Design of Modular Flyback Converter for Hybrid Renewable Energy System

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Abstract

Energy scarcity is one of the global issues in day to day life. The demand and consumption are moving head to head which ended up in considerable dependence of non renewable energy resources. The subsequent rise in the price and unavailability of non renewable energy sources aided to rely on the renewable energy resources in order to meet the power demand. Hybrid Energy System is one of the optimal techniques which can be efficiently utilizing the renewable energy resources. As the renewable energy resources depend upon the climatic condition it is difficult to rely upon a single system. In this paper wind and solar Hybrid Energy System is used. The output of the two different energy systems is fed to the modular DC-DC flyback converter in Input Parallel Output Series (IPOS) configuration. The system enjoys the full advantages of modularity like high efficiency and low cost. The flyback converters boost the input voltage from the hybrid energy system. The output of the system is verified using MATLAB/Simulink environment. The stability of the system is also assured due to modularity. The conventional complex powers electronic circuit can be reduced to certain extend. The system efficiency can further improved by using more number of flyback modules and modern control techniques.

Keywords: Configuration, Hybrid, Input Parallel Output Series, Modular, Renewable Energy System

1. Introduction

Renewable energy demand has been steadily increasing for the past few years; however, drawbacks are also associated with it\(^1\). For rural electrification, where grid extension is uneconomic, renewable energy source is a better option. Hybrid Energy System comprises two or more renewable energy sources to provide an efficient and uninterrupted power supply. The advantages of Hybrid Energy System includes minimum environmental impacts, reduced line and transformer losses, high system reliability, improved power quality, relieved transmission and distribution congestion and increased overall efficiency.

Design of Hybrid Energy System is more flexible for future extension. Majority of the renewable source based electricity generation has minimum running cost and easily available in nature. Renewable Energy Resources are intermittent in nature therefore; hybrid combinations of two or more power generation technologies, along with storage can improve system performance\(^2\). In this paper wind and PV systems are connected together in parallel and fed to a modular DC-DC flyback converter in Input Parallel Output Series configuration.

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2. Solar-wind Hybrid Energy System

Hybrid Energy Systems are those that use more than one energy resources. For the generation of electricity wind-solar system has many advantages. In case of solar-wind hybrid system the chance of interruption of electric power is very less. A hybrid arrangement of combining the power from wind and sun are stored in a battery and can be used when there is no wind or sun. However solar and wind energy technology depends on the condition of climate, weather and location. Wind velocity is relatively small in summer season, but irradiation from sun is very strong which is suitable for solar energy production. In the winter season, the velocity of wind is relatively high and sunny days are shorter. Efficiency of renewable energy systems are varying throughout the year. It is needed to support the systems with each other to sustain continuity of the energy production in the system. The diagram of wind-solar hybrid system with DC bus is shown in Figure 1.

The solar panels convert the energy from sun to electrical energy. In solar panels Photovoltaic cells are used, which is made up of silicon or germanium semiconductor materials. Sun rays are absorbed by this materials and electrons are emitted, which results in electric current. In order to obtain high power, large number of Photovoltaic cells are connected in series and in parallel on a module. The solar panel or array is a group of several modules that are connected electrically in series parallel combination to generate required voltage and current. Solar energy is present on the earth continuously and in abundant manner. Solar energy is freely available in nature. It’s advantages include it’s low initial and maintenance cost. The only disadvantage is, it cannot generate electricity in bad weather condition. But it has greater efficiency than other sources. It has long life span and lower emission.

Wind energy system provides an eco-friendly power generation. It includes wind turbines, control systems, generators, power conditioning devices and interconnection apparatus.

Figure 1. Wind-solar hybrid energy system.
3. Modular Flyback Converter in IPOS Configuration

In an Input Parallel Output Series configuration the number of required modules and type of converters depends on the application. Each module of converters controls its own output voltage. The sharing of output voltage and input current can be easily achieved. The input current and output voltage are equal by control while input voltage and output current is equal by connection in Input Parallel Output Series configuration. This control approach produces accurate input voltage and output current sharing even in the face of component mismatch among the multiple converters.

The commonly used Switched Mode Power Supply (SMPS) circuit is flyback converter. The flyback converter is a buck-boost converter with an isolation transformer. Voltage and current mode control are two control schemes for flyback converter. Both these control scheme require a signal which is related to the output voltage. The modular flyback converter can operate over a wide range of input voltage variation and can offer single or multiple isolated output voltages. The low cost and simplicity makes flyback power supplies popular in low output power range and while considering energy efficiency, it is inferior to other SMPS circuits. Modular flyback converter in IPOS configuration is shown in Figure 2.

![Figure 2. Modular DC-DC converter in IPOS configuration.](image-url)
4. Proposed Hybrid Renewable Energy System with Modular Converters

In hybrid renewable energy system power electronics plays a vital role for transferring the electric power generated to grid. In Photovoltaic system switch mode converters are used for the conversion of DC output obtained from PV module to required level. There are two types of PV systems, on-grid and off-grid PV systems. In order to maximize the performance of the system, Maximum Power Point Tracker (MPPT) controller is used for DC-DC converter. For wind energy system also different types of designs are available.

In this paper, solar and wind hybrid renewable energy system are used as shown in Figure 3. The Photovoltaic system used is on grid type that operates without batteries for storage purposes. In wind energy system permanent magnet synchronous generator is used which generates AC voltage. This alternating voltage is converted to DC by using a three phase rectifier. The output of the hybrid system is connected in parallel. The parallel connection ensures continuous supply of electric power during any climatic conditions. The parallel output is connected to a modular flyback converter that uses two modules of converters connected in Input Parallel Output Series configuration. This configuration ensures equal sharing of input voltage in both modules. The flyback converter boosts the voltage to desired level. The series connection of converters adds up the output voltage in two converters. The output of the modules then fed to a rectifier which convert the DC to AC and finally to utility grid.

5. Simulation Analysis

The configuration chosen to verify with two flyback converters in input parallel and output series connections. The simulation has been verified using MATLAB/Simulink program with the circuit parameters shown in Table 1.
### Table 1. Design parameters

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Parameter Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output voltage of solar energy system</td>
<td>45 V DC</td>
</tr>
<tr>
<td>Output voltage of wind energy system</td>
<td>45 V DC</td>
</tr>
<tr>
<td>Output voltage of hybrid energy system</td>
<td>45 V DC</td>
</tr>
<tr>
<td>Input voltages of converter I and II</td>
<td>45 V DC</td>
</tr>
<tr>
<td>Output voltages of converter I and II</td>
<td>100 V DC</td>
</tr>
<tr>
<td>Inductor value of converter I and II</td>
<td>66 µH</td>
</tr>
<tr>
<td>Capacitor value of converter I and II</td>
<td>150 µF</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>100 kHz</td>
</tr>
<tr>
<td>Turns ratio</td>
<td>2.33</td>
</tr>
<tr>
<td>Output voltage of modular flyback converter</td>
<td>200 V DC</td>
</tr>
</tbody>
</table>

Figure 4. Output voltage of solar energy system.
The graphs obtained from MATLAB/Simulink environment are shown below:

The output voltage of the solar system is shown in the Figure 4. The output of the system is a pure DC wave. The

Figure 5. Output voltage of wind energy system before rectification.

Figure 6. Output voltage of wind energy system before rectification.
The output voltage using wind energy is shown in Figure 5. The output voltage of the system is AC waveform since permanent magnet synchronous generator is used. The output voltage is 60 V peak to peak. This AC voltage will be rectified to obtain DC voltage.

The output voltage obtained from the wind energy system is AC voltage. It is rectified to DC voltage as shown in Figure 6. The output is settled to 45 V steady DC after the transient period. The transient period is found to be 0.2 seconds. The output voltage obtained from the solar energy system is rectified DC voltage. The output voltage obtained from the wind energy system is AC voltage, which is then rectified to obtain DC voltage. The solar energy system output is integrated with the wind energy system output after rectification, i.e. its output is connected in parallel. The hybrid system should be in proper synchronization. The output voltage of Hybrid Energy System is shown in Figure 7.

The two DC outputs obtained from the solar energy and wind energy systems is combined and fed to the modular flyback converter. It contains two modules. That is, module I and module II respectively. The input voltage which has to be given to the two modular flyback converters in IPOS configuration is shown in the Figure 8. The input voltages for modules I and II are shared equally since it is an Input Parallel Output Series configuration. The input currents of the first and second modular flyback converter are shown in Figures 9 and 10 respectively. The input current of converter I is 9A while for converter II it is around 4.5A respectively and is settled at 0.2 seconds after transients.

Figure 7. Output voltage of hybrid energy system.
Figure 8. Input voltage of modular converters I and II.

Figure 9. Input current of converter I.
The two DC outputs obtained from the solar energy and wind energy systems are fed to the two modular flyback converters. The output voltages obtained from the two modules are shown in Figure 11. The output voltage obtained has been found to be boosted. Output is steady DC voltage having a value of 95 V after the transient period of 0.2 seconds.
The output current of the first and second modular flyback converters are shown in the Figures 12 and 13. Both are shared equally since it’s an IPOS configuration. The output current of the modular flyback converter connected in IPOS configuration is shown in Figure 14. The current value is found to be 1.9 A. The output voltage of the modular flyback converter connected in IPOS configuration for Hybrid Energy System is shown in Figure 13.

Figure 12. Output current of converter I.

Figure 13. Output current of converter II.
Figure 14. Output current of modular converter in IPOS configuration.

Figure 15. Output voltage of modular converter in IPOS configuration.
15. The voltage obtained is double the input voltage. It is a steady DC voltage after a transient period of 0.2 seconds. The output voltage is found to be 190 V DC.

6. Conclusions

The power electronics used for Hybrid Energy Systems (HES) are subjected to extensive research for efficient converters and control strategies. This paper gives an overview of wind and solar Hybrid Energy Systems (HES). The power conditioner used is modular flyback converter which is less complex than conventional type hybrid systems and has full advantages of modularity. The Input Parallel Output Series (IPOS) configuration ensures the equal sharing of both voltages and currents among the two modules of flyback converters. By optimizing and synchronizing solar and wind energy systems by using high performance power electronic devices, the reliability of the system can be improved and unit cost of electric power can be reduced. The simulation and experimental results verify the operation and shows voltage and current waveforms.

7. References