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MODELING AND SIMULATION OF SOLAR AND WIND BASED HYBRID ENERGY SYSTEM

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Abstract— **In this paper a solar and wind based non-conventional hybrid energy system using MATLAB software is modeled. As optimum utilization of resources is being observed therefore improves the efficiency as compared to their individual mode of generation. It also increases the reliability and reduces the dependence on single source. The output of solar arrays is variable due to variation of solar irradiation and seasonal weather conditions. Therefore, the maximum power point tracking algorithm is implemented in DC/DC converter to enable PV arrays to operate at maximum power point. This hybrid solar-wind power generating system is suitable for industries and also domestic areas. In India most of the remote and hilly places are still not connected to the grid, thus these places suffer from power scarcity. At such places grid connection is not possible due to economic reasons and difficult terrain. Renewable power plants are useful for such locations. The importance of renewable systems has grown nowadays as these systems use locally available resources and can be the right solution for a clean energy production. As these systems are not in much use, their implementation requires special attention on analysis and modeling. This paper deals theoretical study of models of wind and solar energy sources, , which can be used to study the responces of hybrid systems and most important, software simulation environments. The paper presents the modelling of solar, wind and hybrid power plants**

Keywords- **Solar energy, Wind energy, Micro hydro energy, Renewable energy, power generation, Hybrid energy systems, modeling and simulation**

I. INTRODUCTION

It is a well know fact that there is a major threat of fast depletion of fossil fuel reserves. Fossil fuels and nuclear power plants are used to meet most of the present energy demand. A small part is also being generated using renewable energy technologies such as the wind, solar, biomass, geothermal etc. There will soon be a time when there will be a severe fuel shortage. According to law of conservation of energy, "Energy can neither be created, nor be destroyed, but it can only be converted from one form to another". Most of the researches now are concentrating on how to conserve the reserves of energy and how to utilize the energy in a more efficient way. Researches has also been into the development of reliable and robust systems to harness energy within nonconventional energy resources. Among them, the wind and solar power sources are experiencing a remarkably rapid growth in the past 10 years. Both of them are pollution free sources of abundant power.

Solar cell energy is considered to be a primary resource as there are several countries located in tropical and temperate regions, where the direct solar density may reach up to $1000W/m^2$. **A** solar cell system converts sunlight into electricity. Cells may be grouped to form panels or modules. At present, solar cell (PV) generation is observing increased importance as a renewable energy sources application because it has main advantages such as simplicity of allocation, high dependability, no fuel cost, negligible maintenance and lack of noise and wear as no moving parts are present. Wind turbines are used for the conversion of wind energy into a useful form of energy. For new constructions, onshore wind is an inexpensive source of electricity, competitive with or in many places cheaper. Small onshore wind farms provide electricity to isolated locations. Wind power is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land. The effects on the environment are generally less problematic than those from other power sources. Although wind power is very consistent from year to year but has significant variation over shorter time periods. As the proportion of wind power in a region increases, a need to upgrade the grid and a lowered ability to supplement conventional production can occur. wind turbines made up of synchronous generator with mechanical model. The wind turbine is capable of rotating for small amount of wind change from the ambient. This can further be enhanced to larger value for real time implementation.

II. MODELLING OF SOLAR AND WIND POWER SYSTEM

A. **Wind Power System**

The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The theoretical maximum value of the power coefficient is 0.59. It is dependent on two variables, the tip speed ratio (TSR) and the pitch angle. The pitch angle refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis. TSR is defined as the linear speed of the rotor to the wind speed.

Tip Speed Ratio (TSR)

$$\lambda = \omega^* R/v_w \qquad \text{(i)}$$

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Where:

λ= Tip Speed Ratio

ω= Turbine rotor speed (rad/s)

R= Radius of the turbine blade (m)

v_w = Wind speed (m/s)

Modelling of the wind energy converter is made considering the following assumption:
- Frictionless;
- Stationary wind flow;
- Constant, shear-free wind flow;
- Rotation-free flow;

- Incompressible flow (ρ=1.22 kg/m3);

- Free wind flow around the wind energy converter.

With above assumptions the maximum physically convertible wind energy can be derived by a theoretical model that is independent from the technical construction of a wind energy converter. Flowing air mass has significant amount of energy. This energy is obtained from the air movement on the earth surface created due to pressure gradient. The wind turbines use this energy for obtaining electric power.

Maximum power value taken by wind converter from kinetic energy of air masses, given by equation:

$$P_{max}=(8/27)*A\rho v^3 \qquad \text{(iv)}$$

This power represents only a fraction of the incident air flow theoretical power given by:

$$P_{max}=(8/27)*A\rho v^3$$
$$P_{wind}=0.5A\rho v^3$$
$$P_{max}= P_{wind} .C_p \qquad \text{(v)}$$

Electric generator used may be an induction generator or synchronous generator. The mechanical power that is generated by the wind is given by:

$$P_m=0.5\rho AC_p(\lambda,\beta)v_w^3 \qquad \text{(vi)}$$

where :
ρ - air density;
A - rotor swept area;
C_p (λ, β) - power coefficient function;
λ - tip speed ratio;
β - pitch angle;
v_w -wind speed;

The PMSG is used here in this wind power system instead of an Induction generator because an induction machine is required to be excited with a leading voltage which is generally done by connecting it with grid thereby inefficient for making a standalone power system. The term synchronous refers here to the fact that the rotor and magnetic field rotates in same speed because magnetic field is generated through shaft mounted permanent magnet mechanism and current is induced into the stationary armature.

B. **Solar Power System**

A solar cell system converts sunlight into electricity. The basic element of a solar cell system is the solar cell. Cells are grouped to form panels or modules. Panels can be combined to form large solar arrays. The term array usually describes a solar panel (with several cells connected in series and/or parallel) or a group of panels. Most of the time one are interested in modeling of solar cell panels, which are the commercial solar cell devices.

Since a typical PV cell produces less than 2W at 0.5V approximately, the cells must be connected in series-parallel configuration on a module to produce enough high power. A PV array is a group of several PV modules which are Electrically connected in series and parallel circuits to generate the required current and voltage. PV modules are then arranged in series-parallel structure to achieve desired power output..

Modelling of a solar cell can be realized by an equivalent circuit that consist of a diode with a current source in parallel. The diode determines the I-V characteristics of the cell. The output of the current source is directly proportional to the light falling on the cell. The open circuit voltage increases logarithmic according to Shockley equation which describes the interdependence of current and voltage in a solar cell.

$$I= I_{pv} - I_o\,[\exp(qU/kT) - 1] \qquad \text{(vii)}$$
$$U= kTq\ \ln 1- I- I_{pv}I_o \qquad \text{(viii)}$$

Where: -
k - Boltzmann constant (1.3806* 1023 J/K);
T – Reference temperature of solar cell;
q – Elementary charge (1.6021 *1019 As);
U – Solar cell voltage;
I_o – saturation current of the diode;
I_{pv} – photovoltaic current.

III. SIMULATION OF WIND AND SOLAR POWER SYSTEM

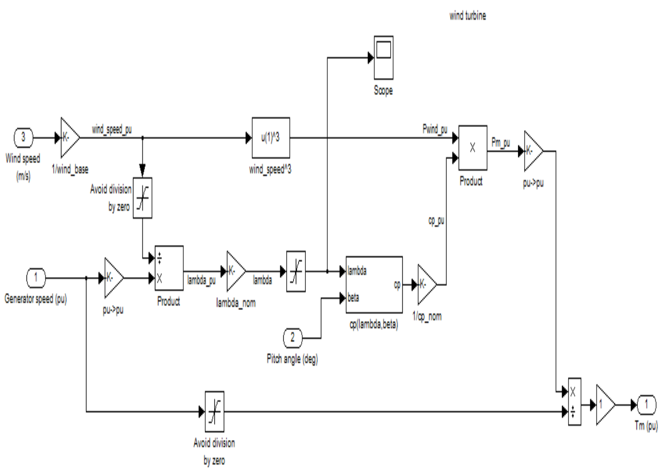

Fig..5 Simulink model of wind turbine

The wind turbine is the most important element of wind power systems. Wind turbines capture the power from the wind by means of aerodynamically designed blades and convert it to rotating mechanical power. The number of blades is normally three. This mechanical power is delivered to the rotor of an electric generator which converts this energy is electrical energy.

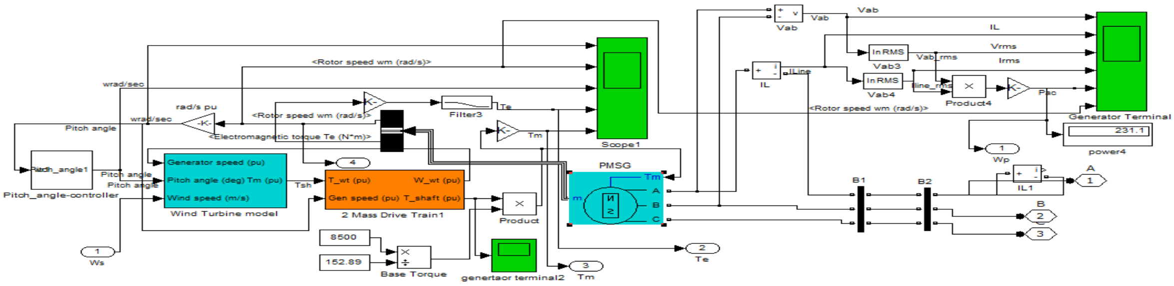

Fig.6 Subsystem

The complete model of the simulink design is given as:

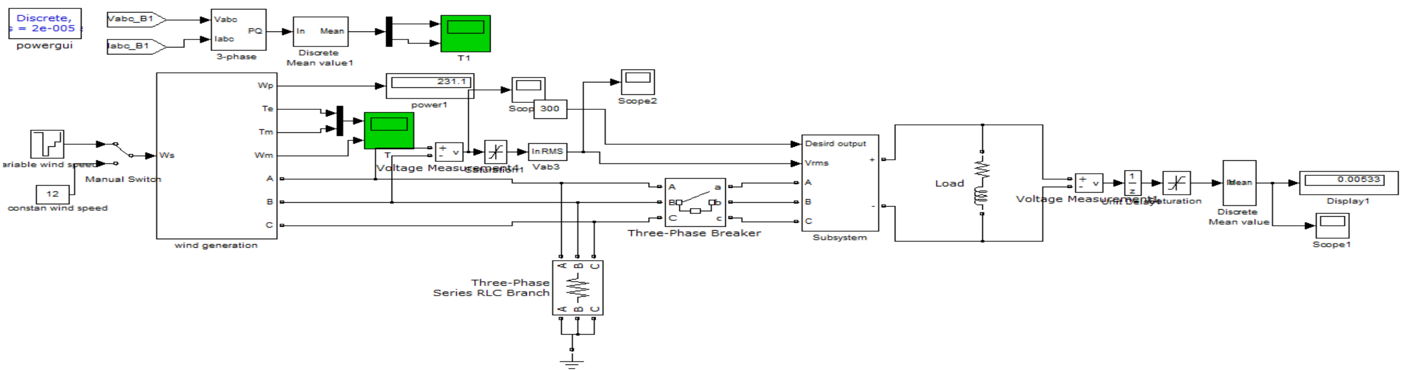

Fig.7 Simulation of wind energy system

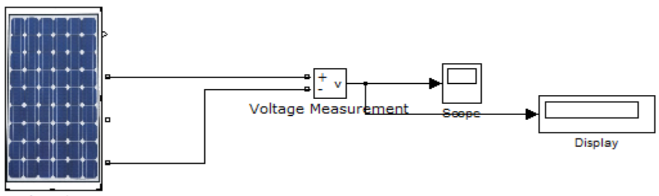

Fig.8 Solar power system model

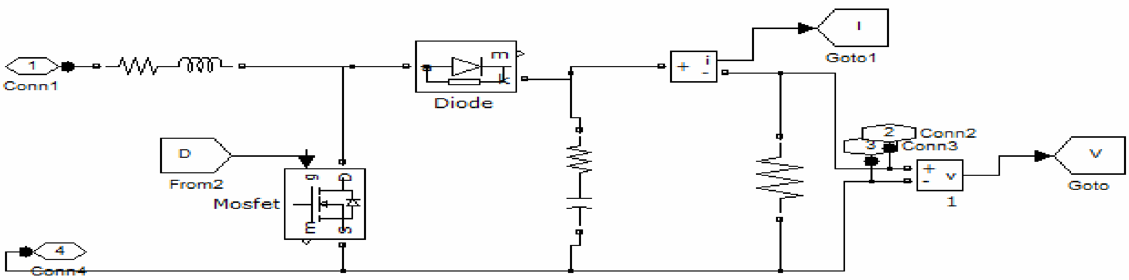

Fig.9 Boost convertor

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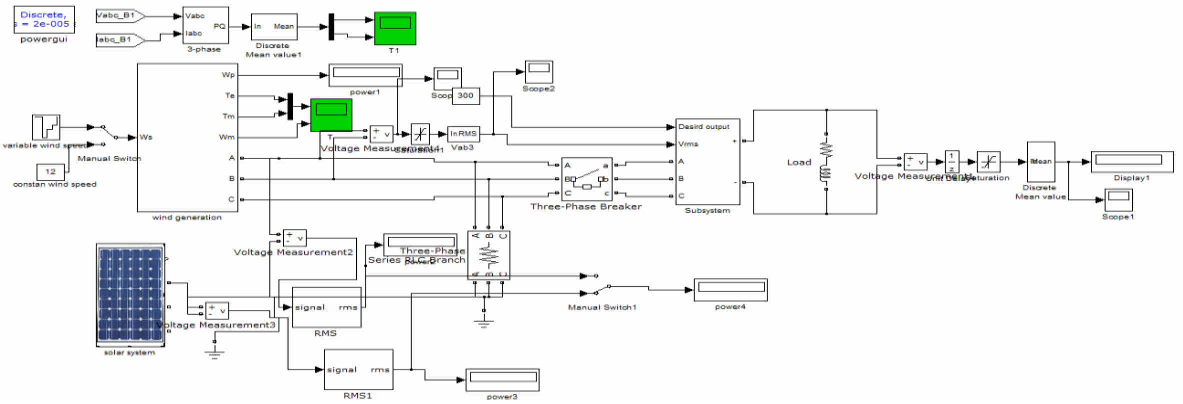

Fig.10 Solar PV and wind hybrid model

IV. RESULTS

Fig.11 shows the relation between line to line Output voltage and time.

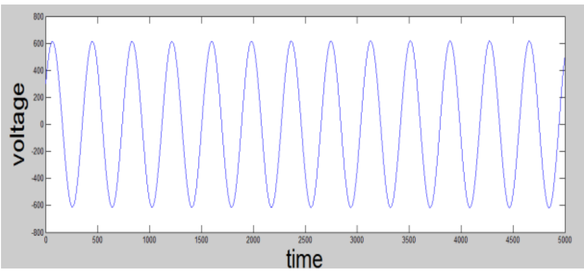

Fig.11 Line to line output voltage w.r.t. time

Fig.12 is about the rms voltage output w.r.t. time

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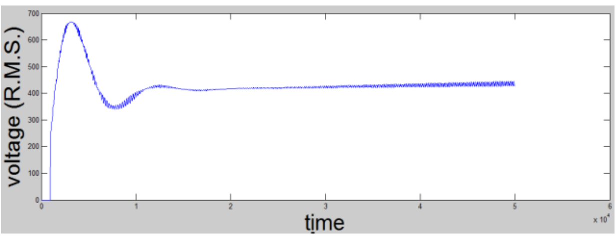

Fig.12 Voltage (R.M.S.)

Fig.13 shows the variation of rotor speed of the turbine w.r.t. time.

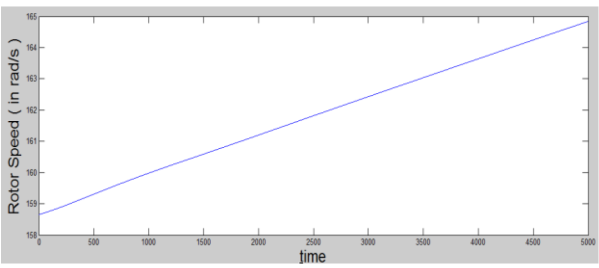

Fig.13 Variation of rotor speed with time

Fig.14 shows the variation of pitch angle of the turbine with time.

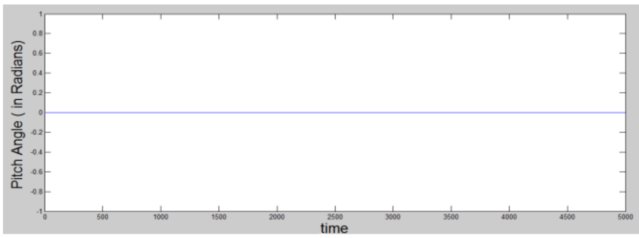

Fig.14 Variation of pitch angle with time.

Fig.15 shows the variation of Mechanical Torque w.r.t. time.

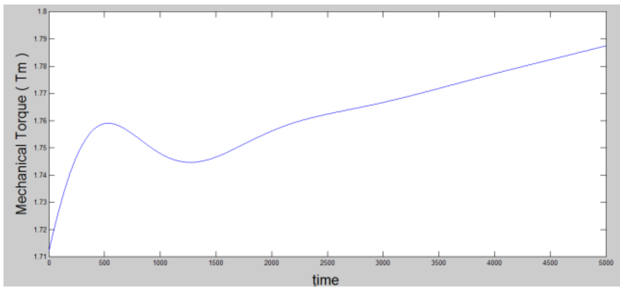

Fig.15 Variation of Torque (mechanical) with time

Fig.16 shows the variation of dc output of solar pv w.r.t. time.

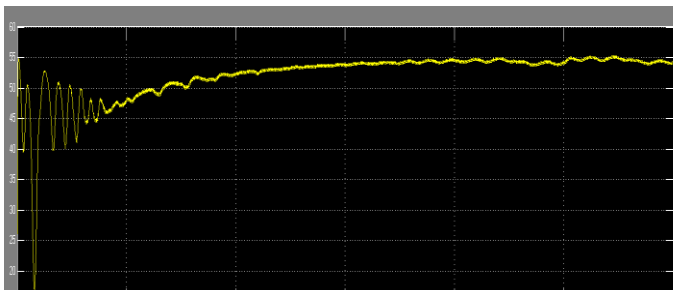

Fig.16 DC output voltage w.r.t. time

Fig.17 shows the variation of ac output voltage with time
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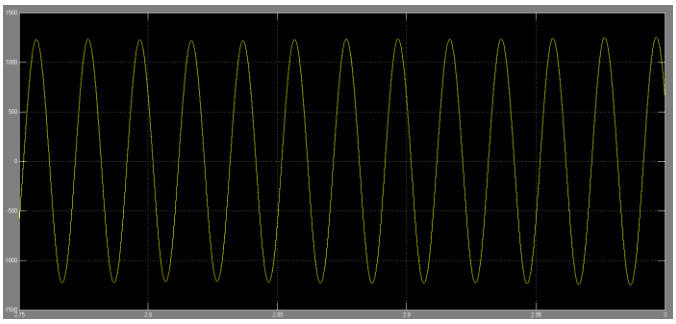

Fig.17 AC voltage w.r.t. time

V. CONCLUSION

As individual renewable systems have their own limitations , Hybrid power systems, generating power by combination of two or more renewable sources can provide power to the fulfill energy demand, Considering the local geography and other details of the place of installation, the best application for these type of systems are in remote places, such as rural areas or hilly villages. The importance of hybrid system has grown as they appear to be the right solution for a clean and distributed energy production The studies have confirmed that the use of a wind power as source of generation of electricity along with other sources of power generation like hydroelectric generation and solar generation have become popular hybrid energy systems. Several advantages of the wind electricity generation are suitable to quote that it is an eco-friendly non-exhausting system that requires a geographical study of the place where the wind turbine is to be setup. In this model simulation has been performed on MATLAB and several output graphs are obtained which demonstrates the performance of a wind and solar energy system. The different graphs are obtained like angular velocity of turbine, rotor speed, mechanical torque, electrical torque, output line to line (L-L) voltage, dc output of solar pv, ac output of the inverter and the output root mean square (R.M.S.) voltage as a function of time. Finally output voltage has been plotted with hybrid system consisting of solar and wind power.

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