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Model of Hybrid Solar Wind Diesel Fuel Cell Power System

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Abstract: *This paper depicts model and simulation of a renewable energy based hybrid power system for improving power quality because optimal utilization of primary energy sources will increase the level of supply reliability. In order to meet sustained load demands during varying natural conditions, different renewable energy sources and converters are need to be integrated with each other. The combination of Photo Voltaic (PV) array System, Wind turbine system, Fuel cell (FC) and Diesel generator systems are used for power generation. Due to variation in output power of solar panel, wind turbine and fuel cell, Diesel engine is also coupled to ensure reliable supply under all conditions. Regenerative cycle of fuel cell helps to dump excess energy from DC bus. The results show that the proposed hybrid power system can effectively manage the optimal utilization of primary energy sources and improves the power quality in an islanding as well as grid connected mode.*

Keywords- *Diesel engine - Synchronous Generator set, Energy Management, Hybrid Power System, Islanding (Isolated) mode and grid connected mode, and Renewable energy Sources.*

I. INTRODUCTION

Energy demand in isolated mode or grid connected mode of applications is steadily increasing. Thus, it is very important to meet the continually increasing demand of power. On the other hand, there is a social interest for global environmental concerns such as greenhouse effect and global warming and a reduction in fossil fuel resources. The solution for these issues can be considered from the recent research and development of alternative energy sources which has excellent potential as a form of contribution to conventional power generation system. i.e., to introduce renewable energy, such as Photovoltaic, Fuel cell and wind energy. This is clean and abundantly available in nature, offers many advantages over conventional power generation system, such as low pollution, high efficiency, diversity of fuels, reusability of exhausts, and onsite installation. The system consists of PV panels, wind power system and fuel cell system. Electrolyzer is used to absorb the rapidly fluctuating output power with load and generate hydrogen. The generated hydrogen is stored in the hydrogen tank and used as fuel for fuel cells, which reduces the fuel cost. Combining several different types of power sources will form the system called "Hybrid Power system". Hybrid power systems (HPS) combine two or more energy conversion devices, or two or more fuels for the same device, that when integrated, overcome limitations inherent in either. Hybrid power systems are designed for the generation and use of electrical power. They are available in two modes; namely islanding (isolating) mode and grid connected mode. In general, a hybrid power system might contain alternating current (AC) diesel generators, an AC distribution system, a Direct current (DC) distribution system, loads, renewable power sources, energy storage, power converters, rotary converters, coupled diesel system, dump loads, load management options, or a supervisory. In the system, the output of the renewable sources cannot feed the load directly because their voltage fluctuations are so large that they will damage the concerned load. So first it needs to be conditioned, for that generally dc-dc/ac-dc converters are used. Thus the varying voltage can be brought to required value and specified variations limits by varying the duty ratio of the converters, and then connected to DC bus.

II. STAND ALONE SYSTEMS

2.1. Solar System

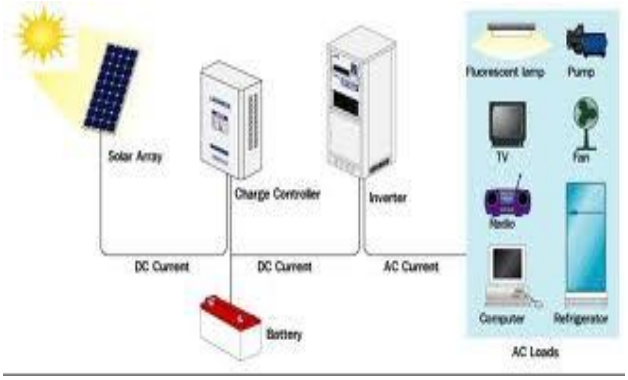

Fig.2.1.1. An illustration of standalone solar system

Insolation (short for **in**cident or **in**coming **sol**ar radi**ation**) is a measure of solar radiation energy received on a given surface area and recorded during a given time. It is also called **solar irradiation** and expressed as "hourly irradiation" if recorded during an hour or "daily irradiation" if recorded during a day. The unit recommended by the World Meteorological Organization is mega joules per square metre (MJ/m^2) or joules per square millimetre (J/mm^2).[1] An alternate unit of measure is the Langley (1 thermo chemical calorie per square centimeter or 41,840 J/m^2). Practitioners in the business of solar energy may use the unit watt-hours per square metre (Wh/m^2). If this energy is divided by the recording time in hours, it is then a density of power called irradiance, expressed in watts per square metre (W/m^2). Solar electric systems sometimes produce more electricity than your home needs. This extra electricity is either stored in batteries or fed into the utility grid. Homeowners can be given credit by their local power companies for the electricity produced at their homes through "net metering" programs.

2.2. Wind Power System

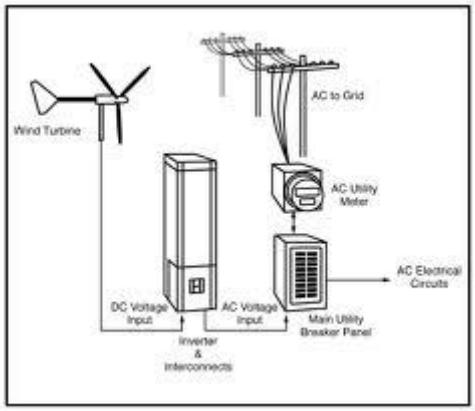

Fig.2.2.1. An illustration of standalone wind power system

A **wind turbine** is a device that converts kinetic energy from the wind into electrical power . A wind turbine used for charging batteries may be referred to as a **wind charger**. A quantitative measure of the wind energy available at any location is called the Wind Power Density (WPD) It is a calculation of the mean annual power available per square meter of swept area of a turbine, and is tabulated for different heights above ground. Calculation of wind power density includes the effect of wind velocity and air density. Wind turbines are designed to exploit the wind energy that exists at a location. Aerodynamic modeling is used to determine the optimum tower height, control systems, number of blades and blade shape.

Fig.2.2.2. Types of wind turbines (Savonius VAWT, Modern HAWT & GDarrieus VAWT)

2.3. Fuel Cell

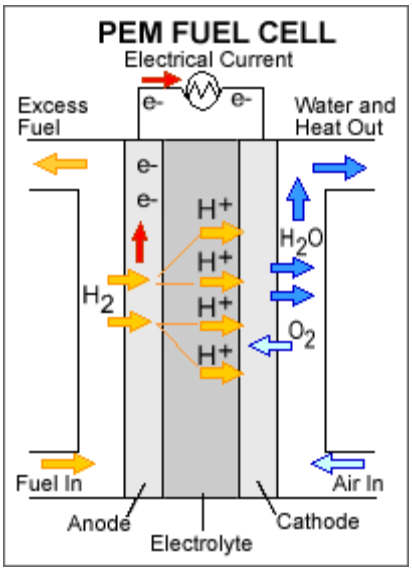

Fig.2.3.1.Schematic of PEM (Proton Exchange Membrane) Fuel Cell

A **fuel cell** is a device that uses hydrogen as a fuel to produce electrons, protons, heat and water. Fuel cells are electrochemical devices that convert the chemical energy of a reaction directly into electrical energy. The fuel cell must provide competitive, reliable, and quality power without emitting pollutants such as oxides of nitrogen, carbon or sulphur. It must respond quickly to changes in load and have low maintenance requirements as well as a long cell life. In the schematic of fuel cell, gaseous fuels are fed continuously to the anode, and an oxidant i.e., oxygen from air, is fed continuously to the cathode compartment, the electrochemical reactions take place at the electrodes to produce an electric current. A fuel cell is individual small unit of around 1.2V. A group of units are connected in series and in parallel to get required voltage and current ratings, that group is called fuel cell stack. Current fuel cells, when operated alone have efficiencies of about 40-55%.

Fuel cell technology is based upon the simple combustion reaction (1):

$$2H_2+O_2 \leftrightarrow 2H_2O \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

2.4. Backup & Storage System

A **diesel generator** is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. This is a specific case of engine-generator. Diesel generating sets are used in places without connection to the power grid, as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid. Sizing of diesel generators is critical to avoid low-load or a shortage of power and is complicated by modern electronics, specifically non-linear loads.

A battery bank is the result of joining two or more batteries together for a single application. By connecting batteries in series, parallel & series and parallel, you can increase the voltage or amperage, or both.

III. PROPOSED SYSTEM

3.1. HPS

Hybrid systems capture the best features of each energy resource and can provide "grid-quality" electricity, with a power range from ONE kilowatt (kW) to several kilowatts. They can be developed as new integrated designs within small electricity distribution systems (mini-grids) and can also be retrofitted in diesel based power systems.

Hybrid systems can provide a steady community-level electricity service, such as **village electrification**, offering also the possibility to be upgraded through grid connection in the future. Furthermore, due to their high levels of efficiency, reliability and long term performance, these systems can also be used as an effective **backup solution to the public grid** in case of blackouts or weak grids, and for **professional energy solutions**, such as telecommunication stations or emergency rooms at hospitals.

Hybrid systems with a backup gen-set run with minimal fuel consumption because the gen-set is brought on line only to assist in periods of high loads or low renewable power availability. This results in a large reduction in fuel consumption as compared to a gen-set only powered system.

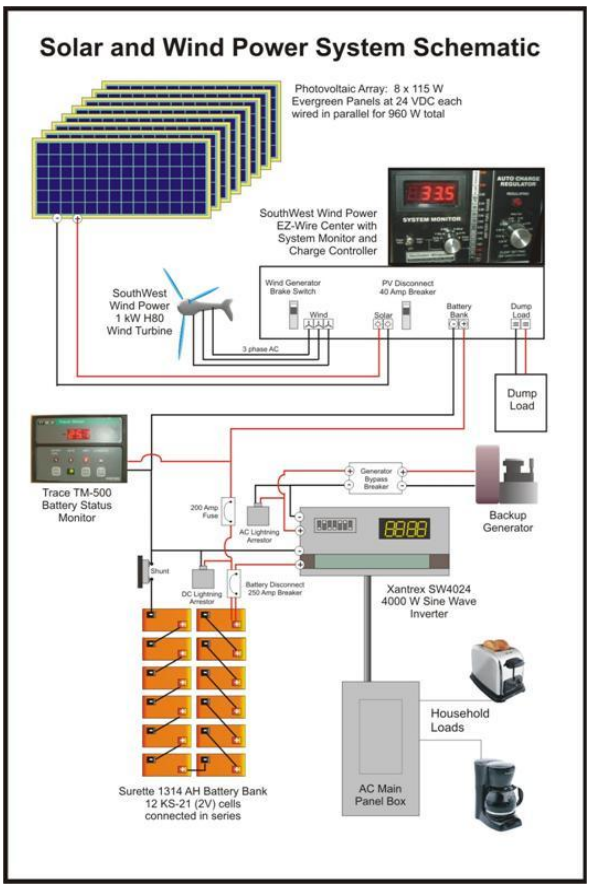

Fig.3.1.1.An illustration of HPS

IV. SIMULATION

4.1. Simulink Model for HPS

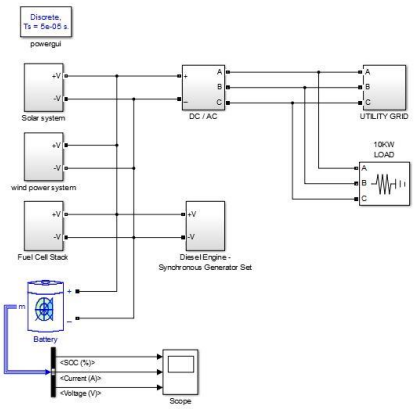

Fig.4.1.1.Simulink diagram of the proposed HPS

Generated power of hybrid system is compare with the load. If generated power exceeds the load, then excess power will be collected by the electrolyzer. The electrolyzer can produce H2 gas and is stored in H2 reservoir tank. Energy management unit monitors the H2 reservoir tank. If H2 reservoir tank is full, and hence excess power is used to charge the battery. The storage batteries compensate the load supply when the output power from the wind power generator, Solar and fuel cell is deficient. And its charging status is also monitored by the EMS on-time. If the load is more than the generated power, then the load is connected to the grid. In that case the EMS checks for the frequency and controls it. In the relatively low capacity of the micro-grid power systems, there are flexible choices for demand side to increase the efficiency of the system operation and economics. Therefore, using demand side management to opportunely control load, would reduce the need of generation capacity and increase the utilization of renewable generation devices and accordingly increase the efficiency of generation investment. Integration of the all blocks by using EMS can provide flexible energy consumption management solution for improving power quality of the renewable energy hybrid micro grid power system. The hybrid power system is based on multi-agents theory [12], so the control subsystem is regarded as an agent. It is composed of human-machine interface (HMI), grid-connected control module, AC multi-function electric power meters, and DC electric power meters, RS485/TCP converter etc., to control and manage the operation of multi-source, such as power grid, wind turbine generation, solar photovoltaic, storage batteries and loads, also to acquire data and communicate with others. The system is composed of several modules.

3.3. Output for HPS

All the components such as PV panel, PEM fuel cell, Wind system, and DC-DC converters, etc., which are individually modeled, and are integrated for simulation. With respect to the variation in natural conditions, the outputs of PV, FC, and Wind turbine systems are primarily controlled by varying duty cycles of DC-DC converters

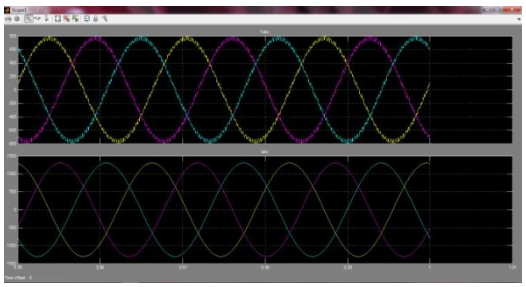

Fig.3.3.1.Simulation result for HPS (from AC/DC)

V. CONCLUSION

In this paper, a renewable energy based hybrid power system, its energy management and control system is proposed. It is modeled for an isolated load/grid connected load using static converters. Diesel engine is also coupled to ensure the reliable supply under all conditions. This proposed system facilitates improvement in power quality which ensures continuous and reliable supply to loads. Therefore, this system can tolerate the rapid changes in load and environmental conditions and suppress the effects of these fluctuations and provides optimum utilization of available resources.

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