Energy Management System on Operation of Smart Grid

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Abstract: The integration of highly fluctuated distributed generations (such as PVs, wind turbines, electric vehicles, and energy storage systems) threatens the stability of the power and distribution systems. The main cause is that the power ratio between the supply and demand may not be in the balanced condition. An excess shortage in the generation or consumption of power may perturb the network and create severe problems such as voltage drop (or) rise and in severe conditions, blackouts. To maintain a proper balance between the supply and the demand in an efficient way, and to reduce the peak load during unexpected periods, energy management systems are utilized. Energy management can be broadly divided into two main categories. The first one is on the side of the supplier such as electric utility, in which some generators are turned ON or OFF to follow the fluctuation of the load demand. The secondary category is that on the consumer side and it is also called as the demand-side management. In the demand-side management, the consumers will manage their energy consumption so that they will manage with the available power from the generation side. The main goal of energy management system is to reduce the cost of operation and consumption, so as to reduce the energy losses and increase the reliability of the network The main goal of using energy management is to reduce the cost of operation and consumption, reduce the energy losses and increase the reliability of the network. Energy management has many barriers and limitations. However, it has a prominent future in which most of the current researchers are focusing on developing sophisticated algorithms and models to better manage the energy on the Power grid.

Terms: Smart Grids, Efficient management, Demand Management, Demand Size Management, Reliability of a network, Optimal Usage.

1. INTRODUCTION

The increase in the use of available energy resources and enhancing the security and access to these resources, particularly in this global economy it is one of the major challenge the society has to deal with. In addition to it the existing energy resources has to be privileged, and efficient management of the resources is also very important.

Subsequently the establishment of Power plants from conventional source of energy resource. Proper measures should be taken in distribution and usage of renewable energy resource which is being produced. Even though renewable energy sources need high infrastructure and initial investment to make necessary connections get connected with the grid, after connecting to the grid and the necessary synchronization had been done then the expensive transmission can be done and it can also reduce the transmission and distribution (T&D) losses, mainly ('Hysteresis And Eddy currents').So the better way to realize this potential obstacle of the distribution system is to get connected with the system approach which views the generation and distribution details associated with the loads as a subsystem or a 'Micro Grid'.

The Economic crisis, new technology inventions and environmental incentives are changing the face of electricity generation and transmission. Centralized generating facilities are giving way to smaller, most distributed generations are partially due to the loss of traditional economies of scale.

The research scholars and on-going researches came to a conclusion that the interaction between the smart grid and the individual interaction with the user will deeply change and Demand side Management (DSM) will play a key role.

The main objective of this paper is to review the work which was already attempted by various research scholars and to provide a consolidated information for management objectives in smart management of a system, such as improving energy efficiency, profiling demand, maximizing utility, reducing cost, and controlling of emission. we explore you to integrate home and building energy management systems like solar PV technology, and energy storage with the microgrid. Microgrid Energy Management System (MG-EMS) prototype which incorporates many software applications that can manage the sensing data and can perform load and generation management. In order to extend the microgrid from one fledge of grid to a full fledge smart grid, the HEMS, BEMS, renewable energy resources typically PV and BESS can be integrated from one type to another type microgrid.

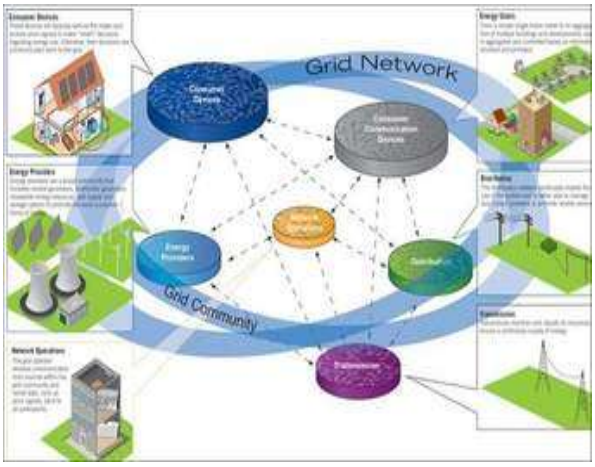

Fig 1: A View of Grid connected to System of Networks

2. ENERGY MANAGEMENT SYSTEM

The Power system active elements require new technology as well as new control methods in order to achieve control on different interconnected elements to the grid, optimising the active elements, network managing will ensure the regulatory on the entire electrical system.

The main elements of the system:

- Remote Terminal Unit;
- Generation Forecast System;
- Load forecast System;
- Supervisory Control and Data Acquisition (SCADA);
- Remote Sensing Terminal Unit;
- Smart Energy Management System.

The SCADA (Supervisory Control and Data Acquisition) transmits the data to Smart energy management system to measure the data which is being collected by the remote terminal unit which are being placed at some strategic positions all around the grid.

In order to access the grid and to get synchronized we need full control over the grid, we need full information of the state of network such as current and voltage profiles of it which are flowing at each node (or) branch.

After getting to know all the parameters the grid is Electricity board (or) State board has kept certain targets and demands which are to fulfilled... To fulfill these demands some set of methods and mathematical rules and procedures are designed.

More over as the load demand increases and the voltage profile estimations are not up to the range, and they suffer from inaccuracy, in order to obtain the accurate state adequate monitoring system and meter infrastructures and wireless/wired automatic metering systems (Smart Meters) are required and continuous monitoring is also required.

Optimising, continuous monitoring and control over the smart grid performance are entrusted to suite a hardware/software application that is also called as "**Smart Energy Management system**". After taking the readings and getting evaluated the data coming from SCADA the necessary optimizations and necessary steps are being taken for achieving the optimal state of Smart Grid.

When the grid reaches to optimal state the combination of variables including the reference values of Reactive power and Active power the Power is transferred to OLTC of transformer in the nearby Sub-station.

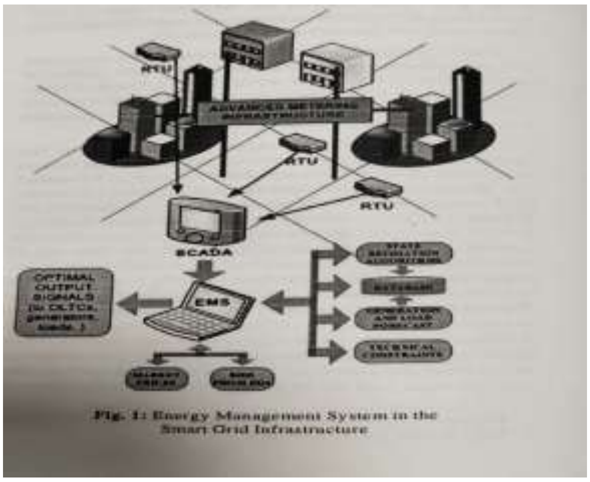

Fig 2: Energy Management System in the Smart grid Infrastructure

3. WHY IS ENERGY MANANGEMENT IMPORTANT?

The integration of highly fluctuated disturbances in the generation (such as PVs, wind turbines, electric vehicles, and energy storage systems) had threatened the stability of the power generation and distribution system. The main reason behind it is that the ratio between the power supply and power demand may is not balanced, and excess/shortage in the generation or consumption of power may lead to create severe problems such as voltage drop/rise and in severe conditions, the whole day is blackout.

To maintain the balance condition between the supply and the demand in an efficient way, and to reduce the peak load during unexpected periods, energy management system is being utilized. Energy management can be broadly divided into two main categories. The first one is on the side of the supplier such as electric utility, in which some generators are turned ON or OFF to follow the fluctuation of the load demand. The secondary category is that on the consumer side and it is also called as the demand-side management.

In the demand-side management, the consumers will manage their energy consumption so that they will manage with the available power from the generation side. The main goal of energy management system is to reduce the cost of operation and consumption, so as to reduce the energy losses and increase the reliability of the network.

Energy management can have many barriers and limitations. However, it had a prominent future in which the current researchers are being focused on developing the sophisticated algorithms and many models to manage the energy on the grid in better way.

In this huge world where there is energy demand on the rise, the power generation should also increase to satisfy the peak demands of load and user needs and to improve their daily life. However, the number of consumers are increasing day by day, and also the unpredictability nature of the electric load, power demand may cause challenges to the electric utilities and system operators. High peak demand have a great probability to occur in many problems and may lead to threat to the system functionality.

To resolve this problem, the electric utility and system management have two solutions available:

The first Solution:

- Increase the size and dimension of the network which is costly and it requires time to implement the network.
- Utilizing the energy management in order to reduce the possibility of high peak demand during peak hours.

The second solution sounds more reasonable:

however, the solution requires much sophisticated algorithms and more methods which are capable of managing energy. Energy management is considered a a better and smarter way for many reasons:

- It is automated and does not require direct intervention from human beings
- It gives accurate results and predictions
- It helps to optimize the functionality of its generation units and reduce the generation cost
- It helps the system to operate in such a way to reduce the energy losses of the network and transmission lines, which may reduce drastically the indirect distribution electricity cost
- It helps the end-users to better manage their load demand and reduce their electricity bill
- It increases the load factor, in which the power profile becomes smoother and less fluctuating
- It increases energy efficiency
- It conserves the resources
- It reduces pollution and protects the climate.

4. CUSTOMER LOAD RESPONSE

Customer load demand response can be characterized by the magnitude and speed of load response. This applies to both dynamic pricing and demand response even signalling.

Depending upon the usage of load performance it can be classified into four categories. Each category, has been described below, each category will have different feedback loop dynamics and it will affect the customer in different ways. Systems with large energy storage capacities are ideal for demand response applications in all categories listed.

Category 1:

Soft demand response:

This response time requires often in soft demand response is more flexible and can be varied from hour to hour and day to day. Soft demand response events are often mostly target to the daily power consumption to macro cycle which is often driven by higher power consumption during the day consequently followed by the lower usage during the nights. Energy curtailment can be typically planned and can be scheduled more in advance.

The Load response time strategies can include both load shedding and as well as load shifting. Load shedding involves curtailing equipment which is not included in the mission critical and load shifting is the rescheduling of energy-intensive operations considering to a different intervals of time periods. This includes both production lines and processing of equipment.

Equipment typically curtailed includes the following components:

- External and internal lights including both parking and lot lighting
- External water fixture
- Air handling
- Anti-sweat heaters
- Chilled water system
- Defrozed elements
- Elevators and escalators
- HVAC(Heat, Ventilation and Air Conditioner System)
- Irrigation pump sets
- Motors
- Outside signage

- Pool pump sets and heaters
- Refrigerators
- Water heating system

The load response time of this system can vary from second to second & hour to hour. Longer response time can be accommodated through a stratergy called pre-ramp down control strategy, while equipment with this faster response time can be actuated directly.

Category 2:

firm demand response:

With this response time the required firm demand response varies from five (5) minutes to ten (10) minutes. This aligns with ten-minute wholesale ancillary in the markets.

Firm demand response can provide the grid balancing authority with an ability to balance a reduction in generation capacity of power with a compensating reduction in the load. This category is appropriate for balancing the variables in renewable generation that has a sufficient inertia, capacity or prediction of load.

Examples of typically capable of firm demand curtailment include the following:

- External and internal lightening including parking and lot lighting

- External water fixture
- Air handlers
- Elevators and escalators
- Irrigation pumps
- Motors
- Outside signage
- Pool pumps

Category 3:

Near real time demand response:

In this Near real time demand response requires the response times of nearly one (1) minute to five (5) minutes. So, these are appropriate for fast responding ancillary energy markets driven by significant quantity of variable renewable generation.

Only these equipment's are capable of high-speed ramp down and can participate in near real time demand response. Typical examples of real time response include:

External and internal lightening including parking lot lighting

- External water fixtures
- Air handlers
- Irrigation pumps
- Motors
- Outside signage
- Pool pumps

Category 4:

Real time demand response

Real time demand response requires response time from one (1) second to one (1) minute. These applications include power frequency and load regulation as well as emergency response to grid faults. Realtime response requires very high-speed equipment and shutdown capability as provided by motor-driven equipment or lightening.

In general, the case with which a customer can react will decrease the movement from category 1 to category 4. In order to achieve these responses from five (5) minute down to one (1) minute response, the decision-making processes can be involved in load shedding, shifting or shaping must be automated and to streamlined in order to provide a high degree of determinism and reliability of the system.

Demand response signals will contain both discrete and continuous signal information. Discrete signal information will often be in the form of dispatch triggers that can perform initiate action. Continuous signal information will be in the form of value matrices such as dynamic pricing which will be used as input into decision-making algorithms.

5. SMART GRID FEEDBACK LOOPS

Bringing the customers further and further into energy loop is also an important assert of smart grid that requires more analysis.

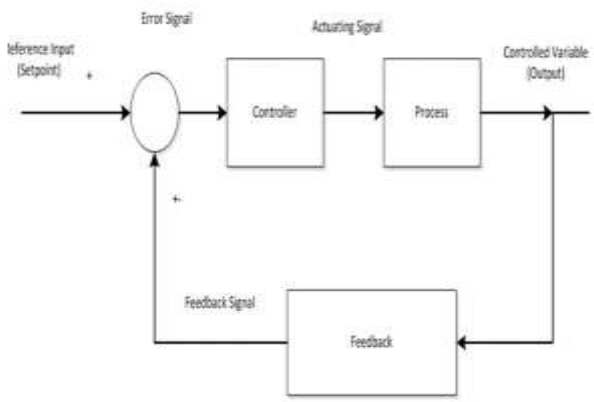

Fig. Balancing Feedback Loop

Smart grid is a system of systems which is interlinked together with large, wide-area feedback loops. These feedback loops constitute the basic behavioural of the operating unit of a system of systems. They can either create the growth or shrinkage of the system.

Feedback loops can return an amplified portion of the output signal feedback around the input loop where either it can add or subtract from the input signal. This simple basic structure forms the foundation for automatic control theory which is widely applied within a number of dominations including manufacturing, automation, aircraft control and automotive systems.

If the fed back signal tends to subtract from, or offset, the input signal and decrease the output, it is a negative or balancing feedback loop. If the fed back signal adds to the input signal, it is a positive or reinforcing loop. The system and feedback loop have transfer function, usually expressed in terms of Laplace transforms, which relate from the output signal to the input signal. The behaviour of the loop when any given input signal is applied can then be determined. The transfer function has a solution called poles and zeros under which it either drives the loop toward oscillation or becomes zero. Both the conditions have an negative impact if the feedback loop is a balancing loop.

An example of a simple on and off balancing loop is the home thermostat. The desired balance point is almost set to the temperature setpoint. The feedback signal is the equal to the room temperature. When the room temperature reaches to the certain setpoint temperature is being turned off until the temperature reaches to the below the setpoint. This digital loop inherently will get oscillated and it will be relied upon the high capacity and slow response of the room and system to make achieve the required acceptable results.

Reinforcing feedback loop will amplify the output feedback signal by building upon themselves resulting in exponential growth or collapse. The rate of growth can be determined by the amount of feedback or gain.

A simple example of reinforcing loop is compound interest where the financial account interest earned is fed back into the account resulting in the exponential growth of the account value all over the time.

The fundamental property of feedback loops is that they have a proportionality to oscillate the feedback loop. This oscillation is caused by loop time-delays, or peak time, this leads to the phase-shifting of feedback signals. If the resulting phase-shift of the signal is equal to 180 degrees, then a negative feedback signal turns into a positive feedback signal. This causes balancing loops to become reinforcing loops and if the strength of the feedback is equal or sufficient (i.e. product of loop gains >= 1.0), then the signal becomes unstable and oscillate. Sufficient upfront system design is required so that this condition does not arise again.

6. SMART GRID TECHNOLOGY TRENDS

Smart Grid technology has enabled two technologies that have a direct impact on the dynamic management of energy systems. These are;

1) microgrids and generation of disturbed energy &
2) Transactive energy

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The grid facilitates to the consumers of electrical energy but only a subset of generated power on-site. The Distribution of generation permits more facilities to generate on-site og generated energy and become self-contained microgrids connected to the electrical system. These micro grids will get benefited to the both the electrical distribution system as well as the to the facility which helps to optimize the system-wide generation and consumption of the energy.

Microgrids are self-contained, grid-connected energy system that can generate and consume the on-site power. The system can either import the power, or export the power to, the grid and having the capability to get disconnected from the grid. The process of decision making is required to determine the mode of operation which is taken into consideration for both local operations as well as grid operations.

When the external power cost is relatively very high, a strategy-based exporting of excess power generation and minimizing the imported power would be the best course of action to be implemented. If the cost of external power reduces, then the cost of self-generated power, will be the maximizing the power imported from the grid while the decreasing on-site generation would be a very suitable strategy. If in case of an emergency or fault condition occurs on the external grid, the microgrid load can be curtailed or disconnected from the grid and after that it can be reconnected when all the conditions permit.

The infrastructure needed to manage the power supply and demand load in context with the power grid enables the economically reliable expansion of on-site microgrid generation which include renewable energy and storage. The distributed energy resources (DER) are then presented as assets to the grid which are being maintained and supported within the microgrid. Renewable energy generation includes not only solar energy and places where wind farms are being fitted but also the power harvested from process of by-product or process energy stored in heat or pressure.

Today the centralized control over power grid which evolve towards the distribution control with more localized, and autonomous decision makers. These decision-maker's & "software agents" will interact with other agents to optimize the energy over utilization of connected devices and systems. These interactions, are well known as transactive energy, and will be in the form of transactions with other systems which will be based on local economy and context.

Today the wholesale markets are providing a bidding service to the all customers with an ability to bid large energy resources (typically greater than 1 MW) while the retail markets will enable only the smaller energy transactions to occur as they become economically reliable. These can be considered as "micro transactions" and which can occur between energy providers and consumers.

Typically, a small microgrid is one form of autonomous system but in context to transactions involving the buying, selling or rent of retail power evolve toward smaller and smaller entities, the decision making will become more and more granular. The huge energy transactions can occur between components within microgrids & between the microgrids and even smaller self-contained energy systems such as "nano grids".

Transactive energy does not change any requirement that the power grid will operate in a stable state of equilibrium position with supply almost equal to demand usage. Autonomous market-driven behaviour will create system oscillations and the instabilities through positive reinforcing in feedback cycles. This behaviour can be very useful for grid-scale operations and must be managed proactively to avoid the effects.

With the variable renewable energy generation, and with the wide increase in the use of value-based economic or market-derived signals, such as the dynamic pricing, to modulate the energy consumption will increase the dynamics of the power grid. The value-based signal which needed to be injected into the customer's feedback loop so that the required stability will be maintained. The new techniques must be implemented so that the operating range in the market activity is permitted.

These techniques not only limit the acceptable operating range of things but must also limit by rate-of-change of activity and duration.

7. RESULTS

The Smart Grid enables the customer to dynamically manage the usage of power based on electrical grid operating conditions and economy of the country. The integration, grid stability and reliability are enhanced, while the customer gets benefitted from lower costs and more reliable electrical power.

The important method to balance the grid is through the use of compensation and negative feedback loops which leverage the customer's demand to offset variation in the power supply.

In future implementing the energy management is prominent. Even though, it takes some time and costs more to shift from a conventional grid to a smarter grid, Energy management plays a crucial role in increasing the efficiency of grid and the reliability of the power and distribution systems.
The Energy management system allows a consumer to reduce their electricity bill cost by about 20 to 30% which is remarkable and beneficial in the long-term period of time. For a better future, it is recommended to have some standards and set of rules and regulations that oblige users to install energy management systems in order to reduce the power consumption as much as possible.

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