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Integrated Smart Grid Technology with Solar and Wind Power Generation System

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Abstract - *The smart grid is basically an upgraded conventional grid that has two-way communication. By using smart grids and the technologies related to it, transmission and distribution losses can be minimized, efficiency can be improved and the overall power system becomes capable of responding power in more optimal ways in comparatively wide range. Besides these advantages, it is also helpful in minimizing demand-supply gap, theft reduction, and load shedding. To change and control the energy flow variations, we need to shift today's grid to integrated and automated substations. The best reliable method is to interconnect the smart system with the renewable system and that renewable system can be either solar or wind or other. If the costing of photovoltaic modules optimizes, then it would be the most appropriate technique of smart substation interconnection. This paper is basically an outline of the smart grid power system and the benefits of it in power factor improvement with reliable and sustainable ways and how PV system can be integrated with the smart system.*

Key Words: Smart grid, PV system, Wind Energy, Solar Energy, Energy Storage System.

1. INTRODUCTION

Presently the government is motivating to increase the utilization of non-conventional energy sources in comparison to conventional energy sources because the conventional energy sources are depleting day by day. To fulfill the power supply demand, it is important to either increase the energy sources or minimizes the power losses.

The smart grid is a digital technology application which offers digital control appliances, smart monitoring systems, and various smart electric networks. By using smart grid technologies electricity is delivered from producers to consumers, losses are reduced, energy flow is controlled and the performance is improved with higher efficiency. And when a smart system is arranged with the renewable sources, then the problem of voltage collapse, and other power failures will be reduced.

The smart grid is started with low voltage substation, ground up, automatic smart meters. Once this smart equipment is rearranged to form a smart grid, we can easily control, detect these components and their losses and leakages and perform various actions on it.

2. SMART GRID & ITS FEATURES

A smart electrical network that integrates all consumers and deliver secure, economic and reliable power supplies. We can say that when information and communication technologies are integrated with conventional grid, then it will form smart grid system.

2.1 The Traditional grid and smart grid

Table -1: Features of traditional and smart grid

FEATURES	TRADITIONAL GRID	SMART GRID
Communication Technology	None or One-Way	Two-Way
Generation	Centralized	Centralized And Distributed
Power Flow Control	Limited	Comprehensive
Consumer Interaction	Limited	Extensive
Type of Meter	Electromechanical	Digital
Maintenance	Manual Equipment Checks, Time-Based Maintenance, IOT	Remote, Monitoring, Predictive, Condition-Based Maintenance
Topology	Radial	Network

2.2 Smart Grid System can be realized by following these steps:

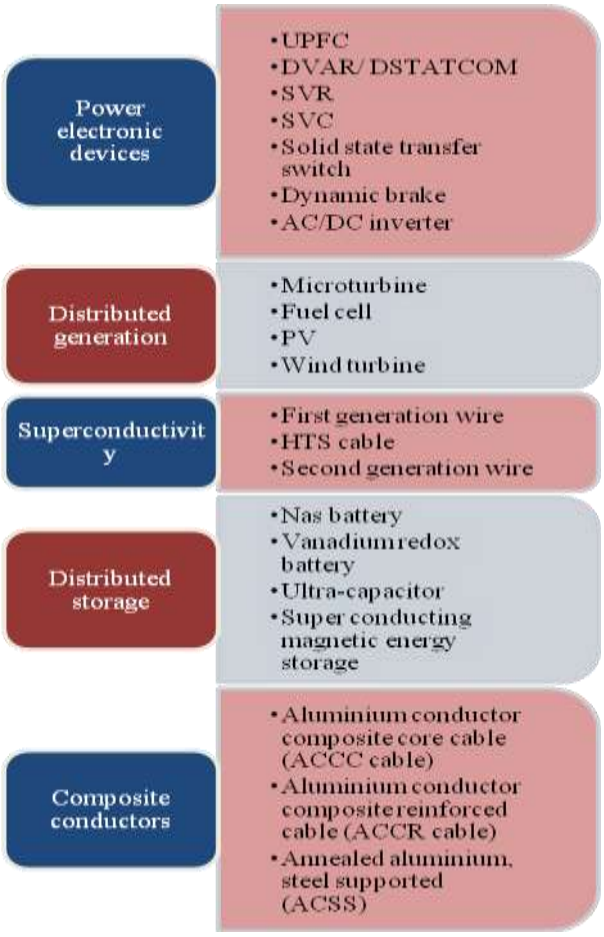
- Integrated Communication: In smart grid system each part of the grid can communicate with another grid

system. By doing this system is more flexible and integrated. It consists of IP based systems which make it into SMART GRID SYSTEM can be realized by following these steps: integrated, high speed, two-way communication, dynamic and interactive for real-time information and power. Communication is done by

- Copper wiring
- Optical fiber
- Power Line Carrier (PLC)
- Wireless technologies
- Broadband over Power Line technologies (BPL)

- Modern Hardware: Hardware that produces high power with more reliability and power quality, enhanced efficiency

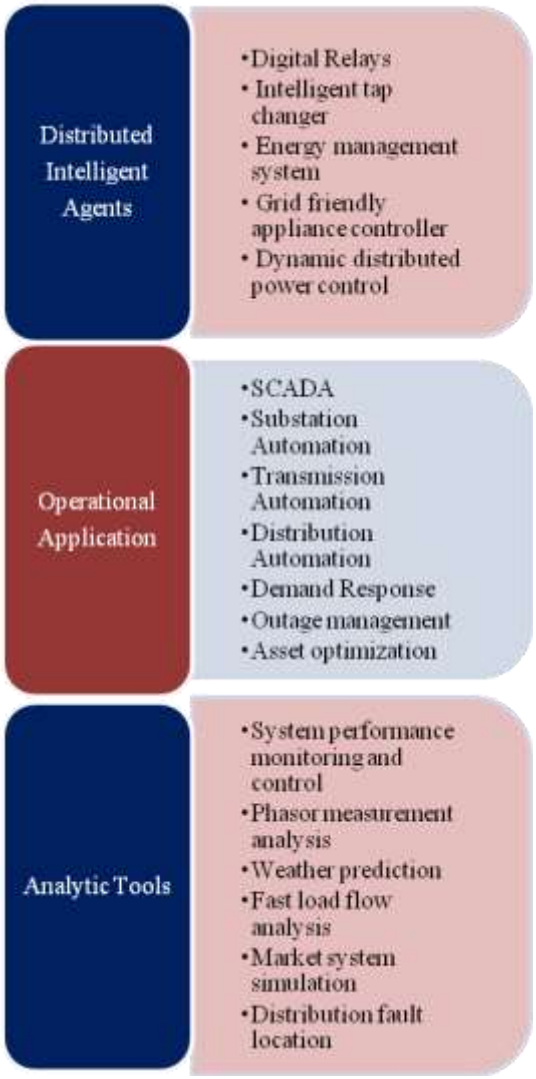
  - Modified Materials
  - Superconductivity materials
  - Distributed Generation
  - Energy storage devices
  - Power electronics devices
  - Microelectronics



- Modern Control Methods and Instrumentation (I&C): Smart grid system contains new methods and algorithms that can monitor, diagnose power system components more rapidly and timely so that faults can be prevented.

- Sensing and Measurement: Frequent meter reading, billing problems and minimizing energy theft can be done by smart meters and smart measurement devices.

- Smart Software: By using smart software and tools grid operators can make quick decisions that will make the system more user-friendly with improved efficiency.



3. SOLAR ENERGY & PHOTO-VOLTAIC SYSTEM

The photo voltaic modules are interconnected in series or parallel to form modules. When photons from sun are absorbed in a semiconductor then they create some free electrons having higher energies. After creation of these electrons there must be an electric field to induce these higher energy electrons to flow out of the semi-conductor to do useful work.

A photo-voltaic system consists of:

- Solar cell array
- Load leveler
- Storage system
- Tracking system (as per necessity)

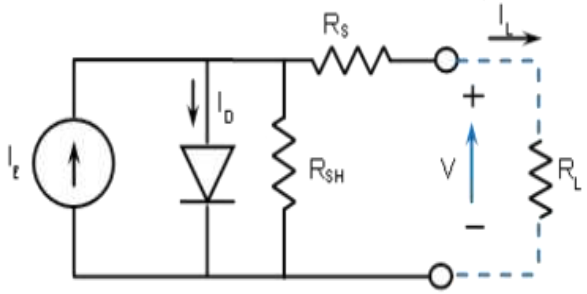


Fig -1: Equivalent circuit of solar system

Fill factor, $FF = \frac{P_{MAX}}{V_{OC}I_{SC}}$

$$\eta_{MAX} = \frac{P_{MAX}}{P_{IN}} = \frac{V_{OC}I_{SC}FF}{P_{IN}} V_{OC}I_{SC}FF$$

$$I = I_l - I_D = I_l - I_S\left(e^{\frac{qV}{kT}} - 1\right)$$

$$I = I_l - I_s\left(e^{\frac{q(V+IR_s)}{nkT}} - 1\right) - \frac{V + IR_s}{R_{SH}}$$

Where, P_{MAX} = Maximum Power
V_{OC} = Open Circuit Voltage
I_{SC} =Short Circuit Current
η_{MAX} = Maximum Efficiency
P_{IN} = Solar Power Input
I =Total Current
I_l = Current Generated by Photo Electric Effect
I_D = Diode Current
I_S = Saturation Current of Diode
Q = Elementary charge=1.6*10-19 Coulombs
V = Measured Cell Voltage
K = Constant=1.38*10-23 J/K
T = Cell Temperature in Kelvin

3.1 For Calculating Solar Energy we should know about

- Life cycle of solar photovoltaic module
- Solar radiation
- Module conversion efficiency
- PV technology life expectancy
- Energy consumption for manufacturing and fuel mix used
- BOS components
- Type of Solar Cell
- Solar Panel orientation and angle

Amongst common photovoltaic system like mono-Si, multi-Si, a-Si, Cadmium Telluride (CdTe), CIS thin film, CdTe has the best environmental issues like shortest energy payback time and the least greenhouse gas emission rate in its whole life cycle.

Silicon based PV systems has the worst environmental effects and especially mono silicon photovoltaic modules have high energy intensity of solar cells production processes. Thin film modules consume less primary energy and have lower EPBT and GHG emission but the efficiency is low. Thin advanced PV systems that have high-concentration, hetero junction and dye-sensitized PV systems also show good environmental performance.

4. WIND ENERGY & POWER DEVELOPED BY IT

Winds are caused due to different temperature in different layers of atmosphere. The energy of motion caused by wind is called kinetic energy. And the conversion of the kinetic energy of the wind into mechanical energy is utilized to complete various useful work, or to generate electricity. Wind turbines produce rotational energy and wind energy is readily converted into electrical energy by connecting the turbine to an electrical generator.

Factors of wind energy converter are

- Wind speed
- Cross section of wind that is swept by rotor
- Efficiency of rotor, generator and transmission system.

4.1 Wind power generated

$$P = \frac{1}{8}\rho\pi D^2 V^3 \text{ Watts}$$

Where, ρ = Density of air
D = Diameter of turbine in horizontal axis
V = Velocity of wind
P = Wind power generated

Power coefficient is the ratio of power output from wind machine to the power available in wind. Its value doesn't exceed 0.593 for horizontal axis wind machine.

5. ENERGY STORAGE AND ITS IMPORTANCE

Energy storage is a very important part in power system that is in electricity generation, transmission and distribution systems. Traditionally, energy storage needs have been met by the physical storage of fuel for fossil-fuelled power plants, by keeping some capacity in reserve and through large scale pumped hydro storage plants. But now the power landscape is changing dramatically with a move to "fuel-free" power, mainly in the form of wind and solar photovoltaic (PV). This shift to renewable sources is good for the environment and sustainability. However, it also makes delivering power

reliably where and when it's needed a bigger challenge than ever before. Since there is no fuel to store, the grid must adapt to store electrical energy efficiently after it is generated.

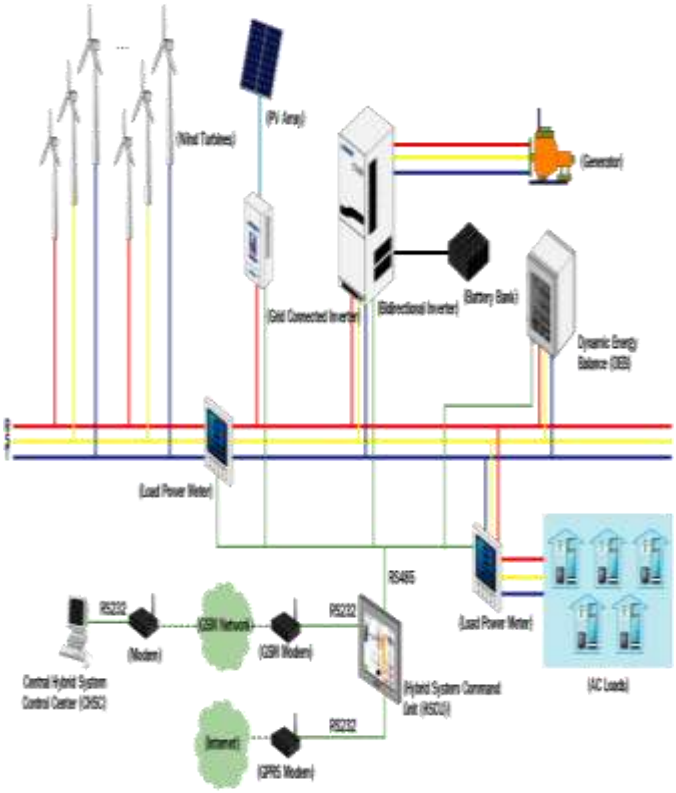


Fig -2: Interconnected Hybrid Smart system

Types of Energy Storage Technologies

Energy storage system covers a wide form of energy, technology and its applications. Electrical energy storage system provides directly or indirectly a variety of electrical input and output.

The main energy storage system technologies that are used:

- Electrochemical systems (embracing batteries, fuel cell and flow cells),
- Mechanical energy storage in the form of either pumped hydro, compressed air storage or flywheel systems.

6. CONCLUSIONS

As we know that photovoltaic technologies in solar energy system and wind energy system are proved to be sustainable and environment friendly and these systems give the best environment benefits such as green house gas emission etc. Separately, their efficiencies are quite low. But due to their ecological benefits we are using them. When these different technologies are combined to form a hybrid system then its efficiency and reliability increases at a very high rate. In addition, advanced hybrid smart improves the total energy production along with its environmental benefits.

In this system we added grid connected inverter after which a bidirectional inverter is used and the energy generated can be stored or used for further transmission and distribution. Interconnection of the system makes it smart which has two way communications. In future we can add some other renewable sources also to improve the efficiency and reliability of the system.

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