HYBRID RENEWABLE ENERGY SYSTEM FOR RURAL ELECTRIFICATION

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Abstract: The major issue of producing electrical energy in remote places are due to lack of energy sources. This paper proposes a standalone hybrid solar and wind energy system for rural electrification. Maximum solar power is extracted by using MPPT perturbation and Observation method and PMSG is utilized to convert the wind kinetic energy into electrical energy. Five level cascaded H bridge inverter is used for converting dc power to ac. Total Harmonic Distortion is reduced by using LC filter and it is verified by FET analysis. Simulation model of hybrid energy system is done by using MATLAB/Simulink software.

Index Terms – Hybrid system, solar and wind generation, Multi-Level Inverter [MLI], Cascaded H Bridge, Total Harmonic Distortion

I. INTRODUCTION

A conventional source has major drawbacks to present and future ecological system and sources will be depleted in a few years therefore it is necessary to adopt renewable energy system to meet the energy demands. Renewable source are clean, ecofriendly and can be installed in rural areas. In remote regions producing electrical energy is difficult with inefficient diesel power plant, which has high production costs and due to lack of power plant which is far away from remote area, energy demand can't be meet [1]. Urbanization and industrialization of regions further increase the need of energy, renewable energy sources that are available abundantly in nature can be considered a better alternative to traditional energy sources [2]. Solar and Wind source are available plenty in nature and can be regarded as a reliable source of electricity generation. Rural electrification can be accomplished with hybrid solar and wind energy system [3].

Solar power generation varies according to environmental conditions, Perturb and observe algorithm is the standard factor for optimization of PV panel and to obtain maximum power point tracking for enhanced efficiency of photo voltaic applications [4]. Energy produced can also be stored in the chemical form and utilized to provide constant power to load due to fluctuation in energy generation because of unpredictable and irregular nature of wind and sun [5]. Solar and wind standalone system are combined to get hybrid system, power generated by both system is converter to alternate current by mounting multilevel inverter at the DC bus. Five-level H bridge inverter improve the ac power quality by performing the conversion in small voltage step [6]. When compared to conventional inverter MLI has lower THD, voltage stress across the switch and superior power rating.

This paper presents a standalone solar-wind hybrid energy system integrated with multilevel inverter. PO algorithm based MPPT has been used to track maximum power for PV application is offered. Simulations are carried out in MATLAB Simulink. Section I and II gives outline of system and proposed methodology. Section three describes the essential parts of hybrid system. Simulation result and conclusions are provided in section IV and V.

II. PROPOSED METHODOLOGY

Combination of solar and wind energy system is presented in this renewable hybrid energy system. Fig.1 shows the block diagram of proposed model. Solar PV array module is connected to inverter via boost converter in order to step up the DC voltage. Maximum Power Point Tracking system is implemented to attain maximum solar energy. Wind turbine is connected to inverter through permanent magnet synchronous generator. PMSG will converts mechanical energy obtained by wind turbine to AC electrical energy. This AC is fed through a rectifier to get DC power. Battery gets charged by DC bus and voltage is transformed to AC by 5-level H bridge inverter. Gained output from inverter is AC, which is given as supply to load.

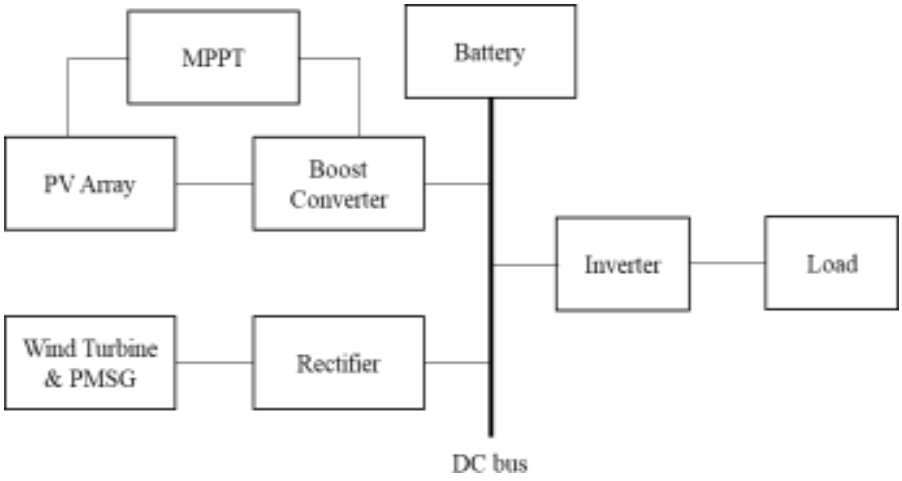

Fig 1: Block diagram of Hybrid renewable energy system

III. HYBRID RENEWABLE ENERGY SYSTEM

The standalone hybrid renewable energy system comprises of wind module and solar module which will supply power to rural areas by using essential power electronic circuits.

3.1 SOLAR ENERGY SYSTEM

Solar system consists of PV panels, boost converter with maximum power point tracking technique.

PV Panel

Photovoltaic cells are primary component of solar system which produce electricity from radiation of sun. PV cells are connected to form a PV module which will further interconnect to get the required PV arrays. Sufficient number of PV cells are connected in series to get adequate output voltage and arranged in parallel for high output current.

MPPT

Maximum power point tracking method is applied to yield excellent performance of photovoltaic module. Output power obtained by PV panel varies frequently depending on light and temperature of the atmosphere. To overcome by this MPPT technique is applied, this will help to track the available maximum power in the environment. Thus, in a PV panel where maximum power is attained is called Maximum Power Point MPP. Proposed system involves perturb and observe MPPT algorithm, which will continuously modify the operating voltage and current of a PV panel to get maximum power.

Boost Converter

DC-DC converter which step up the voltage level is known as boost converter.

If the average output voltage is Vo and the input voltage Vd , then the expression for Vo is Vo = $\frac{Vd}{1-D}$

Switching time of a semiconductor device is regulated by duty ratio D, which is obtain by the MPPT block. The controlled output voltage obtained from boost converter will be supplied as an input to Inverter via dc bus.

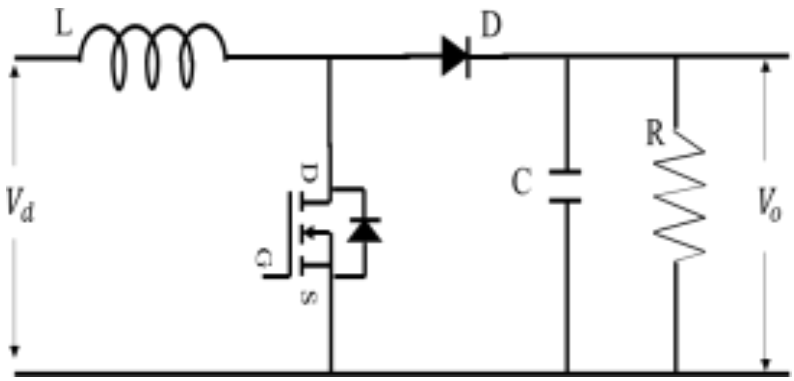

Fig 2: Boost Converter

3.2 WIND ENERGY SYSTEM

Wind power system comprises of wind turbine, generator and rectifier. Wind turbine converts linear motion of air into kinetic energy with the help of blades, which are fixed to the turbine. This rotational energy will drive the permanent magnet synchronous generator and produces three phase AC electric power. PMSG is most commonly used generator because of lost cost, less maintenance, high efficiency and doesn't require a dc supply for field excitation.

Three Phase Rectifier

To couple wind system with solar system we need to include three phase rectifier circuit to convert AC three phase voltage obtained from PMSG to DC since output of solar system is DC.

3.3 INVERTER

Multilevel inverter is a device which converts direct current to alternate current, employed mainly for high and medium power application. Multilevel inverter reduces the total harmonic distortion by increasing the steps in output waveform approaches to a near sinusoidal waveform.

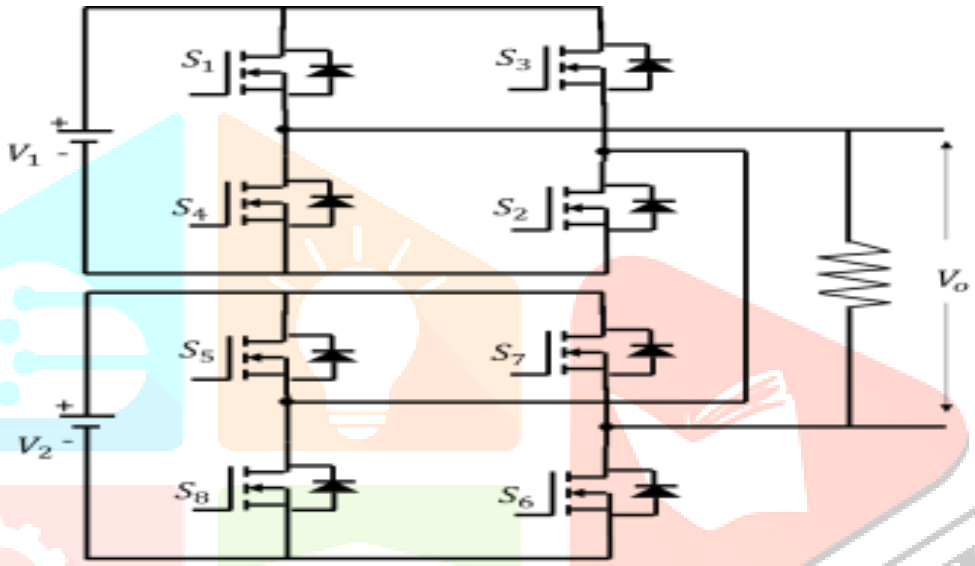

Fig 3: Cascaded H bridge converter

Figure 3 shows five level Cascaded H bridge multilevel inverter, obtained by connecting two full bridge inverters in series. Output voltage levels will be 2V, V, 0, -V, -2V. If m is the output voltage level then 2*(m-1) switches are required. This converter generates a smooth sinusoidal waveform from input voltage produced from hybrid systems. Inverter switching states are controlled by pulse width modulation technique to reduce harmonic distortion. Below table gives the switching sequence of a 5 level cascaded H bridge inverter.

Mode	+2V	+V	0	-V	+2V
S_1	1	1	1	0	0
S_2	1	1	0	0	0
S_3	0	0	1	1	1
S_4	0	0	0	1	1
S_5	1	0	1	0	0
S_6	1	1	0	1	0
S_7	0	0	1	0	1
S_8	0	1	0	1	1

IV. SIMULATION MODEL AND RESULTS

In this segment proposed methodology shown in fig 1 is implemented in MATLAB Simulink software. Fig 4 shows the simulation model of boost converter integrated with PV array.

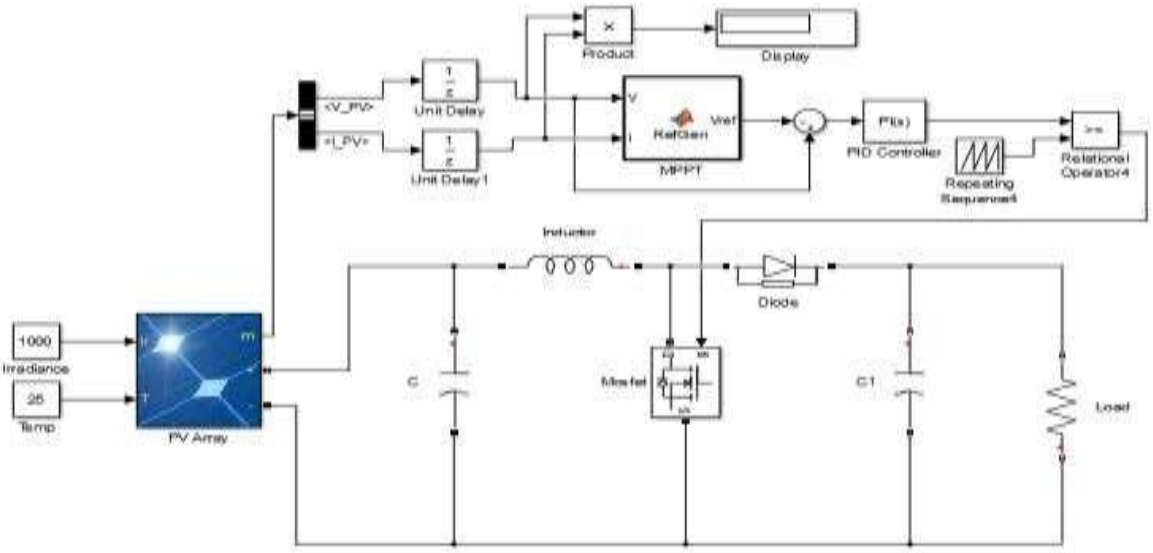

Fig 4: Simulation of solar energy system

The MPPT block output is feed to the mosfet switch. The output power of the PV Array is been increased by the boost converter. The Inductor used in the boost converter is set to 20mH, the capacitance C= 500µF and C1=3000µF, output power obtained is 2094W.

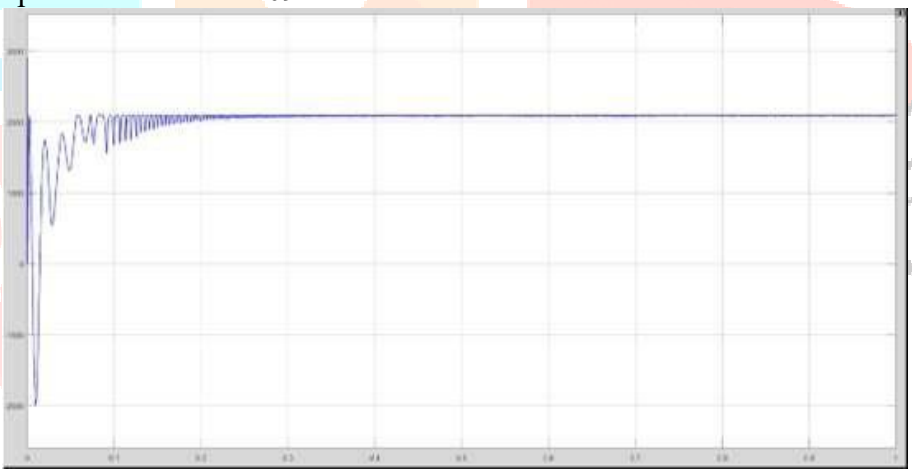

Fig 5: Output power of Boost Converter

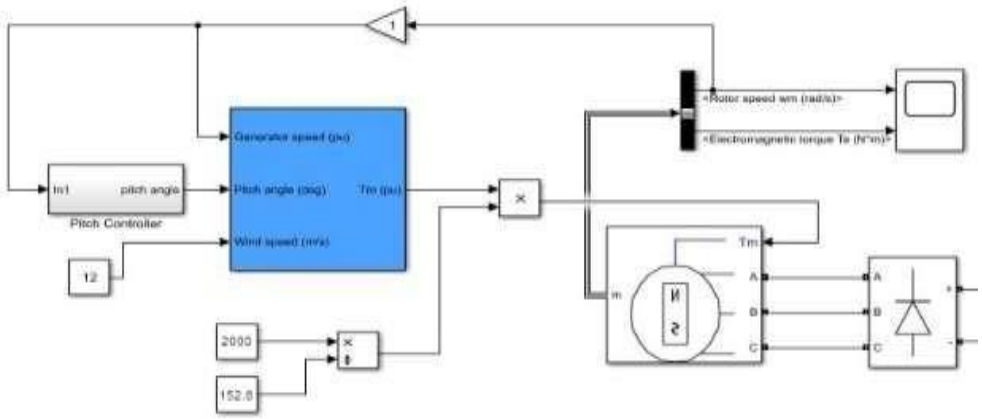

Fig 6: Simulation of wind energy system

Wind power generation model is designed with PMSG. Wind turbine nominal mechanical output power is set to 2000W at a base wind speed of 12m/s.

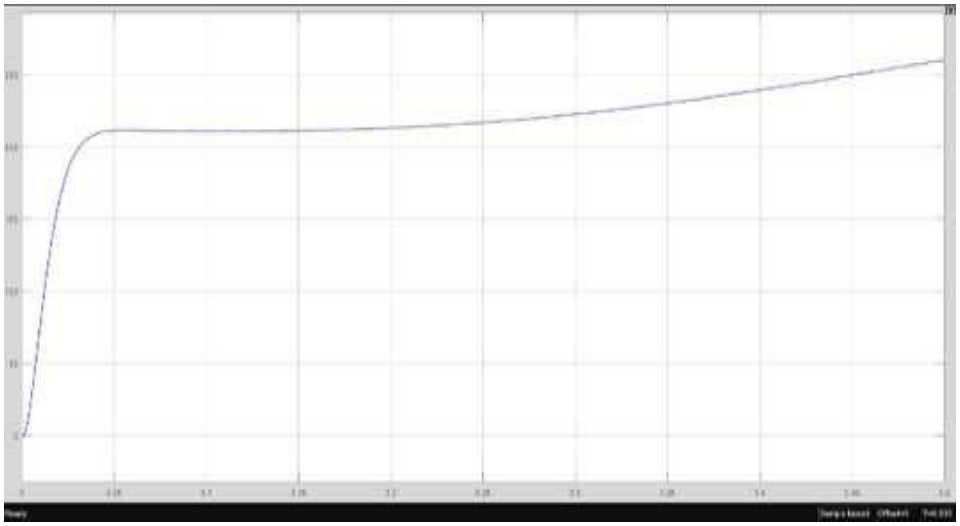

Fig 7: Output voltage of Rectifier

Below figure 8 shows the cascaded 5 level H bridge inverter integrated with phase shift pulse width modulation technique and modulated carrier signal obtained is shown in fig 9

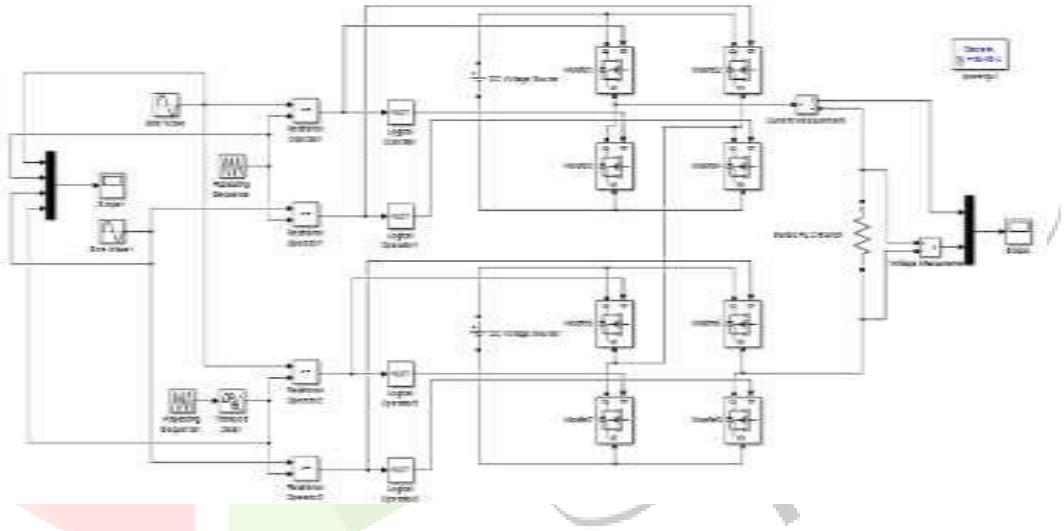

Fig 8: PS PWM Technique for 5 level Cascaded H bridge

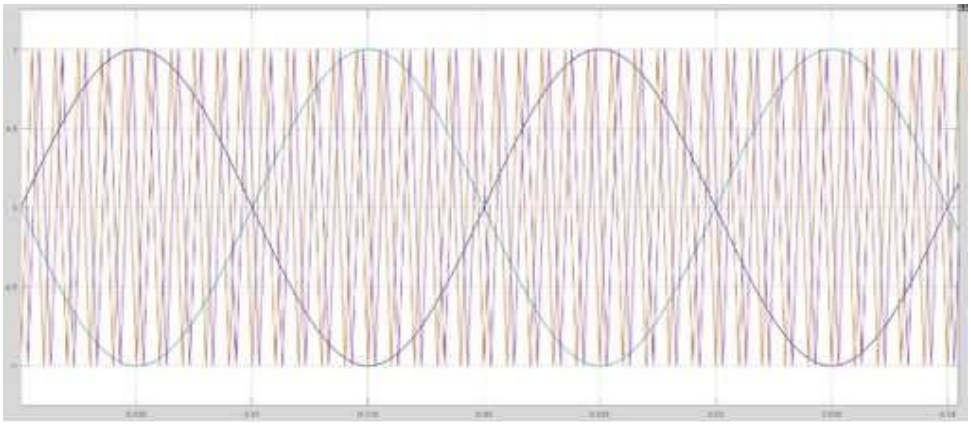

Fig 9: Modulating and carrier signals of PWMmultilevel Inverter

Fig 10 and 11 shows the phase disposition pulse width modulation technique incorporated with inverter and carrier signal of PWM respectively.

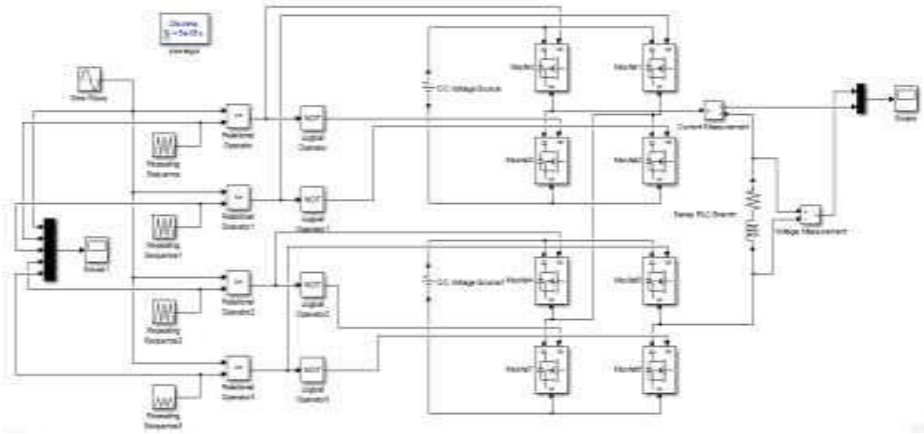

Fig 10: PD PWM technique cascaded with H bridge multilevel

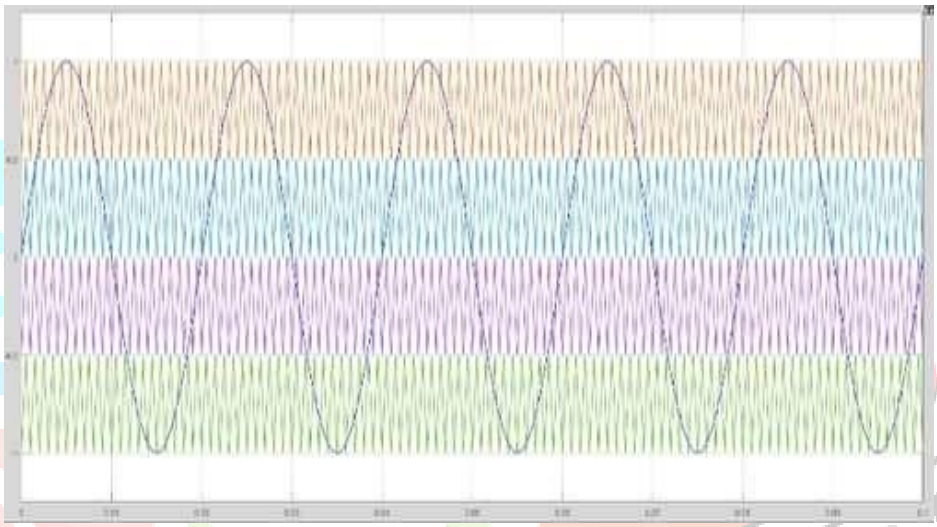

Fig 11: Modulating and carrier signal of PD PWMinverter.

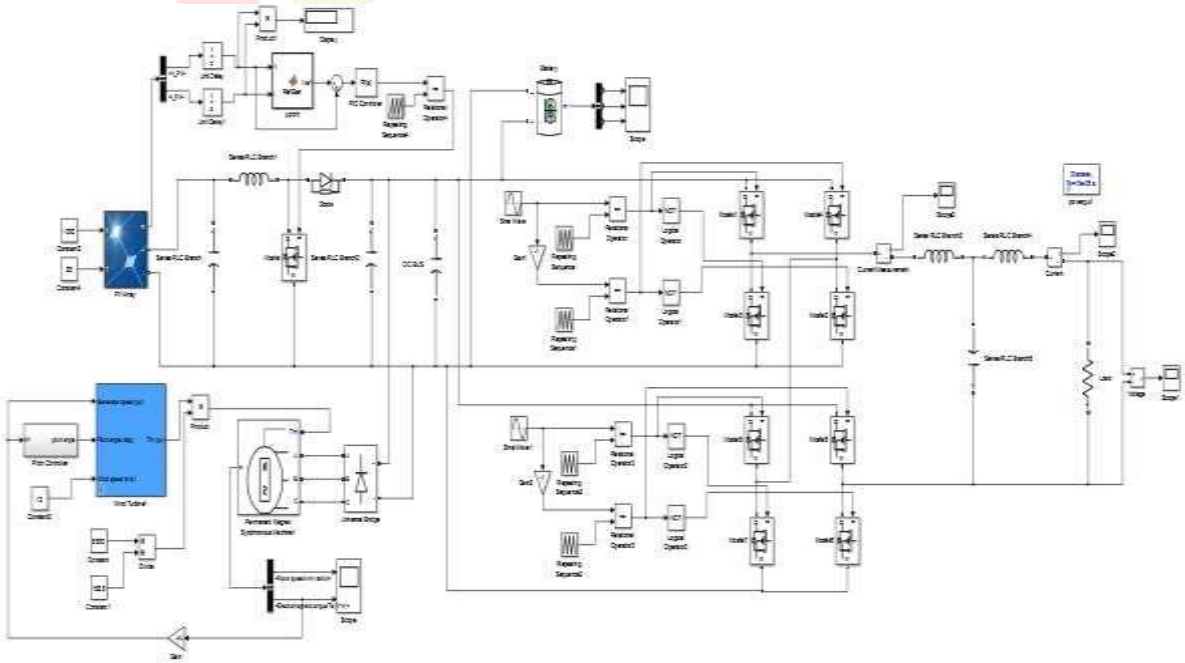

Fig 12: proposed hybrid power system

The solar power and rectified wind power is integrated with 5 level cascaded h bridge multilevel inverter and LC filter is been designed to further reduce the Total Harmonic Distortion of the output. The final simulation performed is been shown in fig 12. Fig 13 shows the output voltage of inverter with harmonics.

Total Harmonic Distortion of the output is reduced to 3.21% by using the LC filter and the FET analysis is shown in fig 14.

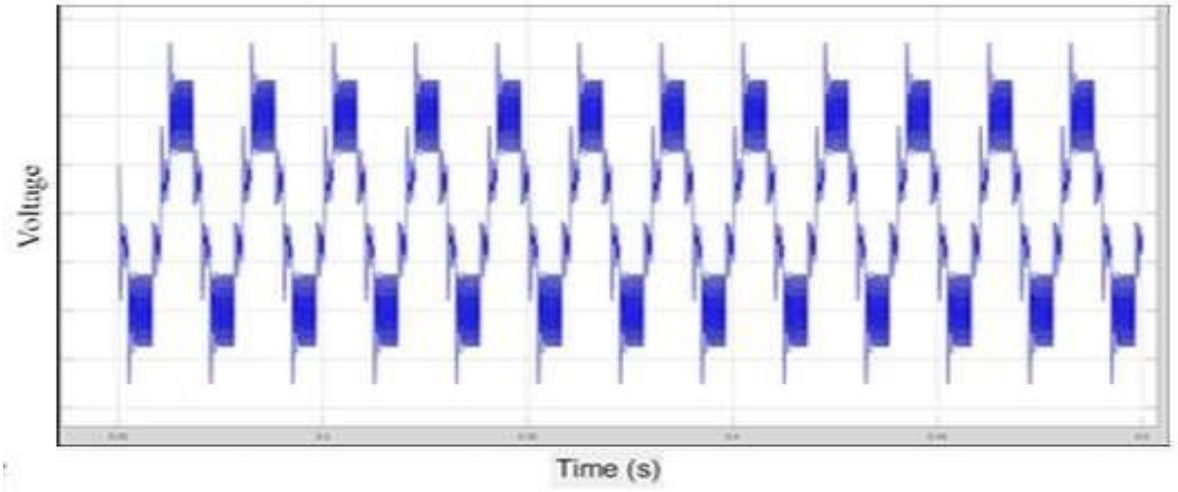

Fig 13: simulation output of proposed system.

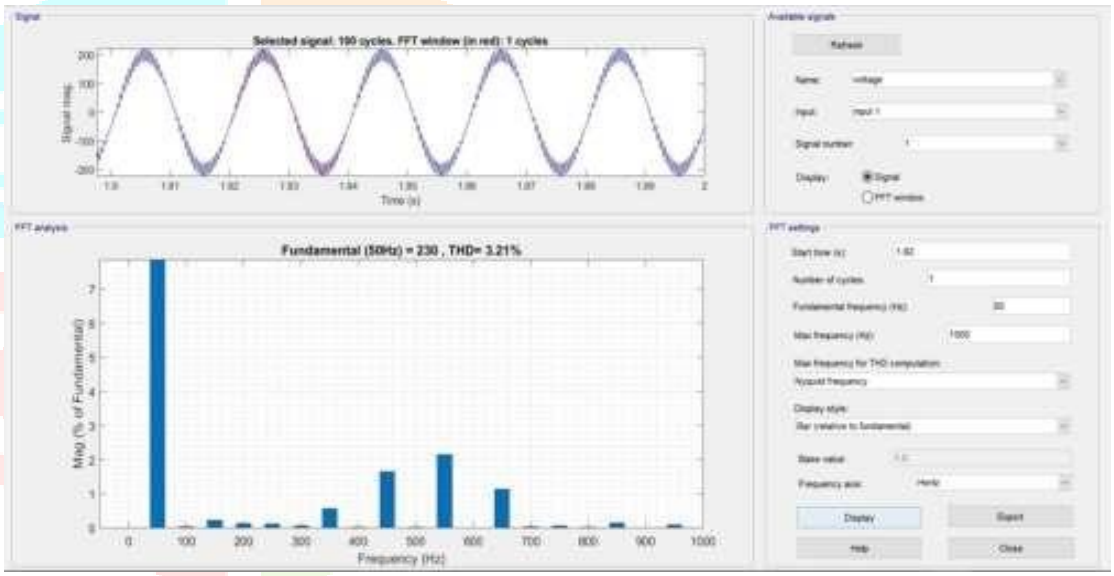

Fig 14: FET analysis of Inverter output voltage

V. CONCLUSION

Hybrid PV-Wind model is proposed to meet the load demands in rural areas and it is better alternative to conventional energy to provide uninterrupted power. The modeling of hybrid system with five level cascaded multilevel inverter is built using MATLAB Simulink. Total harmonic distortion has been reduced and can be observed in FET analysis.

The proposed hybrid model of wind and solar renewable energy system can be connected to the grid in future and multilevel inverter can be analyzed for different output levels by changing the modulation index and switching frequency.

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