefits includes option for selecting billing cycles, enables price structures to better align to customer usage, increased intelligence in the system reduces outages and increases quality power supply for the consumers.

B. *Key challenges of AMI*

Some of the key challenges of AMI system are as follows:

- Cost Implications
- Unification and Process Integration
- Choosing AMI Model/Architecture
- Vendor Compliances
- Handling real time capability issues

IV. DISTRIBUTION MANAGEMENT SYSTEM (DMS)

A Distribution Management System (DMS) is a collection of applications designed to monitor & control the entire distribution network efficiently and reliably [10]. The DMS helps collect information from the growing array of

distribution system information sources and then applies suitable analytics on the acquired information to improve distribution system efficiency, reliability and performance."
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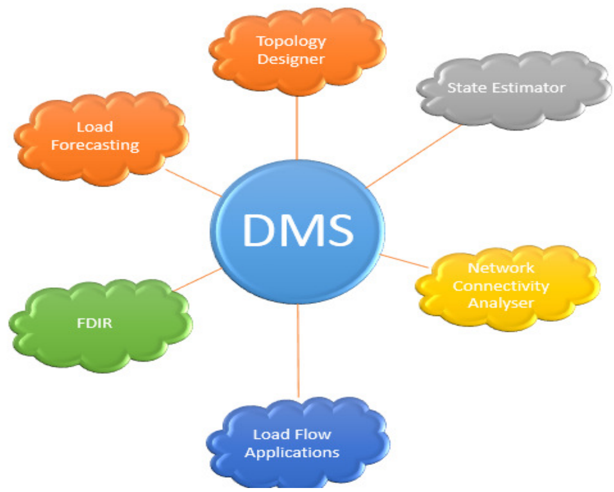
A. Functional modules DMS suite are as follows:

(1) Topology Designer (TD): Topology Designer (TD) is an environment where schematic representation of grid elements can be visualized. TD is used to create the various topological model for Smart Grid Projects. It allows to create Single line diagrams for better and simpler representation.
It has heuristic project templates and configuration managers along with simple editors.
(2) Network Connectivity Analyser (NCA): This analyzer displays various network elements viz, Isolators, Circuit Breakers, potential /current transformers, RMUs along with their real time status. Further it assists the network managers/ operators to know about the feeder configurations (Mesh, Radial, Loop, Parallel, Loop in Loop out (LILO).
(3) State Estimator : Here the phase angles, magnitudes in the in real time bus system are obtained and examination is made for data error thereby alarming the operators to change the bus voltages or transformers tap positions.
(4) Demand Manager: The demand for load is highly volatile and hence based on the availability of power load staggering or peak load clipping / shifting decisions needs to be made and this Demand Manger will make decisions to purchase power when there the frequency is very good thereby reducing the power purchase costs for the utilities.
(5) Load Flow Applications (LFA) [11]
Load flow study is an important tool involving numerical analysis applied to a power system. The goal of a power flow study is to obtain complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions. Once this information is known, real and reactive power flow on each branch as well as generator reactive power output can be analytically determined. Load-flow or Power flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems.

Apart from the above modules various other functional units such as Real-time Load Flow Analysis, FDIR (Fault Detection Isolation & Restoration), VVO (Volt-Var Optimization) [12], Relay Protection Coordination, Integrated Volt VAR Control, Interface with AMI/ OMS/ GIS Systems, Distribution System Real-time Analysis Tools, Emergency System Restoration Support [13], Power Quality Assessments & Demand Response Analysis and Load Forecasting makes up the DMS Suite.

Figure 3: DMS suite components



B. Benefits of DMS

Some of the benefits of DMS are as follows:

- Automation of distribution substations
- Communication in distribution networks
- Decentralized, intelligent application
- Self-healing capabilities
- Online condition monitoring
- Open system architecture
- Scalability
- Safety
- Regulatory compliance systems.

CONCLUSION

To increase choices before consumers and provide reliable quality power supply smart grid is need of the day. The smart grid requires Distribution Automation, AMI, EMS [12] & DMS to optimize the throughput and provide desirable results. Thus, the utilities are seriously considering to adopt advanced technologies for collecting & processing huge data generated by numerous smart devices commissioned in the operating environment. Upon successful implementation of AMI & DMS solutions power supply reliability and quality can be improved.

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