Grid Connected Hybrid Pv And Wind Power Generation System For Improving Power Quality Using Seven Level Cascaded H-Bridge Inverter

[1] Ms. Shalaka D. Kamble, [2] Mrs. A. A. Dhamangaokar

[1]Post Graduate Student, [2]Assistant Professor

[1] Electrical Engineering Department,

Walchand College of Engineering Sangli, India

Abstract: This paper presents a stand-alone Hybrid PV and Wind power energy system for applications to improve power quality in isolated area. The wind and PV energy are suitable for hybrid system because they are environmental friendly and widely available in India. The wind and PV system are connected to the common point of battery through DC/DC Boost converter or are connected electrically through power converters to extract maximum energy using MPPT technique. An inverter has been designed using Cascaded H-Bridge MLI to control the grid parameter as well as PV and Wind hybrid system parameter simultaneously for improving power quality of the system. The modeling and simulation of hybrid system are done using MATLAB/SIMULINK. The performance of the hybrid system is evaluated under different wind speeds and different irradiation levels Simulation results show that the proposed hybrid system has the potential to meet the electricity demand of an isolated area.

Index Terms -Photovoltaic system, Wind energy, battery, DC-DC converter, MPPT Algorithm, Seven Level Cascaded H-Bridge Inverter, hybrid power system, MATLAB/SIMULINK.

I. INTRODUCTION

Since growth in technology, the electricity demand is also increasing. Modern industrialization and urbanization have changed the lifestyle of human society and the requirement for electrical power has enhanced significantly. And increasing in the pollution due to usage of fossil fuels, and initial cost is high researchers have provoked to connect the hybrid generation system to the grid, and will decrease this problem. PV and Wind system has proved to be more reliable sources compare to the other system. To maintain the continuity of power supply in the isolated areas, and reliability of the supply a hybrid generation system is very essential than any other independent systems for power generation. In such isolated areas and remote places, the hybrid PV and Wind system is more demanding and extremely useful. A hybrid power source provides excellent scalability and greater versatility with regard to power management. PV and wind sources are enormously used for clean generation of electricity. The PV and Wind system widely dependent on the environmental conditions such as the variations of speed wind and solar irradiance. A PV system converts sunlight directly into electricity.

A wind turbine convert's kinetic energy into electricity from the available wind speed. The common drawback of both PV and Wind systems are as these generate unreliable power. In order to overcome this problem for both PV and Wind systems, a new technique is implemented i.e. maximum power point tracking algorithm which is functional for both systems. By using incremental conductance Maximum Power Point Tracking technique, maximum power can be extracted for PV system. Grid connected operation of Generation reduces the transmission losses, increases the reliability and efficiency. There are many issues while interconnecting to the grid like stability issue, protection issue, power quality issue and reliability issue. The power quality issue is overcome by using Seven Level Cascaded H-Bridge Inverter. Inverter is used to increase service redundancy, modularity in a grid, especially with non-linear and unbalanced loads. The aim of this controller is to improve the dynamic response and power quality of the grid in the presence of non-linear and unbalanced loads by a voltage control strategy and reduces the total harmonic distortion.

A cascaded multilevel inverter having two separately DC sources, energized by PV and wind hybrid energy system for seven levels are used. The DC sources may be any one from PV and Wind energy sources, batteries, capacitors etc. The turning on and off of the power switches help to obtain at the output stage at a high-level voltage for the multilevel inverter, where the ratings of the switch voltage depend on DC sources. Seven Level Cascaded H-Bridge Inverter controller is used to convert a power in which the voltage output is obtained in steps form, thus gets the output very much similar to a sinusoidal waveform. Multilevel Inverters are playing major role from past few years for high – power applications and DC-AC conversions. Power converters i.e. multilevel inverter to convert the DC into AC. It started with three-level converters: different topologies were built recently for multilevel inverters.

Compared with other traditional topologies, Cascaded H-Bridge Multilevel Inverter has used less number of power switches. A bridge inverter of single phase cascaded multilevel inverter will be designed in series connection. DC sources of the multilevel

inverter generate different output voltages. High switching frequency of the inverters injects the harmonics into the system. To obtain high power, a combination of switches in series and DC sources are used which produces a staircase voltage waveform. Multilevel inverter has more advantages as compare to conventional converter with high Pulse Width Modulation (PWM) switching frequency. Higher the voltage levels of inverter with high resolution, leads to sinusoidal waveform.
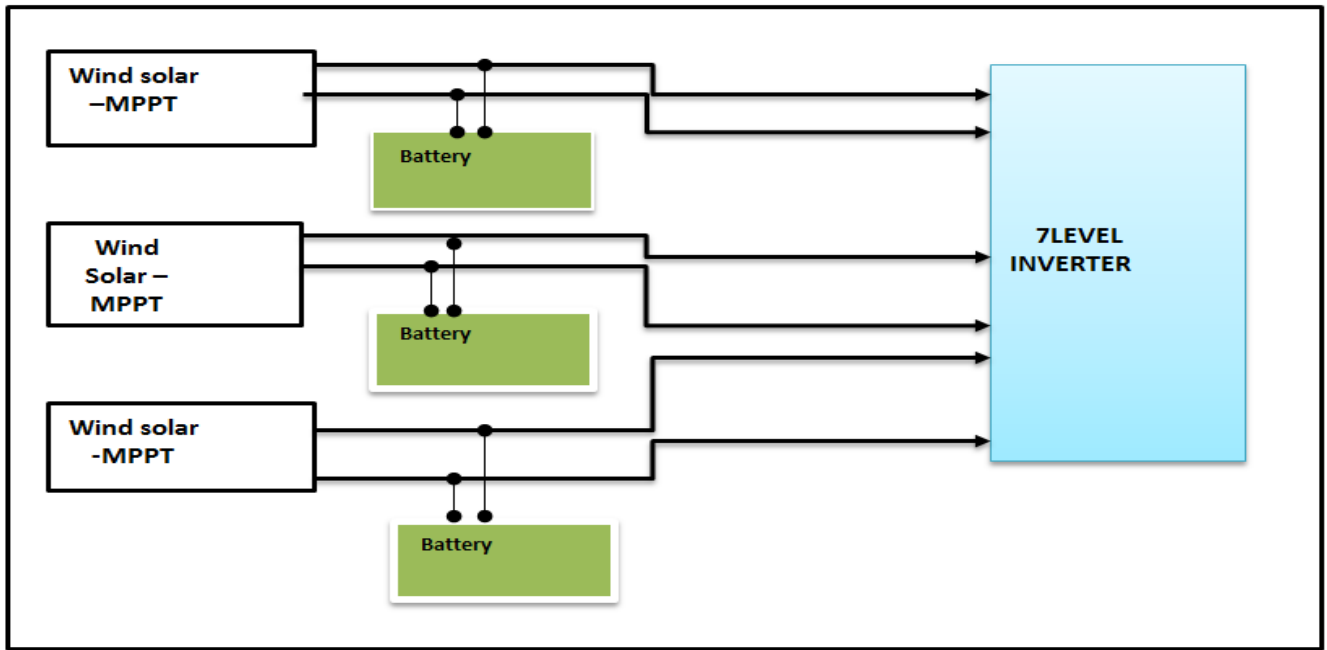
II. PROPOSED METHODOLOGY

Fig 1: Schematic diagram of Proposed Hybrid Energy System

Wind energy conversion system consists of wind turbine, Permanent Magnet Synchronous Generator direct driven Wind energy conversion system which converts mechanical energy of the wind turbine into electrical energy. Three phase rectifier is used to convert extracted AC mechanical power into DC power. The PV system consists of PV arrays and corresponding DC/AC converter modules. Generally, according to the sunlight conditions, the maximum power point tracking control mode is adopted for PV system, which aims to maximum utilization of solar energy. Battery is connected at the common output point of both the sources for the continuous power supply to the load. Seven Level Cascaded H-Bridge inverter is used to connect the load to the hybrid system to convert DC power into AC power. Seven Level Cascaded H-Bridge inverter consists of Three H-Bridges on which every single H-Bridge connected with one Hybrid system to get the output voltage on the grid side.

III. MODELING OF VARIOUS RENEWABLE ENERGY SYSTEMS

This section presents the mathematical models of energy Sources namely, Wind, Solar PV, and power electronic converters used in the proposed hybrid energy system.

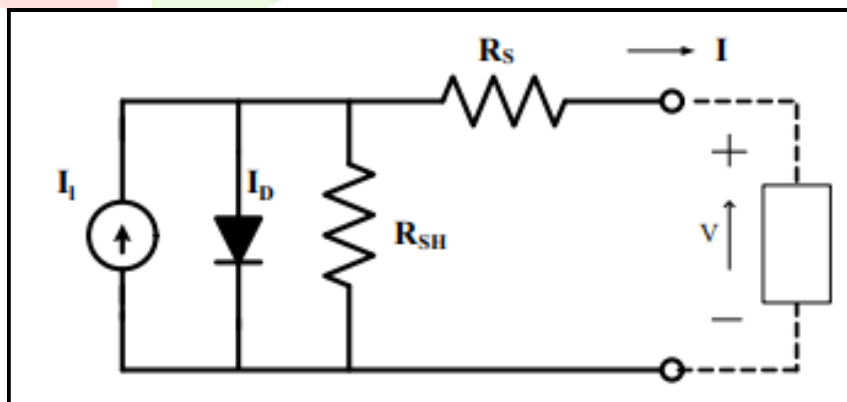### A. Modeling of Photovoltaic System

Fig 2: Model of Solar PV cell

$$I = I_{ph} - I_D - I_{sh} \qquad (1)$$

$$I = Iph - Io\,[exp\,(\,q\,Vd\,/\,Nkt)] - (\,Vd\,/\,Rsh) \qquad (2)$$

In Photovoltaic (PV) system, solar cell is the basic component. PV array is nothing but solar cells are connected in series or parallel for gaining required current, voltage and high power. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material. It produces the currents when light absorbed at the junction, by the photovoltaic effect. It can be seen that a maximum power point exists on each output power characteristic curve.[4] The output of the current Source is directly proportional to light falling on the cell. Naturally PV system exhibits a non-linear Current – Voltage (I-V) and Power - Voltage

(P-V) characteristics which vary with the radiant intensity and cell temperature. The dependence of power generated by a PV array with changing atmospheric conditions can readily be seen in the I-V and the P-V characteristics of PV arrays.[2]

B. Modeling of Wind System

The wind turbine converts wind energy into mechanical energy, this mechanical energy is converted into electrical energy using permanent magnet synchronous generator for extracting maximum wind power wind speed, pitch angle and generator torque are the control parameter.[4] The wind turbine rotor consists of two or three blades Mechanically coupled to an electric generator. The power Captured by the wind turbine is given by the relation

The mechanical power Pm generated by the turbine is given by

$$P_m = 1/2 \cdot \rho \cdot A \cdot v^3 \cdot C_p (\lambda, \beta) \qquad (3)$$

Where, ρ is the air density, C_P is the power coefficient, v^3 is the wind speed in (m/s) and A is the area swept by the rotor in m^2

$$C_p(\lambda, \beta) = C1(C2/\lambda_i - C3*\beta - C4* \beta^x) e^{(-C6/\lambda i)} \qquad (4)$$

$$1/\lambda i = 1/\lambda + 0.08\beta - 0.03/\beta^3 + 1 \qquad (5)$$

The tip speed ratio TSR of the wind turbine is defined as following

$$\lambda = R \cdot W_r / Vw \qquad (6)$$

Where, R is the radius of wind turbine rotor in meters (m), W_r is the rotor speed of a wind turbine.

C. Battery

The battery system stored the energy during normal power system operation and utilizes this stored power during abnormal atmospheric condition at which wind or solar PV system not available and it is also used for continuous operation.
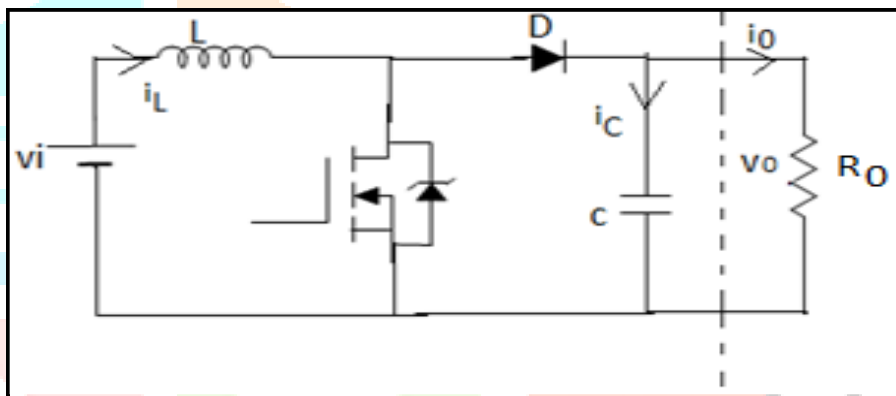
D. DC-DC Boost Converter

Fig 3: DC-DC Boost converter circuit

A DC/DC boost converter is one of the most widely used converters in energy conversion chain. It boosts or increases the input voltage. The boost converter consists of a diode, a capacitor, a switch and a resistive load. It has an adaptation interface between the solar and the electrical load in order to operate the system in its maximum power point by controlling its IGBT transistor using a PWM signal and the duty cycle of the MPPT controller.

$$V_o = 1 - (V_{i\ min}* n)/ D \qquad (7)$$

Where, $V_{i\ min}$ is the input voltage, V_o is the output voltage and D is duty cycle, n is the efficiency of the converter. Given the value of D, it is possible to find the minimum values of inductance and capacitance using the equations given below

$$L = (V_{i\ min}) * (V_o - V_{i\ min}) / dI * f_s* V_o \qquad (8)$$

$$C = (I_o * D) / f_s * dV \qquad (9)$$

Where, dV is the ripple voltage, f_s is the switching frequency, I_o is the output current.

E. MPPT Algorithm

1. **Incremental conductance MPPT Technique**

The incremental conductance algorithm detects the slope of the P–V curve, and the MPP is tracked by searching the peak of the P–V curve. This algorithm uses the instantaneous conductance I/V and the incremental conductance dI/dV for MPPT. The slope of the power-voltage curve of a PV array is equal to zero at the maximum power point. The slope is positive in the area to the left of the maximum power point and negative in the area to the right.
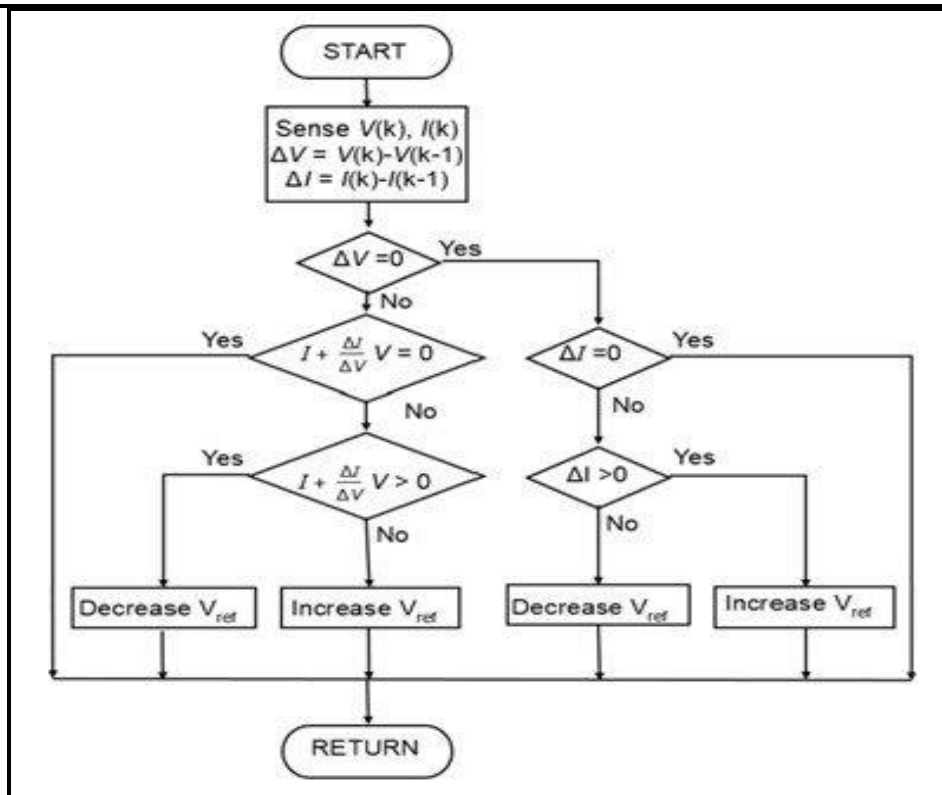
Fig 4: Flow chart for IC MPPT algorithm

F. Seven Level Cascaded H- Bridge Inverter

Among three types of multilevel inverter such as cascaded H-Bridge, Flying capacitor and diode clamped, the Cascaded H Bridge (CHB) is very popular in high power AC supplies. This consists of a series H bridge of which each H Bridge has its own dc source. This DC source can be replaced by means of renewable sources such as photovoltaic system, Wind system or as a fuel cell. The ac terminal voltages of different level inverters are connected in series through different combinations of the four switches as S1,S2,S3 and S4 for a single H bridge system and it generate three different voltage outputs such as +Vdc, 0 and –Vdc. The number of levels is calculated using 2N+1 where N is the number of DC source used in CHB. In this paper N is taken as three, hence seven levels is used to analyses the proposed SPWM. The seven levels cascaded H Bridge is shown in Fig 5.
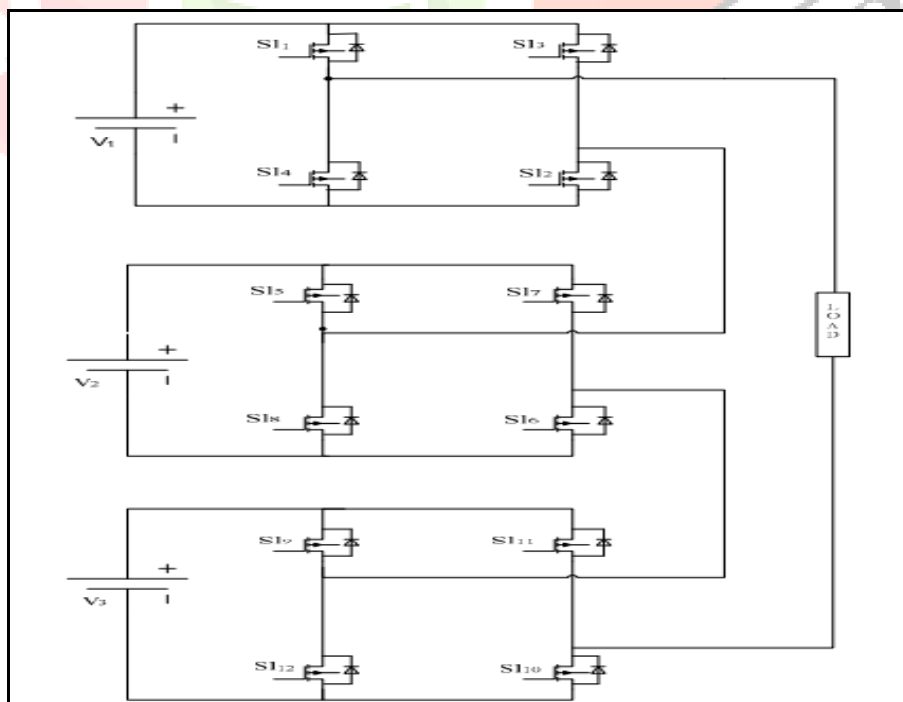

Fig 5: Cascade H-Bridge single phase Seven level Inverter

TABLE I. SWITCHING PATTERN FOR SINGLE PHASE SEVEN LEVEL CASCADED-H-BRIDGE MULTILEVEL INVERTER

V_DC	Switching pattern for seven level cascaded H bridge Multilevel inverter											
	S1 1	S1 2	S1 3	S1 4	S1 5	S1 6	S1 7	S1 8	S1 9	S1 10	S1 11	S1 12
+3	1	1	0	0	1	1	0	0	1	1	0	0
+2	1	1	0	0	1	1	0	0	0	1	0	1
+1	1	1	0	0	0	1	0	1	0	1	0	1
0	0	1	0	1	0	1	0	1	0	1	0	1
	1	0	1	0	1	0	1	0	1	0	1	0
-1	0	0	1	1	1	0	1	0	1	0	1	0
-2	0	0	1	1	0	0	1	1	1	0	1	0
-3	0	0	1	1	0	0	1	1	0	0	1	1

IV. SIMULATION RESULTS

In this section, proposed methodology implemented using MATLAB Simulink software in which Sim power system toolbox utilized for hybrid power system design, wind energy system design, solar PV system, battery energy system and dc to dc converter subsystem design. Figure 14 shows the complete MATLAB simulation model of proposed approach.

A hybrid system consisting of 6KW and 93.7 KW wind and solar PV system is simulated. The subsystem of the Wind and Solar PV system are given in Fig 6 and 9 respectively. The load is connected to the hybrid system through an inverter. First the system is simulated with wind and Solar alone and the performance of the individual generators are evaluated. Next the performance of the hybrid system is evaluated under different load conditions.

Case I: Solar PV alone

A solar PV subsystem in which solar PV cell output dc terminal connected with maximum power point tracking (MPPT) algorithm block for tracking maximum solar dc output voltage according to irradiation available at atmospheric condition. Fig 6 shows the interconnection of 96 solar cells for achieving the desire ratings. After series and parallel connection diode connected to solar cell power output for avoiding the back power or reverse bias condition. That diode is called as revere blocking diode which avoids the reverse current of reverse polarity of solar cell during rainy or cloudy season due to shading effect. The PV system output voltage is 750V and current will be 143.04A.
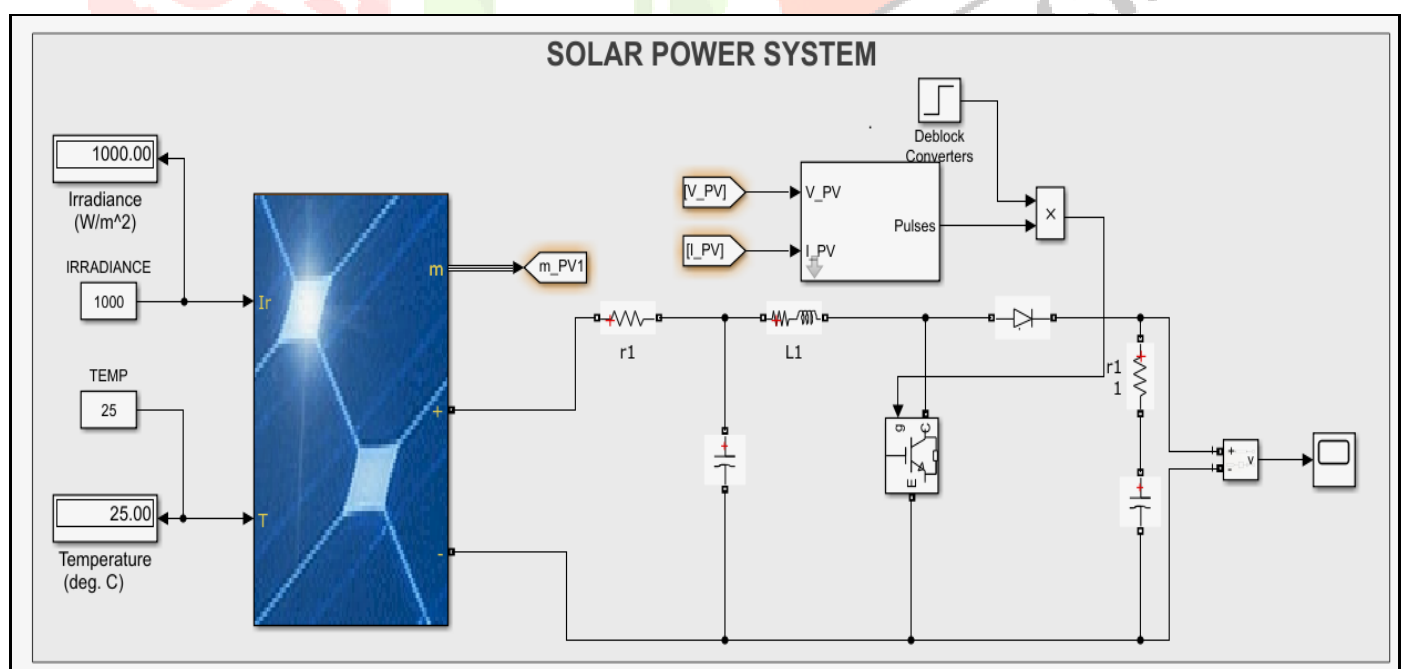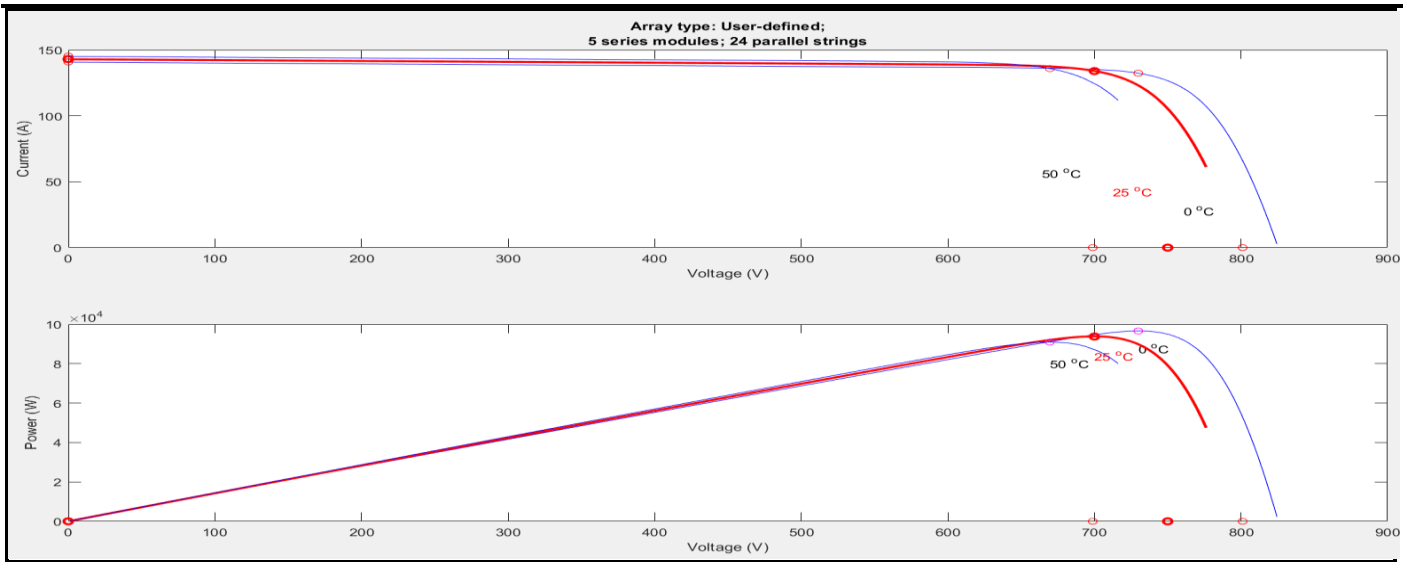

Fig 6: Photovoltaic subsystem

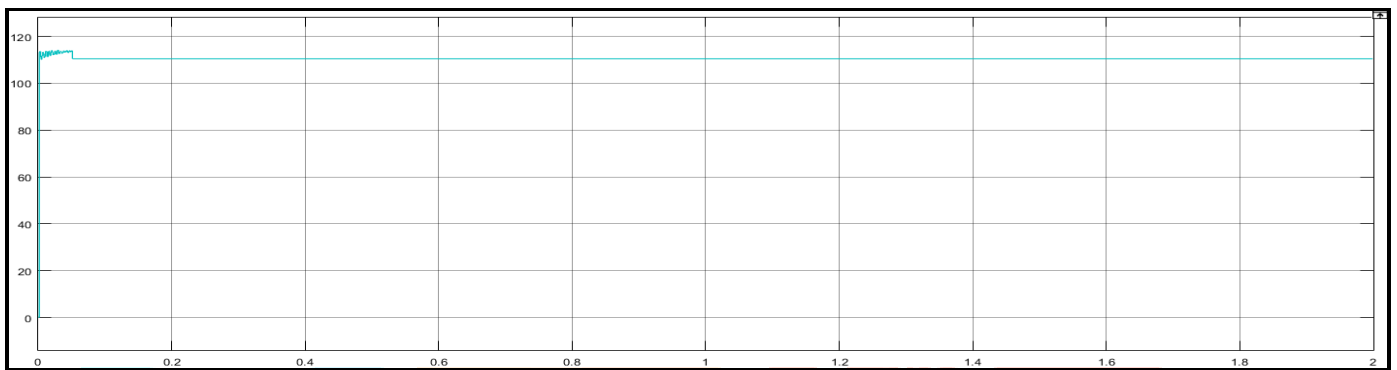Fig 7: V-I and P-V characteristics curve of the PV system

Fig. 8: DC output of boost converter under variable irradiance

Case II: Wind alone

A wind energy turbine system in which wind turbine generates the AC power then transfer to three phase rectifier circuit for conversion of AC power to DC power. Because solar power system output becomes in DC form but wind energy generator power in AC form then for coupling both the solar and wind energy system we need to convert wind energy AC power into DC power with equal magnitude. Fig 10 shows the controlling mechanism for wind energy system which controls the wind turbine, wind speed, mechanical torque, mechanical input, speed of turbine.
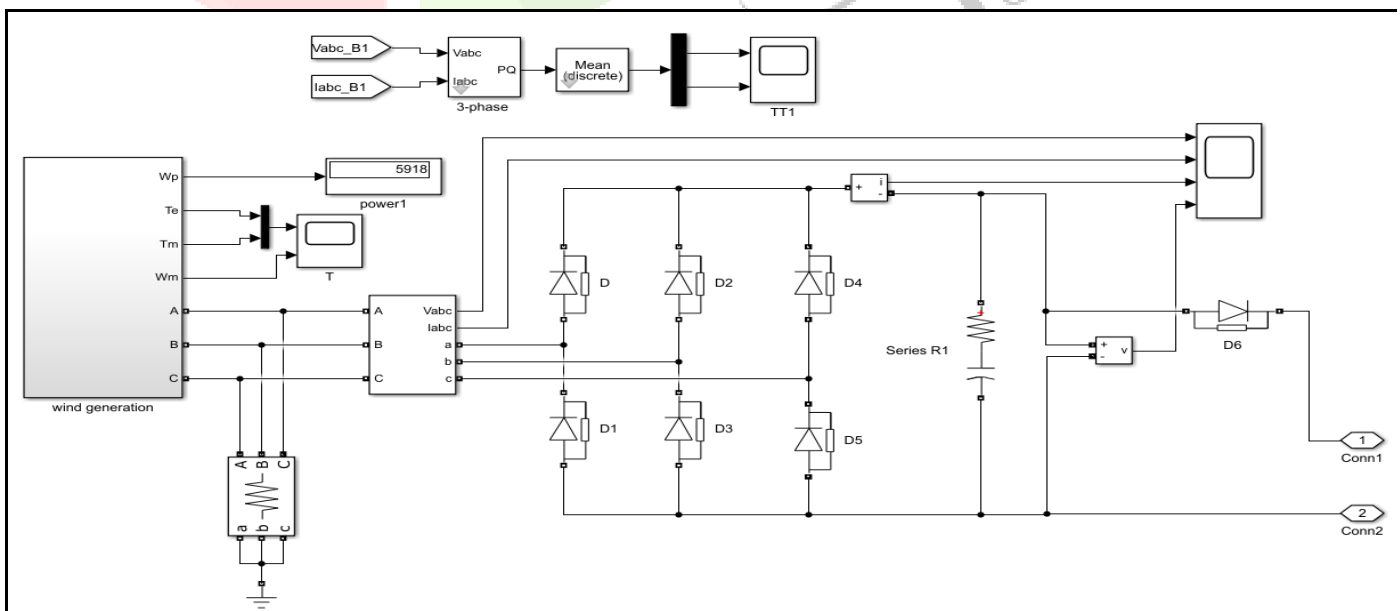

Fig 9: Wind energy MATLAB subsystem model

Fig 10: Wind energy controller subsystem, generator, and mechanical subsystem

Fig 11: Output current and Output voltage of WPG system

Case III: Hybrid System

The complete MATLAB simulation model of hybrid power system in which solar PV system and wind energy system generates DC power. This DC power gets fed to MPPT maximum power point tracking system for reaching the maximum available DC power in case of solar only. Battery is connected at the common output point of both the sources for the continuous power supply. This power then fed to inverter which converts this dc power to ac power which fed to AC grid by proper synchronization.
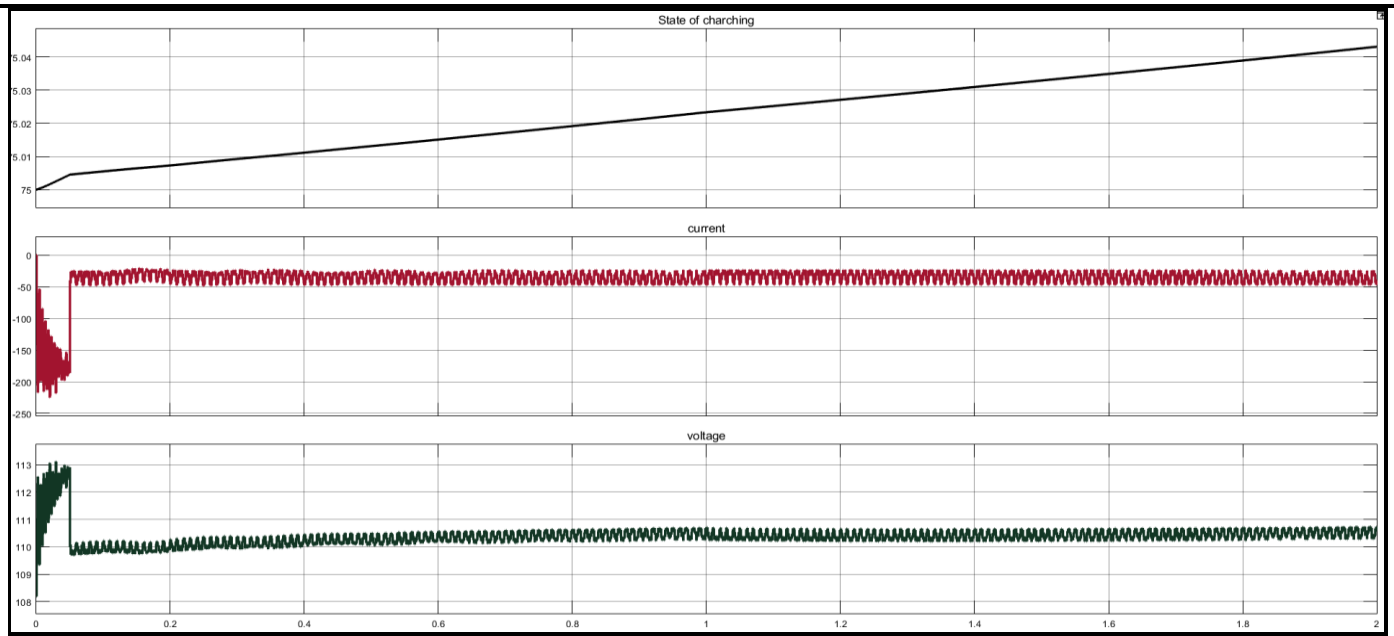

Fig 12: Hybrid sources MATLAB subsystem model

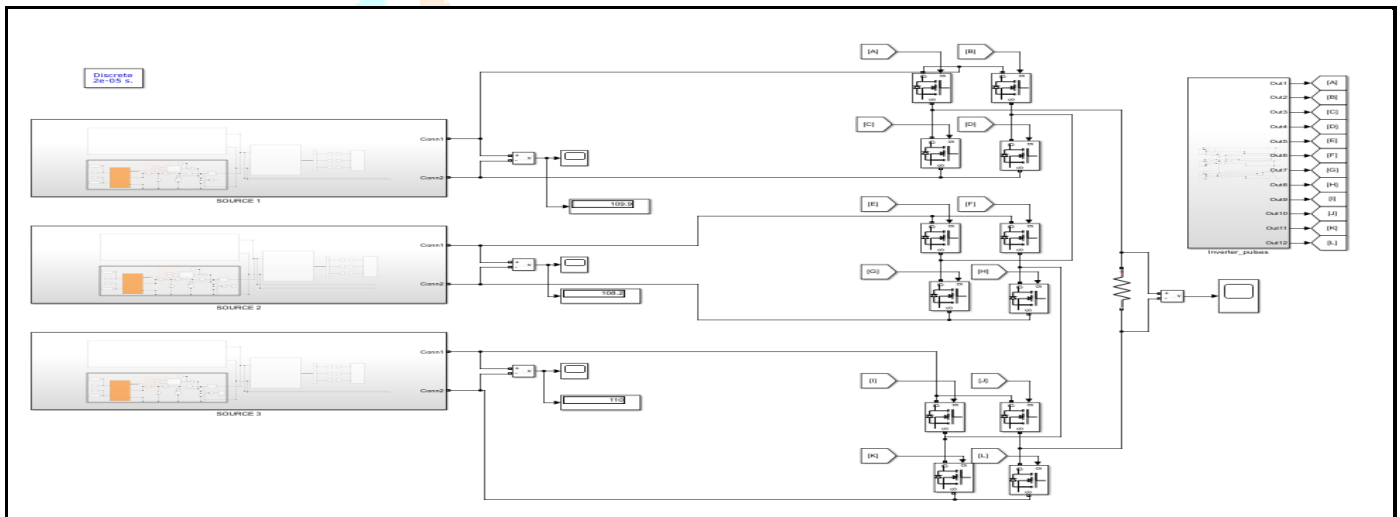Fig 13: Output current, Output voltage and SOC of the battery

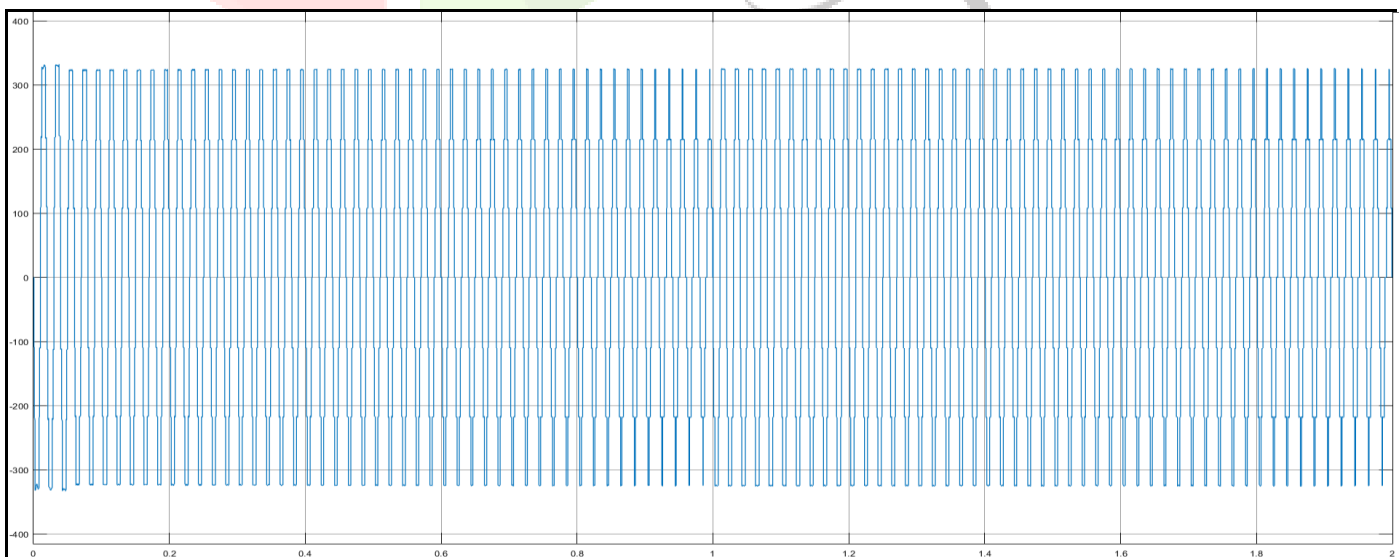Fig 14: Complete MATLAB simulation model of proposed hybrid power system

Fig 15: Output voltage of proposed hybrid power system

TABLE II. MATLAB SIMULATION MODEL PARAMETER FOR HYBRID POWER SYSTEM MODEL

Sr. No	MATLAB simulation block	Parameters Specification
1	Solar PV system	Output voltage= 1500V
2	Wind energy system	Output ac power = 5918 W
3	Battery energy system	Voltage = 100V; Ampere hour rating=50 Ah
4	Inverter	2n+1 (n=3)

V. CONCLUSION

This paper has described a hybrid energy system with variable speed and variable irradiation in wind and photovoltaic system along with power electronic interface under stand-alone mode. Due to variations in wind speed and solar irradiation AC voltage varies. In hybrid system, 12 m/s in wind system and 1000 W/m^2 in solar PV system performance has been analyzed. Cascaded H-Bridge MLI to control the grid parameter as well as PV and Wind hybrid system parameter simultaneously for improving power quality of the system. This system is expected to meet up electricity demand in a remote area. The performance of the developed system is evaluated in MATLAB/SIMULINK platform and the results are presented.

VI. REFERENCES

[1] Shubham Soni "Power quality improvement of integrated PV/wind grid connected system", International Journal of Advanced Research, Ideas and Innovative Technology, Volume. 6, Issue. 5, 2020.

[2] B.Kanagasakthivel "Simulation and Performance Analysis of Solar PV and Wind Hybrid Energy System Using MATLAB/SIMULINK" IEEE International Conference on Power, Control, Signals and Instrumentation Engineering.2017

[3] Ahmed K. Salam Abdel "High-Performance Adaptive Perturb and Observe Maximum Power Point Tracking Technique for PV-Based Micro grids", IEEE Transaction on Industrial Electronics, Volume. 26, No. 4, April.2011.

[4] V Gurusiddappa "Power Quality Improvement in a Micro Grid Integrated Hybrid Renewable Energy Source", International Journal of Scientific & Engineering Research Volume 10, Issue 5, May.2019.

[5] Sandhu Mamatha "Reduction of Harmonics In a Hybrid PV/Wind Micro grid Using a Modified Multilevel Inverter", IEEE Electrical Power and Energy Conferenc.2019.

[6] Kumar Ravi S "Hybrid Wind Solar System for Efficient Power Generation", International Conference on Electronics, Communication and Aerospace Technology ICECA.2017.

[7] S. Kumari, V. Kushwaha and T. N. Gupta, "A Maximum Power Point Tracking For a PMSG Based Variable Speed Wind Energy Conversion System," 2018 International Conference on Power Energy, Environment and Intelligent Control (PEEIC), 2018.

[8] R. A. Gupta, B. Singh and B. B. Jain, "Wind energy conversion system using PMSG," 2015 International Conference on Recent Developments in Control, Automation and Power Engineering (RDCAPE), 2015.

[9] CristianDragosDumitru, and Adrian Gligor, "Modelling and simulation of Renewable Hybrid Power system using MATLAB/SIMULINK Environment.", Scientific Bulletin of the, PetruMaior" vol. 7 ,no. 2, 2010.

[10] K.RVenkateswarlu, and J.Krishna Kishore, " Modelling and Simulation of Micro grid System Based on Renewable Power Generation Units by using Multilevel Converter., " International Journal of Engineering Research and Technology, vol. 10, Issue 6, August – 2012.

[11] N.Sambasiva Rao, "Design and Simulation of Hybrid Solar - Wind Electric Power System Interface to Grid System, "International Journal of Research in Engineering and Advanced Technology, vol.3, Issue 4, August 2013.