Simulating Solar and Wind Based Hybrid Systems Synchronized and Segmented for Grid Connectivity

Md. Sifat Ferdous Chowdhury and Mohammad Abdul Mannan

***Abstract*— This paper introduces the performance of hybrid power system which has a combination of solar power and wind power. PV array is extracting maximum energy from sunlight irradiation by using Maximum Power Point Tracker; it collects the power from the system and sends power to the dummy utility grid. On the other hand, depending on the velocity of the wind available, wind turbine rotates and energizes an asynchronous generator for power supply to the grid. These two separate sources are connected together for hybrid operation and synchronized appropriately for segmented power supply to the grid. For visual retrieve 'SimPowerSystem' tool of MATLAB has been used for simulating the same.**

***Keywords*— Solar Energy, Wind Energy, Hybrid Power System and Matlab/Simpowersystem**

I. INTRODUCTION

The interest in renewable energy has been increased over last few years, especially after global awareness regarding the hazardous effect of fossil fuel burning [1]. Energy is the source of growth and the mover for economic and social development of a nation and its people. Renewable energy is derived from natural processes that are replenished constantly [2].

A photovoltaic material is a device which can capable of converting the energy contained in photons of light in to electrical current. The photovoltaic use semiconductor material for conversion of sunlight into electricity. PV cells do not use the suns heat to produce electricity rather they produce electricity directly when sunlight interacts with semiconductor materials in the PV cells [4]. For increasing both voltage and current level, solar cells need to be connected both in series and parallel combination [6]. Wind energy conversion system is used to capture the energy of wind to convert into electrical energy. Wind part consists of asynchronous generator and wind turbine. Asynchronous generator is basically user friendly and efficiency is good. Wind turbine requires to be kept in such a position so that it can get enough wind velocity and minimum density. In this thesis wind and solar energy makes a hybrid system. Hybrid system means more than one energy conversion system is included. The devices of this hybrid systems are-PV array, boost converter, Maximum Power Point Tracker (MPPT), harmonic reducing filter, IGBT switch, three level bridge inverter, Voltage source converter (VSC), Asynchronous generator, wind turbine, P.F. correction capacitor and transformer for step up the voltage level.

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II. HYBRID POWER SYSTEM MODEL

The simulated hybrid model has shown in figure 1.In this experiment total power output is 150KW. The PV module will supply 100 KW, where consumer loads is10 KW and the wind turbine supply 50KW, where consumer load is 5 KW. Solar and wind power generation parts are connected together for providing power to the consumer and utility grid. At the beginning produced power will go to the consumer then it will go the grid.

A. PV module system

Figure 1 shows the schematic diagram of hybrid system. Here, Solar system comprises PV array, Boost converter with MPPT system and Voltage Source Converter (VSC).The maximum solar radiation of PV array is 1000 W/m^2, and solar spectrum is 1.5 air-mass ratio. Power from PV array is calculated by following equation.

$$\text{Ppv} = IpvVpv = NpIph\ [(\frac{q}{KAT} * \frac{Vpv}{Ns})\ \text{-1}] \quad (1)$$

In this equation, P_{pv} is the generated PV power output .V_{pv} is the generated output voltage, I_{pv} is output current. I_{ph} is photo generated current, 5.96 A, q is charge of electron 1.602 × 10−19 C.K is Boltzmann constant, 1.381×10−23 J/K, A is ideality factor 2.46, T is temperature expressed in Kelvin N_p, N_s is number of parallel module and series module respectively. PV array delivering a maximum of 100 kW at 1000 W/m^2 sun irradiance. 5-kHz boost converter increasing voltage from PV natural voltage (272 V DC at maximum power) to 500 V DC. Switching duty cycle is optimized by the MPPT controller that uses the "Incremental Conductance + Integral Regulator" technique. 1980-Hz (33*60) 3-level 3-phase VSC has been used. Then the VSC converts 500 V DC to 260 V AC and keeps unity power factor. This converter uses

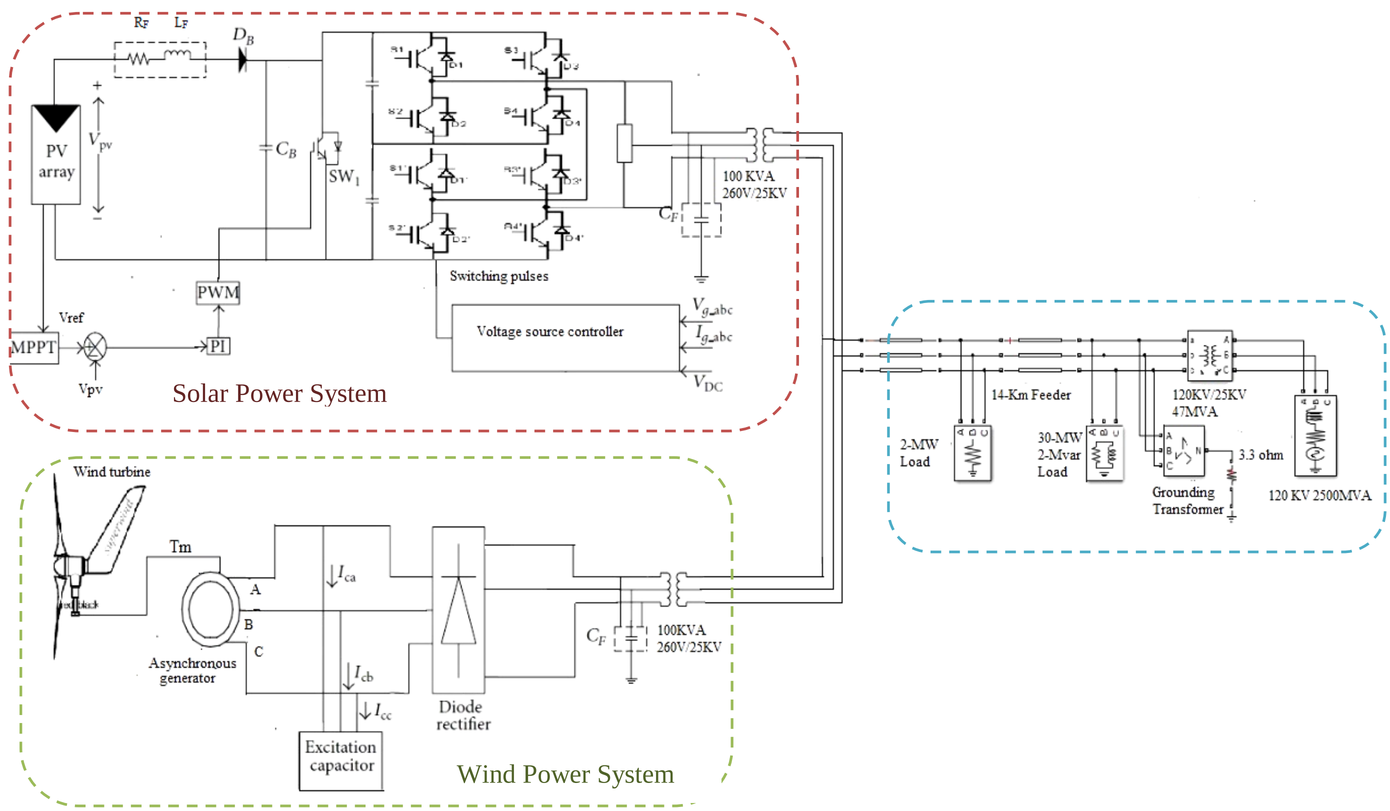


Figure 1: Schematic Diagram of Hybrid Power System

a MPPT system which automatically varies the duty cycle in order to generate the required voltage to extract maximum power. The Filter is reducing the harmonics. 100-kVA 260V/25kV three-phase coupling transformer has been used.PWM sends signal for controlling boost converter. Figure 2 and 3 explains that DC voltage is compared with reference DC voltage [7]. Then this signal goes to PI controller which minimizing the error signal and compared with the waveform for get a pulse. This pulse will give a signal to IGBT. After getting power from PV; inverter will make DC voltage to AC [9]. At the beginning the power will sends to consumer then transformer step –up the Voltage to the grid level voltage.

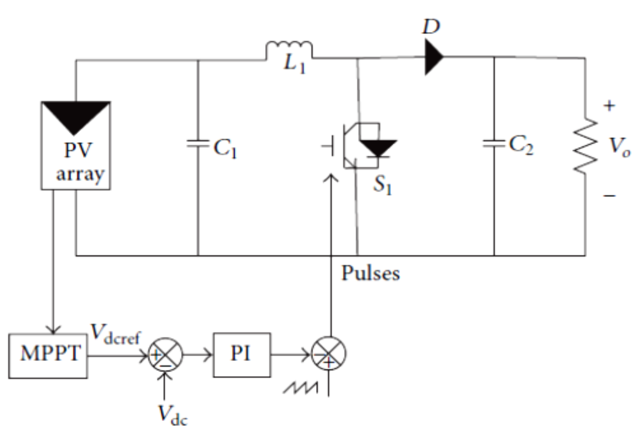


Figure 2: Controller for DC-DC converter

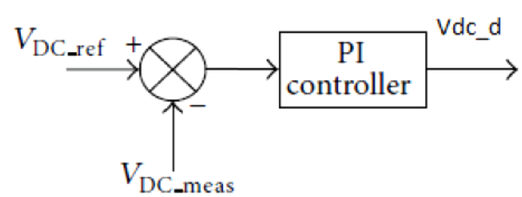


Figure 3: Voltage regulator

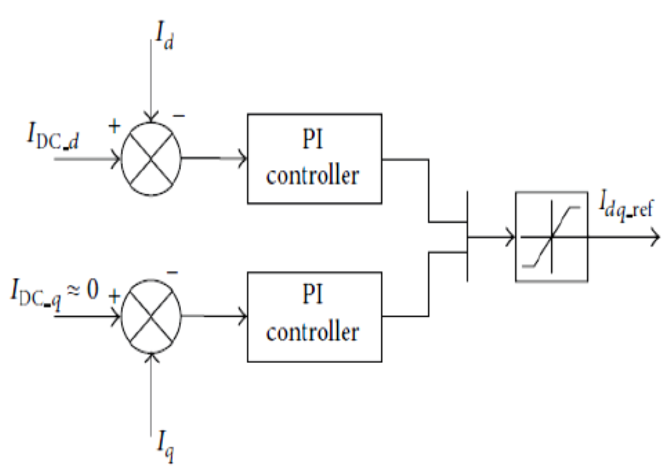


Figure 4: Block diagram of voltage source controller

B. Wind Power Conversion System

The power equation of wind turbine is given by following equation.

$$P=\frac{1}{2}\ \rho\pi R^2 v^3 C_p \qquad (2)$$

In this equation ρ is air density, R is radius, V is velocity, Cp is the rotor efficiency.

$$Cp=\frac{1}{2}(1+\lambda)(1-\lambda^2) \qquad (3)$$

Where, λ is the ratio of downstream to upstream wind speed. Here, $\lambda=(\frac{Vd}{V})$, V_d is the down wind velocity and V is the upwind velocity. For extracting maximum wind energy need to be kept fixed. Different ratings of asynchronous machine are-nominal voltage (L-L) 260V,frequency 50 Hz, Stator resistance (Rs) 0.016 ohm, inductance (Ls) 0.06 H. Rotor resistance (Rr) 0.015 ohm, Inductance (Lr) 0.06 H. Mutual inductance (Lm) 3.5 H .Stator and rotor windings are connected in wye to neutral point. Wind speed is working at 10 m/s at maximum velocity [13]. Larger the tip speed ratio faster the rotation of wind turbine rotor at a given wind speed. High speed turbines are preferred for efficient electricity generation [15].75Kvar P.F correction capacitor has been used for reducing reactive power of wind generation.100KVA, 260V/25KV transformer also has been used for transferring the power to the grid.

C. Voltage Source Converter

The three-level VSC regulates DC bus voltage at 500 V and keeps unity power factor. The control system uses two control loops: an external control loop which regulates DC link voltage to +/- 250 V and an internal control loop which regulates Id and Iq grid currents (active and reactive current components). Id current reference is the output of the DC voltage external controller. Iq current reference is set to zero in order to maintain unity power factor. Vd and Vq voltage outputs of the current controller are converted to three modulating signals Uref_abc used by the PWM three-level pulse generator. The control system uses a sample time of 100 μs for voltage and current controllers as well as for the PLL synchronization unit. In the detailed model, pulse generators of Boost and VSC converters use a fast sample time of 1μs in order to get an appropriate resolution of PWM waveforms.

D. System Modeling

Figure 5 shows the simulation of solar and wind hybrid system output performance. In this configaration, 150 KV utility grid is connected with the solar and wind system. In case of solar system series connected module per string is 5 and parallel string is 66, number of cells per module 96. Under standard test condition (STC), Cell temperature is 25 °C, open circuit voltage 64.2V, Maximum voltage 54.7 V. Boost converter increases the voltage from collected level to desired level. A filter is used for smoothing the dc voltage, which also provides a sinusoid wave shape. Inductance and resistance of that filter are L=250 H, R=0.002 Ω respectively. 100KVA transformer steps up the voltage level and connect with the grid. Figure 5 shows the hybrid simulation model.

III. RESULTS AND DISCUSSIONS

Results of solar System

The solar panel produces 1000 KW power output by using solar irradiation of 1000W/m^2. Figure 6(b) shows the variation of solar panel voltage (Vpv) due to the variation of irradiation level. In the beyond figure output of boost converter has shown. Where P_{mean} (KW) and time has plotted for showing 100 KW continuous power then it decreases. After that voltage and time axis shows that after getting power from PV; power is increased due to boost converter. Duty cycle and time axis shows that power will maximum when duty cycle become 0.5 and within the same time Irradiation and time axis shows that when irradiation will maximum duty cycle will be half, for the time being irradiation falls and finally again it goes up.

Results of Wind System

Asynchronous generator is generating the 260 V AC voltage. The generator is taking 1.0sec for generating the AC power. Figure 6(a) shows the output power curve. In this figure power and time axis shown delivering power of wind. At beginning more wind more output power but after that a stable 50 KW power is provided. 75 KVR P.F. correction capacitor is used for stabilizing reactive power and continuous supply of real power to the load.

IV. LIMITATIONS

Solar panels and required instruments are expensive. All climates are not suitable for solar panels to take out energy. On the other hand, installation cost of wind turbine is also high. Due to variation of wind velocity sometimes wind generation provides low output. During simulation and establishing of this hybrid system some problems were found.

It was tried to minimize the error and make a healthier hybrid system.

V. FUTURE PLAN

In future intelligent devices like microprocessors, PLC (programmable logic controller) may be added to the system to keep the operating point (maximum power point) for maximum efficiency. If the hybrid system can control by using the same controlling method it will provide better performance and cost will be less.

VI. CONCLUSION

The objectives of this thesis paper are to develop and simulate a hybrid system that combines the wind model and the Photovoltaic model. The target was also to build up a hybrid model for greener energy. This system will not emit CO_2 which has a bigger contribution of global warming. The

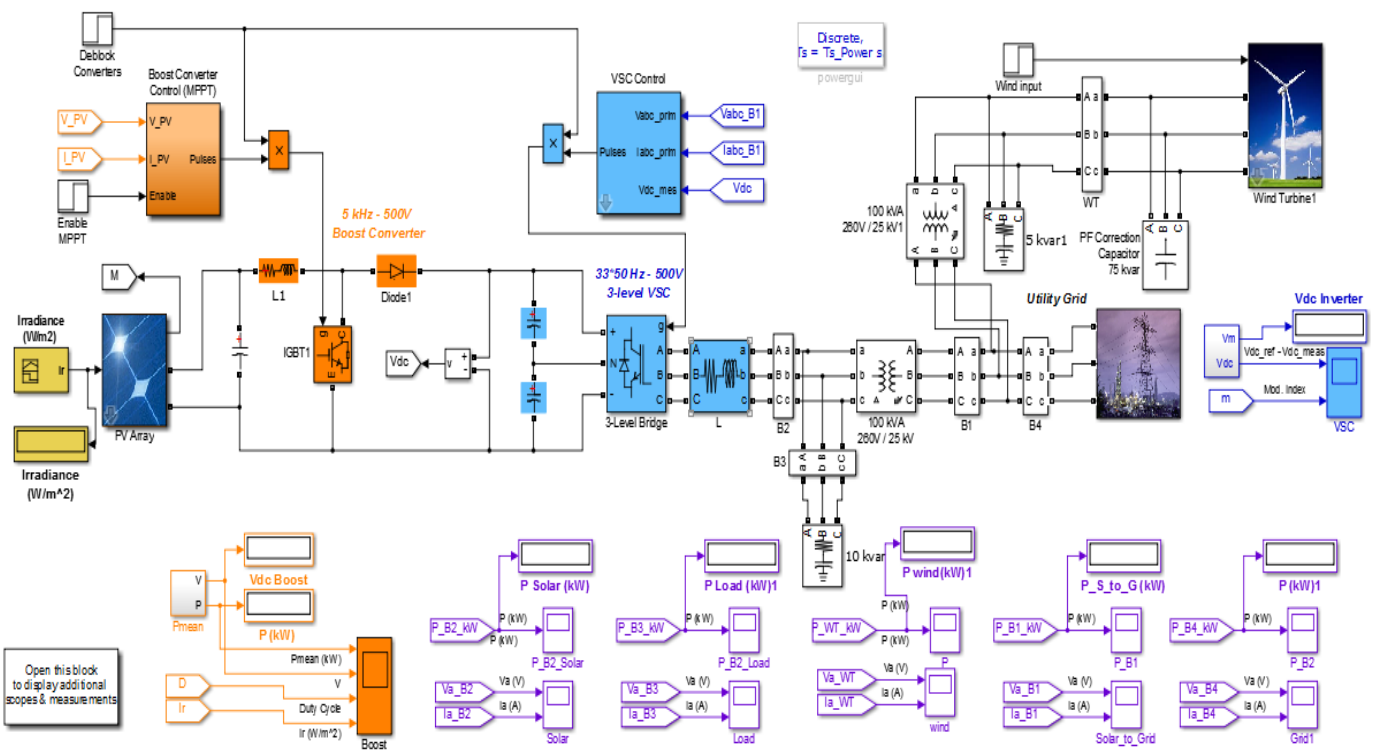
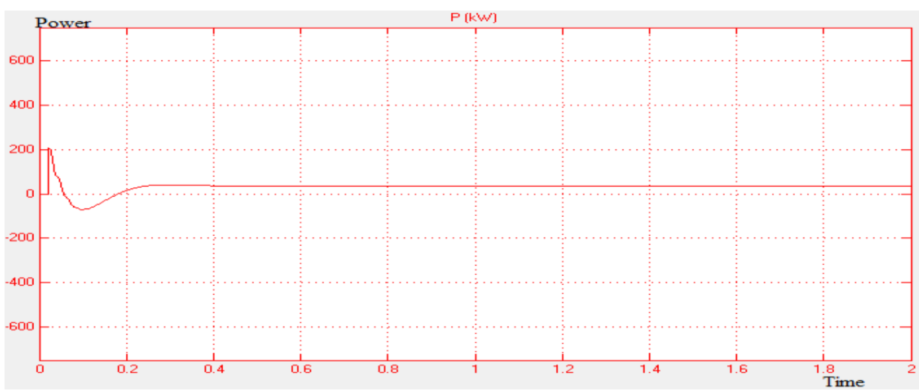
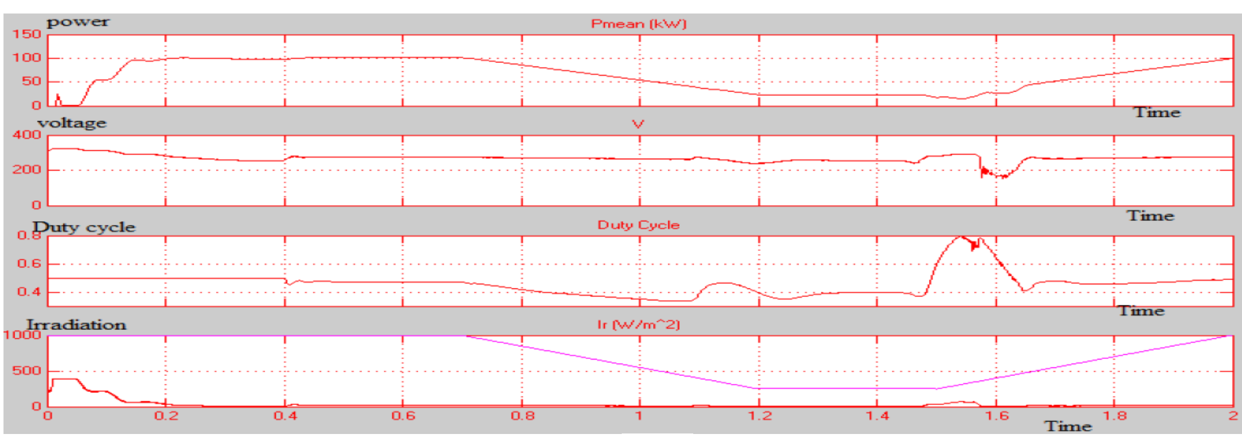


Figure 5: Simulation of Solar and Wind Hybrid System Output Performance



(a)



(b)

Figure 6: Power Output Curve (a) Wind Power System (b) Solar Power System

overall hybrid system has been tested with varying irradiation level for the PV model and wind speed for the wind model to determine the function inside a hybrid system. Simulation results show that hybrid system has greater reliability for electric power generation. Both of the system will work together for fulfilling the load demand and supplying the power to the grid.

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