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Design of High Step up Modified Model for Hybrid Solar/Wind Energy System

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Abstract: Renewable energy resources are the most expected and the important field to overcome the large power demand in the world, especially in the developing countries. In recent years, solar-wind hybrid system has turn out to be the most promising and significant sources of renewable energy with a safe maintenance of system voltages and reliability. This combination overcomes the discontinuous nature of wind and solar energy sources, when one source is not available for power generation, another source can be used. In this paper, the solar-wind renewable sources are designed with the proposed modified converter to increase the power generation and the efficiency of the system. The proposed converter can operate simultaneously or individually, so it can accommodate the hybrid renewable energy variation under different atmospheric conditions. Since proposed converter is operated in interleaved mode, improved performance can be achieved. In the proposed converter high step up voltage can be obtained by recycling the stored energy in the leakage inductance. Maximum Power Point Tracking (MPPT) is used to draw maximum power from PV module and wind turbine. The result proves the feasibility and functionality of the proposed converter.

Key words: Hybrid Wind/PV system · Proposed converter · Maximum Power Point Tracking · High step up voltage

INTRODUCTION

In recent years the electrical energy demand has increased remarkably with growing industrial progress and population. For long time fossil fuels have been used as a major source for electrical energy generation. The limitation of these resources made it necessary to gain from new energy sources like renewable and nuclear energies. The generation, transmission and distribution of energy in the current method cannot meet out the requirement of consumers. In conventional method the losses in transmission line, poor power quality and improper voltage regulation are the major problems faced by consumers. The rapid electricity constraints and worse energy crisis made fossil fuels to be replaced with renewable energy resources. Among the renewable energy resources, Wind and Solar energy has turned much attention due to easy acquirement. In wind or photovoltaic (PV) power generation system, to process the renewable energy sources power converter is required [1-2].

The PV uses semiconductor material for electricity conversion and they directly produce electricity when sunlight interacted with semiconductor materials. Various power converters for PV were proposed [3-7]. Similarly for wind energy conversion system various converters were proposed [8-12]. But these converters can’t deal with multi input, since it can handle only renewable energy of single kind. This makes researchers to propose multi-input converters for hybrid power generation system. Series double-boost converter is proposed to process the PV-wind energy concurrently [13, 14]. While comparing with single boost converter, only one-half of power rating is imposed by power components. Even though voltages are stepped up in the boost type of converter and appropriate for supplying high voltage, it is not suitable for isolated applications. So double input buck boost converter were proposed, which is able to process low/high voltage sources [15]. This kind of converter is still non-isolated like boost type of converter. A magnetic flux based multi input converter is also proposed, but its control is complicated with complex structure. The power

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stage design is simplified by proposing forward derived configuration, but energy cannot be trapped in the leakage inductor and to the application of high voltage output this method is incapable [16, 17]. In this paper enhanced high step up multi input converter is proposed, which deal with wind turbine and PV power simultaneously. In this proposed converter energy leakage inductance are recycled and voltages are stepped up. Comparing with the conventional converters, the proposed converter has simple structure without third winding. The result obtained from the proposed converter will be highly efficient with significantly stepped up output voltage.

WIND/PV Hybrid System Structure: With rising concern of global warming and reduction in fossil fuel reserves, many researchers were looking for sustainable solution for future generation. To meet our energy demands, PV and wind energy were the most potential resources. The general representation of hybrid system is shown in Figure 1. The hybrid system is divided into three main stages. First stage is a power generation which comprises of wind and PV system. The second stage is energy storage and conversion system, which includes DC/DC converter for photovoltaic system and for wind generation system AC/DC converter is used and in the DC bus the DC/AC inverter is connected to supply AC power of 440V to the load. Final stage is a grid, where energy demand of 60% is supplied by the hybrid system.

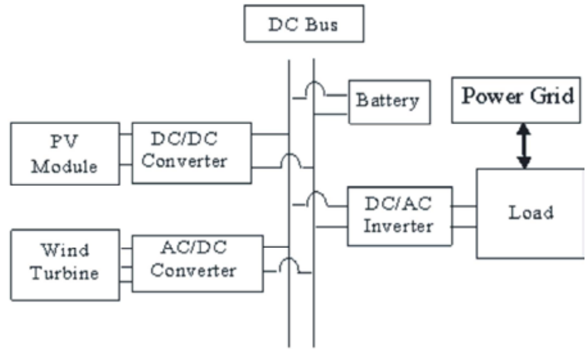


Fig. 1: Wind/Pv Hybrid System Structure

Proposed Converter Configuration: The schematic of the proposed converter with PV array and wind turbine is shown in Figure 2.

The proposed high step up converter is composed of modified upper double ended forward, modified lower double ended forward, system controller and output filter *L*.

The modifiedupper double ended forward deals with the wind energy, while the lower double end forward deals with solar power. Both the optimized double ended forwards can be independently operated, which increases the control freedom. The upper or the lower forward active switches are synchronously switched, so as to release the inductance energy and to trap the leakage energy. C_w and C_p are the secondary winding capacitors which will absorb the magnetizing inductance energy and then can boost

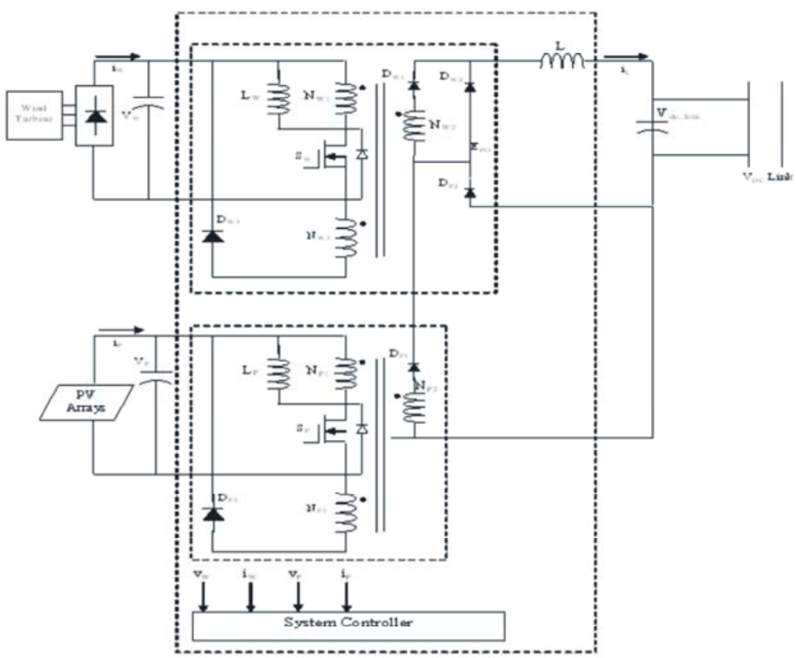


Fig. 2: Proposed converter for wind/PV hybrid systems

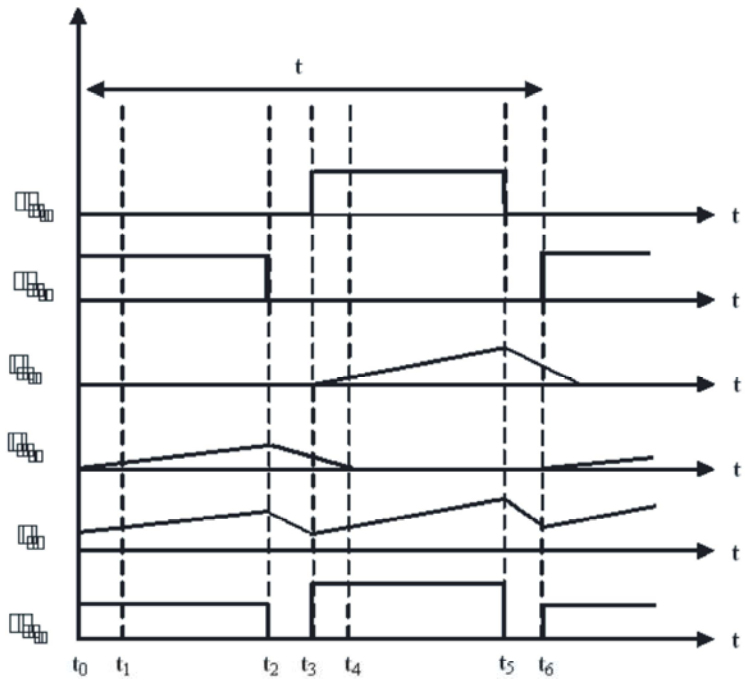


Fig. 3: Proposed converter key waveforms

the voltage output. The control signal is determined by the system controller to perform the power controlling output and Maximum Power Point Tracking (MPPT).

Modes of Operation: The proposed converter can individually operate to deal with wind energy and PV power. To lower the volume of output filter and to achieve the improved output performance, the switches S_w and S_p are alternatively turned on with less than 0.5 duty ratio at same switching frequency. The conceptual key waveforms are shown in Figure 3. According to the switches S_w and S_p conduction status, the operation of the proposed high step up multi input converter can be divided into six main modes.

Mode 1: During the mode interval $(t_0 \leq t, < t_1)$, the switch S_w is ON, but the switch S_p is in OFF state. When the switch S_w conducts at t_0 this mode begins. The active switch S_p is in OFF state and the lower modified forwarded magnetizing inductor discharges energy. In the meantime wind power is forwarded to the output. So i_L is built linearly and this mode ends when magnetizing inductor current L_p drops to zero.

Mode 2: In this mode $(t_1 \leq t < t_2)$, S_w continuously conducts, meanwhile D_{p2} and D_{w1} are turned ON and i_L keeps increasing as represented below,

$$i_L(t) = \frac{1}{L}\left(v_W \frac{N_{w_2}}{N_{w_1}} - v_{dc}\right) + i_L(t_0)$$

Mode 3: In this mode $(t_1 \leq t < t_2)$, all switches which are active are in OFF state. The switch S_w is turned OFF at time t_2 and the lower forward switch S_p still stays in OFF state. The energy stored is released to the load by output inductor L. The sum of cut-in voltages D_{p2} and D_{w2} are equal to voltage v_{po}. In this interval, the output inductor current changes can be determined.

Mode 4: In this mode $(t_3 \leq t < t_4)$, the switch S_p is turned ON at t_3 and thus photovoltaic energy is dealt with modified lower forward. The inductor current i_L linearly increases and the inductor L_w discharges. This mode ends when current flowing through L_w equals zero.

Mode 5: In this mode $(t_4 \leq t < t_5)$, i_L continuously increases and the switch S_p remain in ON state. Diodes D_{p2} and D_{w3} are OFF, while the diodes D_{p1} and D_{w2} are ON. The voltage reversed across the diode D_{p2} is $v_{D,P_2} = \frac{N_{P_2}}{N_{P_1}} v_P$, where v_p is the PV array terminal voltage.

Mode 6: In this mode $(t_5 \leq t < t_6)$, switch S_w is turned OFF at time t_5 and the operation of the proposed converter enters into this mode and to the capacitor C_p the magnetizing inductor L_p releases its energy.

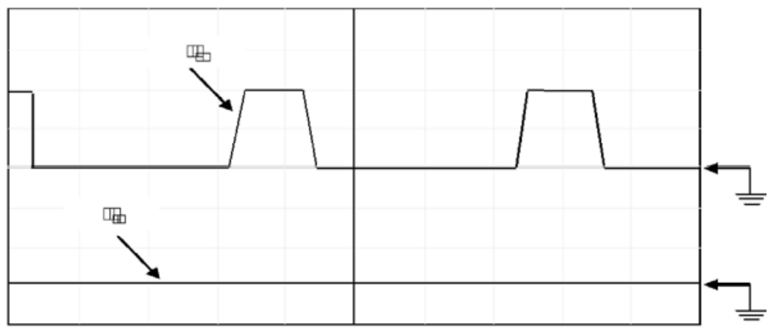
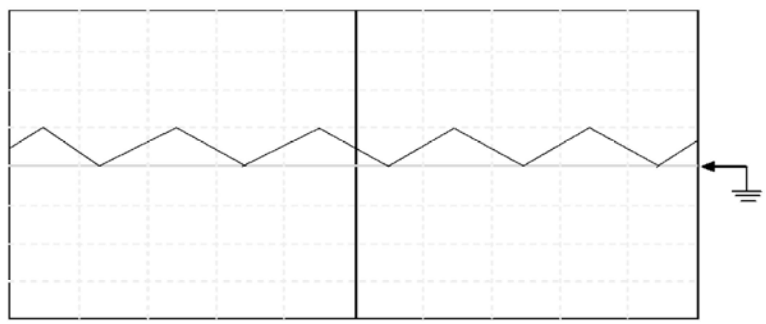
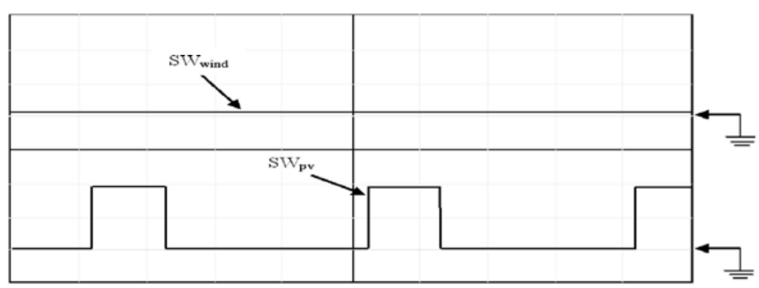


Fig. 4: Control signal of wind turbine



(Current: 5A/div, time: 10μs/div)

Fig. 5: Inductor current output of wind turbine



(Voltage: 5V/div, time: 5μs/div)

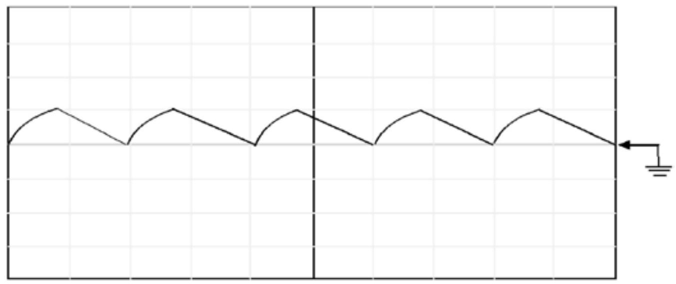
Fig. 6: Control signal of PV module

Meanwhile the current i_L linearly decreases. At t = t_6, the switching cycle is completely terminated and S_w is again turned ON. To draw the maximum power from wind and PV array, the perturb-and-observe method is employed in the proposed converter.

Simulations Result: To verify the operating behavior of the proposed system, detailed evaluation and the entire simulation is carried out on SIMULINK.The simulation of the proposed converter is demonstrated in this section. The evaluation of active switch signals and the corresponding output inductor current for the wind turbine is shown in Figure 4 and Figure 5.

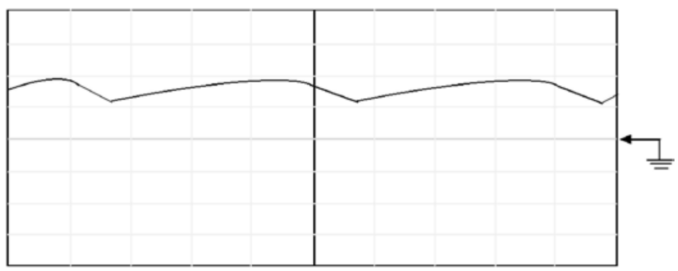
The maximum power can be drawn from the proposed upper modified double-ended forward of wind turbine. The measured result of active switch signals and the corresponding output inductor current for the PV module is shown in Figure 6 and Figure 7. The obtainedresult proves the capability of the proposed system dealing wind turbine and PV module individually.

The simulation of output inductor current and control signal of proposed wind turbine and solar hybrid system is shown in Figure 8 and Figure 9.The lower and upper trace of switch current is drain to source currents of S_p and S_w respectively. The result proves that the proposed converter not only process wind and PV power, the



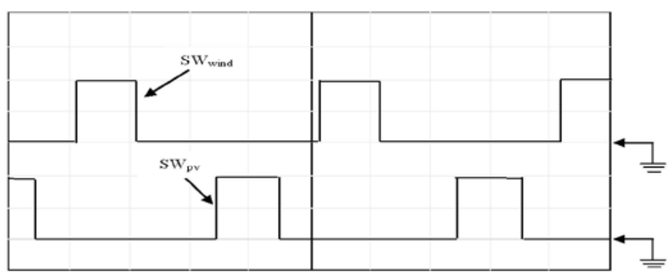
(Current: 5A/div, time: 10μs/div)

Fig. 7: Inductor current output of PV module



(Current: 2A/div, time: 2.5μs/div)

Fig. 8: Inductor current output of hybrid Wind-PV system



(Voltage: 5V/div, time: 5μs/div)

Fig. 9: Control signal of hybrid Wind-PV system

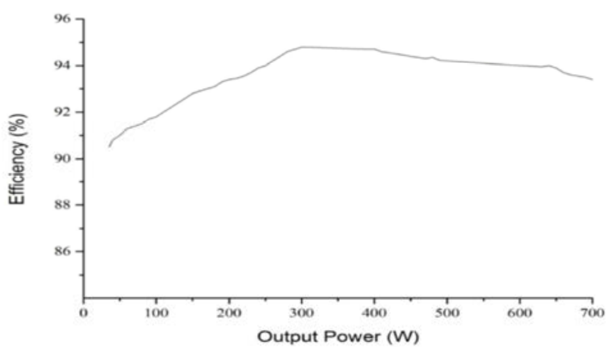


Fig. 10: Proposed converter efficiency

current ripple suppression can also be obtained by operating in interleaved mode. The output inductor current ripple is double the switching frequency as shown in Figure 8, this results in requirement of only lower volume for the output filter inductor. Figure 10 shows the efficiency of the proposed converter. From the result obtained we can conclude that the proposed converter can support simultaneous or individual operation more effectively.

CONCLUSION

This paper proposed an optimized converter to deal with solar power and wind turbine with maximum power point tracking characteristics. The proposed converter integrates two series forward conductor and one output inductor, which can able to process wind energy and PV power individually or simultaneously under different atmospheric conditions. The proposed converter can lower the converter volume by not having the separate converters. The output current ripple is significantly suppressed, since the proposed converter can be operated in interleaved mode. The stored energy can be recycled in leakage inductor. The result proves the feasibility of the proposed optimized converter.

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