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Standalone Hybrid Wind and Solar Photovoltaic Cell Power Generation

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Abstract: In the last few years the wind power generation has been increased significantly. Due to development in renewable energy technologies and continued rise in prices of petroleum products hybrid renewable energy systems are gaining more importance for supplying the power to meet the today's increasing energy demands either as a stand-alone system or as a grid connected system. In this work a model of stand-alone connected hybrid system consists of wind and solar photovoltaic cell system is studied and implemented in MATLAB/SIMULINK. The proposed system consists of a wind turbine, induction generator, a PV solar cell array, boost converter, an inverter and a battery storage system. A simple control technique has been proposed to track the operating point at which maximum power can be coerced from the solar/wind system under continuously changing environmental conditions. A relative study of hybrid model PV/wind system has been made.

Keywords: Photovoltaic Cell, Wind System, Hybrid System, MATLAB / SIMULINK.

I. INTRODUCTION

The development of renewable energy sources is continuously improving due to the critical condition of industrial fuels which include oil, gas and others; This is the reason why renewable energy sources have become more important these days. Few other reasons include advantages like abundant availability in nature, eco-friendly and recyclable. Many renewable energy sources like solar, wind, and tidal are there. Among these renewable sources solar and wind energy are the world's fastest growing energy resources. With no emission of pollutants, energy conversion is done through wind and PV cells. 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 energy sources can be used to bridge the gap between supply and demand during peak loads. This kind of small-scale stand-alone power generating systems can also be used in remote areas where conventional power generation is impractical.

In this paper, standalone a hybrid power generation using wind and solar PV system model is studied and simulated. A hybrid system is more advantageous as individual power generation system is not completely reliable. When any one of the systems is shutdown the other can supply power.

Objective

To implement a power system that is a hybrid of both Photovoltaic and wind powers. The step by step objectives are

- To study and model PV cell, PV array and PV panels
- To study the characteristic curves and effect of variation of environmental conditions like temperature and irradiation on them
- To study and simulate the wind power system and track its maximum power point
- Implement hybrid system.

II. MATERIALS AND METHODS

The entire hybrid system consists of PV, Inverter, Boost Converter and the wind systems. A block diagram of standalone hybrid system is shown in fig. 2.1

The PV system is powered by the solar energy which is abundantly available in nature. The light incident on the PV cells is converted into electrical energy by solar energy harvesting means. The maximum power point tracking system with Perturb & absorb algorithm is used, which extracts the maximum possible power from the PV modules. The ac-dc converter is used to converter ac voltage to dc.

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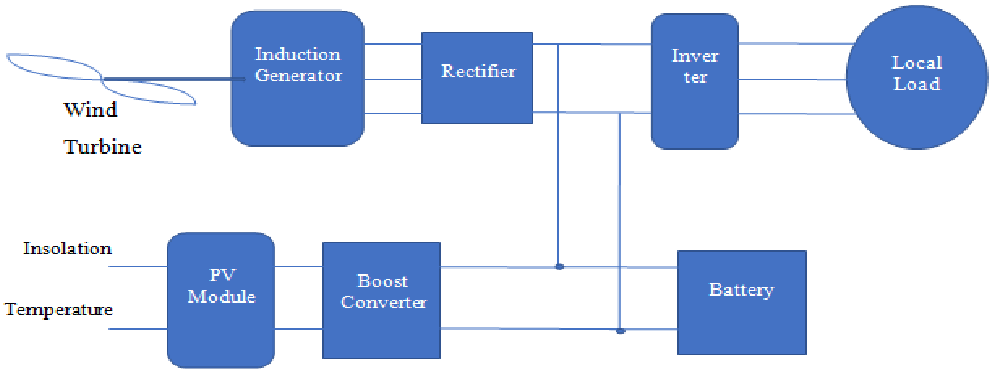

Fig. 2.1 Block diagram of Hybrid System

Wind turbine, gear box, generator and an AC – DC converter are included in the wind energy system. The wind turbine is used to convert wind energy to rotational mechanical energy and this mechanical energy available at the turbine shaft is converted to electrical energy using a generator. To obtain the maximum power from wind energy system we used a maximum power point tracing system. Using bi-directional converter both the energy systems charge a battery. A hybrid generation system that hold more than one power source can substantially increase the certainty of load demands all the time. Even higher generating capacities can be achieved by hybrid system. In stand-alone system, one can able to provide fluctuation free output to the load irrespective of weathers condition. To get the energy output of the PV system that converts solar energy to electrical energy stored, and constant power delivered by the wind energy system, an efficient energy storage mechanism is required, which can be realized by the battery bank.

2.1 Photovoltaic Arrangement

A photovoltaic energy system is mainly powered by solar energy. The configuration of PV system is manifested in fig2.2.

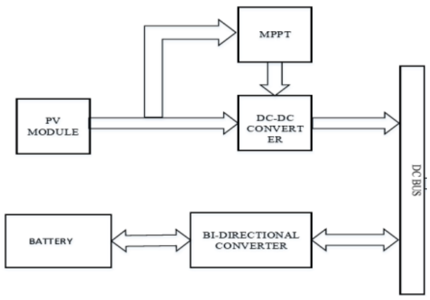

Fig.2.2 Block diagram of PV energy system

It contains PV modules or arrays, which convert solar energy in the form of solar irradiation into electric energy. The dc-dc converter changes the level of the voltage to match it with the electrical appliances that are supplied by this system. This DC -DC converter may be either buck or boost or buck-boost contingent on the required and available voltage levels. The maximum power point tracing system coerces the maximum power from the PV modules. A bi-directional converter which is able to supply the current in both the directions is used to charge the battery when there is a power surplus and the energy which is stored by the battery is discharged into the load when there is a power deficiency.

2.1.1 PV Cell

Photovoltaic cell is the building block of the PV system and semiconductor material such as silicon and germanium are the building block of PV cell. Generally, silicon is used for PV cell due to its advantages over germanium. When photons hit the surface of solar cell, the electrons and holes are generated by breaking the covalent bond inside the atom of semiconductor material & in response electric field is generated by creating positive and negative terminals. When these terminals are connected by a conductor an electric current will start flowing. This electricity is used to power a load.

Working of PV Cell: The basic theory involved in working of an individual PV cell is the Photoelectric effect according to which, when a photon particle hits a PV cell, after receiving energy from sunbeam the electrons of the semiconductor get excited and hop to the conduction band from the valence band and become free to move. Movement of electrons create positive and negative terminal and also create potential difference across these two terminals. When an external circuit is connected between these terminals an electric current start flowing through the circuit.

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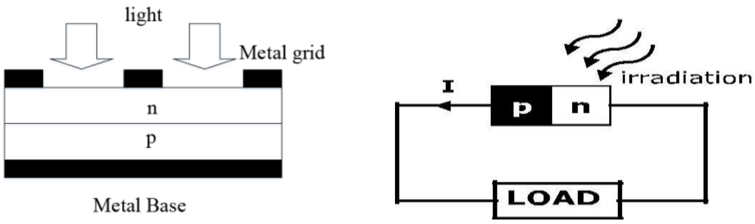

Fig.2.3 Working of PV Cell

2.2 Maximum Power Point Tracking

Maximum power point tracking (MPPT) system is an electronic control system that can be able to coerce the maximum power from a PV system. It does not involve a single mechanical component that results in the movement of the modules changing their direction and make them face straight towards the sun. MPPT control is a system which can deliver maximum allowable power by varying the operating point of the modules electrically. There are many algorithms which help in tracing the maximum power point of the PV module. They are following:

1. P&O algorithm
2. IC algorithm
3. Parasitic capacitance
4. Voltage based peak power tracking
5. Current Based peak power tracking

2.2.1 Perturb and Observe algorithm

Each and every MPPT algorithm has its own advantages and disadvantages. Perturb and observe (P&O) method is widely used due its simpleness. In this algorithm, introduction of a perturbation in the operating voltage of the panel. Perturbation in voltage can be done by altering the value of duty-cycle of dc-dc converter. Fig 2.4 show the P-V characteristics of a photovoltaic system, by analysing the p-v characteristics we can see that on right side of MPP as the voltage decreases the power increases but on left side of MPP increasing voltage will increase power. This is the main idea we have used in the P&O algorithm to track the MPP. The flow chart of P&O algorithm is manifested in fig. 2.5.

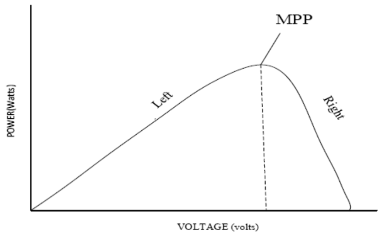

Fig.2.4 P-V characteristics (basic idea of P&O algorithm)

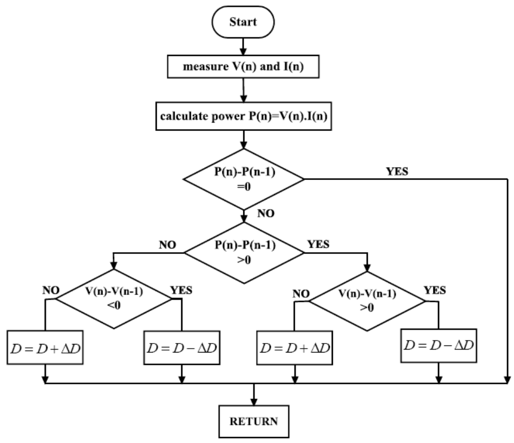

Fig.2.5 Flowchart of P&O MPPT algorithm

As it can see from the flow chart first of all we measure voltage and current, by using these values we calculate power, calculated power is compared with previous one and accordingly we increase or decrease the voltage to locate the Maximum Power Point by altering the duty cycle of converter.

2.3 DC-DC Converter

DC-DC converter is an electrical circuit whose main application is to transform a dc voltage from one level to another level. It is similar to a transformer in AC source, it can able to step the voltage level up or down. The variable dc voltage level can be regulated by controlling the duty ratio (on-off time of a switch) of the converter. There are various types of dc-dc converters that can be used to transform the level of the voltage as per the supply availability and load requirement. Some of them are below.

1. Boost converter
2. Buck converter
3. Buck-Boost converter

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We are using boost converter in our hybrid model for increase the voltage level.

2.3.1 Boost converter

The functionality of boost converter is to increase the voltage level. The circuit configuration of the boost converter is manifested in figure 2.6.

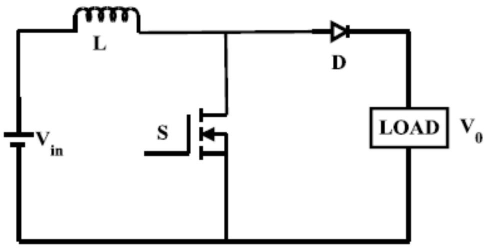

Fig. 2.6 Circuit diagram of Boost Converter

The current carried by the inductor starts rising and it stores energy during ON time of the switching element. The circuit is said to be in charging state. During OFF condition, the reserve energy of the inductor starts dissipating into the load along with the supply. The output voltage level exceeds that of the input voltage and is dependent on the inductor time constant. The load side voltage is the ratio of source side voltage and the duty ratio of the switching device.

2.4 Wind Energy System

Wind power generators are available in small size suitable for standalone system and larger utility-generators that could be connected to the electricity grids. The schematic diagram of the wind energy system is manifested in figure 2.7.

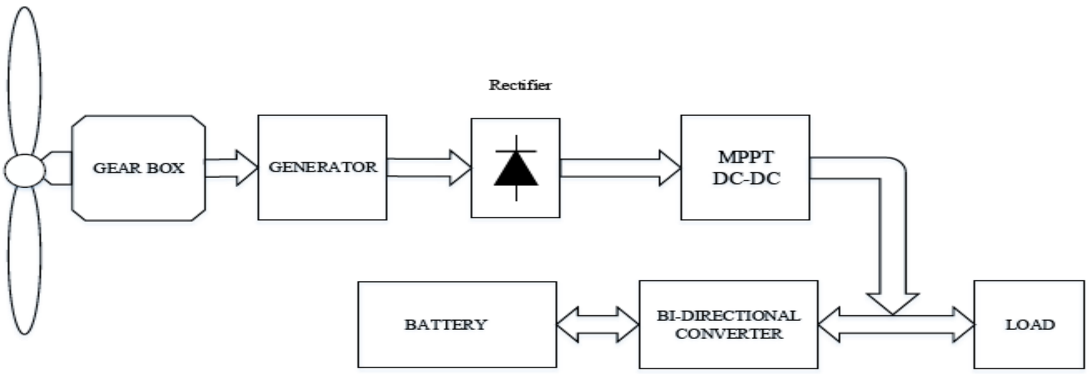

Fig. 2.7 Block diagram of Wind Energy System

This system comprises of a wind turbine which transforms wind's kinetic energy into rotating motion, a gear box to match the turbine speed to generator speed, a generator which converts mechanical energy into electrical energy, a rectifier which converts ac voltage to dc, a controllable dc-dc converter to trace the maximum power point, a battery is charged and discharged through bi-directional converter.

III. SIMULATION MODELS

The overall model of PV/wind hybrid system consists of many parts, which are as follows

1. A 3.7 k watt, 400 volts and 50 Hz IG
2. Wind turbine
3. Battery rack
4. Wind Side converter (WSC)
5. PV panels of 1k watt
6. Boost converter
7. Inverter
8. Controller to generate pulses for inverter
9. RLC filter
10. Load (1HP IM)

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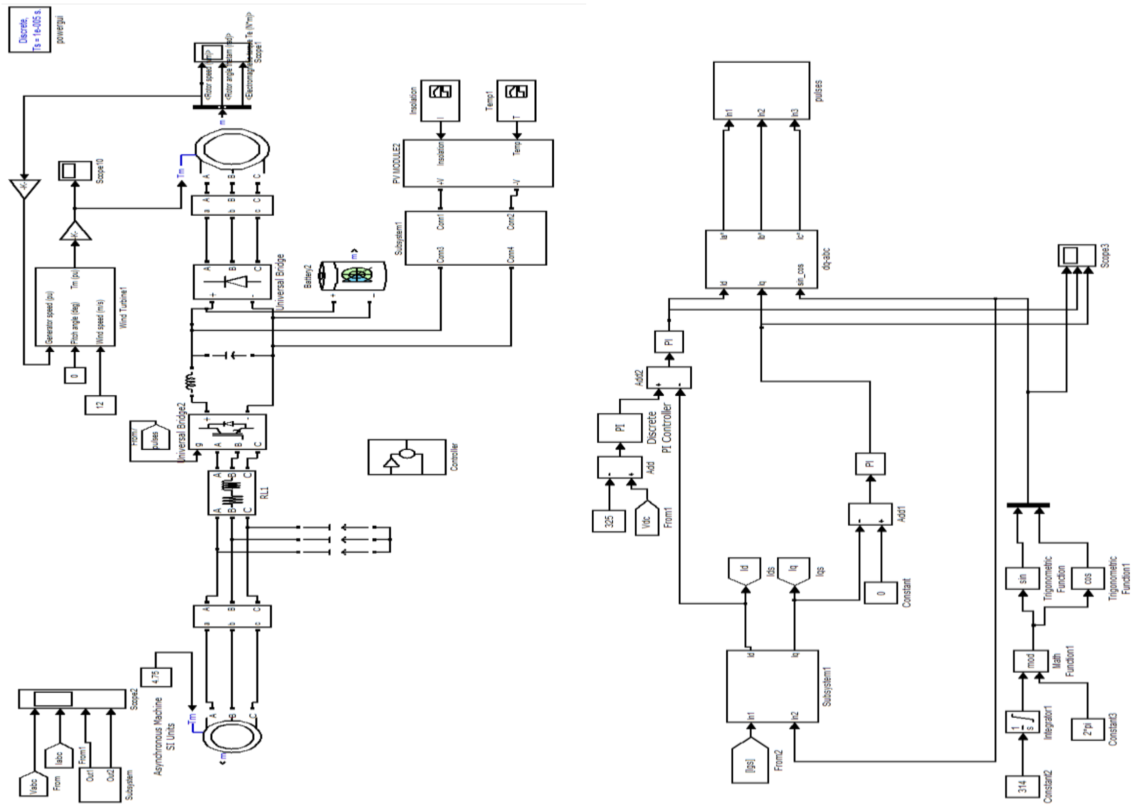

Fig. 3.1Controller model

IV. RESULTS AND DISCUSSION

4.1 Simulation results of PV module

PV module consists of 36 cells in series receiving uniform insolation of 1000W/m2 and temperature of 25℃. Inputs to the PV module are solar insolation, temperature and PV voltage. A PV system is arrangement of 5 modules connected in series and 3 such strings are connected in parallel. Generated current and voltage of PV system is shown in fig. 4.1.

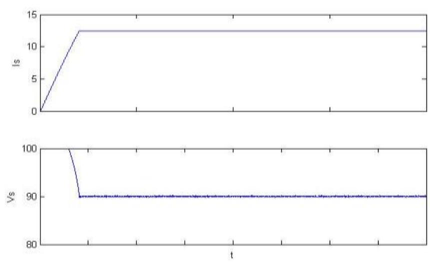

Fig. 4.1 Current and voltage of PV Module

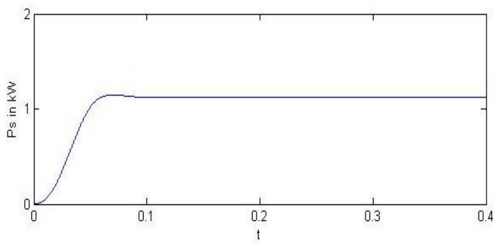

Fig. 4.2 Generated power of PV Module

4.2 Simulation results of Wind energy system

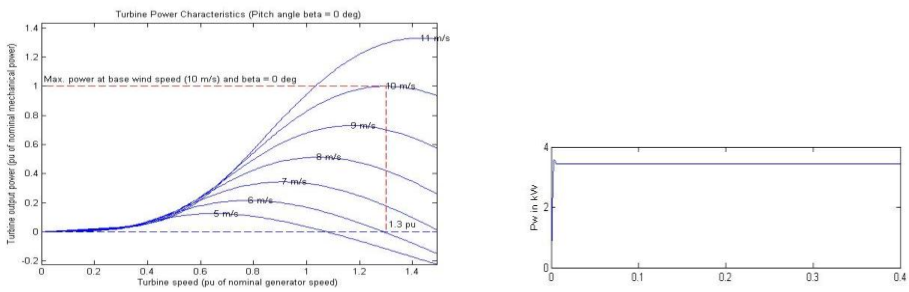

Fig. 4.3 Wind turbine characteristics & Generated power of wind energy system

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Shows the turbine power characteristics at different wind speed From the fig 4.3. We can observe that as wind speed increases turbine output power also increases. Results of wind energy system are shown below at 12 m/s wind speed.

4.3 Simulation result of dc voltage at battery interface

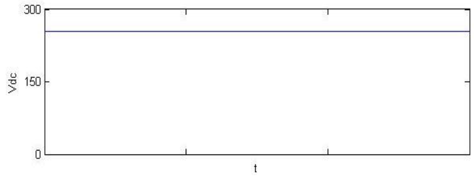

Fig. 4.4 Vdc at Battery interface

4.4 Power contribution of PV and wind energy system

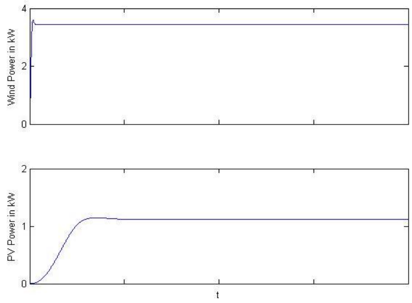

Fig. 4.5 Individual power contribution of PV and Wind energy system

4.5 Overall simulation results of hybrid system with load

Results shown for PV/wind hybrid system consist of 36 cells PV module interfaced with 3.7 kWatt Induction generator along with wind turbine. Hybrid system is supported by battery storage system that consist 22 units of 12 volts, 7Ah are connected in series and two such strings are connected in parallel for the capacity of 3.7 kWh.

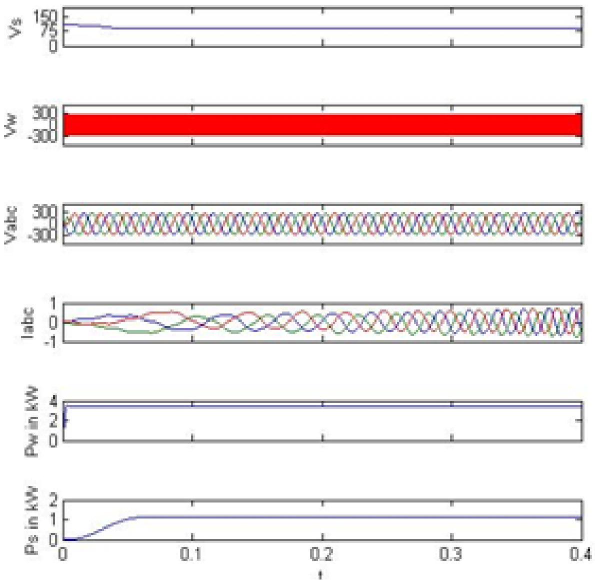

Fig. 4.6 Important result of PV/wind hybrid system

V. CONCLUSION

PV/Wind energy system has been studied and simulated using MATLAB. PV cell, module and array are simulated and effect of environmental conditions on their characteristics is studied. Both the systems are integrated and the hybrid system with battery storage system is used for irrigation purpose.

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