Comparative study on evolution of state of art practices on smart grid with the challenges faced and transitory solutions

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Abstract - *Smart grid (SG) can be the one of the best possible solutions to the ever increasing demand of energy. Maximizing energy utilization is basic need for the coming generation to survive. Now a day's researcher are emphasizing on the implementation of smart grid all across the globe to meet the energy demands in most efficient and reliable fashion. The methodology needs to be accepted globally with little concern on its reliability, durability, flexibility, adaptability, performance and many other factors [12]. Above mentioned factors must be kept in mind while analysing any system. Smart grid is one such kind of system where we find huge data transfer on various network, like grid to grid, vehicle to grid, one machine to another and many more. Looking into this fact there is a strong urge to practice energy in the best possible manner. Along with benefits there remains a major issue to the smart grid is privacy and security. As data transfer is vulnerable to data theft and misuse of the same, hence the key to the successful implementation of smart grid lies in the identification of best solution for security and privacy.*

Keywords: Smart Grid, Security, Distributed generation, voltage profile, cyber security

1. INTRODUCTION

To meet the requirement of energy smart grid has become an excellent solution without any harm to the nature. With advancement in the technologies, addition of state of art equipments like smart meters and inclusion of latest sensors power system has become more adaptable. Evolution in the smart grid system has led to complication in the communication system [7].

The use of information communication technologies (ICT) has made exchange of information more fast, which helps in better monitoring and control of the energy distribution and efficient utilization. Smart grid has enabled us to evolve more robust mechanism for best possible energy utilization of energy. Various features of smart grid make it suitable for competing with the energy demand across the globe [2].

Two way communications makes smart grid the most desirable methodology for power transfer. In current scenario energy (electrical) stands to be the driving force for the development of nation. The benefits of smart grid have come up with challenges also. Application of smart grid is limited to places where the data transfer can be secure and voltage profile must be same. These two aspects are the major hurdles in implementation of smart grid. The systems to be connected on the smart grid have to be stable to have smooth exchange of energy on the grid. In order to achieve stability on the grid most important parameter to be considered is voltage profile and frequency [4].

Once the interconnected achieve sustainable voltage profile then comes the challenge of securing the data transfer on the grid. In this paper the main focus has been put mainly on these two issues.

2. SMART GRID – KNOW HOW?

Smart grid can be defined as a platform in electrical power system for the exchange of power or energy and data among the participants with implication of advanced equipments and methodology along with excellent feedback and control strategies, to save time and energy.

The energy consumers can also be energy producer in a smart grid model. Such entity in the system are known as "Prosumers". This has been possible with inclusion of Renewable energy sources (RES). Distributed energy sources (DES) have into the grid will be added advantage for reliable energy supply. Coordination among the DES is very complex and tedious.

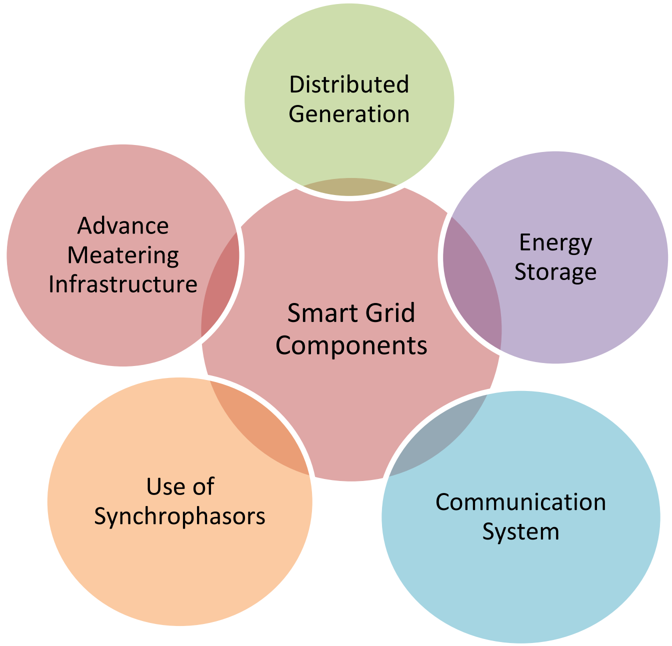

Fig -1: Smart Grid Components

Thus monitoring system have to very accurate and precise for better controlling and uniformity in the distribution of energy to the prosumers.

Communication plays a vital role in making the system "Smart" and hence more reliable. The system enables the intelligent appliances to communicate with the grid and work accordingly. Communication is the back bone of smart grid in a system but serious threats arise if there is security breech [9]. The energy on the grid can be ill handled and even cause a worse situations like black out or grid failure. Real time data analysis and monitoring and its security has become a challenging task.

3. CHALLENGES AHEAD

3.2. Cyber Security:

The transparency in Communication between various clusters in smart grid has though solved many problems related to monitoring and control but led to serious threat to the security of data. As the data exchange is all on web, which is vulnerable, can be easily accessed and tampered. The cyber-attack can mislead with wrong information and even directly or indirectly obstruct the system. The attack can be classified mainly in two categories i.e passive and active attack. Passive attack can be understood as the theft of data and using the same without causing any damage to the existing system. Where as in case of active attack the real time data can be distorted and directly affect the system. Active attack can be dangerous which can even lead to blackout. The entire network can be engulfed by the false data into it.

3.2. Critical Applications:

Smart grid is vast network comprising of various elements, huge energy transfer and big data transfer on network. All these above mentioned entities can be subjected to serious trouble in different manners. The complexity can be in terms of power handling issues or security issues. In case of power handling issues it can be technically resolved [16]. Thus these technical problem are of not much danger as they can be monitored and controlled easily. Whereas there are certain areas and function which needs special attention as these areas are prone to security issues. Such application areas are considered as the critical applications. Some of these are mentioned here. There are Home automation network (HAN), power network monitoring, advance metering infrastructure (AMI), monitoring and automation of substation and demand response (DR) falling in this category [13].

3.3. Voltage Profile:

With integration of DG, RES and RES the system becomes unstable. The stability of the system in smart grid is always under threat because of various sources of energy present in the system. It is very clear that all the sources connected in the SG will not have the same electrical parameters [3]. There is a possibility of sources with different voltage level. If all such generating sources are connected on the same network without proper stability limits, the system can get entangled and finally crash. Thus there comes the challenge to maintain a smooth voltage profile i.e. frequency, power factor, voltage level and reactive power.

3.4. Acceptability:

Apart from all these challenges mentioned above there a big challenge of acceptance. The system must be universally accepted and implemented. Implementation of smart grid needs to win the trust of prosumers and all others associated with the smart grid.

The compatibility of existing equipment on the currently existing grid with the smart grid. There is a need of in depth analysis of the pros and cons of the upcoming smart grid [5]. Weather there is need of modification in the present system, is there a need for modification or replacement of any of the equipment. These things have to precisely observed and noted for corrective measures to implement smart grid with zeal.

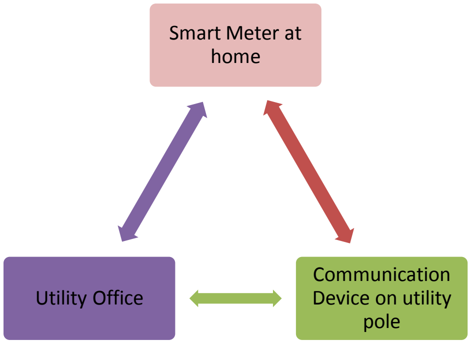

Fig – 2: Advance Metering Infrastructure (AMI)

4. TRANSITORY SOLUTIONS

Several control methodologies for distributed generation, energy storage, demand side load management or a combination of these can be found in literature. Roughly these control methodologies can be divided into two groups:

- agent-based market mechanisms and
- Discrete mathematical optimizations.

The advantage of agent based market mechanisms is that no knowledge of the local situation is required on higher levels; only (aggregated) biddings for generation/consumption are communicated. The advantage of mathematical optimizations is that the steering is more direct and transparent; the effect of steering signals is better predictable. Another important difference is that in an agent based approach often every buildings works towards its own objectives where in a mathematical approach the buildings can work together to reach a global objective.

Table -1: Comparison Between grids

Smart Grid	Conventional Grid
Pervasive Control	Limited Control
Adaptive	Chances of failure
Self-Healing Capacity	Needs manual Attention
Control strategies are digital	Electromechanical Control
Generation is Distributed	Centralized Distribution
Communication is two way	Communication is one way
Flexible and Reliable System	Rigid system

Most of the research considers agent based control methodologies. These agent based control methodologies propose an agent per device. The agents give their price for energy production (switching an appliance off is seen as production); via a market principle it is decided which agents are allowed to produce. Since there are a lot of agents, the information is aggregated on different levels in a hierarchical way.

The research described combines domestic generation, consumption and buffering of both heat and electricity. They propose an agent based system where buildings are divided into groups (microgrids) which are loosely connected to the conventional large-scale power grid. In first instance the goal is to maintain balance within the microgrid without using the large-scale power grid. Furthermore, agents use predictions to determine their cost function [11]. Field studies show that 50 % of the domestic electricity demand can potentially follow a planned schedule (within certain boundaries).

To reach this potential, there have to be incentives for the residents to allow some discomfort. Dimeas and Hatziargyriou [6] compare the results of individual (local) and overall (global) optimizations. They conclude that global optimizations lead to better results. Next, they claim that agent based control methodologies outperform non-agent based control methodologies since agent based control methodologies take more (domestic) information into account.

Microgrid Control strategy:

The key point is to control the parallel inverters so that they can work well to achieve high performances in the microgrid. Therefore, it is essential to develop advantaged control methods for the inverters to control the output voltage. From the perspective of utility/grid, the converters should be controlled not only to capture the maximum real power from the renewable energy sources, but also to provide reactive power according to the requirement to improve power quality and enhance grid stability [1]. In order to propose appropriate control methods for inverter-interfaced DGs in microgrid, it is necessary to investigate the basic principle of power flow. The flow of real power and reactive power between two nodes separated by a line impedance can be expressed as

$$P = \frac{V_1}{R^2+X^2}[R(V_1 - V_2\,cos\,\delta) + XV_2 \sin\delta]\ (1)$$

$$Q = \frac{V_1}{R^2+X^2}[-RV_2 \sin\delta + X\,(V_1 - V_2\,cos\,\delta)](2)$$

where, $V1$ and $V2$ are the magnitudes of the voltages at these two nodes, δ is the angle between these two voltage vectors. R and X are the resistance and reluctance of the connected line, respectively.

Considering δ is typically small and R can be neglected, (1) and (2) can be simplified as

$$P = \frac{V_1 V_2}{X} \sin \delta \qquad (3)$$

$$Q = \frac{V_1^2}{X} - \frac{V_1 V_{2 \cos \delta}}{X} \qquad (4)$$

Equations (3) and (4) indicate that P is predominately dependent on δ while Q mostly depends on the voltage magnitude. Therefore, the real power can be controlled by regulating the voltage frequency while the reactive power can be controlled by regulating the voltage magnitude.

To regulate the real power and reactive power, i.e. control the system voltage magnitude and frequency, many solutions have been proposed, such as

- **centralized control,**
- **master-slave operation,**
- **average load sharing (ALS),**
- **3C, or droop method.**

4.1. Device-level control strategy

When the system is subject to a contingency, a non-zero frequency deviation occurs at every bus in the system. The goal of the device layer controller is to design frequency response rules for individual controllable loads so that the aggregated power change matches the desired amount. For simplicity, it is assumed that the set of controllable loads is composed only by thermostatically controlled loads (TCLs). Some examples of TCLs are refrigerators, HVACs, water heaters, etc. Due to the inherent thermal energy storage, these loads can be switched ON/OFF for 30 second to 1 minute without affecting the end-use performance [9]. The power consumption of the TCLs is assumed to be zero in the OFF state, and is a non-zero constant when in the ON state. The total controllable power consumption at a bus is the sum of the powers of all the controllable TCLs in the ON state on this bus.

Therefore, the objective for each controllable load is to calculate its own probability of turning ON or OFF such that, the change of power consumption of controllable loads by turning ON or OFF at a given bus is equal to the load power modulation command determined at the aggregate level.

4.2. Power electronics control technology

Control strategies of power electronics with excellent steady-state and dynamic performance are very important in active and reactive power regulation, current, voltage and frequency control. Though some methods have been proposed such as improved droop control, for larger microgrids with numerous inverters, the depth of available literature is less comprehensive and doubts remain as to the scalability of techniques proposed for small-scale systems [10].

Silicon-based semiconductor device is reaching its physical limits in power handling and switching frequency capability. Seeking new materials technology is very exigent for smart grid. As the need for renewable energy technologies, energy storage technologies, and smart grid technologies has grown in recent years, power semiconductor devices with high-voltage, high-frequency, and high temperature operation capability is required.

5. CONCLUSIONS

The major hindrance in the application and probable solution to them has been presented in this paper. Mainly the problem of cyber security has been focused for enhanced and reliable system. In order to overcome these problems in the system certain solutions have been presented. Importance of smart grid has been understood and can be considered as the future of energy management system.

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