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Modelling and Simulation of Renewable Energy Based Power Generation System

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***Abstract*—This paper presents a Simulink-based model of a hybrid system based on renewable sources. Photovoltaic system using a single diode and wind system connected with permanent magnet synchronous generator. Both the sources have Maximum Power Point Tracking System (MPPT). Battery is also connected with these sources. Simulation and conclusions about the behavior of the system are presented.**

Keywords— PV Array, Boost Convertor, MPPT, Battery, PMSG.

I. INTRODUCTION

Now-a-days energy generation by renewable energy sources are become very popular due to environmental concerns. There are too many renewable energy sources but in all of these solar and wind are widely used in renewable energy sources. Renewable energy sources have too many advantages like environmentally friendly, abundance etc. [1]

Day by day, the demand for electricity is rapidly increasing. But the available base load plants are not able to supply electricity as per demand. So, these renewable energy sources can be used to bridge the gap between supply demand during the peak loads.

Historically, diesel generators were use as an alternative but now these days due to rising price of fuels and transportation difficulties of diesel, these diesel generators are now replaced by batteries as a way to make system with energy storage in order to improve the overall stability and reliability of the system.

Hybrid system consists of two or more renewable energy sources i.e. solar, wind, biomass etc. used together to provide increased system efficiency as well as greater balance in energy supply. Hybrid system has too many advantages and it is easy too install and its maintenance is also easy. Extra power is stored in batteries using buck-boost converter. This solar-wind hybrid system covers all applications like rural electrification, off grid, on grid, water purification and water pumping and many more.

The objective of this work is to get three phase power supply using hybrid solar and wind energy sources. Here in this paper hybrid system has been made with 4kW wind generator, a 3 kW PV panel and a 500W grid connected inverter [2]. Incremental conductance MPPT algorithm, PWM inverter and LC filters are also used in this model. The above described system has been designed and simulated in MATLAB Simulink environment. A block diagram of hybrid system is shown in fig.1.

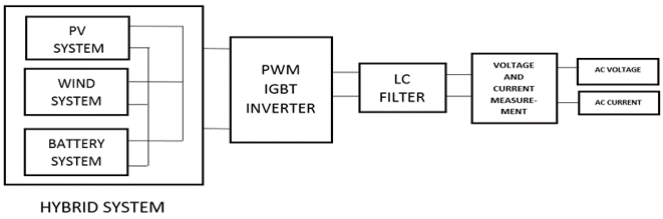

Fig. 1 Block diagram of hybrid energy

II. PV SYSTEM

A photovoltaic system (PV) is a power system which converts solar radiations into electricity. A PV system consists of many PV module in which many PV cells are wired in parallel to increase current and cells in series to increase voltages. A PV cell made up of thin semiconductors wafer, generally highly purified silicon because silicon's energy band (1.5eV) is approximately equals to photons energy band (1.6eV).[5] Equivalent circuit diagram of PV cell with one diode is depicted below

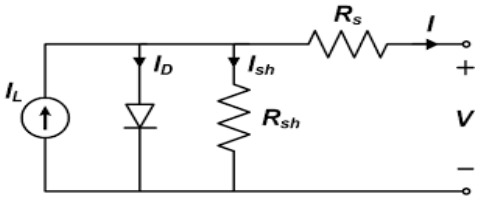

Fig. 2 Equivalent circuit of one diode model of PV cell

The relationship between output voltage (V) and input voltage (I) are

$$I = I_L - I_O * \left\{ \exp\left(\frac{q}{nkT_c}(V + IR_S) \right) - 1 \right\} - \frac{V + IR_S}{R_{sh}}$$

Where q is electron charge, k is Boltzmann constant, I_L is load current, I_0 is saturation current, I is load current, T_c is actual cell temperature, V is output voltage, R_s is series resistance, R_{sh} is shunt resistance, N_s is number of PV cells connected in series.

The I-V characteristic of PV array depends on various factors such as Short Circuit Current, Open Circuit Voltage and fill factor. The I-V curve of PV array is shown below

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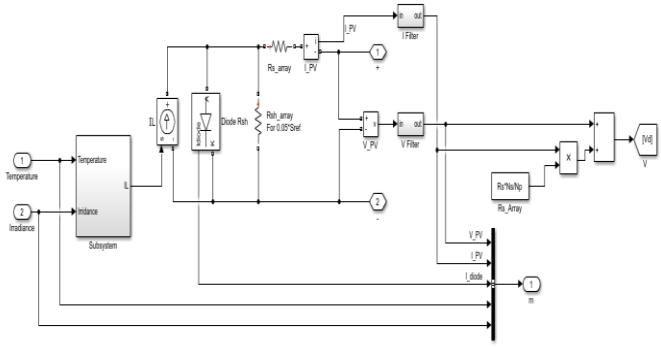

Fig. 3 Simulation diagram of PV Array with one diode

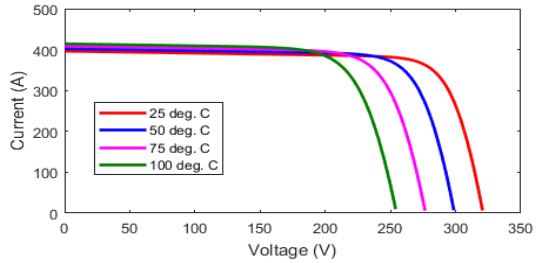

Fig. 4 I-V characteristics of PV array at different temperature

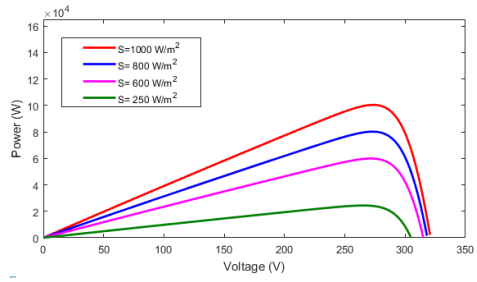

Fig. 5 P-V characteristics of PV array at different irradiance

III. WIND SYSTEM

A wind energy is a device which converts the kinetic energy into electrical energy. They are manufactured in wide range of vertical and horizontal axis type. Small turbine is used in battery changing in auxiliary power for boats or to power traffic warning signs and the slightly larger turbine can be used for making contributions to a domestic power supply. The wind energy technology is more economical and reliable. As wind velocity in the area changes continuously. Because of this dynamic system is needed. Wind energy system convert the kinetic energy of wind into electrical energy.[8]

The equations related to wind power extractions are

$$P_{wt} = \frac{1}{2}\rho A v^3 . C_p$$

$$\lambda = \frac{\omega . r}{v}$$

$$\omega = \frac{1}{J}\int (T_m - T_e).dt$$

Where ρ is air density, A is the area of the turbine blades, v is wind speed, C_p is performance coefficient of the rotor, J is moment of inertia, T_m is mechanical torque, T_e is electromechanical torque of the generator.

The output of a wind system is connected to the PWM inverter through DC-DC boost converter whose duty cycle is determined by incremental conductance algorithm. The boost converter is also increasing the output voltage of wind system.

The simulation diagram of wind turbine and curve between output power and speed is presented in fig.5.

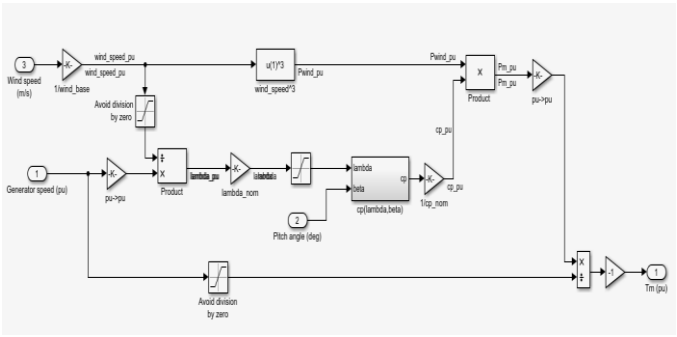

Fig. 6 Simulation diagram of wind turbine

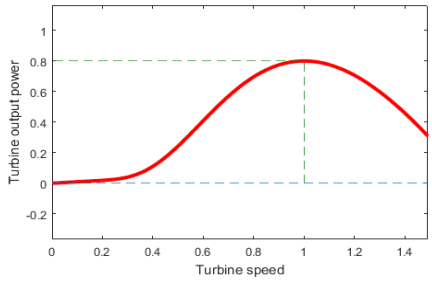

Fig. 7 Power-Speed curve of wind turbine

The output of wind system is connected to the PWM inverter through DC-DC boost converter whose duty cycle is determined by an incremental algorithm. The boost converter also increases the output voltage of wind system.[5]

As a wind system and the output is voltage and frequency variable. For the decoupling of those state variables is done by full bridge diode rectifier. The full bridge diode rectifier is used to obtain DC output voltage from generator.

IV. MPPT

Maximum power point tracking is a technique that is used for maximum power extraction. It is commonly used with wind turbine and PV solar system. The voltage at which maximum power occur is called “Maximum Power Point”. In PV solar system the maximum power point varies with ambient temperature, solar radiations and solar cell temperature. While in wind turbine system it varies with varying with wind speed and pitch angle.

There are too many techniques to extract the maximum power using MPPT. Generally, in solar and wind turbine system incremental conductance technique is used. Incremental method exploits the assumption of the ratio of charge in output conductance is equal to the negative output conductance. We have,

P= VI

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Applying the chain rule for the derivative of products yields to

$$\frac{\partial P}{\partial V} = \frac{[\partial(VI)]}{\partial V}$$

At MPP, as ∂P/∂V=0

The above equation could be written in terms of array voltage V and array current I as

$$\frac{\partial I}{\partial V} = -\frac{I}{V}$$

The MPPT regulates the PWM control signal of the dc-dc boost converter until the condition (∂I/∂V) +(I/V) =0 is satisfied. In this method the peak power of the module lies at above 98% of its incremental conductance.

In the incremental conductance method determines the maximum power point (MPP) in the MPPT and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dI/dV and -I/V. This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than P and O. This algorithm has advantages over P&O. The simulation diagram of incremental conductance is shown in fig 8 below.

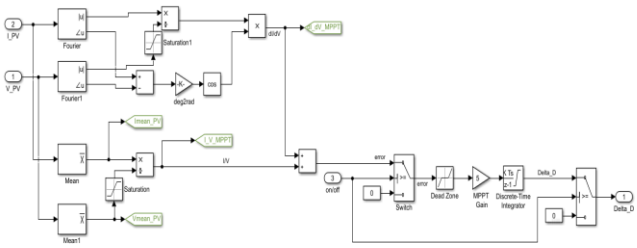

Fig. 8 Simulation diagram of incremental conductance method

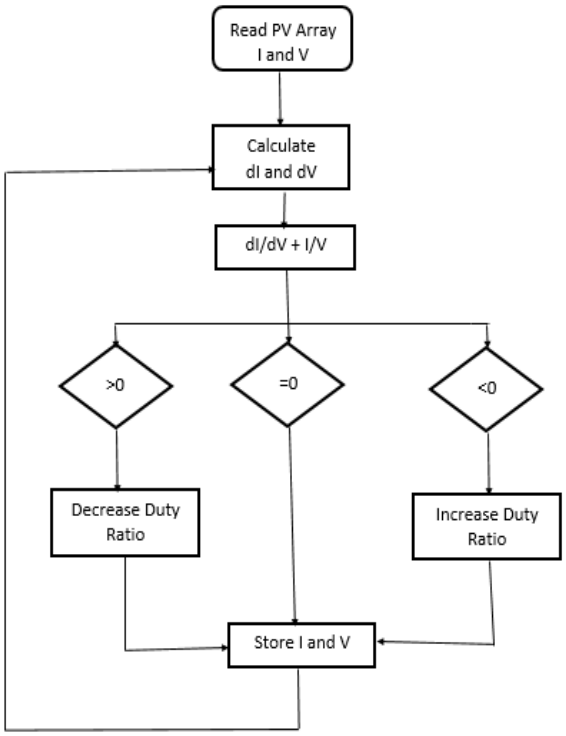

Fig. 9 Flowchart of incremental conductance algorithm

Generally, in solar and wind turbine system hill climbing technique is used. But there are also too many techniques to extract the maximum power point using MPPT such as hill climbing method, fuzzy logic control, neural network, fractional open circuit voltage, fractional short circuit current, current sweep, MPP current and voltage computation, state based MPPT technique, Multiple maxima search.

V. BOOST CONVERTER

Boost converter or step up converter is used to increase the DC output voltage and decrease the output current. In this hybrid model boost converter with IGBT is used. Both PV system and wind system output voltage are increased by boost converter. The main advantage of boost converter is easy to control. The input current is continuous which is very desirable for sources like PV, wind and battery.

The DC input of boost converters are form too many different sources such as batteries, solar panels, wind turbine generators etc. The duty cycle can be given in IGBT or MOSFET, it depends on which is used in boost converter. The duty cycle is connected to the maximum power point tracking system which control the power of the system.

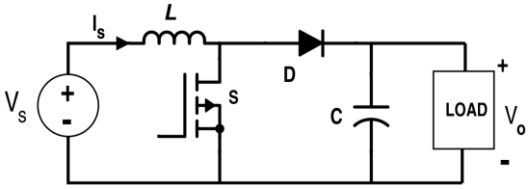

Fig. 10 Equivalent circuit diagram of Boost converter

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VI. PWM INVERTER

The three phase inverters are generally used in the high-power applications to generate balance three phase AC voltage with desired frequency. Pulse Width Modulation inverter is used to give steady state output voltage irrespective to the load. The PWM based technology are more superior than the conventional inverters. This type of inverters is generally use MOSFETs in output switching stage. The PWM based inverters technology has a lot of protection and control circuits.

There is various type of topology to convert the DC input into three phase AC output but the common topology is the voltage source inverter. The commonly used pulse width modulation is sinusoidal pulse width modulation.

VII. BATTERY

Now-a-days the electric storage technology has been on better storage in the form of chemical. In a chemical battery, charging cause reactions in electrochemical compounds to store an energy in a chemical form. There are various type of energy storage system but among various storage technologies battery storage system is more reliable, flexible and responsive. The main advantage of battery storage system is that they are modular and non-polluting.

Battery is an electrochemical device where electrochemical reaction occurs. It is also called energy storage device. Basically, it has three parts i.e. electrode, electrolyte and charge transfer. In hybrid systems different types of battery are used. They all have advantages and disadvantages also. Some different type of batteries are lithium ion battery, nickel- metal hydride battery, nickel cadmium battery etc.

Parameters of lithium ion battery which is used in this hybrid system are shown below in table 1.

Type	Li-Ion Battery
Nominal Voltage (V)	300
Rated Capacity (Ah)	6.5
Exponential Voltage (V)	24.11
Exponential Capacity (Ah^{-1})	0.3193
Cut off Voltage (V)	225
Internal Resistance (Ohms)	0.46154

Table 1 Parameters of Lithium ion Battery

VIII. SIMULATION RESULT

The PV, wind and battery system all three are connected in parallel. A PWM inverter is connected with this parallel connection which converts the DC voltage and DC current into AC voltage and AC current. To reduce harmonics in the output parallel RC and RL filters are used. Its one side is connected with PWM inverter and the other is connected with three phase measurements. The simulation diagram and waveforms of AC voltage and AC current are shown in fig respectively.

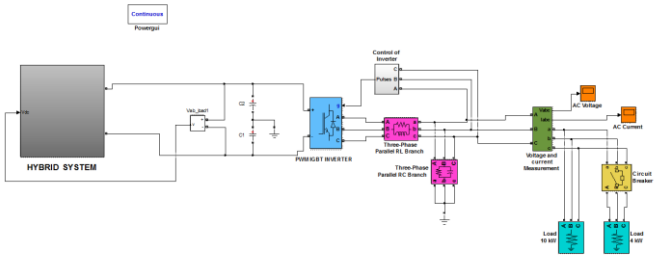

Fig. 11 Simulation model of hybrid system

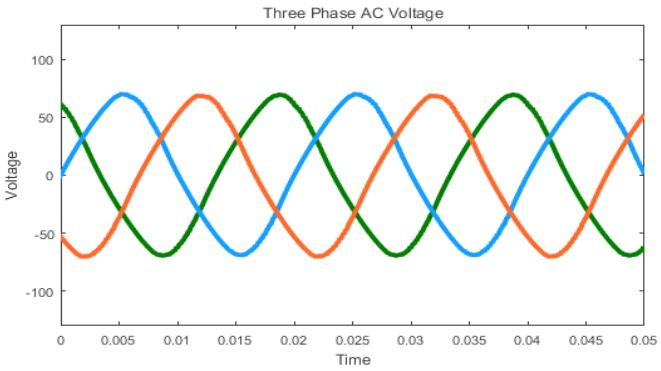

Fig. 12 Output waveform of AC voltage

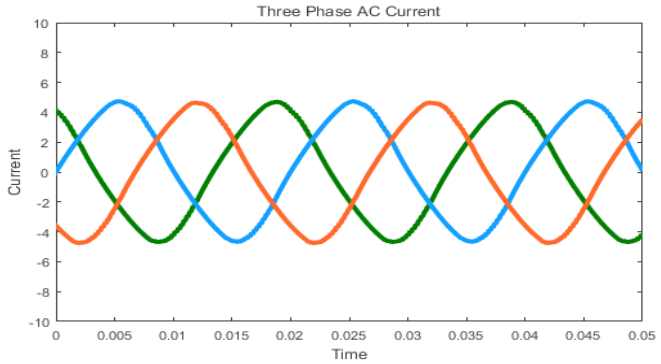

Fig. 13 Output waveform of AC current

IX. CONCLUSION AND FUTURE SCOPE

The objective of this paper is to represent the AC power by using PV-wind hybrid system with MPPT control and PWM inverter. The use of hybrid system allows a more controllable produce power. The advantage of hybrid system is that even in the absence of one renewable source i.e. if solar or wind system is shut down for a while power continuously can be delivered by one source and battery which storage the energy. The main advantage of MPPT is it track the point where maximum power occurs in the system. In future, instead of incremental conductance fuzzy logic controller can be used. DFIG is also used in place of PMSG.

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