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Multi input SEPIC converter based hybrid voltage source inverter for grid connected applications.

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Abstract— Renewable energy sources have become a popular alternative electrical energy source where power generation in conventional ways is not practical. In the last few years the photovoltaic and wind power generation have been increased significantly. In this study, we proposed a hybrid energy system which combines both solar panel and wind turbine generator as an alternative for conventional source of electrical energy like thermal and hydro power generation. A simple control technique which is also cost effective has been proposed to track the operating point at which maximum power can be coerced from the PV system and wind turbine generator system under continuously changing environmental conditions. The entire hybrid system is described given along with comprehensive simulation results that discover the feasibility of the system. A software simulation model is developed in Matlab/Simulink and the proto type is implemented by using DSPIC30f4011 controller.
Keywords- SEPIC converter, Inverter, Solar panel, Wind energy, DSPIC,

I. INTRODUCTION

Recent developments and trends in the electric power consumption indicate an increasing use of renewable energy. Virtually all regions of the world have renewable resources of one type or another. By this point of view studies on renewable energies focuses more and more attention. Solar energy and wind energy are the two renewable energy sources most common in use. Wind energy has become the least expensive renewable energy technology in existence and has peaked the interest of scientists and educators over the world. Photovoltaic cells convert the energy from sunlight into DC electricity. PVs offer added advantages over other renewable energy sources in that they give off no noise and require practically no maintenance. Hybridizing solar and wind power sources provide a realistic form of power generation.

Many studies have been carried out on the use of renewable energy sources for power generation and many projects were presented earlier. The wind and solar energy systems are highly unreliable due to their unpredictable nature. In a PV panel was incorporated with a diesel electric power system to analyze the reduction in the fuel consumed. It was seen that the incorporation of an additional renewable source can further reduce the fuel consumption. When a source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference. Several hybrid wind/PV power systems with Maximum Power Point Tracking (MPPT) control have been proposed earlier.

They used a separate DC/DC buck and buck- boost converter connected in fusion in the rectifier stage to perform the MPPT control for each of the renewable energy power sources. These systems have a problem that, due to the environmental factors influencing the wind turbine generator, high frequency current harmonics are injected into it. Buck and buck-boost converters do not have the capability to eliminate these harmonics. So the system requires passive input filters to remove it, making the system more bulky and expensive.

In this project, a new converter topology for hybridizing the wind and solar energy sources has been proposed. In this topology, both wind and solar energy sources are incorporated together using a combination of two modified SEPIC converters, so that if one of them is unavailable, then the other source can compensate for it. The boost converter is the usual structure utilized in high-power-factor (HPF) rectifiers in order to improve power factor (PF) and to reduce the total current harmonic distortion (THD). However, for universal input voltage application, the efficiency can be reduced mainly in the lowest input voltage and the worst operation condition must be considered in the power converter design procedure .The improvement of the efficiency at lower line voltage is important because the thermal design and heat sinks size are defined considering the worst operation point. Many works were developed in order to improve the operation characteristics of the power converter utilized in HPF universal input rectifiers.

The use of high-static gain and low switch voltage topologies can improve the efficiency operating with low input voltage. The voltage multiplier technique was used for a boost converter in order to increase the static gain with reduced switch voltage. However, the boost voltage doubler cannot be used for a universal input voltage HPF rectifier because the output voltage must be higher than the double of the maximum input voltage. A modification in the multiphase boost voltage doublers was used for a universal input HPF rectifier, in order to obtain high static gain at the lower input voltage with the same DC output voltage level of a classical boost converter. The integration of a voltage multiplier cell with a classical SEPIC converter is proposed in this work in order to obtain a high step-up static gain operating with low input voltage and a low step-up static gain for the high input voltage operation. The operation characteristics obtained with this modification makes the proposed structure an interesting alternative for the universal input HPF rectifier or wide input voltage range applications, operating with high efficiency. The proposed converter operates with a switch voltage lower than the output voltage and with an input current ripple lower than the classical boost converter. The power circuit of the proposed converter can be integrated with a simple regenerative snubber, obtaining soft-switching commutation and increasing the efficiency.

The SEPIC-SEPIC fused converters have the capability to eliminate the HF current harmonics in the wind generator. This eliminates the need of passive input filters in the system. These converters can support step up and step down operations for each renewable energy sources. They can also support individual and simultaneous operations. Solar energy source is the input to one modified converter and wind energy source is the input to the other modified SEPIC converter. The average output voltage produced by the system will be the sum of the inputs of these two systems. All these advantages of the proposed hybrid system make it highly efficient and reliable.

II. SEPIC CONVERTER

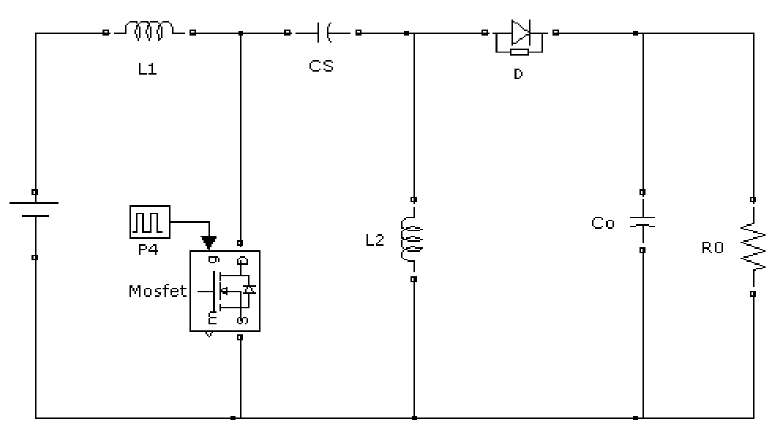

Fig 1. Single Ended Primary Inductance Converter

Single-ended primary-inductor converter (SEPIC) is a type of DC-DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input; the output of the SEPIC is controlled by the duty cycle of the control transistor. A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output voltage is of the same polarity as the input voltage), the primary means of coupling energy from the input to the output is via a series capacitor, and true shutdown mode.

III. PROPOSED SYSTEM OPERATION

With the increasing concern of global warming and depletion of conventional resources we have to look at sustainable energy solutions like renewable energy sources. This project proposes a renewable hybrid wind solar energy system fed single phase multilevel inverter. The hybrid system is the combination of photo voltaic (PV) array and wind generator. Solar energy is generated by using PV arrays, wind power is generated by using wind generator and both the generated voltages are boosted up or down by SEPIC converter. These boosted voltages are fed to the single phase inverter.

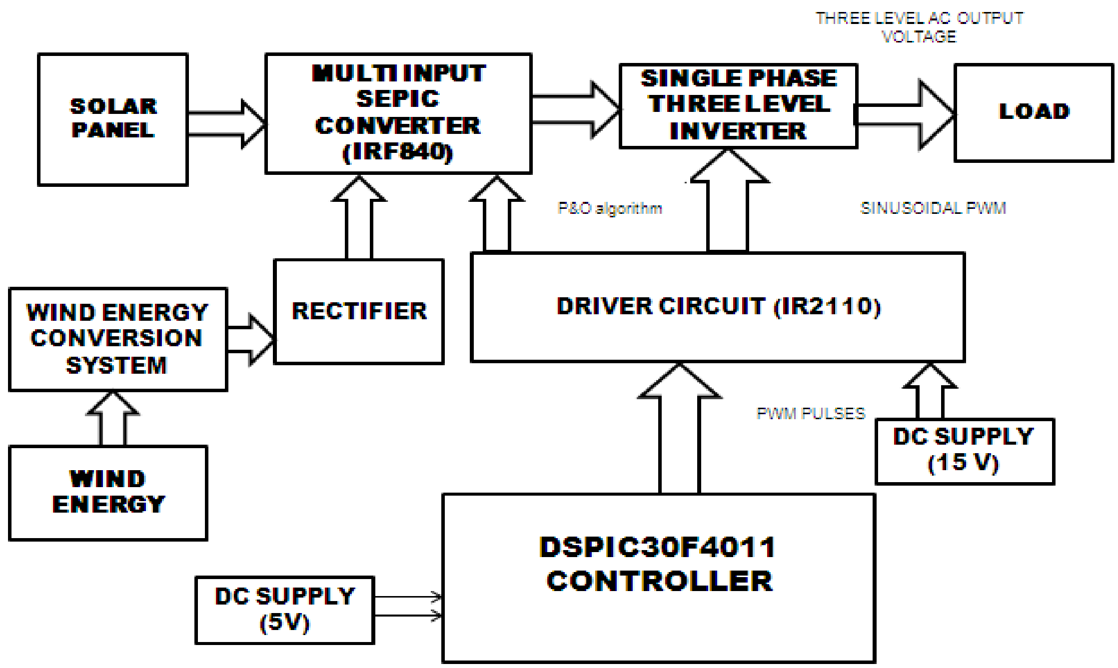

Fig 2. Proposed system block diagram

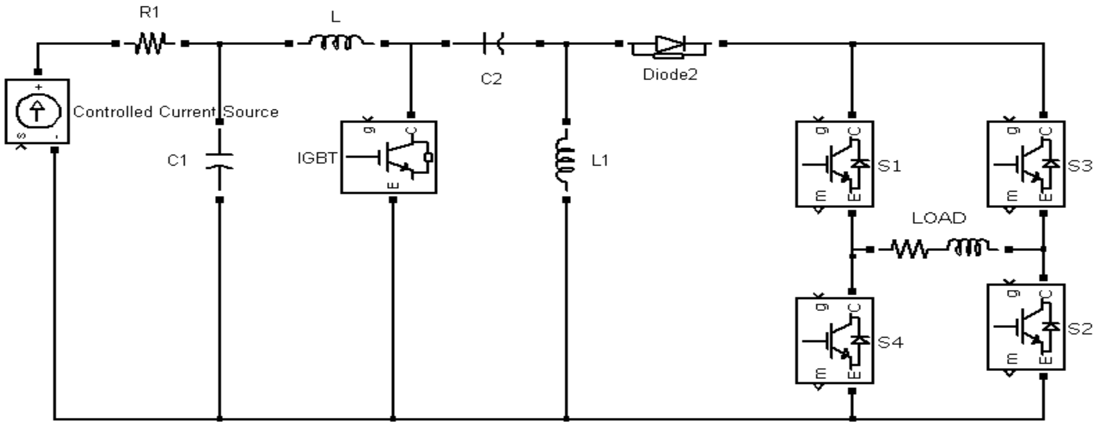

Fig 3. Proposed system circuit diagram

Single-ended primary-inductor converter (SEPIC) is a type of DC-DC converter that allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input; the output of the SEPIC is controlled by the duty cycle of the control transistor. A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output voltage is of same polarity as the input voltage), the isolation between its input and output (provided by a capacitor in series), and true shutdown mode: when the switch is turned off, its output drops to 0 V.

SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. For example, a single lithium ion battery typically discharges from 4.2 volts to 3 volts; if other components require 3.3 volts, then the SEPIC would be effective.

The power circuit of the classical SEPIC converter is presented in Fig 3. The step-up and step-down static gain of the SEPIC converter is an interesting operation characteristic for a wide input voltage range application. However, as the switch voltage is equal the sum of the input and output voltage, this topology is not used for a universal input HPF rectifier. The voltage multiplier technique was presented in order to increase the static gain of single-phase and multiphase boost DC-DC converters. An adaptation of the voltage multiplier technique with the SEPIC converter is presented in Fig3. The modification of the SEPIC converter is accomplished with the inclusion of the diode Dm and the capacitor Cm. Many operational characteristics of the classical SEPIC converter are changed with the proposed modification.

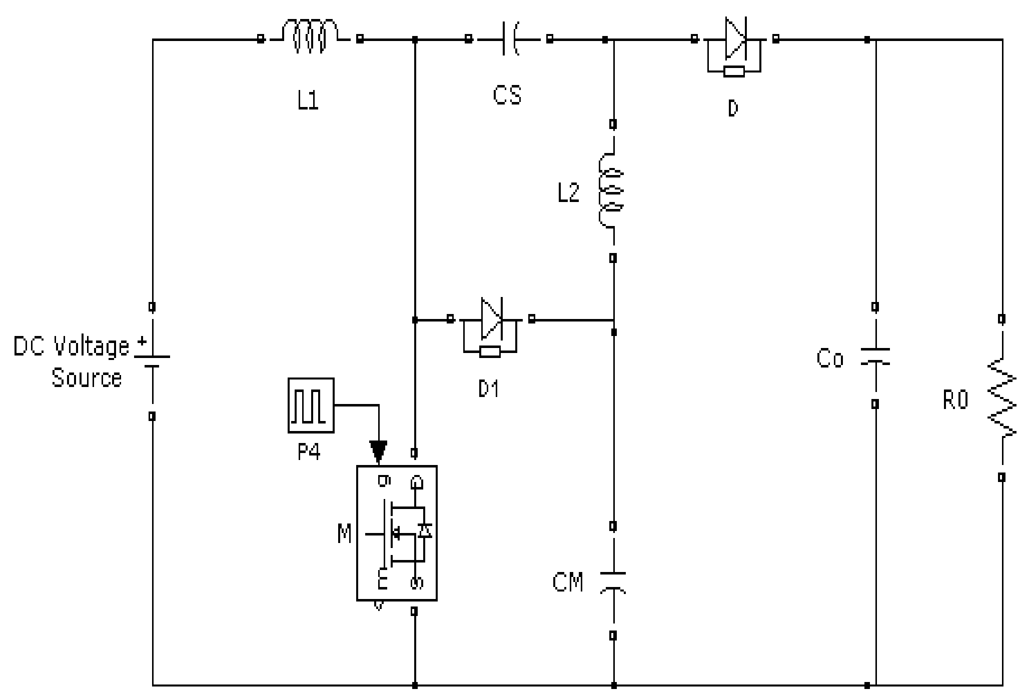

Fig 4. Single Ended Primary Inductance Converter

The capacitor Cm is charged with the output voltage of the classical boost converter. Therefore, the voltage applied to the L2 inductor during the conduction of the power switch (S) is higher than in the classical SEPIC, increasing the static gain. The polarity of the voltage stored in the capacitor Cs is inverted in the proposed converter and the expressions of the capacitors voltages and others operation characteristics are presented in the theoretical analysis. The continuous conduction mode operation of the modified SEPIC converter presents two operation stages. 1) First Stage ([t0, t1] Fig4) - At the instant t1, switch S is turned-off and the energy stored in the input inductor L1 is transferred to the output through the Cs capacitor and output diode Do and also is transferred to the Cm capacitor through the diode Dm. Therefore, the switch voltage is equal to the Cm capacitor voltage. The energy stored in the inductor L2 is transferred to the output through the diode.

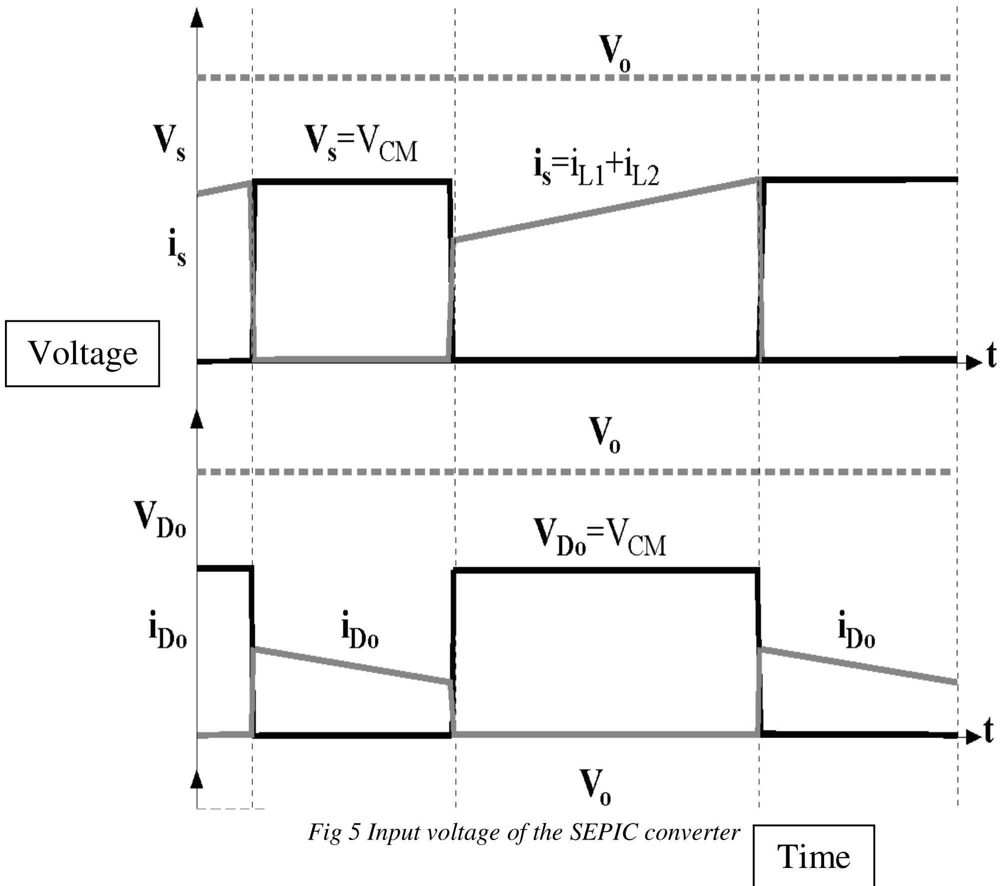

Fig 5 Input voltage of the SEPIC converter

Second Stage ([t1, t2] Fig5) - At the instant t1, switch S is turned-on and the diodes Dm and Do are blocked and the inductors L1 and L2 store energy. The input voltage is applied to the input inductor L1 and the voltage Vcs-Vcm is applied to the inductor L2. The Vcm voltage is higher than the Vcs voltage. The main theoretical waveforms operating with hard switching commutation are presented in Fig4.4. The voltage in all diodes and in the power switch is equal to the Cm capacitor voltage. The output voltage is equal to the sum of the Cs and Cm capacitors voltage. The average L1 inductor current is equal to the input current and the average L2 inductor current is equal to the output current.

The main equations and the theoretical analysis of the proposed converter are presented in this session. The results of the theoretical analysis are compared with the classical boost converter in order to show the positive and negative aspects of the proposed converter.

Some comparison with the classical SEPIC converter is also presented because the proposed topology is obtained from this converter. The equations defined by the theoretical analysis are utilized for the determination of the inductances and capacitances of the proposed converter. The theoretical analysis is developed considering the operation as a HPF rectifier and the utilization of an AC voltage source and a full-bridge diode rectifier connected to the input of the proposed converter is considered. All analysis is accomplished for an application with an AC input voltage changing from Vi=100Vrms to Vi=240Vrms, an output voltage equal to Vo=425Vdc and a nominal output power equal to Po=650W.

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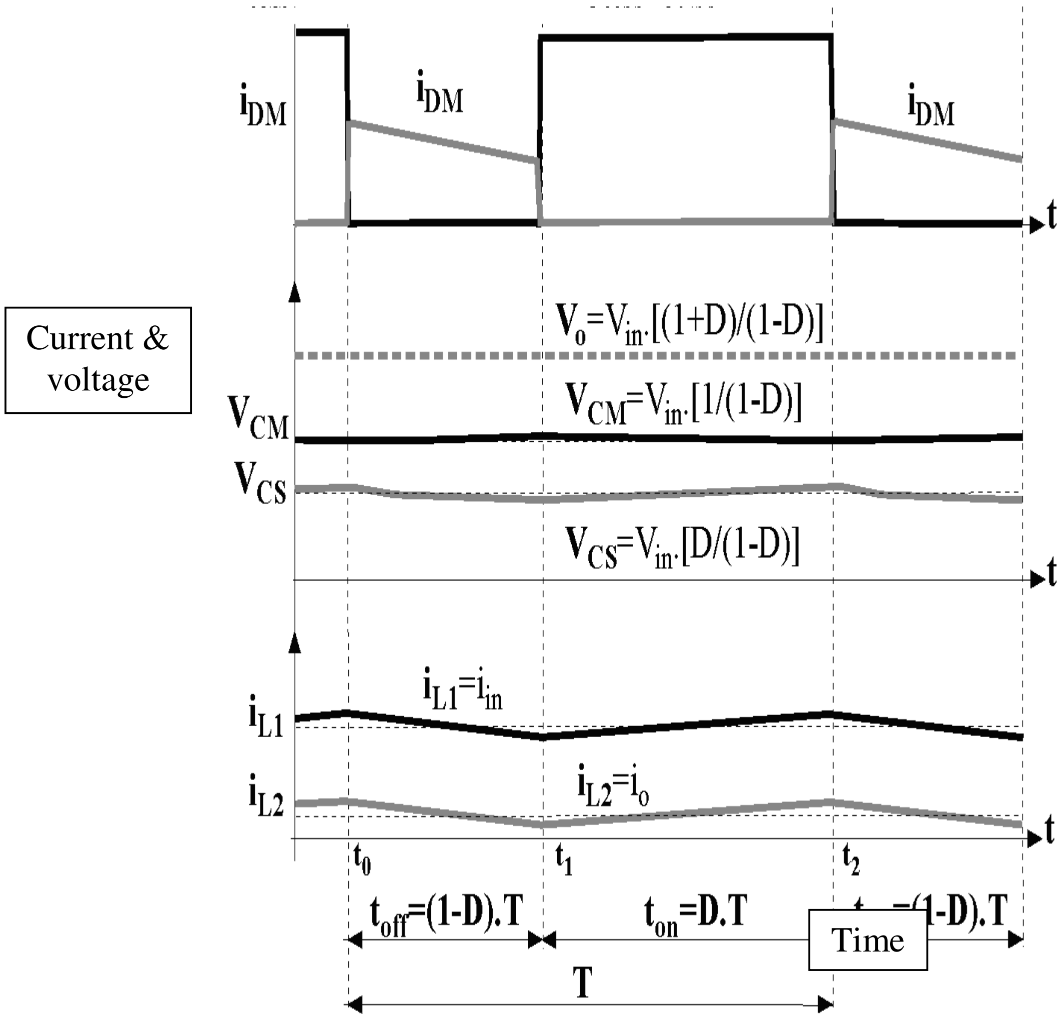


Fig 6. Output of the SEPIC converter

INTEGRATED CONVERTER TOPOLOGY

The integrated converter topology has reduced the circuit components and also increases the system efficiency. The features of the proposed integrated topology are:

1) The inherent nature of these two converters eliminates the need for separate input filters for power factor correction.

2) It can support step up/down operations for each renewable source (can support wide ranges of PV and wind input).

3) System works on the presence of both or any one of the Renewable resources.

4) Individual and simultaneous operation is supported.

A system diagram of the proposed rectifier stage of a hybrid energy system is shown in Figure 4.4, where one of the inputs is connected to the output of the PV array and the other input connected to the output of a generator. This configuration allows each converter to operate normally individually in the event that one source is unavailable.

Applications:

- Speed control of DC motor.
- Speed control of Servo motor.
- Battery charging.
- Renewable energy system
- Telecommunication applications

To extract the maximum power from the solar array and wind energy, and to track the changes due to environment, maximum power point tracking should be implemented. The hill climbing mppt method involves moving the operating voltage by one step and then examining the change in generated power. If the power increases, the operating point moves in the same direction; otherwise it moves in the opposite direction. The wind power system design must optimize the annual energy capture at a given site. The only operating mode for extracting the maximum energy is to vary the turbine speed with varying wind speed such that at all times the TSR is continuously equal to that required for the maximum power coefficient. The power generated from a given PV module mainly depends on solar irradiance and temperature for a system without MPPT, the voltage will quickly collapse to zero. A system with MPPT avoids the voltage collapse by keeping the operating point near the Maximum Power Point. The advantages of MPPT algorithm are robustness and the easy to implement. The three level inverter will convert the DC voltage into AC voltage.

IV. SIMULATION RESULTS

To verify the feasibility of the proposed strategy, simulations are carried out.

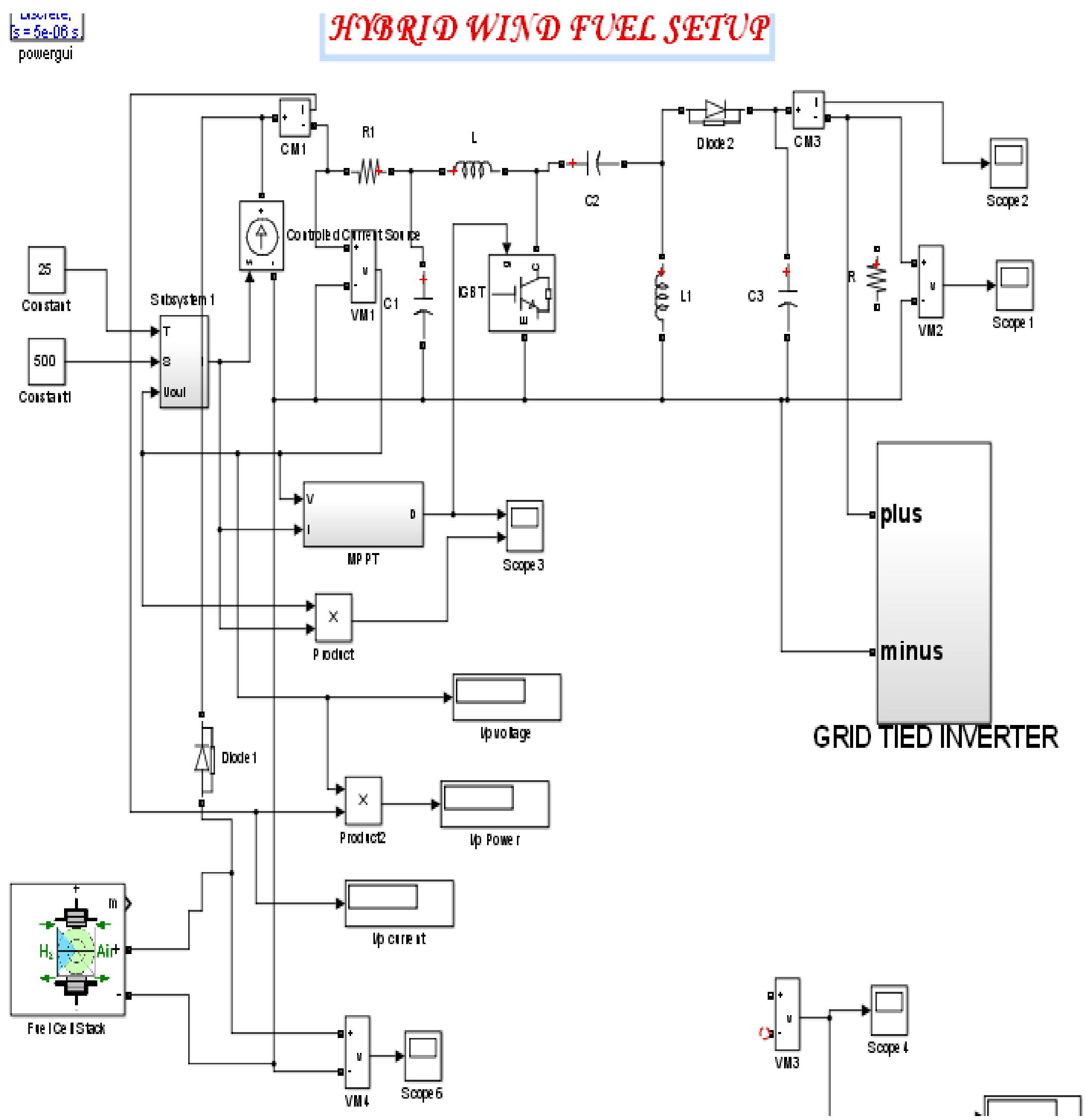


Fig.7. Proposed system Simulink diagram

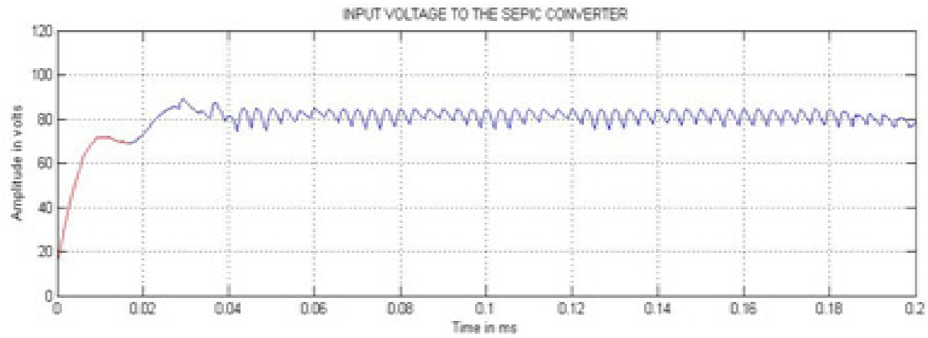


Fig.8.Input voltage to the SEPIC converter

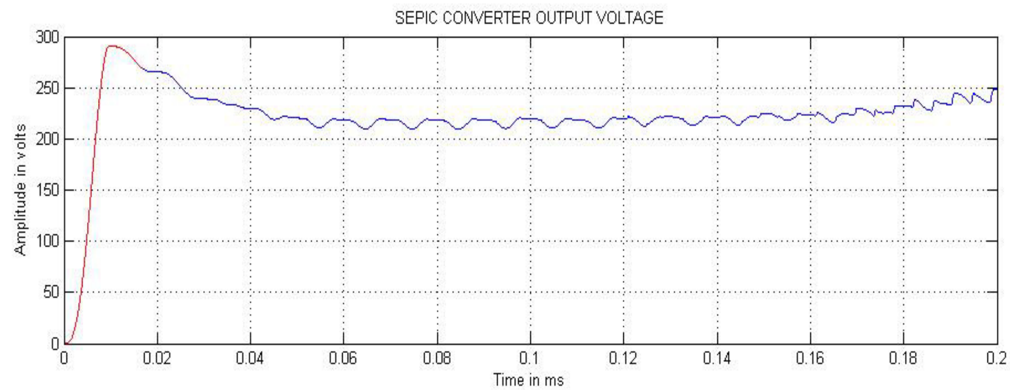


Fig.9. Output voltage of the SEPIC converter

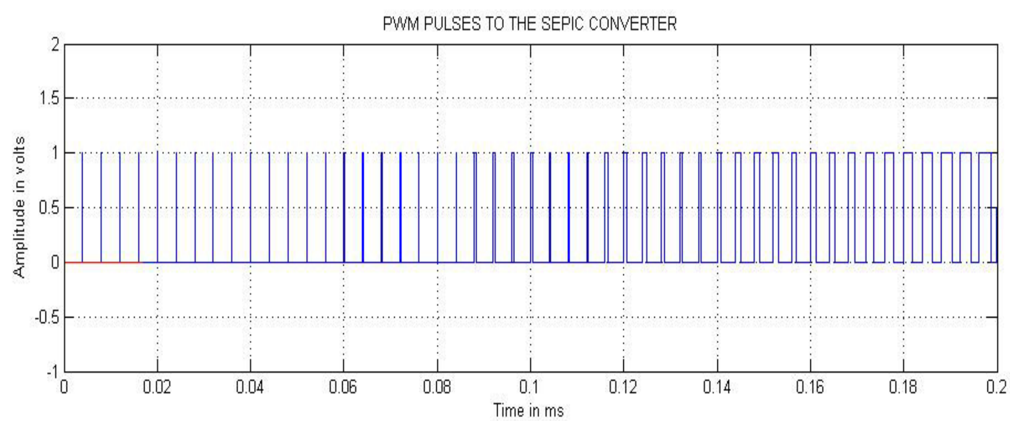


Fig.10. Gate pulses to SEPIC converter

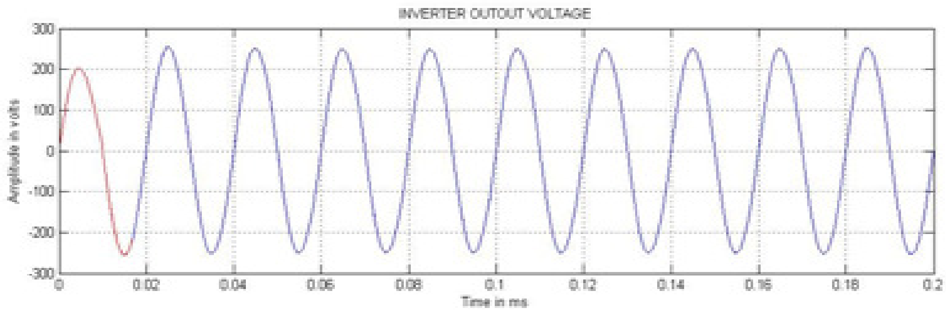


Fig.11. Inverter output voltage

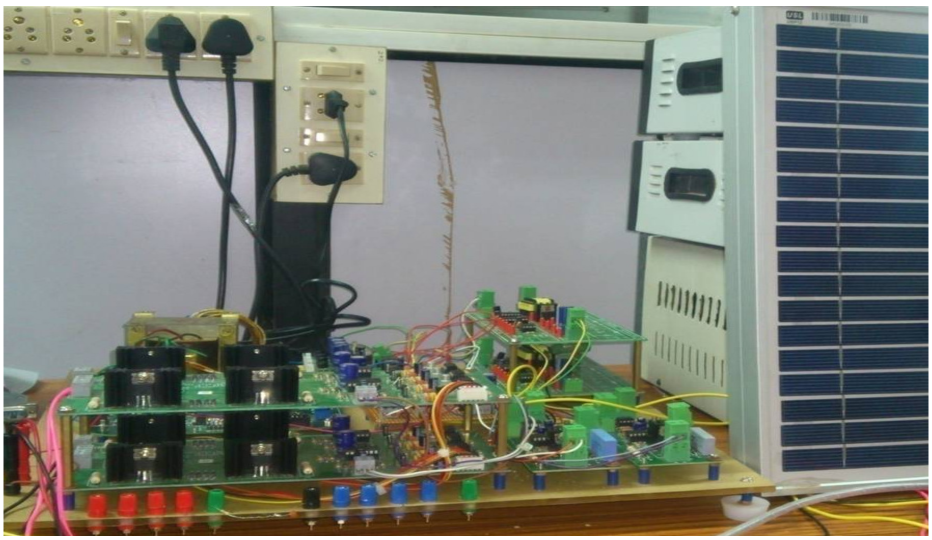
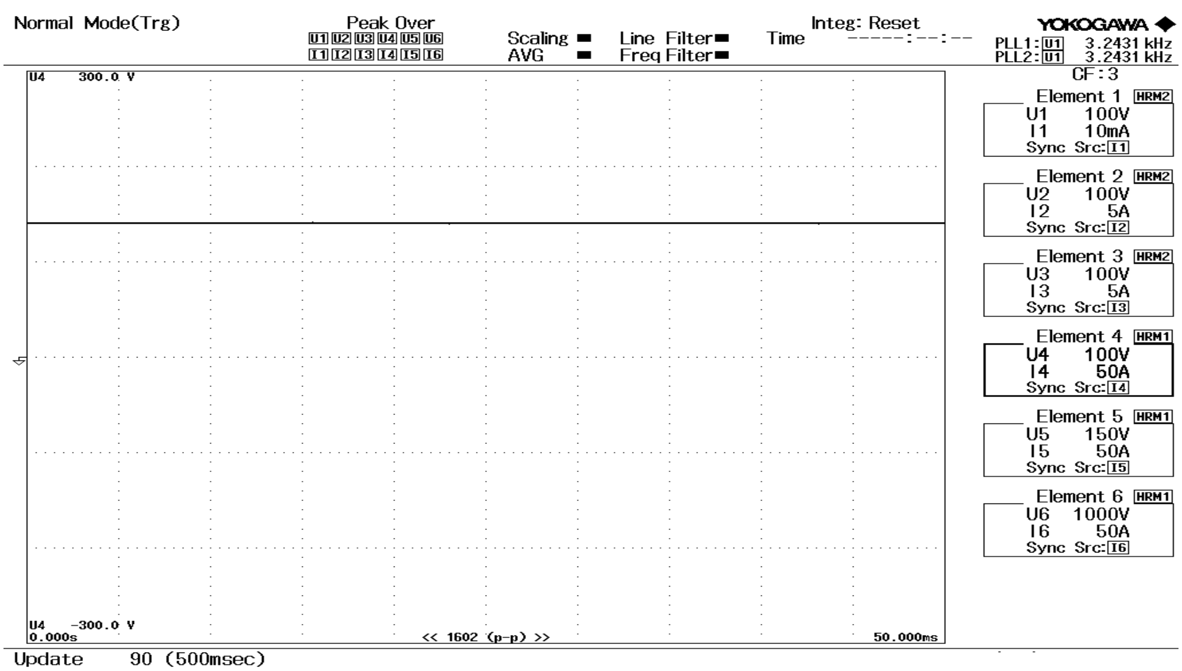


Fig.12. Proposed system hardware view



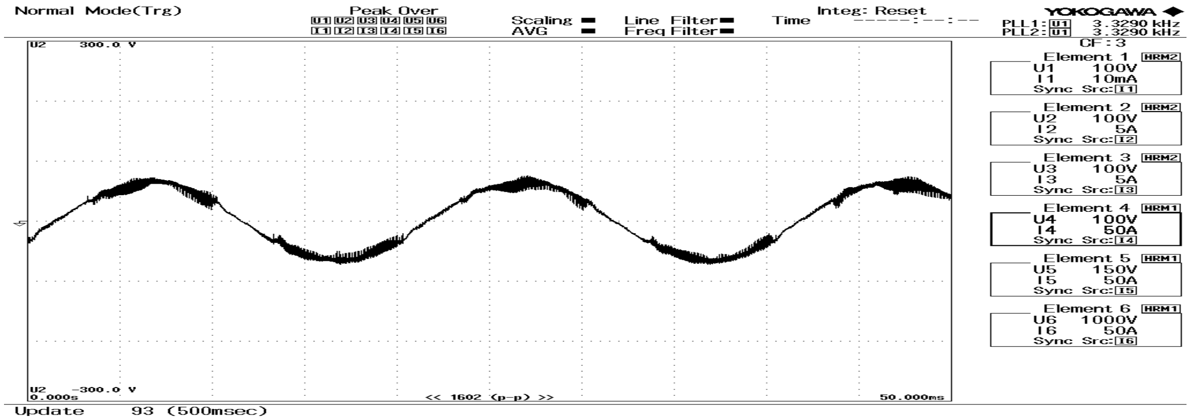


Fig.13. Proposed system hardware input and output voltage

V. CONCLUSIONS

Renewable energy sources also called non-conventional type of energy are continuously replenished by natural processes. Hybrid systems are the right solution for a clean energy production. Hybridizing solar and wind power sources provide a realistic form of power generation. Here, a hybrid wind and solar energy system with a converter topology is proposed which makes use of two modified SEPIC converters in the design. This converter design overcomes the drawbacks of the earlier proposed converters. This topology allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The output voltage obtained from the hybrid system is the sum of the inputs of the modified SEPIC converters. The separate converters are integrated in order to minimize the circuit components and to improve the circuit efficiency. This system has lower operating cost and finds applications in remote area power generation, constant speed and variable speed energy conversion systems and rural electrification. MATLAB/ SIMULINK software is used to model the PV panel, wind turbine, DC-DC converters and the proposed hybrid system. The hardware is implemented by using dspic30f4011 controller.

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