# Integration of Renewable Energy in Smart Grid

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**Abstract -** The renewable energy sources have increased notably due to environmental issues and fossil fuels elevated cost. combination of renewable energy sources to utility grid depends on the scale of power generation. Large scale power generations are connected to transmission systems where as small scale distributed power generation is connected to distribution systems. There are certain provocations in the integration of both types of systems directly. Due to this, wind energy has gained a lot of investments from all over the world. However, due to the wind speed's undetermined behavior it is difficult to obtain good quality power, since wind speed fluctuations reflect on the voltage and active power output of the electric machine connected to the wind turbine. Solar perforation also changes the voltage profile and frequency response of the system and affects the transmission and distribution systems of utility grid. In this report is discussed the potential of the energy storage technology to enhance the integration of renewable energy to the smart grid the issues, challenges and utilization of renewable energy sources (RES) - Grid Integration.

**1. *Key Words***: Renewable Energy, Smart Grid, Renewable energy sources.

## 1. INTRODUCTION

While renewable energy technologies like wind and solar have huge potential to reduce both greenhouse gas emissions and other negative environmental impacts from electricity generation, integrating these technologies into the electric power grid poses ongoing technological and institutional challenges. Large-scale development of renewable power requires modernization of the electric power grid: both the high voltage transmission needed to transport and integrate electricity generated from large, and variable renewable energy projects and the low-voltage distribution network needed to integrate small-scale, decentralized renewable energy. The term "smart grid" represents these advances and includes a broad array of individual technologies including advanced meters, sensors, energy storage, and others that are crucial for the integration of more renewable and low carbon electricity into the electric power link. Smart grid also encompasses the development of new standards, management practices, and systems to increase reliability, ensure affordability and manage temporal and spatial variability of renewable electricity generation.

Smart grid has the potential to deliver multiple social benefits including a more reliable and secure energy sector, a more powerful economy, a cleaner environment, and an empowered citizenry engaged in energy system management. In different contexts and among different key actors, the potential benefits (and risks) of smart grid are prioritized differently. Although the critical links between a "smarter" grid and renewable energy are among the most prominent justifications for smart grid, the multiple promises of smart grid result in a complicated policy discourse that extends beyond connections between smart grid and renewable. Developing a smarter grid involves the evolution of intertwined technical and social systems linking public and private stakeholders at federal, regional, and state levels.

## 2. ROLE OF SMART GRID:

Most of the world relies on electricity system built around 50 years ago. These are inefficient and cannot offer an appropriate response to today's urgent global challenges. There is an estimated $13 trillion investment required in energy infrastructure over the next 20 years. This poses an imminent need and opportunity to shift towards a low carbon, efficient and clean energy system. Smart Grids will be a necessary enabler in this transition. Smart grid is a expanding network of transmission lines, equipment, controls and new technologies working together to respond immediately to our 21st Century demand for electricity. It makes possible efficient and reliable end-to-end intelligent two-way delivery system from source to sink. In this way the system brings efficiency and sustainability in meeting the growing demands of power with reliability and best of the quality. Smart Grids also enables real time monitoring and control of power system. The basic objectives of Smart Grids is to initiate active participation of customers, accommodate renewable energy generation and storage options, enable new products and services which would provide a better economy, optimise strength utilisation and operate efficiently, address disturbances through automated prevention, containment and restoration and operate resiliently against all hazards.

Existing grids were designed to deliver electricity to the consumers and bill them once a month. The energy demands have been rising and it has become difficult for the existing grids to cope up with it. Smart Grids introduces a two-way transmission where electricity and information can be exchanged between the customers and utilities. Smart Grids integrates advanced new technologies, Smart meters and there is a provision for data monitoring and control. It also integrates renewable energy such as the wind and solar energy to the grids. Besides that, the consumers can manage their electricity usage by measuring the electricity consumption through the Smart meters installed at their homes. Smart instruments can be designed which would adjust their run schedules to reduce electricity demand on the grid at critical times and lower the energy bills. Electricity is more costly during peak times because additional and often less efficient power plants must be run to meet the higher demand. Smart grids will enable utilities to manage and moderate electricity usage with the cooperation of their customers. Operators can manage the electricity consumption in real-time. The current distribution system is inefficient and any break in this system due to bad weather or storms or sudden changes in electricity demand can lead to power outages. Smart Grids distribution intelligence counters these energy fluctuations and outages by automatically identifying problems and re-routing and restoring power delivery.

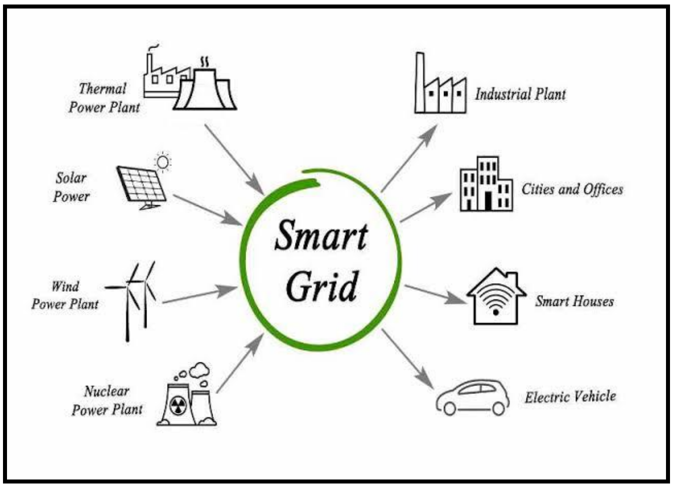


Fig.2.1: Smart Grid

### 3. GENERAL FEATURES OF SMART GRID:

Smart grid has different features and can be distinguished as follows:-

a) Interactive with users and markets
b) Adaptive and scalable to varying situations
c) optimized to make the best use of resources and equipment
d) Pro-active instead of reactive to prevent emergencies
e) Self-healing grids with advanced automation
f) Integrated, merging monitoring, control, protection,
g) Maintenance, EMS, DMS, AMI, etc.
h) Having plug-and-play –features for network equipment
i) ICT solutions
j) Secure & reliable
k) Cost efficient
l) Provides real time data and monitoring

Traditional grid includes centralized power generation, and at the distribution level unidirectional power flow and weak market integration. Smart grids include centralize power generation produced considerably by renewable energy sources. They integrate spreaded and active resources , into energy markets and power systems. Smart grid is the electrical network that smartly combines producers and consumers to efficiently deliver electricity which is sufficiently capable and coverage area accessible, safe, economic, reliable, efficient, and sustainable. Smart grid development tends to be driven by one of the two principal visions for enhancing electric power interactions for both utilities and end use customers.

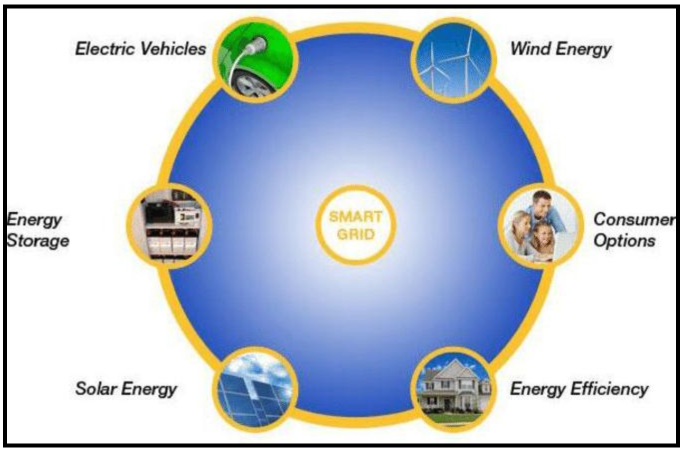


Fig.:Smart Grid Features

| Comparison | Conventional Grid | Proposed Smart Grid |
|---|---|---|
| Information flow | Unidirectional | Bidirectional |
| Electricity generation | Central generation | Distributed generation |
| Overall efficiency | Low | High |
| Environmentalpollution | High | Low |
| Sensors | Few | Many |
| Monitoring Ability | Usually blind | Self-monitoring |
| Grid topology | Radial | Network |

Table :Comparison between existing grid and smart grid

**4. SMART GRID TECHNOLOGY:**

Renewable energy systems (RESs) cannot directly replace the existing electric energy grid system. The new technologies are not developed enough to meet the total energy demand. Therefore, there is need to use renewable energy sources into existing grids and transform the system.

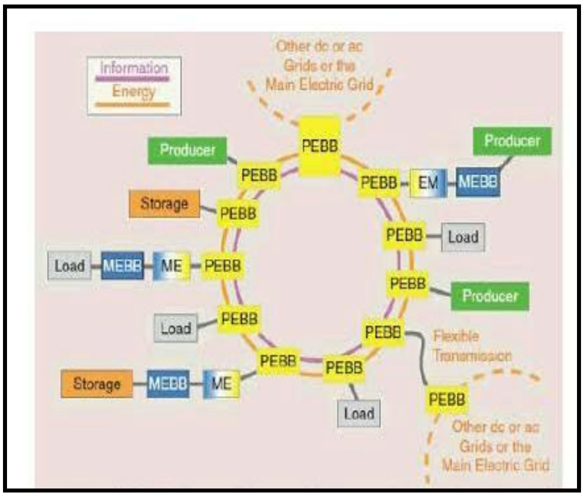


Fig. Intelligent energy conversion nodes.

A smart grid is modelled by two concentric circles the outer circle represents energy flow and the inner circle represents information flow over communication networks. Different approaches to manage energy flow in grids combining distributed power generation have been imposed. One interesting idea is the energy hub to manage multiple energy carriers. Within each hub there are energy converters that transform one part of energy flow into another form of energy. Fig. 4.1 is a possible scenario of the future power system based on smart-grid technologies, with power electronic building blocks (PEBBs). With the development of smart grid technology, the meters will control home appliances, where users can adopt more unique strategies to reduce the cost of electricity during the high electricity price. Hence peak load shifting can be achieved, and the system will tend to be more economic and environmental friendly.

**5. CHARACTERSTICS OF SMART GRID:**

The principal characteristics of a smart grid to full-fill the objective of electrical power sector, the Smart Grid has the great characteristics are:

**1. Safe and Reliable:** The electricity is still on the power supply capacity for the user, rather than a large are a power outgain large electricity failures, malfunctions, natural disasters and extreme weather, or man -made damage done to maintain.

**2. Efficient and Economical:** power grid, will be able to improve the economic benefits through related Policy innovation, management and energy efficient, and market competition orderly. Power networks are supported to provide for rational allocation of resources to power deal effectively with the electricity market, to reduce power loss and improve the energy efficiency and finally.

**3. Clean and Green**: With the large-scale of renewable energy sources, Smart Grid can reduce the potential impact on the environment e.g., carbon emission reduction, more green energy.

**4. Optimization:** The most appropriate price of the electrical energy provided to the society. Smart grid to optimize resource utilization; reduce investment costs and operation and maintenance costs. Power quality meets industry standards and consumer demands too.

**5. Interactive:** With the interaction and real-time response to the power market and users, the services are increased. Mature wholesale market operations in place, well integrated nation and integrated with good coordinators.

**6. Self-healing**: The new power grid has a features Self-healing. It is a process that improves services quality, enhances reliability and reduces costs. It identifies and correct supply demand imbalance instantaneously and detect faults.

**7. Ductile and Compatible:** The new power grid can support correct, reasonable integration of renewable energy resources and it is suitable for integration of distributed generation and micro power grid .Moreover, it can improve and enhance the function of demand side management to achieve the efficient interaction capability with consumers. It is compatible with the present grid also.

**8. Integrated:** A unified platform and model are employed on a grid. It can obtain good quality of integration and information sharing of power grid and to achieve standard, normative and refined management that integrates the infrastructure, processes, devices, information and structure of market so that electricity can be generated, distributed, and used more efficiently and cost effective.

## 6. PROBLEMS WITH THE CURRENT GRID:

An electrical grid is an interconnected network to distribute Electricity from suppliers to consumers. The electrical grid has evolved from an insular system that serviced a particular geographic area to a wider, expansive network that incorporated multiple areas. The electric power grid is a complex system that transfers electricity generated at power plants to substations via transmission lines, and then to a variety of consumers throughout the nation via distribution lines. This system was developed by connecting local grids to form more robust and larger networks. While this methodology worked in the past, widespread development has overburdened the grid in high-demand regions. As a result of this increase in demand, the grid often experiences disturbance in electric service. Many of these interruptions occur due to problems at the distribution level and may be mitigated by distributed energy storage approaches. Service interruptions exhibit the inefficiencies of current grid networks and emphasize the dire need to modernize the electric grid so that it can respond to increasing electricity demands and shifts in generation sources. While building new generation plants and transmission and distribution lines is a costly and time-consuming endeavour, energy storage can optimize the capacity factor of current grid operation.

Advanced storage could provide a dependable and cost-effective another to infrastructure expansion. Perhaps the most significant trend driving the need for grid-scale energy storage is the shift to renewable energy sources, such as wind and solar. While coal has traditionally been the largest fuel source for electricity generation, emphasis on cleaner energy and decreased reliance on fossil fuels and other non-renewable sources has placed greater attention on renewable sources for electricity generation.

### 6.1 Technical Benefits:

The most relevant technical benefits of EES are the following:

a) Bulk energy time-shifting, for load levelling and peak shaving, providing electricity price arbitrage. For instance, electric vehicles represent one type of EES that can provide these power management benefits, leading to smart grid and RES integration.
b) More efficient use and contribution of renewable energy is guaranteed using EES, also fomenting the use of distributed energy supply options in grids.
c) Efficient storage can be used to provide up to two times its capacity for regulation applications; using full charge (down) and full discharge (up).
d) Storage output can be changed rapidly giving a ramping support and black-start to the grid (from none to full or from full to none within seconds rather than minutes)
e) Energy storage can be used as a solution for improving grid service reliability.
f) Energy storage can benefit utilities or independent system operators allowing transmission and distribution upgrade deferrals.

### 6.2 Economic Benefits:

The most relevant economic benefits of EES are the following:

a) Energy storage can reduce costs of customers electricity.
b) In general, off-peak electricity is cheaper compared to high-peak electricity, and this also benefits the seller of electricity.
c) It plays a key role on stabilizing the electricity market price freeing the power sector from
a) Speculations and the volatility imposed by fossil fuels.
d) It will contribute to the economic development and employment opportunities for many countries.
e) It will allow more efficient use of renewable and off-peak generation capacity, encouraging more investment opportunities on these technologies.
f) EES may help to avoid transmission congestion charges, which are very expensive and most of utilities try to avoid them in a deregulated market environment.
g) Reduces the need for transmission and distribution capacity upgrades, thus minimizing unnecessary investments.

h) Increases and improves availability of ancillary services, reducing penalties to generators and the cost of over dimensioning infrastructures.
i) Allows a market-driven electricity dispatch, stimulate proactive participation of the customers to secure their benefits and creates a cost sharing scheme in the power system.

**7. RENEWABLE GRID INTEGRATION:**

Increasing renewable electricity generation is an essential for achieving double renewable energy share in the global energy. Such a transformation is technically feasible, but will require upgrades of old grid systems and new innovative ideas to accommodate the different nature of renewable energy generation. In addition, smart grids offer benefits that can further be easy for transition of renewables. There are several alternatives to conventional, utility-scale Power plants.

These include:

- Supply-side options, such as distributed generation.
- Demand-side options, such as demand-side management.
- Storage options, such as EVs, batteries, and thermal storage.

Smart grid technologies allows for optimal use of these alternative technologies, and hence avoid the need for new large power plants. These alternatives are generally manageable to direct private sector investment and can help address utility under investment and capital constraints. This integration can help enable both utility-scale renewable and smaller distributed renewable generation. New resources such as DSM and distributed storage make it possible to incorporate higher levels of variable resources (such as wind turbines) in a system. Supervisory Control and Data Acquisition system that will enhance renewable integration support DSM and help pinpoint losses.

**8. ISSUES OF RENEWABLE ENERGY SOURCES SYSTEMS – GRID INTEGRATION**

**8.1 Wind Energy System:**

Due to availability of wind renewable energy sources abundantly, wind energy generation is increasing day by day to develop rural electrification, increase job opportunities in technology. But there are some restrictions to the powerful wind energy into the grid. Wind speed forecasting has high uncertainty, high volatility and low predictability reduces the system security and wind revenue. Problem in maintaining voltage profile. Most of the wind turbines are coupled with SCIG, which are not able to support reactive power within the system. More stress on breaker, transmission line, bus bar at the time of fault occurs, due to high penetration of wind energy resources due to low fault ride-through (FRT) capability of wind generator. High pungent of wind energy creates stability problem, and possible blackouts thus wind energy penetration is limited by ATC (available transfer capability) of the system. Frequency behavior of the system also changes with wind pungent due to lower inertia of distributed wind generators. Finally, wind energy pungent reduces overall efficiency and power quality

**8.2 Solar Energy System:**

The huge amount of solar energy is available on the earth. Humans consume almost 15 TW of solar energy. Customers are interested in solar power due to low cost, environment friendly, flexible installation and no reactive power consumption by solar panel. But constraints of solar generation are: high installation cost of solar panels, low generation capacity, uncertainty of solar irradiance, and power fluctuation due to intermittency behavior of sunlight . Solar pungent also changes the voltage profile and frequency response of the system. PV system is drawn with unity power factor and the characteristics of output power are dependent on the inverter. Since photovoltaic system has no inertia, some more devices are needed to maintain frequency oscillation.

**A. Technical Issues:**

The technical issues are described as

1. Power quality

a. Harmonics

b. Frequency and voltage fluctuation

2. Power fluctuation

    a. Small time power fluctuations

    b. Long time or seasonal power fluctuations

3. Storage

4. Protection issues

5. Optimal placement of RES

6. Islanding.

**B. Non- Technical Issues:**

1. Due to scarcity of technical skilled workers.

2. Less reachable transmission line to accommodate RES.

3. RES technologies are excluded from the competition which demoralize the installation of new power plant for reserve purpose.

**9. VARIOUS SOLUTIONS OF RES UTILIZATION**

The renewable energy sources such as solar, wind etc. has accelerated the transition towards greener energy sources. Keeping in view of the aforesaid some of the key solutions for RES utilizations are:

1. The power balance using RES can be carried out by integrating RES with energy storage unit. The benefits of battery energy storage system (BESS) are classified based on end – users as: Transmission level uses, System level uses, ISO Market uses.

2. Intermittence of power generation from the RES can be controlled by generating the power from distributing RES to larger geographical area in small units instead of large unit concentrating in one area.

3 In case of agricultural load, the load is fed during the night time or off peak load time and this is fed by conventional grid. On other hand power generated by RES like solar PV is generated during day time so we can use this power for agricultural purposes instead of storing the energy for later time which increases the cost of the overall system. Using the solar water pumping for irrigation gives very high efficiency approx 70% to 80% and the cost of solar water pumping is much lesser than the induction motor pumping type.

4. In large solar PV plant output power oscillating during the whole day and this power is fed to the grid, continuously fluctuating power gives rise to the security concern to the grid for making stable grid.

Solar PV plant have to install the different type of storage system which gives additional cost to the plant owner. Once the storage system is fully charged then this storage components gives no profit to the system owner. Therefore solar based water pumping system may be installed substitute of storage system.

**10. CONCLUSION:**

In recent years in the power generation and distribution system shows that penetration level of DG into the Grid has increased considerably. End user appliances are becoming more careful to the power quality condition. This Case presents a technical review of causes of Power quality Problems associated with renewable based distribution generation system (wind energy, solar energy). Voltage decrease with wind penetration and increase with solar perforation. To minimize the fluctuations and intermittent problems power electronic devices are viable options. Further, energy storage and use of dump load could be used for reducing the power fluctuations in PV systems. The up-gradation in balance of systems by incorporating the new materials and storage elements could reduce the problems associated with grid integration.

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