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PV based High Boost Ratio DC-DC Converter with BLDC Motor Drive Control

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Abstract: This paper focuses on wide input range and voltage applications with a high boost ratio dc-dc converter utilizing the Brushless DC Motor (BLDC). Due to higher efficiency and easy control strategies of Brushless DC Motor (BLDC), the controller leads to improve the behavior of the motor. By the cooperation of proposed converter with a hybrid transformer, the energy transfers continuously which lead to achieve an high boost ratio. This converter transfers the capacitive and inductive energy simultaneously to increase the total power delivery reducing losses in the system. The conduction losses in the transformer and MOSFET are reduced as a result of low-input RMS current and switching loss is reduced with a lower turn-off current. The Proportional and integral (PI) Controller used is functioning based on the technique known as Pulse Width Modulation (PWM). Finally, the simulation has been carried out using MATLAB/Simulink and the performance has been studied

Key words: Brushless DC Motor (BLDC) · High boost ratio dc–dc · Hybrid transformer · Proportional and integral (PI) Controller · High efficiency · Photovoltaic (PV) module

INTRODUCTION

Now a days we are facing a major threat of global warming, fast depletion of the fossil fuel reserves and limited amount of non-renewable energy resources, there is an increasing demand of utilization of renewable energy sources such as PV modules is more important in day to life. The demand for alternative energies has grown for several years. With this demand more efficient technologies have been explored. Distributed generation is becoming more common as a benefit of producing power near the desired load becomes clear. Solar panels are attractive distributed generation sources. Photovoltaic (PV) cells are environmentally friendly but produce a low voltage that is not compatible with the electric grid and common appliances. This means that the power must first be converted into a higher voltage and then inverted to an AC voltage. Power extracted from the panel is not constant always; it varies with atmospheric conditions via; irradiance and temperature. Also, the PV voltage is prone to fluctuations due to variables like shading and angle of the sun. In order to extract maximum and constant power from the system a control circuit is needed between PV panel and load. By adopting the appropriate technology for the concerned geographical location, we can extract a large amount of power from solar radiations. The power from PV module into existing power distribution infrastructure can be achieved through power conditioning systems (PCS) as shown in Fig.1. Typical PCS consists of a dc –dc converter requires a high boost ratio to increase the low dc input voltage from the PV panel to a higher dc voltage.

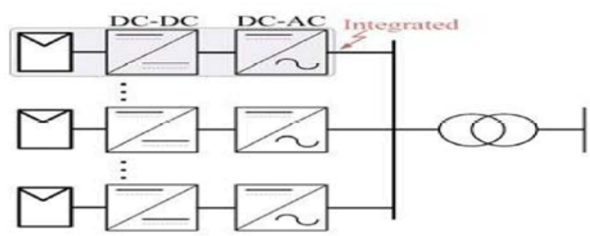

Fig. 1: Two level Photovoltaic module integrated micro inverter

The dc–dc converter in the power conditioning systems can be isolated or non isolated; however, transformer-isolated converters are less efficient and more expensive due to the increased manufacturing costs. For a two-stage PCS a nonisolated dc–dc converter with a high boost ratio would be advantageous because it can be easily integrated with current PV systems. From the PV panel we are getting the different output voltages, therefore to have a system with a high efficiency over the entire PV voltage range to maximize the use of the PV during different operating conditions is advantageous.

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Another important function of the dc–dc converter for PV applications is being able to implement maximum power point tracking (MPPT). The ability to implement MPPT for an individual PV panel would ensure that a large cluster of PV could maintain maximum power output from each panel without interfering with the other panels in the system. The major consideration for the main power stage of the converter in being able to implement an accurate MPPT is that the input current ripple of the converter has to be low. So in this converter contains an hybrid -transformer to transfer inductive and capacitive energy simultaneously to increase the total power delivery reducing losses in the system. The conduction loss in the transformer and MOSFET is reduced as a result of low-input RMS current and switching losses is reducing with a lower turn-off current. Because of this features the output power becomes higher as compared to normal boost converter.

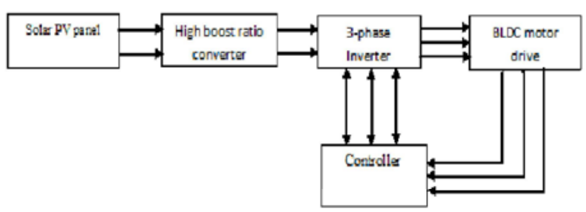


Fig. 2: Block diagram

Thus, it deals with a high boost ratio hybrid dc-dc converter fed brushless dc motor (BLDC) motor drive control to achieve a high system level efficiency over wide input voltage and output power ranges. Due to the introduction of the resonant portion of the current the turn off time current of the switch is reduced.In addition of the resonant capacitor to transfer the energy to the output side of the converter, all the voltage stresses of the diodes are kept under the output dc bus voltage and independent of the input voltage.

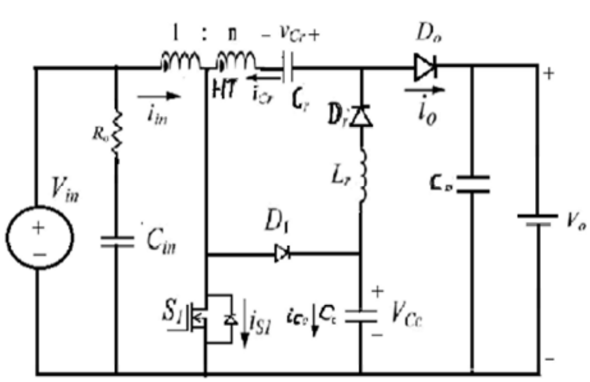


Fig. 3: Proposed high step-up dc/dc converter with hybrid transformer

Proposed Converter Topology and Operation Analysis: Figure 3 shows the circuit diagram of the proposed converter. C_{in} is the input capacitor; Rin is the input resistance; HT is the hybrid transformer with the turns ratio 1:n; S1 is the active MOSFET switch; D1 is the clamping diode, which provides a current path for the leakage inductance of the hybrid transformer when S1 is OFF, Cc captures the leakage energy from the hybrid transformer and transfers it to the resonant capacitor Cr by means of a resonant circuit composed of Cc, Cr, Lr and Dr ; Lr is a resonant inductor, which operates in the resonant mode; and Dr is a diode used to provide an unidirectional current flow path for the operation of the resonant portion of the circuit. Cr is a resonant capacitor, which operates in the hybrid mode by having a resonant charge and linear discharge. The turn-on of Dr is determined by the state of the active switch S1. Do is the output diode similar to the traditional coupled-inductor boost converter and Co is the output capacitor. The load specified in the circuit is BLDC drive with three phase inverter. Fig. 4 illustrates the five steady-state topology of the proposed converter with one switching cycle.

Modes of Operation: The modes of operation of the High boost ratio dc-dc converter fed Brushless DC motor drive (BLDC) has discussed briefly as follows;

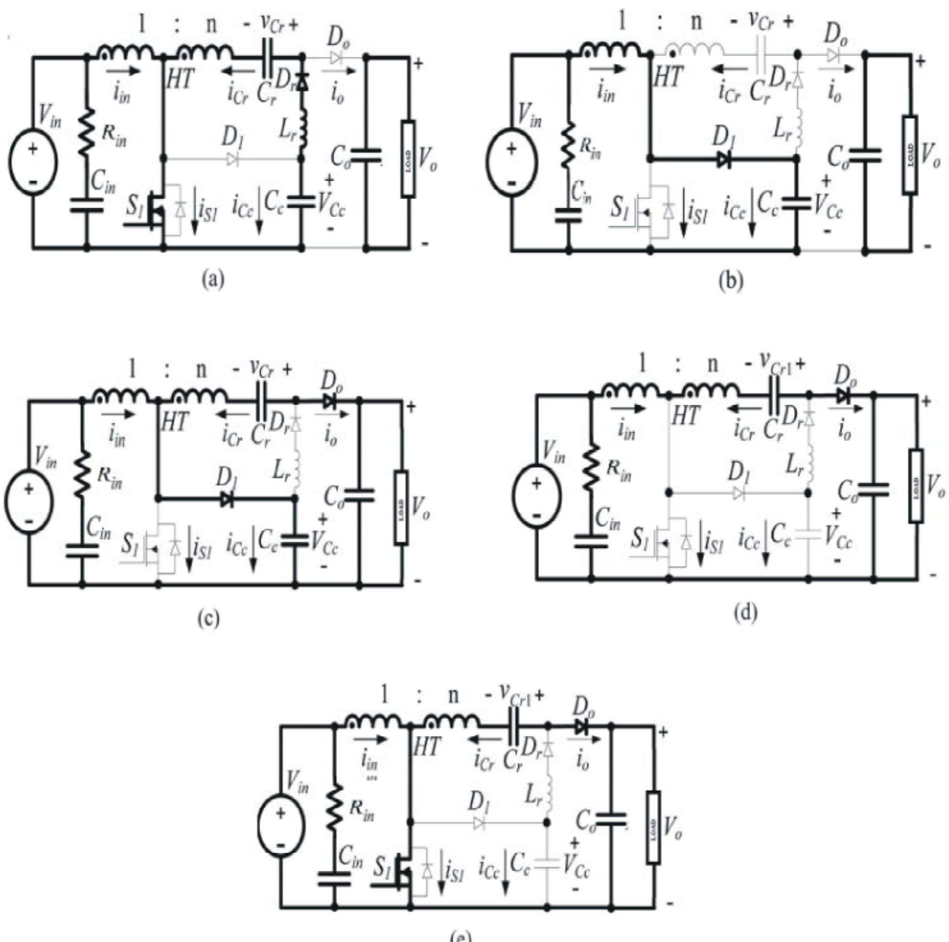
Mode 1: *[t0,t1], [see Fig. 4(a)]:* In this period, MOSFET *S*1 is ON, the magnetizing inductor of the hybrid transformer is charged by input voltage, *Cr* is charged by *Cc* and the secondary-reflected input voltage *nV*in of the hybrid transformer together by the resonant circuit composed of secondary side of the hybrid transformer, *Cr*, *Cc*, *Lr* and *Dr*. The energy captured by *Cc* is transferred to *Cr*, which in turn is transferred to the load during the off-time of the MOSFET. The current in MOSFET *S*1 is the sum of the resonant current and linear magnetizing inductor current as shown in Fig. 5. There are two distinctive benefits that can be achieved by the linear and resonant hybrid mode operation. The first benefit is that the energy is delivered from source during the capacitive mode and inductive mode simultaneously. Compared to previous coupled-inductor high boost ratio dc–dc converters with only inductive energy delivery, the dc current bias is greatly reduced, decreasing the size of the magnetic. Second, the turn off current is decreased,which causes a reduction in the turn-off switching losses.

Mode 2: *[t1,t2], [see Fig. 4(b)]:* At time *t*1, MOSFET *S*1 is turned OFF, the clamping diode *D*1 is turned ON by the leakage energy stored in the hybrid transformer during the time period that the MOSFET is ON and the capacitor *Cc* is charged which causes the voltage on the MOSFET to be clamped.

Mode 3: *[t2,t3], [see Fig. 4(c)]:* At time *t*2, the capacitor *Cc* is charged to the point that the output diode *Do* is forwarded biased. The energy stored in the magnetizing inductor and capacitor *Cr* is being transferred to the load and the clamp diode *D*1 continues to conduct while *Cc* remains charged.

Mode 4: *[t3,t4], [see Fig. 4(d)]:* At time *t*3, diode *D*1 is reversed biased and as a result, the energy stored in magnetizing inductor of the hybrid transformer and in capacitor *Cr* is simultaneously transferred to the load. During the steady-state operation, the charge through capacitor *Cr* must satisfy charge balance. The key waveform of the capacitor *Cr* current shows that the capacitor operates at hybrid operating mode.

Mode 5: *[t4,t0], [see Fig. 4(e)]:* The MOSFET *S*1 is turned ON at time *t*4. Due to the leakage effect of the hybrid transformer, the output diode current *io* will continue to flow for a short time and the output diode *Do* will be reversed biased at time *t*0 ; then the next switching cycle starts.



HT- Hybrid transformer
Cr-resonant capacitor
Lr-resonant inductor
Cc-clamp capacitor
Do-output diode
Dr-resonant diode
D1-clamped diode

Fig. 4: Topological stages (a)t0,t1 (b)t1,t2 (c)t2,t3 (d)t3,t4 (e)t4,t0

Controller Analysis: A controller used in the proposed topology of high boost ratio dc-dc converter fed brushless DC motor (BLDC) drive is proportional and integral controller. Generally, the PI Controller is functioning based on the technique known as Pulse Width Modulation (PWM). Therefore, two controllers are incorporated in general (ie) PI controller for speed control and P controller for current control. The feedback measures the actual speed and subtracted from reference speed and error is given as input to the speed PI controller and output of the PI is subjected to current limiter.The current reference from which actual current is subtracted and error is given input to the current P controller. This output of the PI is the dc value that is compared with a continuous triangular pulse of 40 kHz.

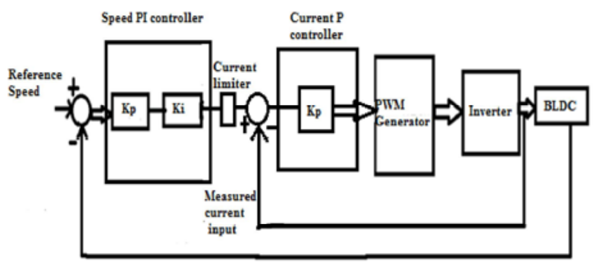


Fig. 6: Closed loop PI for speed control

The output is anded with gate pulse to produce a pulse modulated wave, which triggers the inverter to generate required voltage to maintain the speed at varying load torques and also speed reference conditions. Thus, a closed loop PI speed controller for Brushless DC motor which provides higher efficiency and leads the behavior of the dc motor efficiently.

Simulation Results and Discussion: In order to verify the effectiveness of the proposed High boost ratio converter fed with Brushless dc drive control, used for various commercial applications that has been showed in the block diagram in Fig. 2 has been successfully simulated by using the MatLab R2010b simulink environment and the following results have been observed.

Proposed Converter fed BLDC: Figure 8 shows the complete simulation model of photovoltaic (PV) fed high boost ratio dc-dc converter for BLDC drive control. And the input voltage source obtained from photovoltaic (PV) panel is varying around 70-80 Volts normally and minimum of 15V to maximum level of 120V will be gained which purely depends on the atmospheric condition.

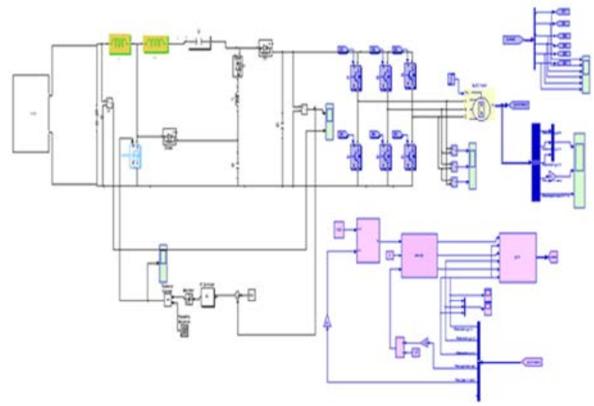


Fig. 7: High boost ratio converter fed BLDC

The voltage at the MPP (Vmp), the current at the MPP (Imp), the open-circuit voltage/temperature coefficient (Kv), the short circuit current/temperature coefficient (Ki),and the maximum experimental peak output power (Pmax,e). This information is always provided with reference to the nominal condition or standard test condition (STC), where the temperature is 250C and solar irradiation is 1000 W/m2.

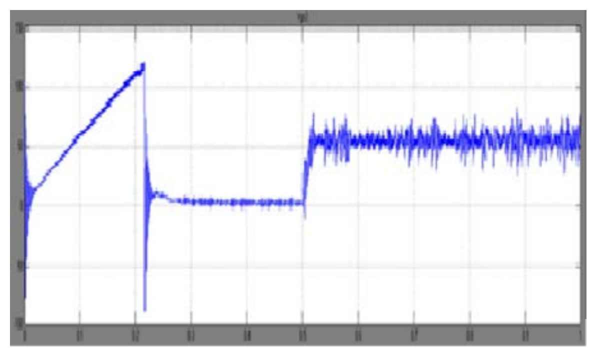


Fig. 8: Solar output voltage

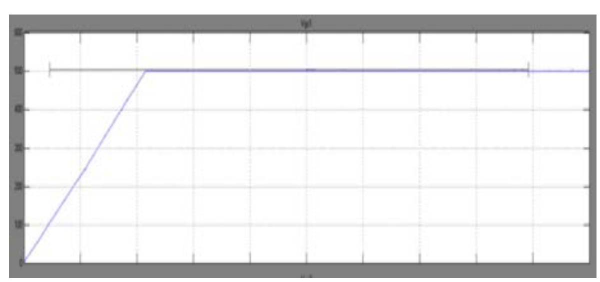


Fig. 9: High boost ratio voltage

The above fig.9 shows the boost ratio voltage obtained from the proposed converter circuit of range 500 Volts.

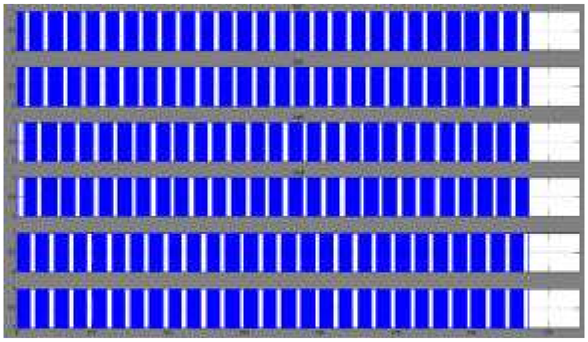


Fig. 10: PWM signals

The gate signal to six inverter switches shown in fig.10 is given to a 3-phase inverter circuit and the speed of the motor will be controlled by varying its input voltage.

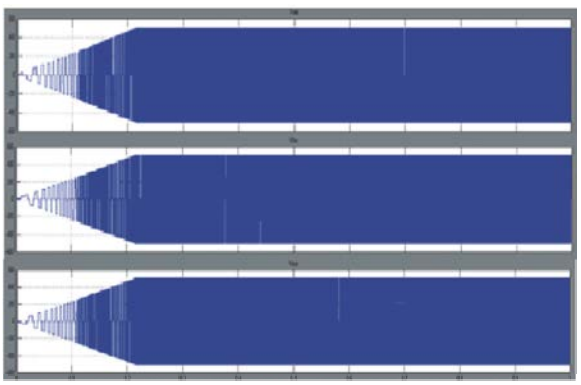


Fig. 11: Three phase inverter voltage

Results Obtained from BLDC Drive: For High boost ratio converter fed BLDC motor, the range of Torque, Current and Speed observed is as follows; 6.3 N-m of torque and 4.1 Amps of current at a speed of 1200 rpm.

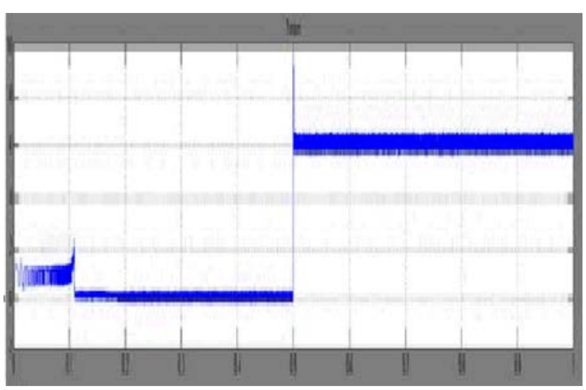


Fig. 12: 3-phase Torque

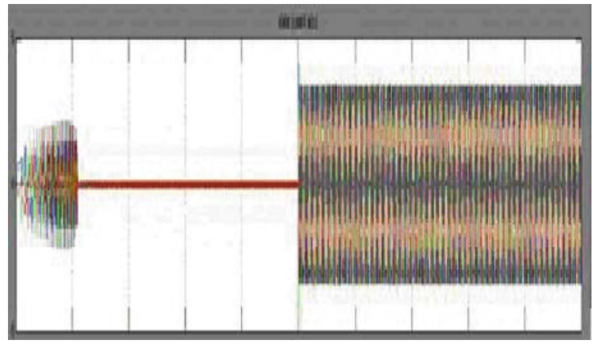


Fig. 13: 3-phase current

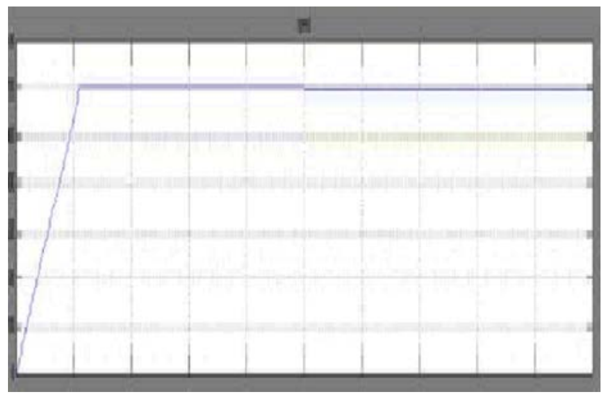


Fig. 14: speed of BLDC motor

CONCLUSION

A high boost ratio dc–dc converter with hybrid transformer suitable for alternative dc energy sources with varying dc voltage input with Brushless dc motor at load edge is proposed in this paper. The following features and benefits are obtained by incorporating resonant conversion mode:

- This converter transfers the capacitive and inductive energy continuously to increase the total power delivery reducing losses in the system.
- As a result of the low-input RMS current the conduction loss in the transformer and MOSFET is reduced and switching loss is reduced with a lower turn-off current.

With these improved performances, the converter can maintain high efficiency under low output power and low-input voltage conditions. The controller leads to improve the behavior and control the speed of the BLDC drive to maintain good performance.

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