I J C T A, 9(5), 2016, pp. 2483-2490

Hybrid Energy System using Three Port Converter

C.K. Kishore* and Ramesh G.P. **

ABSTRACT

Three Port Converters are used for merging more than a single source in order to improve the power handling capability. Here the first two ports acts as the sources and the third port acts as the output or to the Load. The objective is combining the Wind Energy Systems with the Existing Three Port Converter System instead of a Battery Storage. The proposed system is simulated and verified using the MATLAB/SIMULINK Software and output waveforms have been obtained. The Output Power and Voltage is also improved while using the two sources at the input ports compared to the existing Three Port Converter system using Battery at one of the input ports.

Keywords: Three Port Converter, Wind Energy Conversion System, Three Port Half Bridge Converter, Dual Input Single Ended Primary Inductor Converter.

1. INTRODUCTION

The three port converter is a device that consists of two different sources at the two input ports and the load acts as the third port. The sources at the input side is DC source, where for the wind energy the output AC source is rectified using diode rectifier. Thus the important feature of the three port converter is to regulate the two inputs and feed it to the third port. The conventional systems consists of the battery in the second port while here the second port consists of the wind energy system [1,5]. The conventional standalone system with PV and the battery as the input ports and the load at the output is shown in the Fig. 1(a), where the proposed system with the combination of PV and the Wind Energy System is shown in the Fig. 1(b). Here the diode rectifier is used in the case of the Wind Energy system as the output from Wind Turbine is in the form of AC and needs to be rectified to DC voltage. The Fig. 1(a) shows the PV input with Battery. But in the proposed system the Battery is replaced by the Wind Energy Systems shown in the Fig. 1(b), here the power sources PV and Wind Energy System are in parallel with one another and merged using Three Port Converter topology.

The TPHBC system mentioned in the existing system uses four switches and an isolation transformer for separating the input and the output side [3]. Thus the entire system size gets reduced for a standalone renewable system. In the integrated four port converters the usage of the two sources as the first two ports and the use of the storage device at the third port and load at the fourth port makes the entire system complex and thus the number of devices used is also increased [4]. The bidirectional converter uses the three power switches. Thus the power flow from the dc bus or other dc sources can be charged to the battery or storage device in the case of the excess dc voltage availability. The Multiple Input Converters (MIC) consists of the multiple inputs at the input terminal and the output can be fed to the load. Thus for such a system with more number of input terminals, the output power can be improved by using the closed loop configurations [6].

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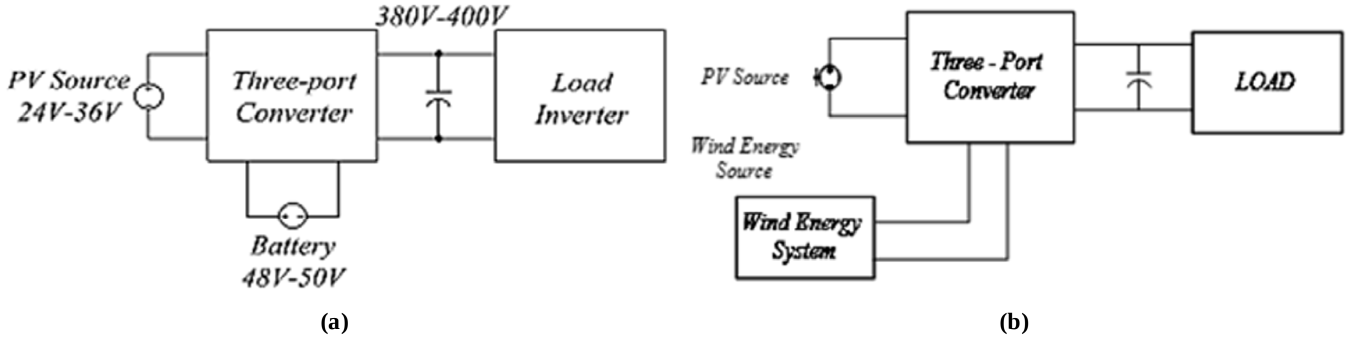

Figure 1: Standalone renewable power systems using Three Port Converter: (a) TPC with PV and Battery (b) TPC with PV and Wind Energy System.

The three input DC-DC converters utilizes the two power sources and the single energy storage device [9]. The TPHBC system mentioned in the existing system uses four switches and an isolation transformer for separating the input and the output side [3]. Thus the entire system size gets reduced for a standalone renewable system. In the integrated four port converters the usage of the two sources as the first two ports and the use of the storage device at the third port and load at the fourth port makes the entire system complex and thus the number of devices used is also increased [4].

The bidirectional converter uses the three power switches. Thus the power flow from the dc bus or other dc sources can be charged to the battery or storage device in the case of the excess dc voltage availability. The Multiple Input Converters (MIC) consists of the multiple inputs at the input terminal and the output can be fed to the load [12]. Thus for such a system with more number of input terminals, the output power can be improved by using the closed loop configurations [6]. The three input DC-DC converters utilizes the two power sources and the single energy storage device [9]. But in the proposed system the storage device is connected in parallel with the wind energy system, which reduces the complexity of the entire system. The non-isolated three port converters can be derived from the Dual Input Converters (DIC) and the Dual Output Converters (DOC) [7]. This kind of Multi-Port Converters has the feature of the single stage power conversion, high power integration and high efficiency [5]. LCL – Resonant Circuit may be used for the Bidirectional DC-DC Converter in order to control the DC Link at the constant value [8].

The active clamping technique can also be used for achieving the Zero voltage switching in Single Input Time sharing DC-DC converters and the efficiency of the converters also shown improved with reduced switching and conduction losses [2]. The conventional System consists of the recharging of the battery with the help of LCL Circuit or Bidirectional Switch and the Battery gets charged during this mode of operation. But in the Proposed System consists of Hybrid System of two renewable energy sources, it delivers the power output to the load and no storage or battery system is used in the Proposed System.

The Multiple Input Converters can also be realised using the Dual Input SEPIC Converter (DI-SEPIC) for achieving the active clamping without the use of any soft-switching techniques, moreover efficiency is also proved to be improved by using this topology [10].

2. OPERATION OF PROPOSED THREE PORT CONVERTER

The Proposed Three Port Converter consists of the 6 Capacitors, C_o, C_1, C_2, C_3, C_{pv} and C_{wind}, and three switches S_1, S_2, S_3, and the diodes D_1, D_2, D_3, D_4, D_5. Thus coupled inductor consists of the Magnetizing Inductance L_m, Leakage inductance L_{lk}, and the Primary section of the transformer N_p, where the secondary N_s is connected to the Capacitor C_3 and Diode D_4 respectively. Thus the output capacitor C_o, is used to reduce the output ripples. The current through the output capacitor is termed i_{Co}, and the current and the voltage through the Resistance R is termed as I_o and V_o respectively. The converter is analysed in the Continuous Conduction mode. The Coupling Coefficient is given by $k = L_m/(L_m + L_{lk})$. C_{pv} and C_{wind} are the

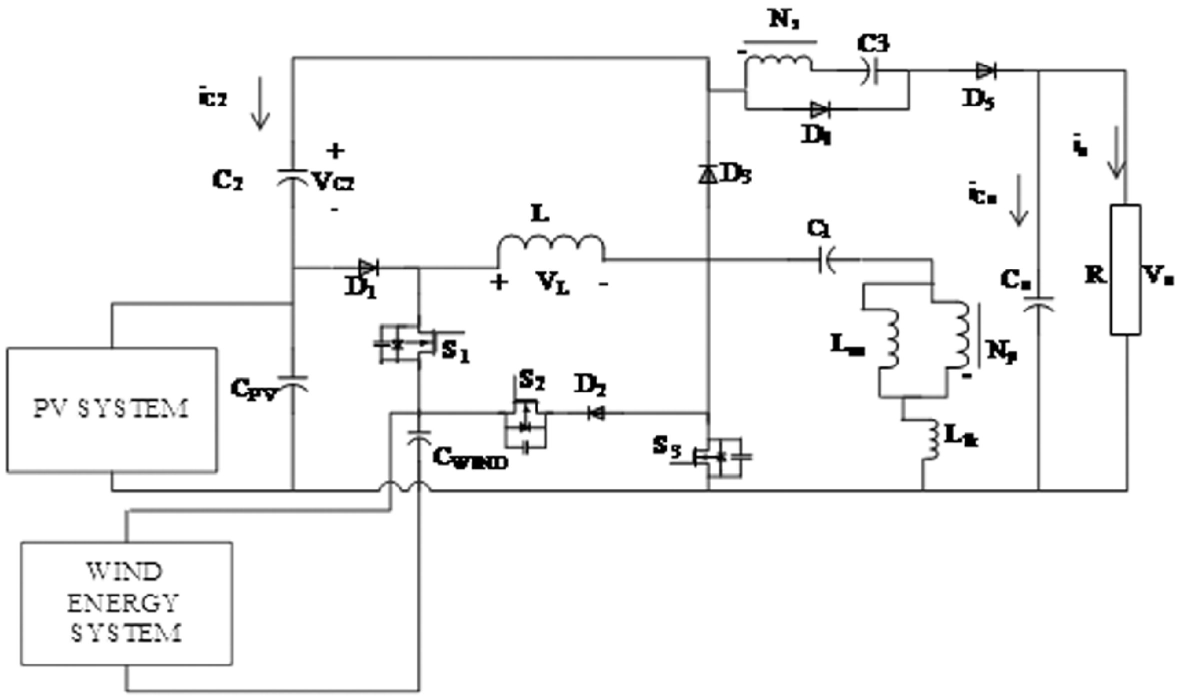

Figure 2: Proposed Converter Topology with Photovoltaic and the Wind as the input sources

capacitors connected across the PV and the Wind Energy Systems respectively. The Lmand $L_{lk}$are Mutual and Leakage inductances respectively. Here the PV source connected in parallel with the Wind Energy System. Here the value of k, i.e. Coupling Coefficient is given by the $k = L_m/(L_m + L_{lk})$.

Thus the Capacitors C_1, C_2, C_3 are maintained at the constant voltages. Thus the *Ns* and *Np* refers to the Primary and the Secondary Turns in the Coupling Transformer. The Inductance L is charged when the Power flows from Solar cell. In Three Port Converter System, the Power flows in two different directions one is via Capacitor C_2, Diode D_4 and D_5 to the Load and another is via diode D_1 and Inductance "L" to the primary of the Coupling Transformer Np. Fig. 2 represents the circuit of the proposed hybrid Three Port Converter System. The Switches are turned ON an OFF according to the different modes of operation by using the gate pulse signals.

2.1. Parameters of Proposed System

Table 1 shows the control parameters of PV and the Wind Energy Systems. Three Port Converter has three different modes of operation including Single Input and Double Output (SIDO) Mode, Dual Input Single Output (DISO) mode, Single Input and Single Output (SISO) Mode depending on the number of energy sources used [1, 4]. Table I shows the Photovoltaic and the wind energy converter system parameters of the proposed three port converter system.

Table 1
PV and Wind Systems Parameter Specification

Parameters	*Value*
Irradiance Level	1000 W/m^2
Temperature	25 °C
Wind Speed	12 m/s
PV Voltage	24 V
Wind Energy Voltage	48 V

The proposed system consists of the DISO mode with Photovoltaic and wind energy systems as the input voltage sources and Resistive load at the output. Here the Output Capacitance C_o can be tuned to obtain the immediate response in the output power and voltage waveforms.

The formula for finding the Coupling Coefficient "*k*" is given by the following equation,

$$k = L_m/(L_m + L_{lk}) \tag{1}$$

2.2. Gate Pulse for the Proposed Hybrid System

Figure 3 represents the gate pulses given to the switch S_1, S_2, S_3 respectively. The two stage discharging of Inductor L takes place when the Switch S_3 is in OFF condition. Switch S_1 is used to regulate the output whereas the Switch S_3 may be used for Maximum Power Point Control. Inductor "L" will be discharging on the two ways, (i) Through Diode D_3 and (ii) through Linear Transformer.

Fig. 5 (a) shows the operation of the Proposed System when D_1 is ON and Switch S_1 is OFF, and Fig. 5 (b) represents the operation when Switch S_1 is ON and Diode D_1 is in OFF condition. This type of discharging the inductor "L" in two ways one through Diode D_3 and another through coupling transformer is known as two way discharging of Inductor "L". While in the Dual Input Single Output Mode, both the output power and the voltage is improved due to the case that both the input to the converter ports are of power sources.

Figure 4 represents the charging of the Inductor L through the Switch S_3, while the Switch S_1 and S_2 are switched OFF. During the first mode of charging of the inductor "L", the Switch S_3 is turned "ON", while the diode D_3 is non-conducting. From the figure 5(a) and 5(b), the D_3 conducts while the Switch S_3 is turned "ON", thus the operation is performed alternatively, it represents the two way discharging of the inductor.

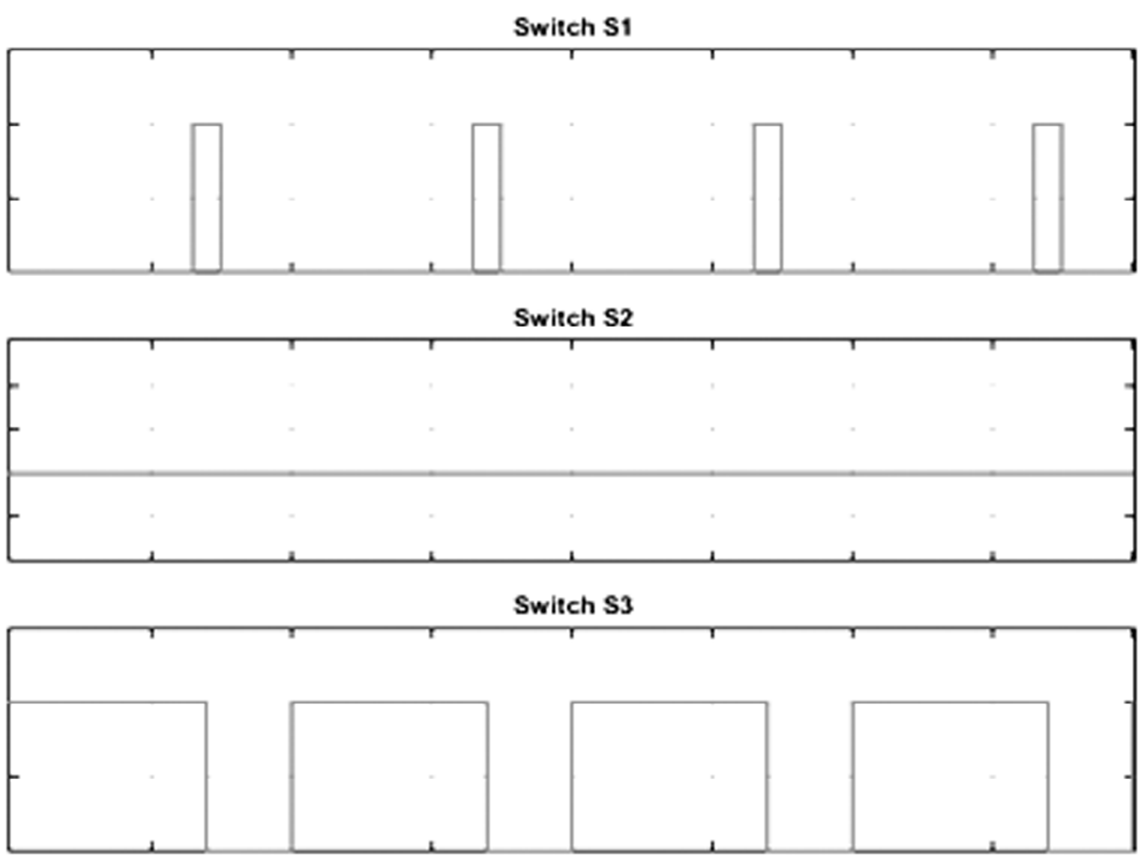

Figure 3: Gate pulse generation for the Switches S_1, S_2, S_3.

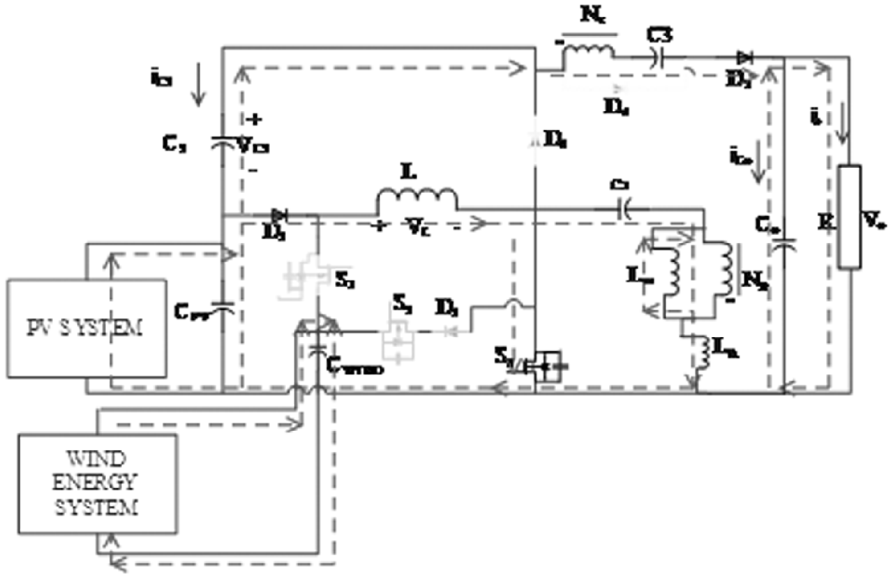

Figure 4: Charging of Inductor *L* through Switch S_3

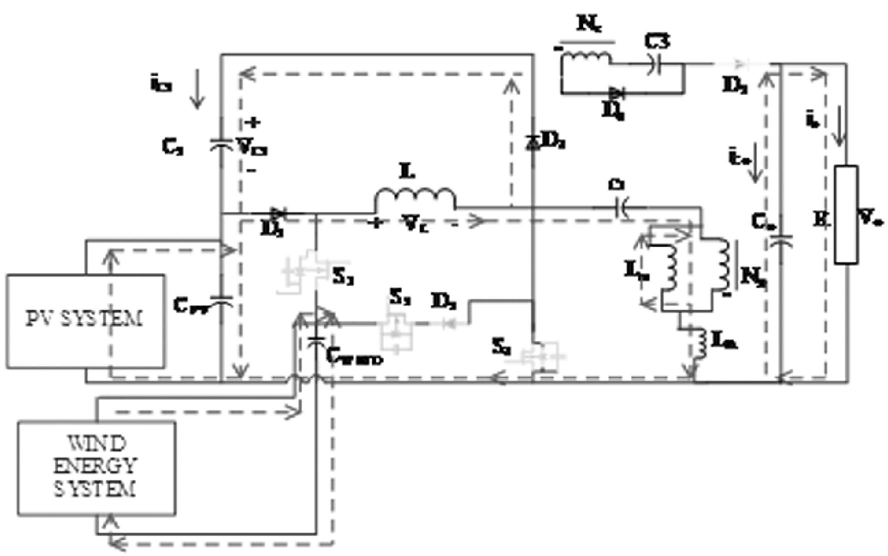

Figure 5: (a)

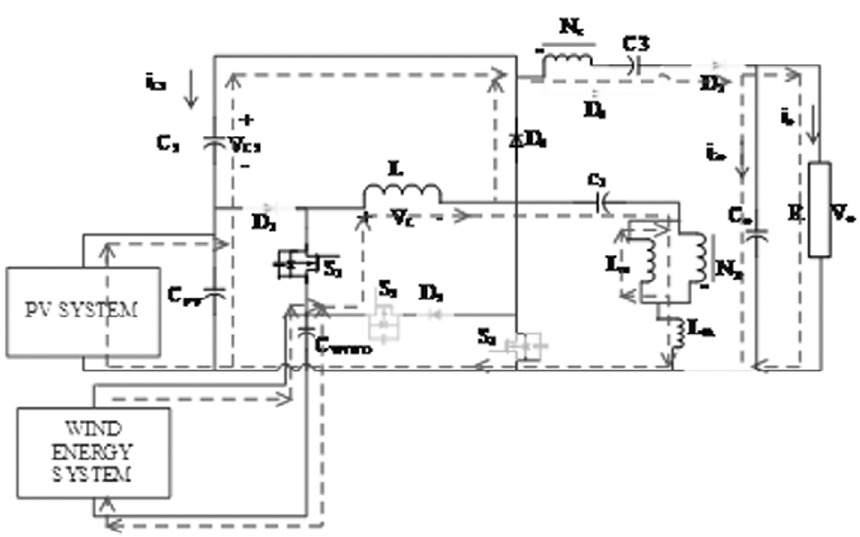

Figure 5: (b)

3. WIND ENERGY CONVERSION SYSTEM

The Wind Energy Conversion system consists of the Two Mass Drive Train model and the wind turbine is controlled using the pitch angle controller. The Pitch angle input to the wind turbine is controlled using the pitch angle controller. Thus the output torque from the wind turbine is given to the Two Mass Drive Train model. Thus the Motor Torque (Tm) from the Drive train model is given as the input to the Permanent Magnet Synchronous Generator (PMSG) to generate three phase supply which in turn is rectified using the Bridge rectifier to convert it into DC waveform[13].

Figure 6 represents the two mass drive train model connected between a wind turbine and the Permanent Magnet Synchronous Generator. The Output three phase AC supply is fed to a diode bridge rectifier for the generation of the DC Output which is then fed to the input of the three port converter system. The Wind Energy Conversion System can be realised either through Horizontal Axis Wind Turbine (HAWT) or by using Vertical Axis Wind Turbine (VAWT) [11]. PID controllers can be used along with the wind turbines as they possess the advantages including quick response, high power density and low maintenance [14].

4. SIMULATION RESULTS

The proposed system with two sources as the inputs and one port for the load is simulated using the MATLAB/Simulink software. Figure 7 and 8 shows the output power and voltage waveforms for the proposed hybrid converter system. The motor used for the Wind Turbine is the Permanent Magnet Synchronous Generator (PMSG). Here the net voltage input to the Three Port Converter System is given by the sum of voltages from the Photovoltaic and the Wind Energy Conversion System. The table 3 shows the Circuit

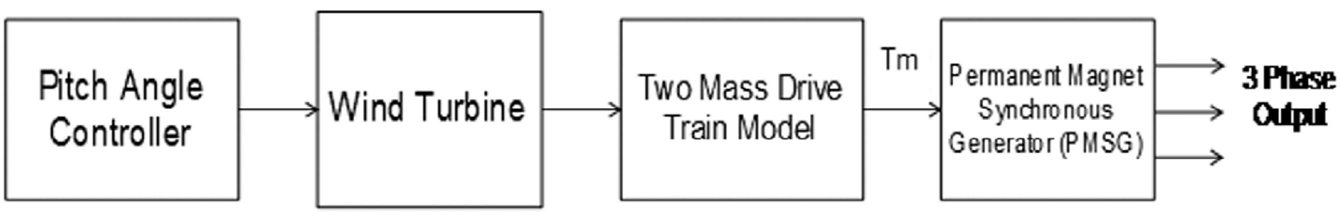

Figure 6: Two mass drive train model

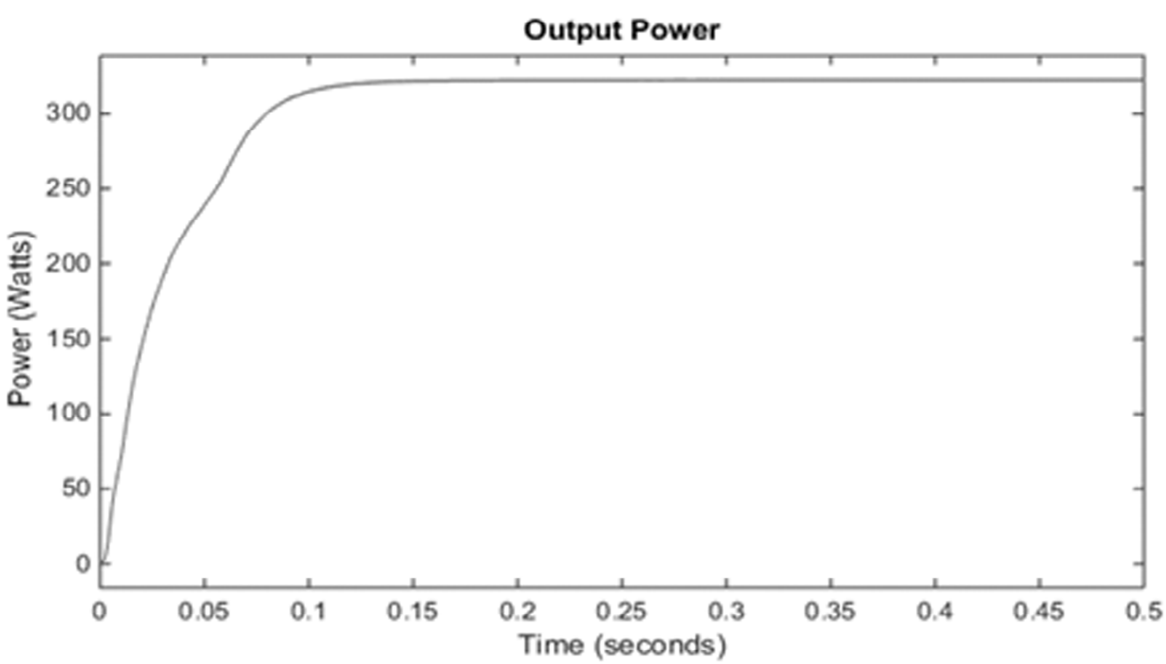

Figure 7: Output Power Waveform of Proposed System

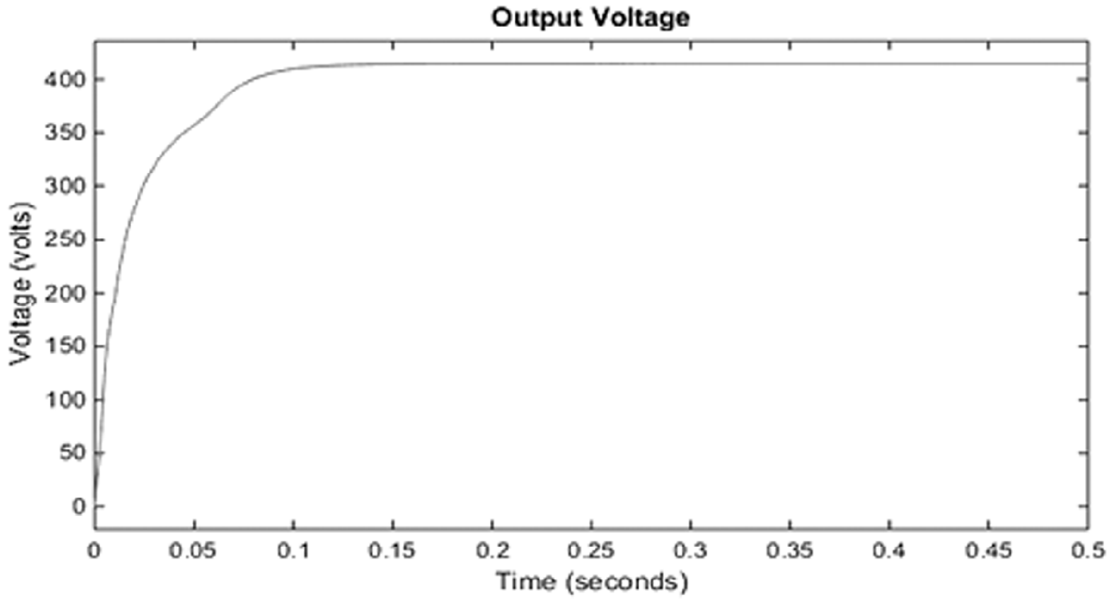

Figure 8: Output Voltage Waveform of Proposed Hybrid Converter System

Table 2
Existing System Parameter Specification

Parameters	*Value*
Voltage from PV Port V_{pv}	24 V
Voltage from battery port V_{bt}	48 V
Load Voltage V_o	400 V
Maximum Output Power across the Load P_o	300 W
Output Current	0.3 A
Switching Frequency fs	50 kHz

Table 3
Proposed System Parameters

Parameters	*Value*
Voltage from PV Port V_{pv}	24 V
Voltage from the V_{wind}	48 V
Load Voltage V_o	415 V
Maximum Output Power across the Load P_o	320 W
Output Current	0.5 A
Switching Frequency fs	50 kHz

Specification of the proposed type of converter system. Thus the Output voltage and the power is improved in compared to the Existing system. The output values obtained from the existing system is shown in the table 2.

The output current of the Proposed Converter with Wind Energy System is also improved compared to the existing system as shown in the table 3.From the Table 2 and Table 3, the voltage, power and the current improved using the wind at the second port can be noted. This proves the feasibility of the proposed type of converter system. The net voltage input to Three Port Converter System is 72 Volts and is boosted to 415 Volts at the Load.

5. CONCLUSION

Thus the Hybrid Three Port Converter System with Photovoltaic and the Wind Energy System is presented. The advantages of the proposed system consists of the Wind Energy instead of the battery. The Proposed System is a kind of the Distributed Energy Resources and is used for the remote area power supply units. Thus the Proposed System has the capability to handle medium to high power applications with better power handling capability. The proposed type of converter systems can also be interfaced with the High Voltage DC Power Transmission systems.

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