ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology (IARJSET)

National Conference on Renewable Energy and Environment (NCREE-2015)

IMS Engineering College, Ghaziabad

Vol. 2, Special Issue 1, May 2015

Efficient Power System with Micro Grid and Smart Grid and its Environmental Impact

Md. Sohrab Ali[1], Ajad kumar[2], Ms Annu Govind[3]

Student, Deptt. of Electrical & Electronics, IMS Engineering College, Ghaziabad, India [1,2]

Associate Professor, Deptt. of Electrical & Electronics, IMS Engineering College, Ghaziabad, India[3]

Abstract: Smart grid is regarded as the next generation power grid, which provides bi- directional flow electricity and information, with improving the power grid reliability, security, and efficiency of electrical system from generation to transmission and to distribution. This reviews on the current state of technology in physical protection and also focuses on the system reliability analysis and failure in protection mechanism and its connection with renewability and micro grid.

Keywords: smart grid, physical protection, system reliability analysis, renewability mechanism and micro grid.

I. INTRODUCTION

SMART GRID

Reliable and affordable electrical power is essential to the modern society. The modern electrical power systems cater the demands in wide range of areas which include the major components such as generators, transformers, transmission lines, motors and etc. The availability of new advanced technologies has made a smarter, more efficient and sustainable grid to ensure a higher reliability of electrical power supplied to mankind. Regarded as the next generation power grid, smart grid has transformed the interconnected network between electricity consumers and electricity suppliers. The smart grid system involves transmission, distribution and generation of electricity. In a smart grid, the operation of power systems infrastructure has evolved into a dynamic design instead of a static design. As smart grid technology and its adoption are expanding throughout the world, realization in smart grid protection is important. Protection plays an important role to ensure realization of power grid reliability, security, and efficiency in generation, transmission, distribution and control network. It is a subsystem of Smart Grid which provides advance grid reliability and security analysis in physical protection and information protection services. In view of the enhanced capability of Smart Grid with its smart infrastructure and management, the role of Smart Grid in a protection system which supports the failure protection mechanisms effectively and efficiently.

Micro grid

A small scale system and located near the consumer is called the Micro-Grid (MG) system. The interconnection of small generation to low voltage distribution systems can be termed as the Micro Grid. Micro Grids can be operated with and without a connection to the main power network. Small Capacity Hydro Units, Ocean Energy and Biogas Plants ,wind, diesel-generation, PV, energy storage etc are the various energy resources in MG for electrification of areas mainly rural areas where there is no possible access to grid electricity due to poor access of remote areas to technical skills. The micro grid has to be designed in such a manner so that there is ease in installation, commissioning, operation and maintenances. The micro grid helps in reducing the Expenditure by reducing network congestion &line losses and line costs and there by higher energy efficiency [. Today's challenge is the implementation of renewable energy into existing power systems. MG provide higher flexibility and reliability as it is able to run in both grid connected and islanded mode of operation and its components may be physically close to each other or distributed geographically .

To meet the increasingly growing demand of electricity, and to improve energy utilization efficiency and reliability , new power generation technologies, including renewable energy , clean and efficient fossil fuels, distributed generations have been developed .

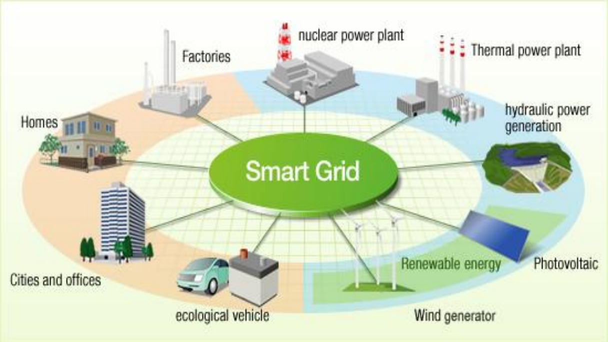
The micro grid concept is based on the assumption that large numbers of micro generators are connected to network to lower the need of transmission and high voltage distribution system .However the micro grid can be integrated with the distribution system but it can also produce a threat to the safe and reliable operation of the grid due to the net loss in line flow , voltage and power quality.

CONTENT

Today's world faces a global dilemma of increasing demands for energy. The existing electric power plants convert only one third of fuel energy into electricity.

Almost 8% of the generated electricity is lost in transmission while 20% of the electric energy is generated to meet peak demands for only a short period of time (5%) [1]

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology (IARJSET)
National Conference on Renewable Energy and Environment (NCREE-2015)
IMS Engineering College, Ghaziabad
Vol. 2, Special Issue 1, May 2015



OPERATIONAL EFFICIENCIES

The smart grid will be expensive to develop and deploy, but if implemented pragmatically should provide operational efficiencies that outweigh these costs. The electricity industry went through a growth phase in the 1970's and 1980's, and aging infrastructure is coming due for replacement. The cost of replacing assets is very high. This is a cost that must be incurred with or without the automation of the grid. Rather than replacing assets with identical assets, however, the smart grid, if planned pragmatically, represents the technological upgrades that will pay a positive return on the investment over the deployed life cycle through energy demand reductions, savings in overall system and reserve margin costs, lower maintenance and servicing costs (e.g. reduced manual inspection of meters), and reduced grid losses, and new customer service offerings. While some benefits to operational efficiency, it quite nicely into a business plan, such as line loss reduction or improved asset management, some elements rely on a societal assessment of worth,
rather than an accountant's calculation of "value". For example, new subdivisions since the 1960s have been built with a preference for hiding distribution wires underground. While this practice provides tangible benefits that can be measured (i.e. extending the life of wires because they are not exposed to the elements), the business case is also supported by intangible benefits (i.e. the aesthetics value of not seeing the distribution system running through the neighbourhood). This concept of tangible versus intangible operational efficiencies can also be illustrated through workplace safety, a topic that Canadian utilities take very seriously. This commitment to safe work environments is supported by several functionalities available through the smart grid, notably by reducing time on the road for meter reading, alerting workers of islanding, and allowing for some grid repairs to be performed remotely. Avoiding injuries certainly provides tangible operational benefits such as reducing lost time due to injury, but a portion of the benefit is attributed to the intangible health and safety benefits accrued to any worker whose job is made safer.

Capabilities of smart grid:

A) Demand Response

This capability refers to the capacity of the user or operator to adjust the demand for electricity at a given moment, using real-time data. Demand response can take the form of active customer behaviour in response to various signals, generally the price of electricity at the meter, or it can be automated through the integration of smart appliances and customer devices which respond to
signals sent from the utility based on system stability and load parameters. For example, a residential hot water heater could be turned off by a utility experiencing high electricity loads on a hot day, or could be programmed by its owner to only turn on at off-peak times. Active demand management can help smooth load curves, which in turn can reduce the required reserve margins maintained by electricity generators. Some pilot projects can already claim results in this respect: the Olympic Peninsula Project, overseen by the Pacific Northwest National Laboratory on behalf of the US Department of Energy, dropped peak power usage by 15 percent. A similar project from Constellation Energy in Baltimore, Maryland, cut peak power demand by at least 22 percent—and as much as 37 percent[2]. These capabilities have been rolled out in several Canadian jurisdictions to date; however the value of this technology depends on a number of factors. The First, of course, is customer take-up. If electricity customers do not sign up for voluntary utility load control programs or do not purchase the smart appliances and devices required, demand response programs will have little effect. Additionally, if the generating mix in a particular jurisdiction allows it to economically adapt to electricity demand, the value of demand response programs is diminished. In Alberta, for example, the average power divided by the peak power output, or "load factor", for the province is about 80%, which is quite high. As such, the value of peak shaving programs is diminished as compared to other Canadian jurisdictions with load factors below 80%. It is important to note that demand response and energy conservation are not one and the same. Successful demand response smoothes out consumption levels over a 24-hour period, but does not encourage decreased consumption. Smart grid technologies that promote a reduction in the use of electricity include the Advanced Metering Infrastructure (AMI) and the Home Area Network (HAN), both of which allow for increased customer control over their energy use.

B) Facilitation of Distributed Generation

As demand response is the management of system outputs, the facilitation of distributed generation is the management of system inputs. Some in the Industry refer to the combined optimal management of both to be the "achievement of flow balance." Traditionally, the grid has been a centralized system with one way electron "flows from the generator, along transmission wires, to distribution wires, to end customers. One component of the smart grid allows for both movement and measurement in both directions, allowing small localized generators to push their unused locally generated power back to the grid and also to get accurately paid for it. The wind and the sun, however, generate energy according to their own schedule, not the needs of the system. The smart grid is meant to manage intermittency of renewable generation through advanced and localized monitoring, dispatch and storage. In Ontario, the Energy Board has directed that it is the responsibility of the generator to mitigate any negative effects that connected supply may have on the distribution grid in terms of voltage variances and power quality. The optimal solution set to accomplish this, however, is still being examined. In addition to intermittency challenges, distributed generation can cause instances of "islanding" in which sections of the grid are electrified even though electricity from the utility is not present. Islanding can be very dangerous for utility workers who may not know that certain wires have remained live during a power outage. Ideally, real time information will allow islanded customers to remain in service, while posing no risk to utility workers.

C) Facilitation of Electric Vehicles

The smart grid can enable other beneficial technologies as well. Most notably, it can support advanced loading and pricing schemes for fuelling electric vehicles (EVs). Advanced Metering Infrastructure would allow customers to recharge at off-peak hours based on expected prices and car use patterns, while bidirectional metering could create the option for selling back stored power during on-peak hours. Although significant EV penetration is still a medium to long-term projection, some cities and regions have started experiments and the existence of a smart grid is essential to their uptake. This area of the smart grid provides an illustrative example of the potential risk to utilities of getting caught in the middle. Many policy makers and car manufacturers correctly point out that widespread charging infrastructure may help the customers to switch to electric vehicles. While this is true, we must recognize that charging infrastructure alone may not be enough to change customer behaviour; until a breakthrough technology is discovered by the automotive industry, electric vehicles will still have relatively high price tags and limited range. As such, prudence dictates that utility investments in EV infrastructure ought to respond to the automotive purchasing patterns of their customers rather than laying the groundwork for a fuel switch that is still largely dependent on technological breakthroughs. If utilities invest in infrastructure now, and the EV market takes longer than promised to develop, customers may not feel well served.

D) Optimization of Asset Use

Monitoring throughout the full system has the potential to reduce energy losses, improve dispatch, enhance stability, and extend infrastructure lifespan. For example monitoring enables timely maintenance, more efficient matching of supply and demand from economic, operational and environmental perspectives, and overload detection of transformers and conductors. Or as Miles Keogh, Director of Grants and Research at the National Association of Regulatory Utility Commissioners in the US, argues in a recent paper, system optimization can occur "through transformer and conductor overload detection, volt/var control, phase balancing, abnormal switch identification, and a host of ways to improve peak load management." Thus, as he concludes, "while the smart meter may have become the 'poster child' for the smart grid, advanced sensors, synchro phasors, and distribution automation systems are examples of equipment that are likely to be even more important in harnessing the value of smart grid[3]. In addition, network enhancements, and in particular improved visualization and monitoring, will enable "operators to observe the voltage and current waveforms of the bulk power system at very high levels of detail." This capability will in turn "provide deeper insight into the real-time stability of the power system, and the effects of generator dispatch and operation;" and thereby enable operators to "optimize individual generators, and groups of generators, to improve grid stability during conditions of high system stress[4].

E) Problem Detection and Mitigation

Many utility customers do not realize the limited information currently available to grid operators, especially at the distribution level. When a blackout occurs, for example, customer calls are mapped to define the geographic area affected. This, in turn, allows utility engineers to determine which lines, transformers and switches are likely involved, and what they must do to restore service. It is not rare, in fact, for a utility customer care representative to ask a caller to step outside to visually survey the extent of the power loss in their neighbourhood. It is a testament to the high levels of reliability enjoyed by electric utility customers that most have never experienced this; however, it is also evidence of an antiquated system. While SCADA and other energy management systems have long been used to monitor transmission systems, visibility into the distribution system has been limited. As the grid is increasingly asked to deliver the above four capabilities, however, dispatchers will require a real-time model of the distribution network capable of delivering three things:

1)real-time monitoring (of voltage, currents, critical infrastructure) and reaction (refining response to be monitored events);

2) anticipation (or what some industry specialists call "fast look-ahead simulation");

3) isolation where failures do occur (to prevent cascades).

With proper monitoring, now capable through smart grid innovations, some proponents believe that a cascading blackout mirroring that of 2003 should become so remote a possibility as to become almost inconceivable.16 Intelligent monitoring on a smarter grid allows for early and localized detection of problems so that individual events can be isolated, and mitigating measures introduced, to minimize the impact on the rest of the system. The current system of supervisory control and data acquisition (SCADA), much of it developed decades ago, has done a reasonably good job of monitoring and response. But it has its limits: it does not sense or monitor enough of the grid; the process of coordination among utilities in the event of an emergency is extremely sluggish; and utilities often use incompatible control

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology (IARJSET)
National Conference on Renewable Energy and Environment (NCREE-2015)
IMS Engineering College, Ghaziabad
Vol. 2, Special Issue 1, May 2015

protocols i.e. their protocols are not interoperable with those of their neighbours. If Ohio already had a smart grid in August 2003, history might have taken a different course[5].To begin with, according to Massoud Amin and Phillip Schewe in a Scientific American article, "fault anticipators would have detected abnormal signals and redirected the power to isolate the disturbance several hours before the line would have failed Similarly, "look-ahead simulators would have identified the line as having a higher than normal probability of failure, and self-conscious software would have run failure scenarios to determine the ideal corrective response." As a result, operators would have implemented corrective actions. And there would be further defences: "If the line somehow failed later anyway, the sensor network would have detected the voltage fluctuation andcommunicated it to processors at nearby substations. The processors would have rerouted power through other parts of the grid. In short: customers would have seen nothing more than a brief flicker of the lights. Many would not have been aware of any problem at all[6]. Utility operators stress that the smart grid does not spell the end of power failures; under certain circumstances such as these, however, any mitigation could prove very valuable indeed.

Demand Response:

It is going to become a part of the system operations in the smart grid driven restructured power system around the world in the near future. DR implementations are more active at the retail level than the wholesale level. To enhance competition at the retail level, separate entities called retailers have also come into the scenario. The increased retail level competition is associated with a variety of problems which can be categorized as market based and network based problems [7]. The former problems occur when the generators or the retailers face financial risks caused by spot price volatility in the wholesale electricity market. The latter problems occur when TSO and DSOs have to maintain reliable power supply during times of peak demand or low operating reserves or when constrained networks are operating at their limits. Traditionally, problems of the latter type have been handled single sidedly, by the generating utilities who have to either ensure a security margin of generation to be always available to be dispatched when asked to do so. A resource which is left unused is the demand side resource which can also be helpful in such situations.

Demand Side Management was introduced by Electric Power Research Institute (EPRI) in the 1980s. DSM is a global term that includes a variety of activities such as: load management, energy efficiency, energy saving, etc. The problems mentioned above can be categorized as short term problems whereas problems such as environmental effects of burning coal to produce electricity can be categorized as long term problems. DSM schemes like energy efficiency and energy saving schemes are potential inhibitors of such problems whereas the short term problems can be tackled by efficient load management programs which are collectively referred to as Demand Response.

Advance Metering Infrastructure (AMI):

It is the integration of systems and networks for measuring, collecting, storing, analysing, and using energy usage data. It uses the monitoring and measurement of consumer information through smart meters installed at users premises The information Is transferred to utility control centre through communication mode such as GPRS/PLC/RF. Smart meters will also enable Time of Day (TOD) and Critical Peak Pricing (CPP)/Real Time Pricing (RTP) rate metering and monitoring based on energy consumption. There are basically four parts of AMI technology which are as follows.

- Smart meters
- Wide area communication network
- Meter data management system(MDMS
- Home area network(HAN)

Features of AMI-

- Two way flow of communication.
- Time based pricing signal for Demand Response.
- It can communicate with other smart devices at user end.
- It can communicate other meters data within the home.
- Report's when the meter is tampered.
- Records energy consumption data (i.e. KWh, KVARh, pf, max demand)
- Remotely connect and disconnect the individual supply.
- Automatically send the consumption data to the utility at pre defined time interval.
- Limits the load at peak load demand.
- Net metering for effective integration of distributed generation.

AMI in the Indian Context:

Modernizing India's grid system by investing in AMI promises to mitigate a number of strains placed on the grid due to growing demand for electric, gas and water resources. In particular, AMI will improve three key features of India's grid system including:

System Reliability: AMI technology improves the distribution and overall reliability of electricity by enabling electricity distributors to identify and automatically respond to electric demand, which in turn minimizes power outages.

Energy Costs: Increased reliability and functionality and reduced power outages and streamlined billing operations will dramatically cut costs associated with providing and maintaining the grid, thereby significantly lowering electricity rates.

Electricity Theft: Power theft is a common problem in India. AMI systems that track energy usage will help monitor power almost in real time thus leading to increased system transparency.

Outage Management System (OMS): The smart grid provides a complete and real-time picture of outages and

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology (IARJSET)
National Conference on Renewable Energy and Environment (NCREE-2015)
IMS Engineering College, Ghaziabad
Vol. 2, Special Issue 1, May 2015

corresponding restoration activities because devices on the smart grid system can communicate real-time outage information back to a utility operations centre. For example, smart meters send a notification when they lose power and transmit restoration messages when power is back on. These active notifications, along with other features embedded in the smart grid network and back-office software, give utilities a powerful new tool for improving outage management. OMS controls and managethe scheduled and unscheduled outages of distribution system like as Distribution Transformers, HT/LT feeders etc. it collects and proceeds the information about outage including customer query and report the operator for taking corrective action through crew management and remote control enabling customer satisfaction, improve system availability and reliability.

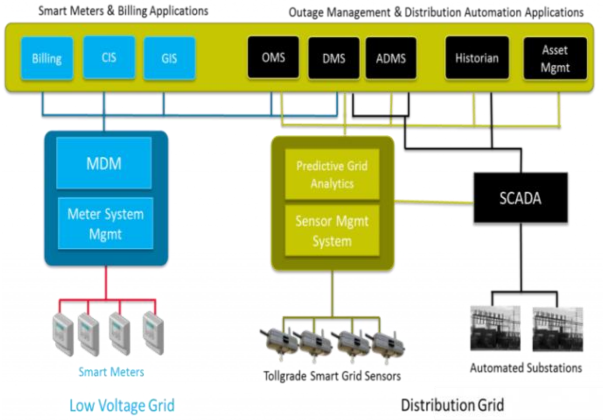
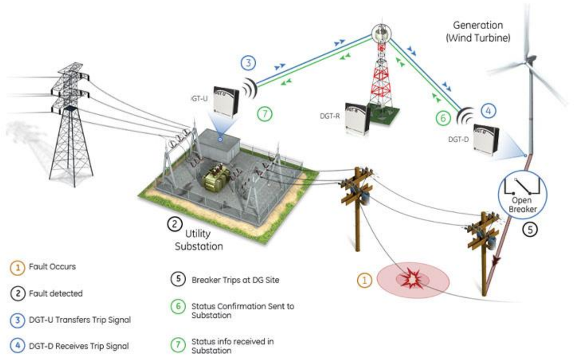


Fig: Outage Management System

Smart grid protection system:



ENERGY STORAGE:

Large scale energy storage devices shall act as energy reservoir injecting electricity in maintaining grid parameters during contingencies such as sudden loss of renewable power etc. It shall also provide thrust for use of renewable energy available during off peak hours. It shall also facilitate in peak load management as well as load curve flattening.

Storage technology broadly includes Pumped storage plants, Batteries (both conventional and advanced) with Power electronics, and control system.

Electric Vehicles: Electric vehicles have very large potential to offset portions of the environmental impacts from both the direct transportation sector and from the electricity generation sector. With the expansive adoption and integration of EVs into the marketplace, the displaced emissions from Internal combustion engine could be substantial. From the standpoint of the electric utility grid, EVs offer an opportunity to facilitate increased penetration of renewable and reduce the need for peaking generation units during the day by acting as a distributed storage and generation source.

EVs, however, pose a tremendous threat to the current grid infrastructure if not managed appropriately. Depending on when they charge, their strain on the generation and Transmission and distribution networks could be substantial, prompting the need for additional investment in generation capacity. Further, their ability to facilitate increased renewable generation comes from the grid's ability to effectively pair their charging requirements with intermittent renewable generation cycles, and to be able to draw down their batteries during the daytime when energy storage has the highest value. EV market adoption will likely also lead to increased usage of coal generation in the short term, resulting in increased emissions from the electric power sector. Whether or not a net decrease in emissions is realized will depend on numerous factors including: regional power generation mix, increased efficiency of Internal combustion engines, utilization of renewable, and the increased efficiency of carbon intensive generation sources.

The role of Smart Grid in managing EVs while they are charging and discharging will be invaluable. Without intelligent grid technologies, the necessary management tools such as Demand response, variable charging rates, and renewable generation pairing will be difficult to attain. In this capacity, the Smart Grid will have a strong influence on the environmental impact reductions realized by an EV fleet. The metering and accounting technologies needed for vehicle-to-grid discharging will be computer based, intelligent information systems similar to the Internet, where the data metrics from individual vehicles can be transmitted and processed in real time by the electric utility (or some energy broker) to make decisions about generation dispatch.

A study by Electric Power Research Institute (2007) analyzes the green house gases (GHGs) of PHEVs over the period of 2010 to 2050. The projections provide estimates on CO2 reductions associated with various PHEV penetration rates. However, this study does not explicitly disaggregate these reductions between Smart Grid and non-Smart Grid enabled utility infrastructure. Therefore, it is difficult to assign specific estimates of the impacts of Smart Grid technologies on these reductions; rather, it is assumed that high penetration rates and the reductions as detailed in the report could not exist in the absence of Smart Grid infrastructure. For example, the "high" penetration scenario listed below assumes 80 percent of the new vehicle market is from PHEVs. At this level of

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology (IARJSET)
National Conference on Renewable Energy and Environment (NCREE-2015)
IMS Engineering College, Ghaziabad
Vol. 2, Special Issue 1, May 2015

market penetration, the effective load and Vehicle to grid management of the vehicles would be impossible without intelligent, automated communications networks.

2050 Annual GHG Reduction (million metric tons)		Electric Sector CO_2 Intensity		
		High	Medium	Low
PHEV Fleet Penetration	Low	163	177	193
	Medium	394	468	478
	High	474	517	612

Table: Annual GHG Emissions Reductions from PHEVs in the Year 2050.

A study by Pacific Northwest National Laboratory (2010) looks at the incremental impact of the Smart Grid on Plug-in hybrid electric vehicle and how it affects the overall reduction in emissions. The analysis is based on the level of Plug-in hybrid electric vehicle penetration that would require "smart charging" technologies to be installed to avoid additional generation capacity investments. The study finds that the Smart Grid has the potential to reduce overall electric sector GHG emissions by 3 percent. Notably, this analysis neglects to include the potential environmental benefits of more aggressively and strategically managing the charging and discharging (Vehicle to grid of an EV fleet. Therefore, the estimates from this study represent a very conservative outlook on the value of the Smart Grid to the EV industry.

Another study by Electric Power Research Institute (2008) looks more specifically at the Smart Grid and PHEVs, estimating overall avoided emissions of 10 to 60 million metric tons of CO2 in 2030. This estimate is based entirely on "judgment" of the attribution of benefits to the Smart Grid, making this estimate very uncertain. The conceptual framework for the EPRI study is based on the usual dimensions of PHEVs, including charging regulation, Vehicle to grid, and consumer/utility investment frameworks.

In looking at these respective reports in comparison to each other, the clearest differences are in their underlying assumptions. They all use judgment to determine at what levels of market penetration the Smart Grid technologies become necessary information and decision-making conduits for the grid. None of the studies examines in detail the comprehensive portfolio of potential environmental impact offsetting of EVs. The quantitative estimates provided, as discussed above, are generally based on broad assumptions about Smart Grid technology penetration, and general grid capacity to handle increased EVs without the need for intelligent information and data management. In most of the literature, the virtues of the Smart Grid's ability to manage EV charging and discharging are discussed, but nowhere are they estimated using rigorous analytical methodologies [8].

Micro Grid: Microgrids are self-sufficient collection of local generators, loads, and storage devices. It acquires a wide range of environmentally friendly power generation technologies such as hydro power, wind turbine, photovoltaic, solar etc. With respect to the distributed energy generation, the microgrids usually have electric power generators nearby the customers. Microgrid can be operated by the customer. The microgrids have then the potential of reducing greenhouse gas emission by addressing the major shortcomings of the existing power grid, such as the transmission and the distribution losses. They empower consumers to interact with the energy management system to adjust their energy usage in order to reduce their energy costs. Also, the smart microgrids, as two way energy distribution and communication networks, have access to the real-time user demand and are able to optimize customers power consumption [9].

Features of Microgrid:

• Efficiency – Reduce fuel consumption, Supply close to demand minimize distribution losses, Combined electricity and heat generation.

• Reliability – Optimally manage on-site energy resources 24/7, Power quality and reliability at the local level.

• Energy Security – Ensure energy supply for critical loads utilizing on-site generation, Grid independence capability.

• Economic Savings – Peak Shaving/Load shifting and supply management with demand response, Enables hedging against energy cost fluctuation – Reduction of cost of electricity with on-site generation and effective energy management.

• Sustainability – Reduction of carbon footprint by integrating cleaner fuel resources.

Microgrid – Applications

• Microgrid candidates are Institutional/Campus sites, Hospitals, Universities, Commercial/Industrial facilities, Remote "off grid" communities, Military Bases, Municipalities and so on.

• Microgrids can vary in size (MW), Generation resources types, Energy storage system – Advanced controls.

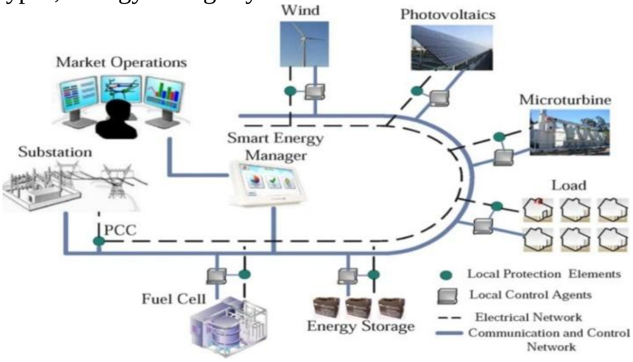


Fig.2. Microgrid Structure

CONCLUSION

Smart grid and micro grid have very important role to play in recent future. Using smart grid and micro grid we can use the renewable energy in most efficient and conservative way. Both the grids have the ability to make an eco-friendly environment which is most important in sustainable development of our country and in the global development.

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology (IARJSET)
National Conference on Renewable Energy and Environment (NCREE-2015)
IMS Engineering College, Ghaziabad
Vol. 2, Special Issue 1, May 2015

REFERENCES

[1] H. Farhangi, "Path of the smart grid," IEEE Power & Energy magazine, pp. 18-28, January/February, 2010.
[2] Paul Murphy et. al., Enabling Tomorrow's Electricity System: Report of the Ontario Smart Grid Forum, http://www.ieso.ca/imoweb/pubs/Smart_grid/Smart_Grid_Forum-Report.pdf (September, 2010).
[3] Miles Keogh, The Smart Grid: Frequently Asked Questions for State Commissions, The National Association of Regulatory Utility Commissioners,May2009,p.2, http://www.naruc.org/Publications/NARUC%20Smart%20Grid%20Factsheet%205_09.pdf, (June, 2010).
[4] OECD, "Smart Sensor Networks: Technologies and Applications for Green Growth," OECD Report, December 2009.
[5] David Biello, The Start-Up Pains of a Smarter Electricity Grid, Scientific American, May 10, 2010,http://www.scientificamerican.com/article.cfmid=start-up-pains-of-smart-grid (September 2010).
[6] Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects, EPRI, January, 2010, p. 4–21 (July, 2010).
[7] DuyThanh Nguyen, Michael Negnevitsky and Martin de Groot, "Poolbased demand response exchange– concept and modeling," IEEE Trans. on Power Syst., vol. 26, no. 3, pp. 1677-1685, Aug. 2011.
[8] American Clean Energy Leadership Act (S 1462). Passed U.S. Senate Committee on Energy and Natural Resources, June 17, 2009.
[9] The Smart Grid: An Introduction, U.S. Department of Energy, http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages (1).pdf (September, 2010).