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Renewable Energy Based Bidirectional Converter for Grid

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Abstract

This paper presents a Hybrid Photovoltaic and Wind based energy system for power flow management in grid based applications. The power flow is managed effectively by a DC-DC Converter and a multilevel inverter. A Cuk Converter is used as a DC-DC Converter with reduced number of power conversion stages and the multilevel inverter is used for conversion of dc power to ac power and supply it to the grid. The system is simulated using Matlab Simulink and results tabulated. The simulated results have also been verified experimentally with a Hardware implementation.

Keywords: Bidirectional Converter, DC-DC Converter, Grid, Wind Energy System, Cuk Converter, Photovoltaic Energy System.

1 Introduction

Electrical Industry has attained its utmost importance after the growth of Power Electronics Converters. Nowadays, many researches have started to focus on the converters for Power Grid. Power Grids constitute of many devices such as transformers, smart meters, converters, Inverters, renewable

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sources, etc., The Grid has become very popular as it can store power, which is only possible because of Bidirectional Converters. These Bidirectional Converters are so called as they are capable of conduction in both the direction i.e., from producers to consumers and from consumers to producers. Many Bidirectional dc-dc Converters like Boost, Buck-Boost, Luo, and Cuk are being used for these Purposes. Also Renewable Energy Sources serve as an important component nowadays because of the unavailability of fossil fuels. Renewable Energy is the inexhaustible Energy given by Nature. The Efficient use of the renewable energy resources serve to be beneficial in various ways like saving money, less maintenance cost, less pollution, more good effects in environmental aspect, etc., Out of many renewable resources available, Energy conversion from Solar and Wind has become predominant in the past few years. Even though these Energy sources demand a higher Initial or installation cost, their advantages outcome the initial cost as it is a single investment.

2 Related Works

There has been a tremendous increase in the usage of solar and Wind in the last few years by various countries in which India has also become one among the group. Different control Algorithms are used for Bidirectional Converter to transmit power to Grid. The Renewable Energy sources when used for Grid has to be stable but it is highly fluctuating due to Environmental factors. The voltage has to be maintained stable at a nominal level in spite of Environmental issues. A Power management strategy unit for DC Micro grid has been verified experimentally with the selector based control algorithm to maintain stability [1]. A five level Bidirectional Multilevel Converter has reduced the switching losses, Voltage stress and Harmonic distortion. Multilevel Inverters can basically be a Diode-Clamped Inverter, Flying Capacitor or H-Bridged Inverter. The author has proposed a strategy in which the converter can operate in Inverter Mode and Rectifier Mode [2].

The next development seems to be a Bidirectional AC-DC Converter which constitutes of AC-DC Grid Bidirectional Converter and DC-DC Bidirectional Converter. A hysteresis Current Control Algorithm is proposed to improve the power factor and to reduce the Switching losses [3].Like the previous work, two controllers were used, one for the grid operation and

other for Renewable sources. The proposed control algorithm is capable of maintaining the Voltages at the Permissible levels [4].

A fuzzy PI Control System was simulated for the Bidirectional Converter to keep the load in stable operation. So by introducing a fuzzy logic controller, the system had proved to be reliable [5,19]. The author Sergio has made a detailed review on Hybrid Micro grids, its control strategies and certainties related to different types of Batteries. The usage of Electric Vehicle Chargers has been helpful for energy storage [6, 13, 15]. The Bidirectional DC-DC Converter meets the load demand by having optimal power sources from its various sources. The additional power is sent to the Grid and the Battery for storage [7].Energy Management Control is done for small scale micro grids. Even though optimum energy is supplied by means of calculations based on the algorithm the battery and the supercapacitor are isolated from the direct current [8, 9]. The Converter to be connected in series with a Renewable Source can be an Isolated or Non-Isolated or a single stage or Multistage Converter according to the requirement of the application [10]. A Quasi Z-Source Inverter can be used for Buck-Boost Conversion. Mathematical Modelling was done and current to control relation was developed [11]. The Bidirectional Converter can work in charge mode (to charge battery) and in discharge mode (to supply to the Smart Grid).Also sensitivity analysis was done to check the validity [12].The Power flow is managed efficiently by connecting a multi-input transformer with a bidirectional converter with control strategies [14]. A boost Converter is used as a dc-dc converter connecting to the grid and the renewable energy source. Steady state and dynamic response of the controllers have been analysed for high efficiency [16]. Instead of a boost converter a buck and boost converter is made to operate in two modes. The two modes are power transfer from grid to bus and from bus to grid. The converter's duty cycle has been altered with respect to MPPT Controller [17]. The simultaneous power management of Photovoltaic system and Battery is being done efficiently by buck and boost converter [18].

Thus when a renewable Energy Source is connected with a DC-DC Converter, Control Algorithms are used to improve the power factor and increase the efficiency. The work proposed in this paper doesn't include a transformer for boosting operation. As the transformer is not used, the circuit is free from losses. This work comprises of Introduction, related works and System Configuration in Section 1,2 and Section 3. Section 4, 5 and 6 constitutes of Proposed wotk, Simulation, Hardware Implementation and Conclusion respectively.

3 Existing System

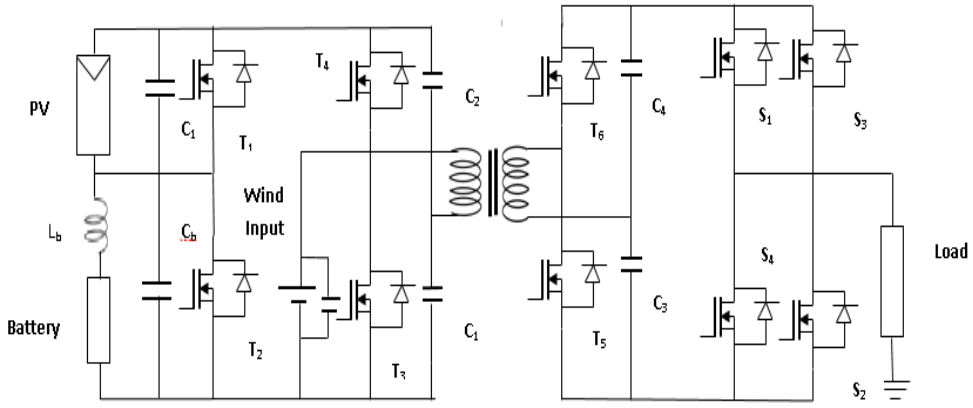

Figure 1 Existing Circuit Diagram

Figure 1 shows the Existing Circuit Diagram in which Solar and Wind Energy Sources are connected to a Bidirectional Buck-Boost Converter and a transformer coupled converter respectively. The output of the transformer is connected to an Inverter and Grid. The transformer Coupled Half-Bridge converter pumps power from the Wind Source whereas Buck-Boost Converter pumps Power from Photo Voltaic Systems.

4 Proposed System

The Figure 2 represents the Block diagram of proposed system. The sources of power are Photovoltaic System and the Wind energy system. A Battery is also Connected in between the renewable sources to store energy.

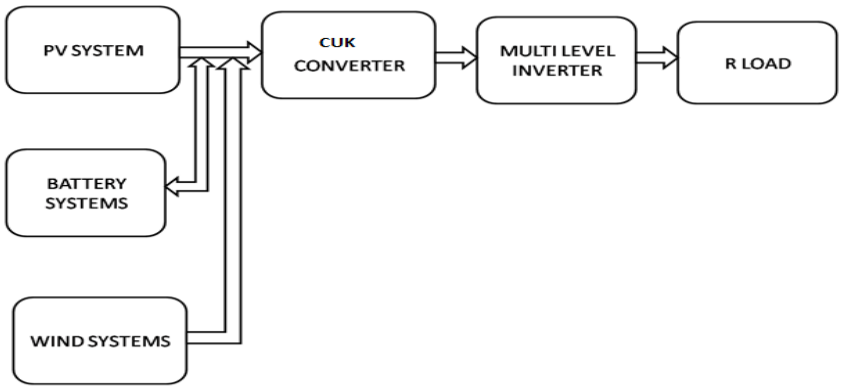

Figure 2 Block Diagram of Proposed System

This is connected to a cuk converter which boosts up the voltage. Then the voltage is fed to multilevel inverter for conversion from dc to ac and then the output is given to the Load or grid.

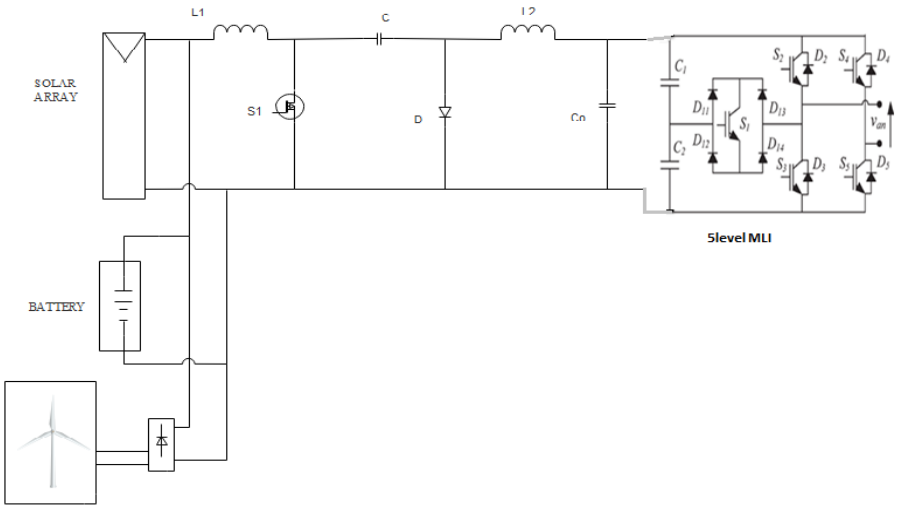

Figure 3 Circuit Diagram of Proposed System

The Figure 3 represents the Circuit diagram of the proposed system. The Proposed system is suitable for household applications. As the proposed system does not have a transformer, the configuration is simple and the cost involved is very less compared with the existing Circuit. As the system is very compact, it can be operated separately wherever required.

4.1 Photovoltaic System

Photovoltaic systems are capable of converting solar energy into electricity. The Photovoltaic System consists of Solar cells, made up of semiconducting material which converts photon energy into power. Almost many countries have started to make a better usage of solar energy, out of which European countries takes the first place. Maximum Power Point tracker is used to deliver maximum power to the converter.

4.2 Wind Energy System

Wind energy Systems constitutes of the Wind turbines which are capable of converting Mechanical energy into Electricity. Wind Energy systems have become popular in the last few years due to its easy operation, cleanliness and abundant availability of the fuel source. Even though its initial installation cost is high, many Countries look at its low maintenance cost.

4.3 Battery

The Renewable energy systems such as Solar and wind are being used in the system. As both these sources are not always available, there is a need for power storage which can be accomplished effectively by a battery. Battery is used not only for storage but also as a charge controller to limit the charge storage in it. In the proposed system, Charge can be stored either from Photovoltaic systems or from wind energy systems or vice versa.

4.4 CUK Converter

Cuk Converter is a type of DC-DC Converter which can act as a step-up or step-down converter. This converter has filters both on input and output side so the output voltage from Cuk converter is always free from ripples. The Converter also as a tank circuit which can also be tuned by varying the resonant frequency. The energy is transferred by means of a capacitor. Figure 4represents the Cuk Converter.

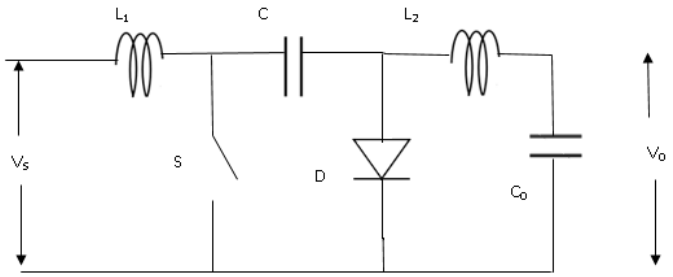

Figure 4 Cuk Converter

$$\frac{V_0}{V_s} = -\frac{\propto}{1-\propto} \quad (1)$$

$$\text{Where } \propto = \frac{T_{ON}}{T} \quad (2)$$

4.5 Multilevel Inverter

Multilevel Inverters are booming nowadays in the power electronics industry due to advantages like

- These are capable of producing higher voltage with low device rating.
- Many voltage levels can be produced.
- Pulse Width Modulation concept is useful for varying the frequency.

Multilevel Inverters are of different types out of which a cascaded H-Bridge Inverter is used in the Circuit.

5 Simulation Results

The figure 5 shows the Simulation diagram of the Bidirectional DC-DC Converter connected with the Grid. The solar system, wind energy system and the battery are connected to the DC-DC Converter whose output is connected to the multilevel inverter. The Inverter is connected to a LC filter which removes the harmonics before feeding it into the grid. As the Grid can be connected to domestic and Industrial Purposes, it is necessary for the Grid to be supplied with a ripple free voltage.

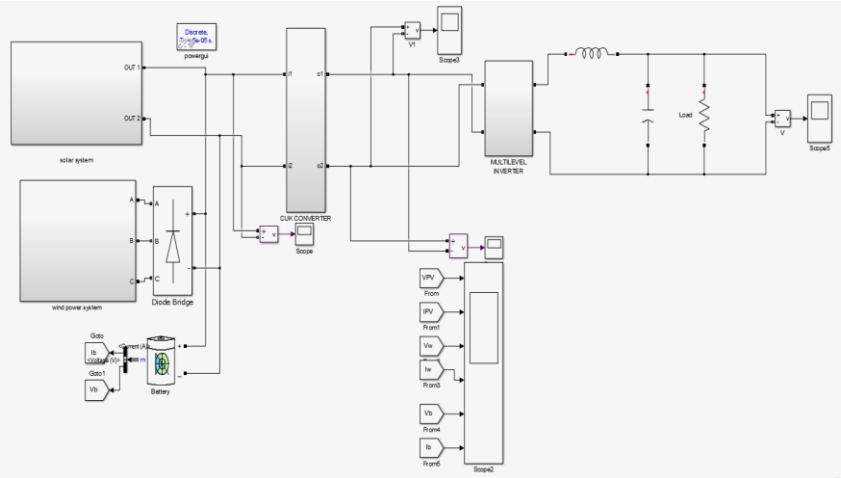

Figure 5 Simulation Diagram

The figure 6 shows the output voltage and output current of the photovoltaic system. It gives an output voltage of 215 v and a current of around 600 milli amperes. The output voltage is a constant dc voltage of 215V but that of current goes on decreasing and settles down around 600 milli amperes. A irradiation level of 1KW/m^2 is being maintained constant for the PV Module. The Voltage from Photovoltaic cell is free from ripples whereas the current has some ripples.

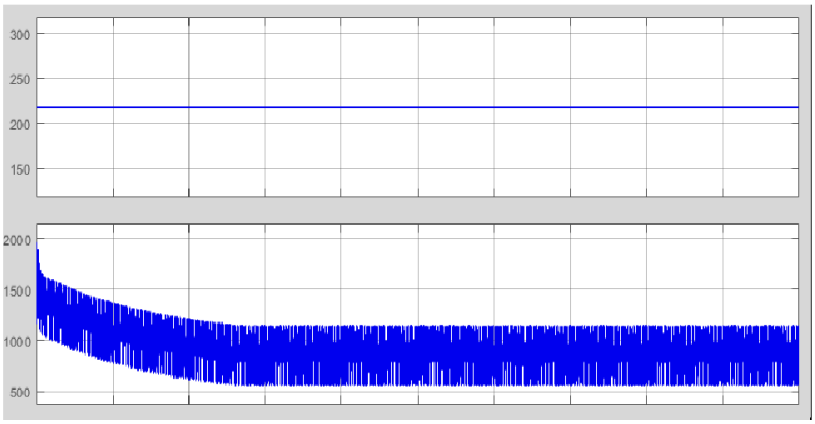

Figure 6 Voltage and Current of PV Cell

The figure 7 shows the Output voltage and output current of Wind energy systems. It gives an Output voltage of around 210V and a output current of around 6milliamperes.The entire simulation is run for about 5 seconds and the outputs observed.

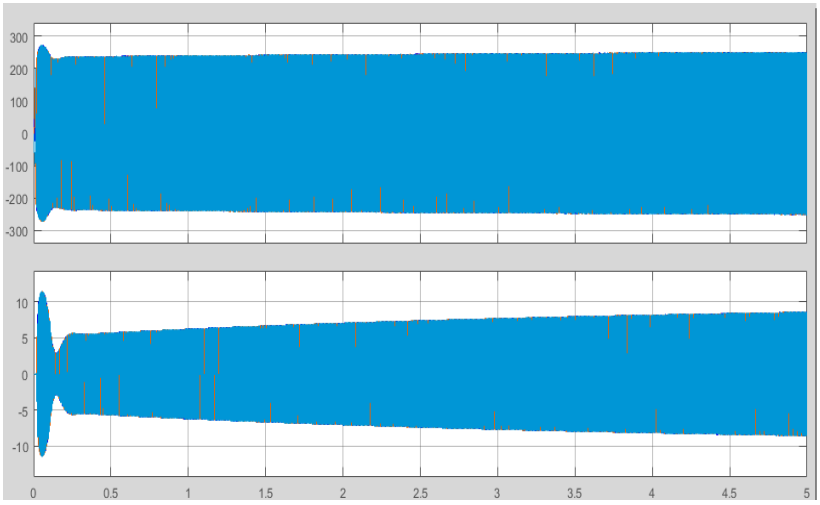

Figure 7 Voltage and Current of Wind

The figure 8 shows the Voltage and Current of the Battery cell.

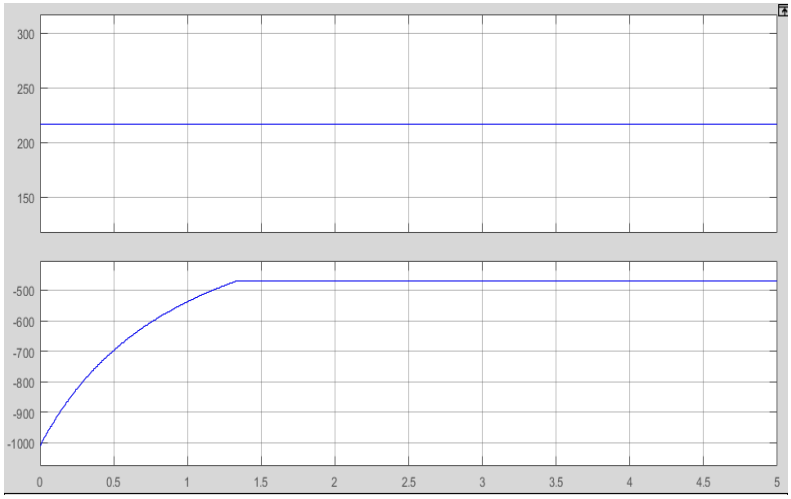

Figure 8 Voltage and Current of Battery

The output from the multilevel inverter is shown in figure 9. It converts the dc voltage from the cuk converter into ac voltage and gives it to the filter. A seven stage output voltage is obtained from the inverter. The LC filter removes out the unwanted disturbances and gives a ripple free voltage at its output end. The output voltage is connected to the Grid, which supplies different loads. LC Filter gives a better ripple free voltage rather than any other filter.

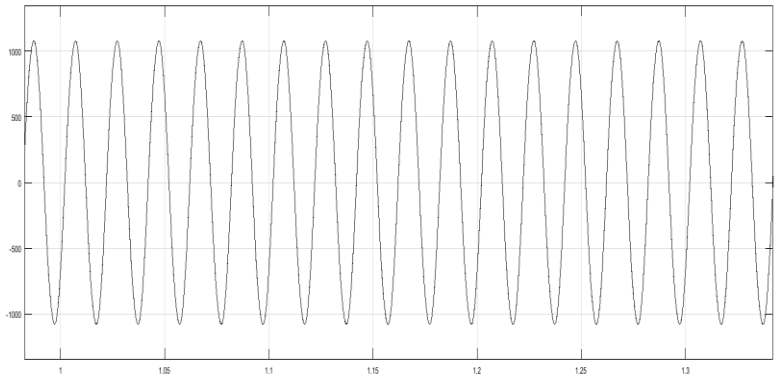

Figure 9 Output of Multilevel Inverter with filter

6 Hardware Implementation

The figure 10 shows the Hardware setup which was done based on the simulation. The hardware consists of a Photovoltaic panel, battery of specification 12V, 3Watts and 12V respectively. The transformer used is a step up transformer with turns ratio of 1:4.The transformer is connected to a Cuk Converter and a 9 level multilevel inverter. A PIC Microcontroller (16F877A) is used to generate 5V and 12V Power supply which is further regulated by IC7805 and IC7812 for giving supply to the diodes and capacitors. A high frequency semiconductor switch, MOSFET (IR2112) is used in DC-DC Converter for Switching on and off the circuit. The load Resistor designed is of a higher value 1Megaohm or otherwise the Voltage drop across the load will be higher.

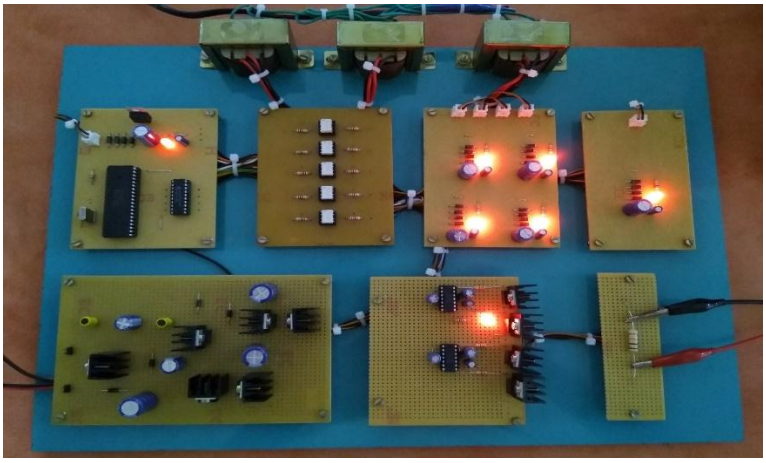

Figure 10 Hardware Implementation

The output voltage obtained was about 13.8 Volts which is a prototype of the simulation. Figure 11 shows the experimental verification of the output voltage.

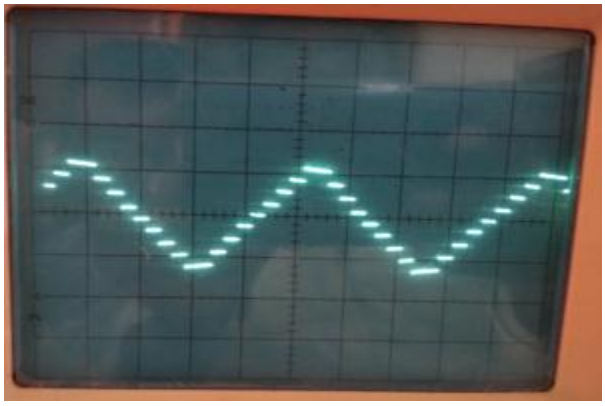

Figure 11 Experimental Verification

7 Conclusion

In this study, a new method of wind-Photovoltaic hybrid power generation has been proposed and implemented. In this system the wind and the solar panel extract the maximum power. The cuk converter is used to reduce the switches and also it acts as a filter for dc supply, it gives a continuous input current by using multi-level inverter harmonics and distortions are reduced. A control power flow management which achieves better usage of solar, wind power and battery capacities without effecting the life of battery and feeds the power to ac load. The proposed system is capable of supplying un-interruptible power to ac load.

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