Integration of Renewable Energy with Smart Grid - Futuristic Energy System

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Abstract— As we know, in current scenario of increasing energy demand, the conventional grid is unable to fulfill new challenges regarding reliable, efficient and clean energy. Hence, improvement and modernization of conventional electrical grid is necessary to overcome such issues. For this, the only solution is 'Smart Grid'. Smart grid is nothing but improvised version of conventional grid. Smart grid technology gives roadmap for efficient, reliable & clean future electric power delivery system. This paper describes the role of smart grid in the effective integration of renewable energy to fulfill increasing energy demand along with the use of smart home technology.

Keywords: Renewable Energy, Futuristic Energy System, Smart Grid

I. INTRODUCTION

The increasing complexity of the existing power grid due to rapid population growth, development in technology, infrastructure and computational tools are the factors that contribute to the need of deployment of smart grid for secure and efficient use of electrical energy. The modernization of electric grids towards a smart grid is being carried out to improve reliability, facilitate integration of renewable energies, and improve power consumption management. Due to continuous depletion of primary fuel resources and global concern about the environmental pollution, the development of smart grids based on renewable energy resources has gained huge strategic significance now a days to resolve the energy crisis[3]. In 21st Century traditional electric grid is unable to meet new challenges of world regarding reliable, efficient & clean energy. Therefore new advanced version or modernization of traditional electrical grid is necessary to overcome such problems. And the smart grid is the solution. Smart grid is nothing but future vision of traditional electrical grid. Smart grid technology gives roadmap for efficient, reliable & clean future electric power delivery system [1].

II. OBJECTIVES

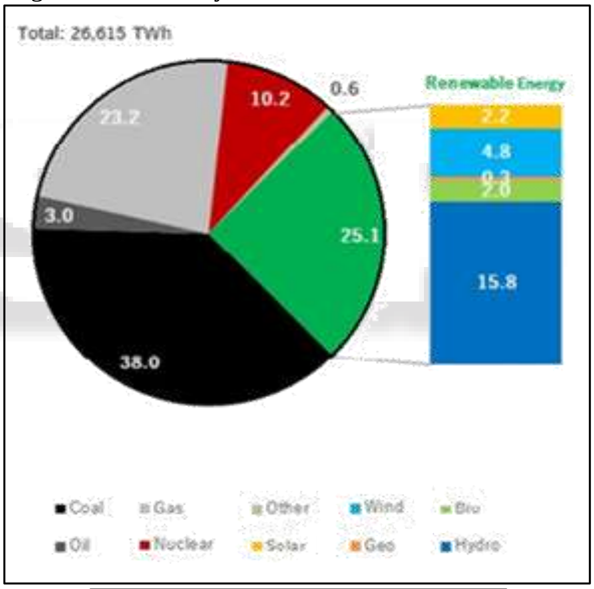
The objectives of the system are as follows:
1) Efficient use of renewable energy along with conventional energy.
2) Increasing energy efficiency.
3) Making power grid less prone to dynamic faults.
4) Increasing power stability and reducing carbon footprint.
5) Making operation of power flow more Resilient.
6) Enhancing bulk power generation.

III. RENEWABLE ENERGY

Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources. They have significant opportunities for energy efficiency existing over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy with energy efficiency, and technological diversification of energy sources, would result in significant sustainabilty and reduce environmental concerns such as air pollution caused by burning of fossil fuels, global warming and improve public health, reduce premature mortalities due to pollution and save associated health costs[3].

A. Global Energy Stats

Global Energy Stats provides comprehensive world energy statistics on supply and consumption of all energy sources – coal, gas, oil, electricity, renewables and waste.



Energy Stats : 2019

B. Solar Power

Solar energy is widely distributed over the territory and it can be harnessed by the use of different ever evolving technologies i.e. solar thermal electricity, Solar photovoltaic (PV) that are classified on the basis of their mechanism of capturing the solar radiations and its conversion into electrical energy. Solar thermal power plant is an indirect method of transferring solar energy into electrical energy, in which thermal power is generated by aggregating the sunlight radiations and then steam is produced that drives the turbine. The photovoltaic power plant, main form of solar energy, is a direct method of converting the solar radiations into electricity. Photodiodes are used in these plants for the efficient absorption of sunlight. This whole system is generally composed of rechargeable battery, controller, inverters, load bank etc. PV power plants can be used as standalone source of energy and it can also be connected to main power grid. Less environmental pollution, inexhaustibility, no geographical restrictions, and flexible plant scale are the major advantages of the use of solar energy; however there are certain drawbacks in it such as high cost of installation of PV plants, power losses in converter switching mechanisms [3].

C. Wind Power

Wind energy is considered as one of the most effective and potential alternate energy resource due to its renewable and clean nature. The kinetic energy of wind molecules is converted into mechanical energy with the help of wind turbine that is connected with the rotor blades. The rotor is further coupled to the generator (usually doubly fed induction generator) for the conversion of mechanical energy into electrical energy. The power derived from the wind turbine at specific location generally depends upon the wind velocity, at tower height and turbine speed characteristics. Power law equation is used to calculate the wind velocity at hub height [3].

D. Hydel Power

Hydro power is the largest renewable energy resource so far and it is harnessed from the gravitational force of the moving water. Hydro power is widely used worldwide and it contributes about 16% of the global electricity production. The potential energy from the falling water is converted into mechanical by hydel turbines.

E. Geothermal Power

Geothermal power is produced by using the geothermal energy that is the heat harnessed from the depth of earth. The heat extraction process requires the circulation of fluid down in the earth through the reservoir that brings heat to the surface where it is used for the electricity generation or in direct heating applications. Geothermal power system works similar to conventional thermal plants except here steam is produced from geothermal energy that is result of chemical and ecological processes deep in the earth [3].

F. Biomass Generation

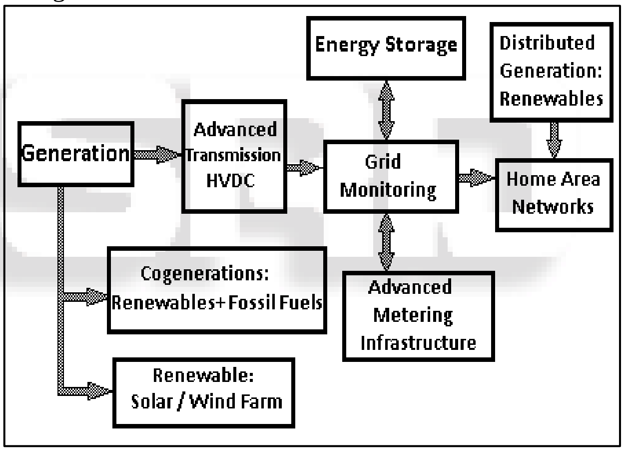
Biomass is another widely used form of renewable energy resulted from the organic matter. As a result of different chemical and biological processes in trees and agricultural products, gaseous fuel is produced that is used to produce electricity through gasification process. A number of technologies are available for the production of gaseous fuel from biomass depending upon the specific requirements. Instead of electricity generation it also has chemical feedstock, transportation fuel, direct heating and cooking applications [3].

IV. SMART GRID

The smart grid (SG) is the next generation electric grid which merges information and communication technologies (ICT) and control systems with the power grid. The SG becomes “smart” when it fully supports two-way information flows and two-way energy flows that are efficiently controlled based on real-time information. An SG consists typically of home area networks, neighborhood area networks, and a wide area network [2].

A. Operation and Block Diagram

Smart grid includes a variety of operation and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the smart grid [3].



B. Smart Grid Domains

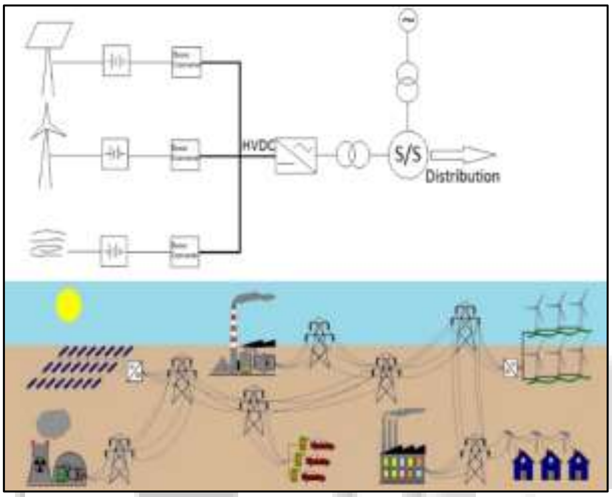
GRID: Interconnection of n number of generating stations and substations.
Introducing the digital controlling and operating techniques.
Duplex mode of Communication among various utilities of a power system.
Automation and quick sensing of faults across transmission lines.
Identify possible communication paths
Consists of seven domains

1) Customers
2) Market
3) Service providers
4) Operations
5) Generation
6) Transmission
7) Distribution

V. RENEWABLE ENERGY INTEGRATION IN SMART GRID

Today's power system is dominated by centralized grid in which electrical power distributed by Macro-grid. But with the use of macro-grid it's quite impossible to control power loss, energy demand management and global greenhouse gases emission. To overcome drawbacks of macro-grid a new technology that is Smart Grid integration -micro-grid comes in existence. Microgrid is an advanced, intellectual, localized, small scale grid which can be disconnected from centralized grid and operate. Renewable energy distributed generation (DG) integrated with smart grid technology operate in standalone with Macro-grid in case of peak demand and urgent cases is called micro-grid concept [1].

A. Perspective Model of the System



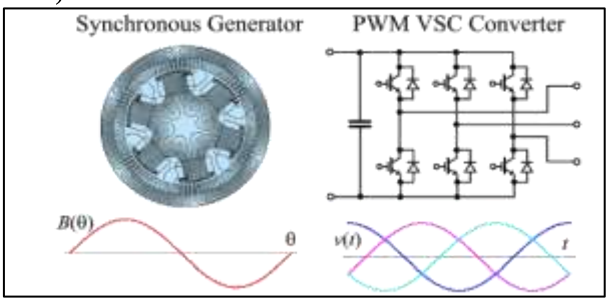
Renewable Energy Integration with Smart Grid – Perspective Model

B. Grid Integrations

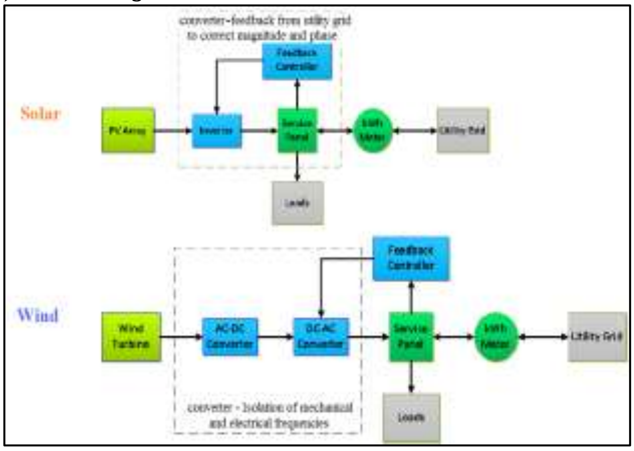
Various Grid Integrations are utilised in the system. These are described below.

1) Grid Integration – AC Generators

These are found in wind turbines, smaller hydroelectric, etc. – sources that are turbine-connected. Single-phase or three-phase AC output from generator, with fine control (turbine speed, current, excitation) is achived. The controlling devices consists of switching semiconductor or capacitor-based Voltage Source Converter (VSC) with further grid adjustment control (semiconductor switching speed, current).



2) Grid Integration – Load-level



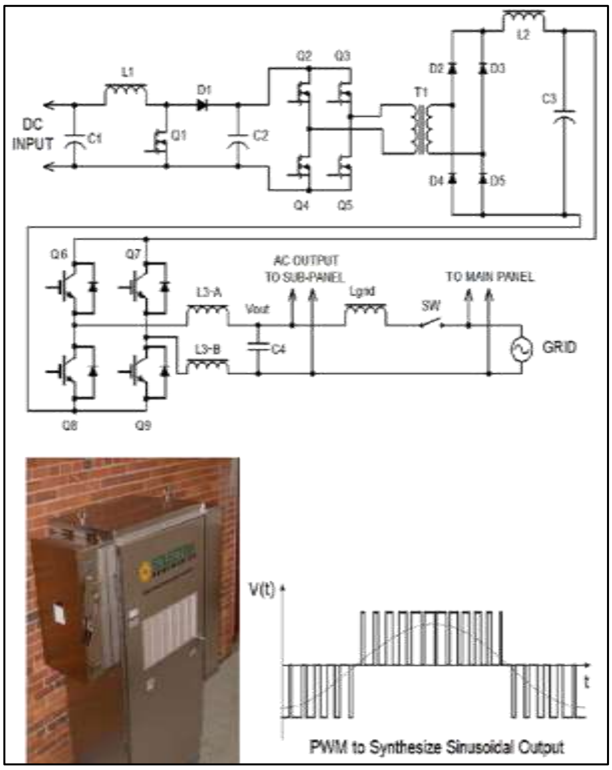
In this level of integration AC-DC converters (rectifiers) and DC-AC converters (inverters) are employed.

3) Grid Integration – Grid-tie Inverter

A grid-tie inverter converts direct current (DC) into an alternating current (AC) suitable for injecting into an electrical power grid, normally 120 V RMS at 60 Hz or 240 V RMS at 50 Hz. Grid-tie inverters are used between local electrical power generators: solar panel, wind turbine, hydro-electric, and the grid.[1]

To inject electrical power efficiently and safely into the grid, grid-tie inverters must accurately match the voltage and phase of the grid sine wave AC waveform.

Single or three phase, synchronous inverters are used to allow connection back into the grid. It provides seamless integration with utility power in grid-connected loads i.e. pull from the grid when local renewables are insufficient and push back into the grid at overcapacity (net metering, etc.)The grid connect /disconnect response time: ~100ms.



4) Grid Integration – High-Voltage DC (HVDC)

It is better to transmit power using direct current. It acts as link between two unsynchronized AC power systems.

The main advantages of HVDC are:

– No requirement of reactive power compensation.
– Lesser ohmic losses.
– Lesser conductor is required for transmission
– Thus lesser amount to supporting structures and insulating discs.
– Transmission line become electrically more stable.
– Chances of grid failure decreases as there is no fluctuation in frequency.

VI. ENERGY DEMAND MANAGEMENT BY SMART HOME TECHNOLOGY

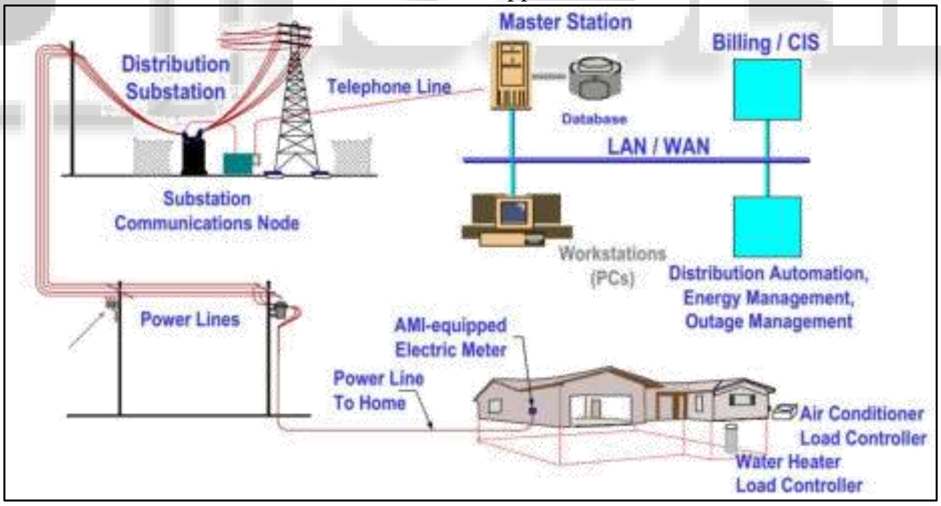
To meet growing energy demand of booming population, there must be some advanced technology with the help of it at the end of consumer side optimize use of energy can possible. Smart home technology is the best suited technology to optimism the energy demand at the consumer side. Smart home technology emerging from smart grid sector contributes effective energy management by using concept of home area network (HAN).Smart Home is a future home which is designed to proper energy demand management by using smart meters & smart appliances. Home area network makes the intelligent combination & control between smart appliances with smart metering system. In the home area network (HAN) smart home appliances & smart meters communicate intelligently to manage Peak electric demand [1].

A. Smart Home

In Smart home, information and communication technology is used in houses, where intelligent home appliances & smart meter are communicating via a home area network. In home area network, intelligent home appliances can able to make intelligent decision according to peak load. These home appliances report their energy consumption to the home energy controller and respond to its commands. This technology allows accessing and operating home appliances smartly & optimally to save electricity. Smart home appliances also used for monitoring, warn and carry out functions according to selected criteria of consumers. This technology also makes the automatic communication with electricity utility to manage peak load demand of electricity [1].

B. Smart Meters

Smart meter is digital meter which is used to record consumption of electrical power with advanced intelligent and communication system. It measures instantaneous power, amount of energy consumed, pf, reactive power, system voltage and frequency with high accuracy. Advanced feature of smart meter is that it can communicate with smart home appliances and utility. Smart meter enables give and take of digital information between utility and smart home appliances i.e. two way communication between smart home appliances, smart meter and utility. This system is known as advanced metering infrastructure (AMI). AMI technology supports to demand side management. It stores data at specific interval and transmit it to utility control center for demand side management and other demand management applications [4].



Advanced Metering Infrastructures in Smart Meters

C. Energy Demand Management of Smart Home

The Smart meter enables give and take of digital information between utility and smart home appliances i.e. two way communication between smart home appliances, smart meter and utility. This system is known as advanced metering infrastructure (AMI). AMI technology supports to demand side management. It stores data at specific interval and transmit it to utility control center for demand side management and other demand management applications. The different components of AMI are electronic meter module, network system and software. All these components of AMI are combined together with communication path and sensor nodes for interval data measurement. Two type of information infrastructure are needed for information flow in AMI. First from sensors and electrical appliance to smart meters called home area network (HAN) and second between smart meters to utility data center. First data flow is accomplished through power line communication or wireless communication [1].

VII. Conclusion

To meet the increasing demand of energy due increasing population industrialization and urbanization along with environmental issues such as air pollution, global warming, etc.; it is necessary to enhance the existing grid with smart grid equipped with various renewable energy systems such as solar PV, wind, hydroelectricity, geothermal, biomass, etc. Hence this ensures long term sustainability, reduced pollution, resource conservation, greater reliability, convenient power-delivering system etc. Smart grid also gives advanced facility to consumers to adjust their power consumption. So they can directly contribute energy demand side management. As far as its limitations are concerned, major researches are currently done regarding issues of power quality improvement, efficiency of PV cells, wind energy production, etc.

References

[1] Surekha S. Bhalshankar, Dr C.S.Thorat; "Integration of Smart Grid with Renewable Energy for Energy Demand Management:Puducherry Case Study"; 978-1-5090-4620-1/16/$31.00 ©2016 IEEE
[2] Mubashir Husain Rehmani, Martin Reisslein, Abderrezak Rachedi, Melike Erol-Kantarci, and Milena Radenkovic; "Integrating Renewable Energy Resources into the Smart Grid: Recent Developments in Information and Communication Technologies"; 10.1109/TII.2018.2819169 , IEEE
[3] S. Zafar, K. Nawaz, S.A.R. Naqvi and T.N. Malik; "Integration of renewable energy resources in smart grid"; https://www.researchgate.net/publication/315669268
[4] Hussein Al Haj Hassan, Alexander Pelov, and Loutfi Nuaymi;; 10.1109/ACCESS.2015.2507781 , ©2015 IEEE
[5] Carlo Cecati, Costantino Citro, and Pierluigi Siano; 10.1109/TSTE.2011.2161624 , © 2011 IEEE