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A Simple Control Strategy for Boost Converter Based Wind and Solar Hybrid Energy System

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***Abstract*: ** This paper deals about the improvement of output from hybrid (Wind and PV) system through the maximum power point technique (MPPT). Though various power tracking techniques are available, Constant Voltage method is simple and effective way to track the maximum power. In this method output voltage is compared with the maximum voltage and based on the comparison gate signal is generated to the boost converter switch. Two boost converters are used individually for PV and Wind system. The whole system is modeled by using the Matlab/Simulink Model.
***Key words**: Renewable Energy, PV array, Wind Generator, Boost Converter, MPPT, Constant Voltage Method*

I. INTRODUCTION

With increase in fuel cost for power generation and limited availability of fossil fuels, much attention has been focused on the use of renewable energy sources for electrical power generation. Renewable Energy Sources are those energy sources which are not depleted when their energy is harnessed. Use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Among these, tapping wind energy with wind turbines appears to be the most promising source of renewable energy. Wind energy conversion systems are used to capture the energy available in the wind to convert into electrical energy. The advancements in power electronics has modified the basic characteristic of the wind turbine from being an energy source to be an active power source.

The standalone solar photovoltaic and wind systems have been promoted around the globe on a comparatively larger scale. These independent systems cannot provide continuous source of energy, as they are seasonal. For example, standalone solar photovoltaic energy system cannot provide reliable power during non-sunny days. The standalone wind system cannot satisfy constant load demands due to significant fluctuations in the magnitude of wind speeds from hour to hour throughout the year. Therefore, energy storage systems will be required for each of these systems in order to satisfy the power demands. Usually storage system is expensive and the size has to be reduced to a minimum possible for the renewable energy system to be cost effective. The power generated from both wind and solar components is stored in a battery bank for use whenever required.

A hybrid renewable energy system utilizes two or more energy production methods, usually solar and wind power. The other advantage of solar / wind hybrid system is that when solar and wind power production is used together, the reliability of the system is enhanced. Additionally, the size of battery storage can be reduced slightly as there is less reliance on one method of powerproduction. Often, when there is no sun, there is plenty of wind.

The power converter acts as the interface between the generator and the grid. Typically, the power flow is unidirectional from the generator to the electrical network. Three important issues are of concern usingsuch a system namely the reliability, the efficiency and the cost. Currently, the cost of power semiconductor devices is decreasing 1/5 % every year for the same output performance and the price per kW for a power electronic system is also decreasing.

The breakdown voltage and/or current carrying capability of the components are also continuously increasing. Important research is going on to change the material from silicon to silicon carbide, which may dramatically increase the power density of power converters as well as their voltage capability. The fig.1, fig.2 shows the stand alone wind, PV and their power electronics respectively

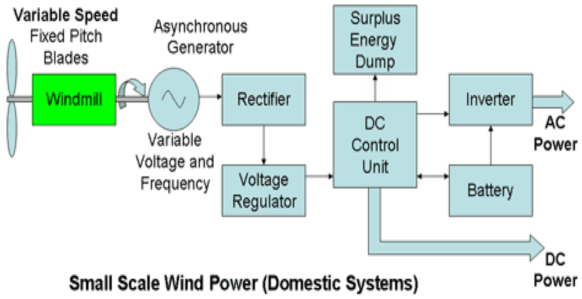

Fig.1 Stand-alone Wind Energy System

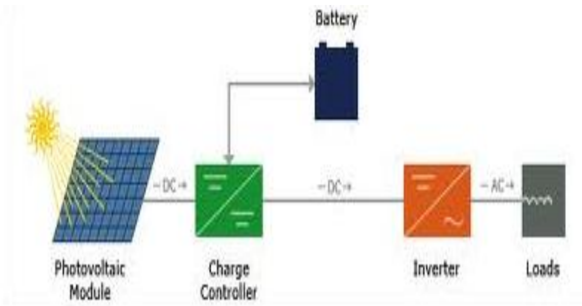

Fig-2 Stand-alone PV system

The proposed system combines both the system through dc-dc boost converter. The boost converter is used because of its simple nature and it will boost up the voltage without using transformer (i.e., like transformer in AC side).

II. HYBRID SYSTEM

The fig.3 shows block diagram of proposed hybrid system via boost converter. The output from wind and PV system are connected to the input of boost converter topology. The output from PV is directly connected to the DC-DC boost converter but the output of wind is rectified through diode rectifier circuit and is connected to the DC-DC boost converter circuit.

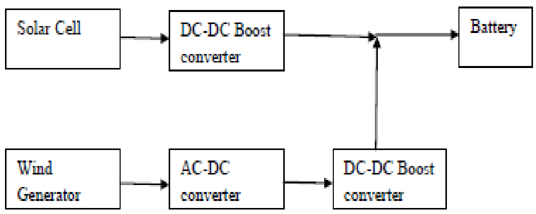

Fig-3 Block Diagram of Proposed Work

Here diode rectifier is used in the place of AC-DC converter, because it does not need any additional control signal/circuit for commutating the devices due to natural or line commutation of diode. The boost converter uses the MOSFET as a switch. The control signal for this switch is generated through the constant voltage method. This method is modeled in the Matlab-Simulink model. The combined DC output is connected directly to the load or it is inverted through inverter to load. Battery is used for storage purpose; it is used between the load and the converter output.

III. CONSTANT VOLTAGE METHOD

Constant voltage method uses the fact that the ratio of the array voltage (V_{MPP}) corresponding to MPP and the open circuit voltage (V_{OC}) is nearly a constant (V_{MPP} / V_{OC} = 0.78), independent of any external conditions. The sensed PV array voltage is compared with a reference voltage to generate an error signal which, in turn, control the duty cycle, as shown in fig.4

The duty cycle of the power converter ensures that the PV array voltage is equal to 0.78 X V_{OC}. Kobayashi et al. (2006) have proposed a method on similar lines, where V_{OC} is determined using a diode mounted at the back of the array. A constant current is fed into the diode and the resulting voltage across the diode is used as the array's V_{OC} which is then utilized in tracking V_{MPP}. The fig – 4 shows the block of constant voltage method.

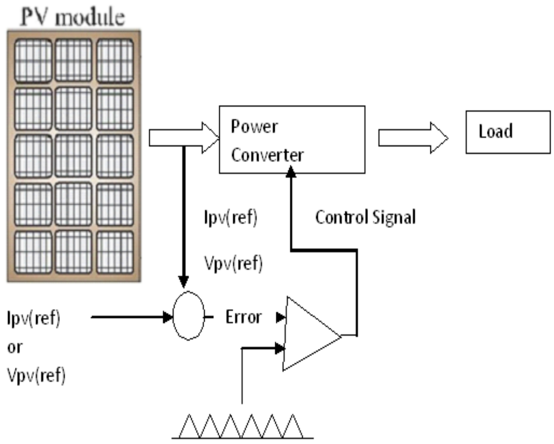

Fig-4 Constant Voltage Method

In this method reference signal is the maximum output voltage and is compared with the instantaneous output voltage from PV.Fig.4illustrates the control of PV, the same methodology is carried out for wind generator. The compared signal is processed through the algorithm and finally the control signal is generated to the power converter.

IV. MODELING OF THE PROPOSED SYSETM

For PV system solar cell is the basic building block, that is solar array is the group of solar modules and module is the group of solar cells. The solar cell is modeled in the Matlab as shown in fig – 5. The output voltage of each solar cell is 0.8V (open circuit voltage) and the short circuit current is 7.32A. To get the required output voltage and current number of solar cells are get connected in series and parallel combination. In this work we need 30V as output; to achieve this 40 solar cells were connected in series. The output of solar module is based on the irradiation level; in this work 1000 is used as standard value. The irradiation is measured by the following equations,

$I_m=I_{pv} - I_0 * \text{Exp}((V+I_{rs})/V*T_a) - 1$ (1)

$Ipv = (K_i\Delta t + I_{pv},n)\ G/G_nI_0=I_{scn}+(K*I*\Delta t)/\exp(((V_{on}+K_i\Delta t)/V_{ta}$ (2)

Where, I_{pv} is Photovoltaic current, K_i is Current temperature co-efficient, G is Actual sun irradiation (W/ms), G_n is Nominal sun irradiation,Δt is Difference between actual and nominal temperature($T-T_n$), I_0 is Diode saturation current, A is Diode identity factor, V_t is Junction thermal voltage = (KT/q), K is Boltzman constant it is equal to $38065*10^{-33}$ J/k, q is Electron charges equal to $1.607*10^{-9}$ c, T is Nominal temperature and is equal to 298.5k.

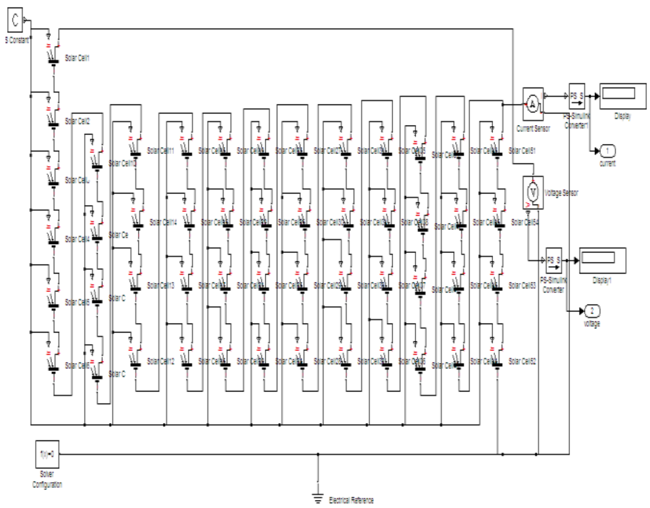

Fig-5 Solar Cell Modeling

The wind generator is modeled by using PMSG; the advantage of using the PMSG is it provides the constant speed operation. The output from wind generator is given to the diode rectifier; dc output is given to boost converter. The boost converter output is controlled by changing the duty cycle of switch; for this purpose only constant voltage method. Fig.6 shows the schematic diagram of wind generation and fig.7 shows the Simulink model of the generating system.

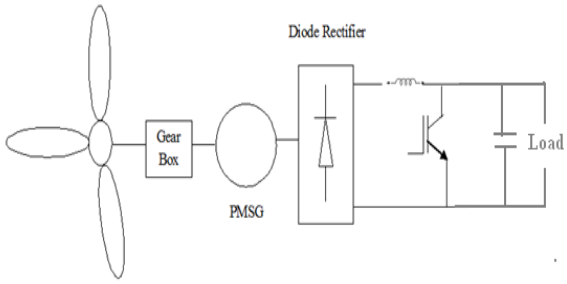

Fig.6 Schematic of wind generator

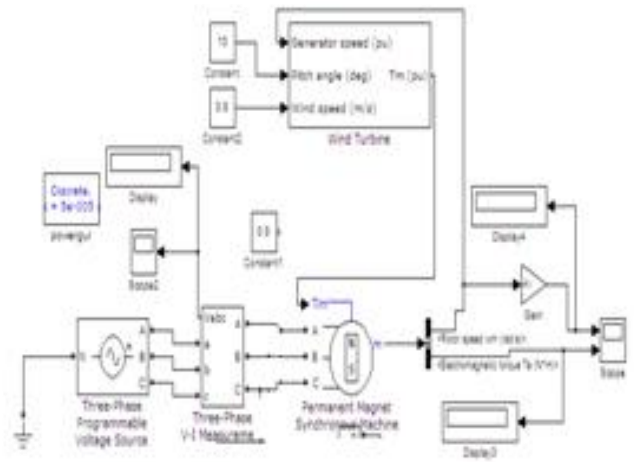

Fig- 7 Modeling of Wind Generator

Input for the wind generator is given through the wind turbine. The permanent magnet synchronous motor is operated as a generator that is when the torque is negative, motor is operated as a generator. This is controlled through turbine; the turbine is controlled by three inputs: Generator Speed, Pitch Angle and Wind Speed. In this work pitch angle and wind speed is considered as a constant value. The wind power is measured as follows:

$$T_m=C_t(\lambda)[0.5\frac{\rho\pi R\,t3}{\eta g}]V_w^2 \quad (3)$$

$$P_m=1/2\ C_p\rho A_r V_w^2 \quad (4)$$

Where, P_m is Power in watts, ρ is air density in $g/m^{3,}$ C_p is Dimensionless factor/ Power co-efficient, A_r is Turbine rotor area in m^2, λ_{gear} is efficiency , V_w is wind speed in m/s.

$C_p=0.73(\frac{151}{\lambda i}-0.58\beta-0.002\beta 13.2)e^{-18.4/\lambda i}$ $\lambda_i=\frac{1}{\frac{1}{\lambda-0.02\beta}-\frac{0.003}{\beta 3+1}}$; $\lambda=\frac{\varpi rRr}{Vw}$; $C_t=C_p/\lambda$;

r = Angular speed of the turbine shaft

Power from the wind turbine, real and reactive power, is basically controlled by the wind-side converter and stalled by the wind blade. Below rated wind speeds, the real power from the wind generator is regulated to capture the maximum wind energy from varying wind speed. Reactive power generation is maintained at zero to minimize the thermal rating of the generator and the converter.

Above rated wind speeds the maximum power control is overridden by stall regulation for constant power. Typical small scale stand alone system is composed of permanent magnet synchronous generator and diode bridge rectifier. The output from the rectifier is given to boost converter to boost up the voltage and to reduce the ripples. Also the dc-dc converter will avoid the mismatching between generator and constant dc voltage which will limit the transfer of power to the dc system.

The Fig-8 below shows the power electronics interface composed of wind generator and its dc-dc converter, PV with its dc-dc converter. The boost converter modeling is shown in fig.8, the constant input source is used in the boost converter topology. Because from PV or wind we get the physical signal, to make is as the simulation signal controlled source is used. This will provide the constant voltage to the circuit. The input side filter will reduce the source harmonics and provides the smooth dc voltage to the link. The output side filters will eliminates the output harmonics and the capacitor at this end will provide the un-interrupted voltage to the load. The load may be of any type or it may be a battery.

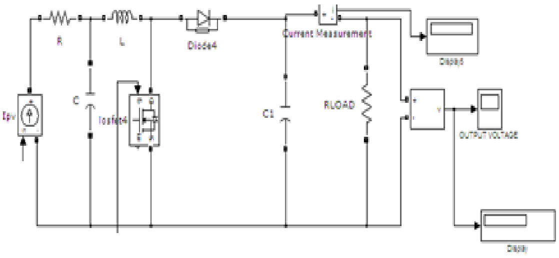

Fig- 8 Boost Converter Topology

The Fig.9 shows the interfacing of PV array with boost converter. The value of L and C are designed based on the input and output voltage.

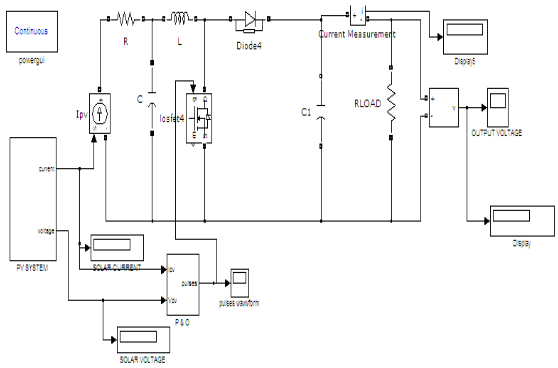

Fig- 9 PV array with Boost Converter

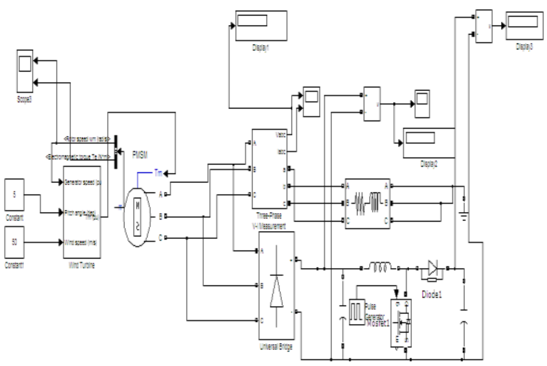

Fig- 10 Wind Generator with Boost Converter

V. RESULTS

From the proposed system we take three parameters as output: voltage, current and power. Following figures will show the output waveforms:

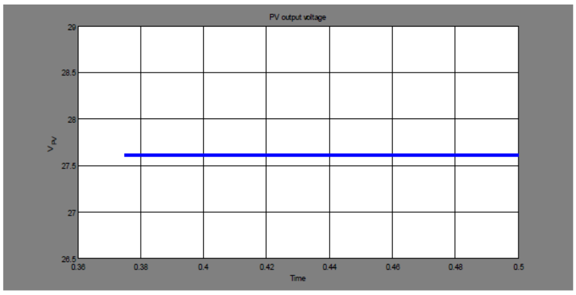

Fig-11 PV Output Voltage

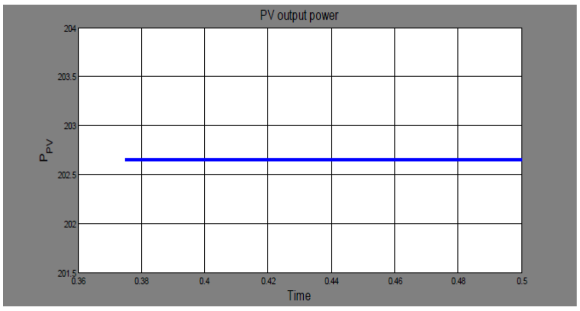

Fig-12 PV Output Power

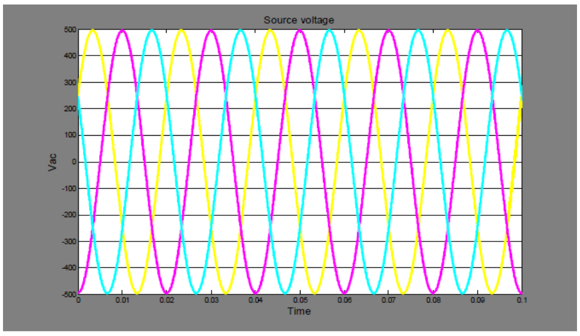

Fig- 13 Wind Input Voltage

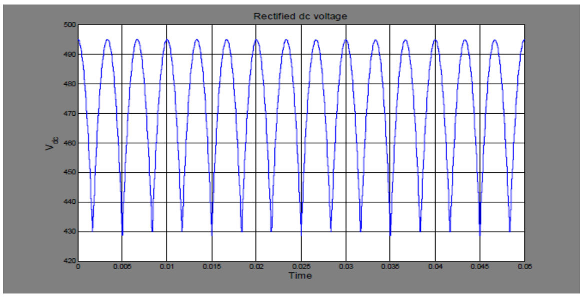

Fig- 14 Wind Output Voltage (DC)

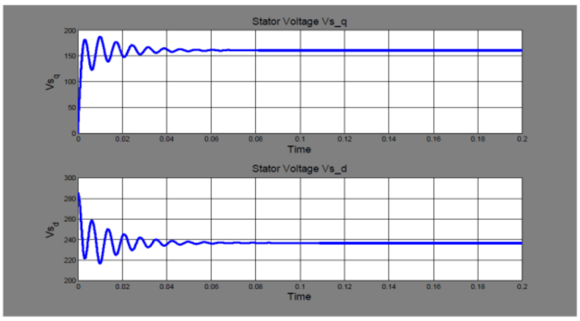

Fig- 15 Wind Generator Output Voltage (AC)

VI. CONCLUSION

This paper presents the simple control algorithm for tracking the maximum power in the hybrid system. In earlier works P&O algorithm is used for this purpose, the drawback of that algorithm was it needs tedious process and continuous monitoring. For the same results constant voltage method becomes simple and less working time. Also modeling of this method is simpler than the perturbation and absorption method.

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