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Green Energy Based Coupled Inductor Interleaved Converter with MPPT Technique for BLDC Application

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ABSTRACT

This paper presents a high step-up converter with combination of battery and solar energy source application. The proposed green energy source boosted by using coupled inductor interleaved converter. The coupled inductor and voltage double circuit can reach the high voltage gain without more stress on the converter circuit as well as much changes in duty cycle. The photo voltaic system maximum output is 12volts it can be varied by changes of irradiation level .The maximum output voltage is tracking by using MPPT and supplies to the coupled inductor interleaved boost converter. The MPPT working based on the P & O algorithm .The output level of the photo voltaic is high then the battery is charging as well as BLDC motor also being driven efficiently.Whenever the irradiation level will be low the output level of the photo voltaic is less than the battery will be charging and then the motor will running by battery power.

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1. INTRODUCTION

The main objective of this research work is to overcome the problem due to the use of fossil fuel for the energy generation for the society. The impact of the fossil fuel aspects becomes increasing harmful effects for environment. Photo voltaic cell is observing the irradiation from the sun which will be converted into electrical energy [1]. The solar energy from the sun is converterd into electrical energy by PV cell delivering fluctuating energy which is not suitable for utilization for the load demand. To avoid the fluctuating energy supplied to the load it requires high gain DC-DC converter [2]. In future most of application requires renewable energy based DC-DC converter. Energy reserves are running out, but also, their exploitation leads to different climatic changes, which causes striking events. They are many incidents have occurred recently, we will quote, for example, the green house effect, the increase of the sea level. The photo voltaic cells converting solar energy to electrical energy with the help of solar cells.

2. CONVENTIONAL METHOD BLOCK DIAGRAM

Figure 1 shows the complete block diagram structure of proposed system. Instead of conventional boost converter the Coupled inductor interleaved converter [3] transfer the boost voltage therefore the duty cycle will be less. In this converter the high frequency operation is implemented. The photo voltaic can be observes, the irradiation and converted to electrical energy. The maximum output of the photo voltaic panel is 12volts dc supply. The MPPT can be tracking the maximum power from the photo voltaic panel and deliver to the coupled inductor interleaved boost high frequency converter. The coupled inductor interleaved converter boosting the voltage by changing the duty cycle. The boost converter output is less then 24volt it cannot drive the BLDC motor [4], in this condition the battery will be charging first , it is ready to discharge the voltage then the 24volt BLDC motor will be running with the help of battery power. The 24 volt supply is given to the BLDC stator winding is based on rotor position.The rotor position is sensed by the hall sensor , They are three numbers of hall sensor fixed in the motor for sensing the rotor position, namely Ha, Hb, Hc. A DSPIC30F2010 controller [5] sense the rotor position given to signal to the MOSFET switching device. A three phase BLDC motor stator having a six number of winding, Namely RY, YB, BR, RY', YB', BR'. The exciation supply is given to the BLDC motor by MOSFET switching. There are six number of MOSFET fast switching is based on rotor position the supply is given to the stator winding. The stator winding having to the supply simultaneously then the motor is running continously.

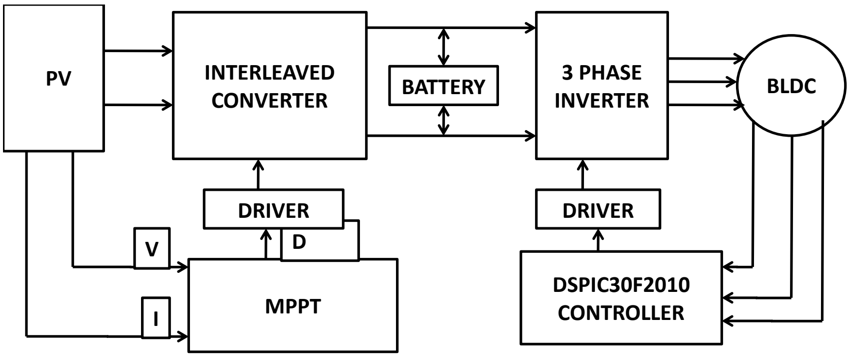

Figure 1. Block Diagram of proposed system

3. CONVENTIONAL METHOD CIRCUIT DIAGRAM

Green energy based coupled inductor interleaved converter with MPPT technique for BLDC motor as shown in figure 2.The photovoltaic system will observe solar energy and delivers electrical energy for the converter system. The input power of the boost converter [6] is varying because of the varioation in the irradiation level. The boost converter output power maintained constantly by changing the duty ratio of the converter switch. The coupled inductor interleaved boost converter [7] is incorporated with MPPT charge control technique which connect to the photovoltaic system which will be tracking the maximum power to gives the boost converter [8]. The battery will be charged effectively with the help of MPPT control method [9]. Once the battery is fully charged the photovoltaic output [10]-[12] directly goes to motor inorder to drive BLDC.

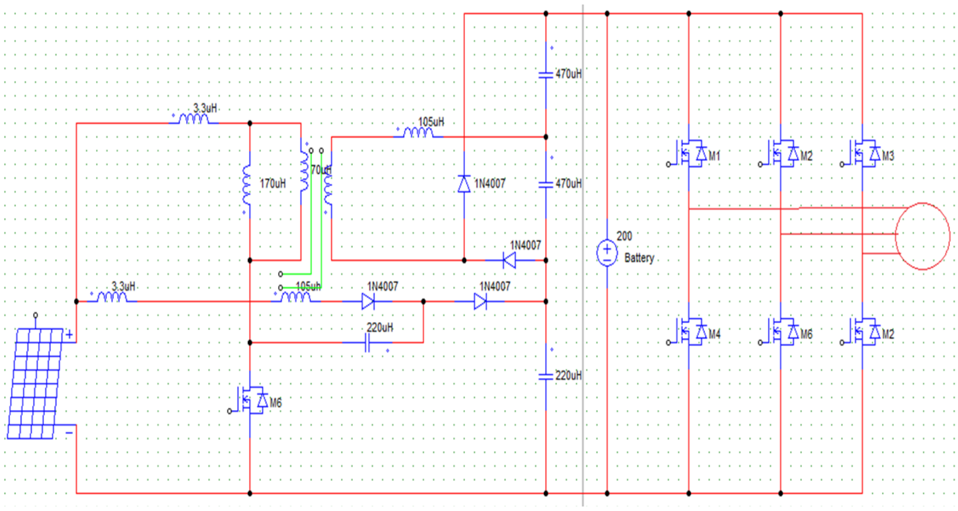

Figure 2. Circuit diagram of propsed system

4. MODES OF OPERATION

The BLDC motor is three phase ac motor. It will run based on the rotor position. The rotor position is sensed by using hall sensor which is placed inside the BLDC motor. The supply is given to the BLDC motor through the 3phase inverter. In each mode only two MOSFET will be turned on. The supply is given to the 3phase BLDC motor has 6 modes they are

MODE 1: In this mode the MOSFET 5 and MOSFET 1 will be turned on. The supply is passing through the MOSFET 5, BLDC motor and the current flow will be closed via MOSFET 1 in circuit. The Other four MOSFET will be in turned off condition.

MODE 2: In this mode of operation the MOSFET 5 and MOSFET 2 will be turned on. The supply will be flowing via MOSFET 5, BLDC motor and to the MOSFET 2. Other four MOSFET remains in off condition.

MODE 3: Here in mode 3 the MOSFET 4 and MOSFET 3 will be turned on. The supply will flow through the MOSFET 4, BLDC motor and the current flow will be closed via MOSFET 3 in circuit. Remaining switches are in off condition.

MODE 4: In this operating mode the MOSFET 4 and MOSFET 1 will be turned on. The supply is passing via the MOSFET 4, BLDC motor and the current flow will be closed via MOSFET1 in circuit. Other four MOSFET will be in turned off condition.

MODE 5: The supply is given to the BLDC motor through the 3phase inverter.. In mode one the MOSFET 6 and MOSFET 3 will be in ON condition. The supply is passing through the MOSFET 6, will be exciting the BLDC windings and the current flow will be closed via MOSFET 3 in circuit Remaining switches are in off condition.

MODE 6: Here inoperating 6 the MOSFET 6 and MOSFET 2 in ON condition. The supply will flow through the MOSFET 6 will be exciting the BLDC windings and the current flow will be closed via MOSFET 2 in circuit remaining switches are in off condition.

5. BATTERY STATUS (SOC)

The battery state of charging graph is drawn between time and voltage which is shown in the Figure 3. When the output of the photo voltaic is high the battery will be charged and the BLDC motor will be driven. Incase if the output power of the photo voltaic is low then the PV power output cannot be used for charging the battery. In this condition the battery will be discharging inorder to drive the BLDC.

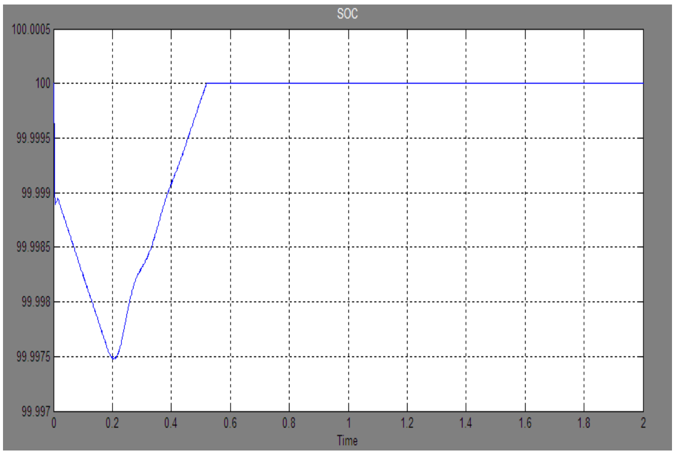

Figure 3. Battery Status (SOC)

6. PV VOLTAGE AND CURRENT AND POWER WAVEFORM

Graph for PV voltage, current and power is drawn across the time as shown in Figure 4. The radiation level will be high the solar panel will be observes to the electrical power. The output of the PV voltage, current and power will be high.around 37v is obtained from the PV array and 8-9 A current will delivered by the PV source. 300 Watts of power will be obtained from this PV array.

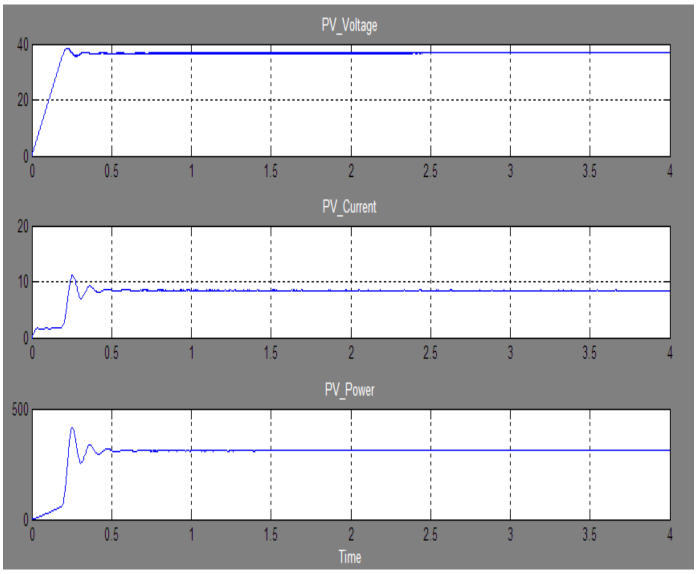

Figure 4. PV voltage and current and power waveform

7. CONVERTER VOLTAGE, CURRENT AND POWER WAVE FORM

Graph the converter voltage, current and power is drawn across the time as show in the Figure 5. If incase the irradiation level is high, the increment of the duty cycle of the converter switch is not required for maintaining the required output. If incase the irradiation level is low the increment of the duty cycle of the converter switch is required for maintaining the required output voltage, current, power.

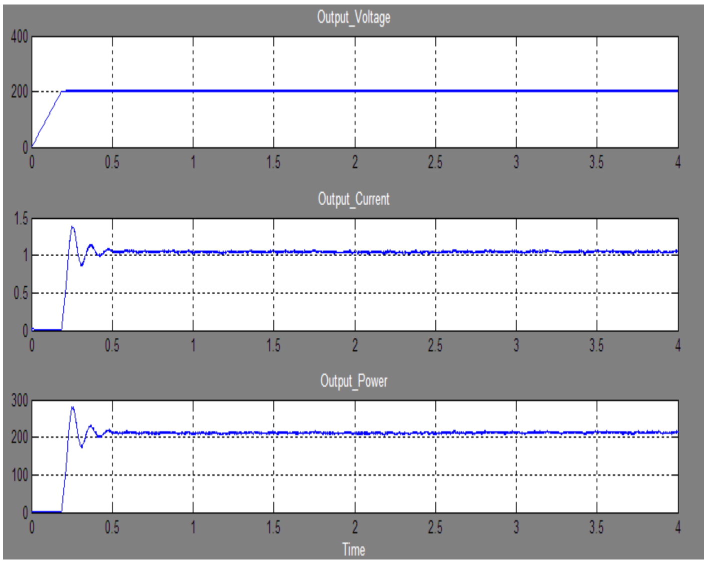

Figure 5. Converter voltage and current and power

8. BLDC MOTOR

In the Figure 6 BLDC motor 6 winding are placed in stator namely RY, YB, BR, R'Y', Y'B', B'R'. The hall sensor will be sensing the rotor position and given the signal to the driver circuit for which MOSFET will be turned on. In the open loop operation of forward direction the duty cycle is varying manually. In the open loop operation of reverse direction the duty cycle is varying manually [11].

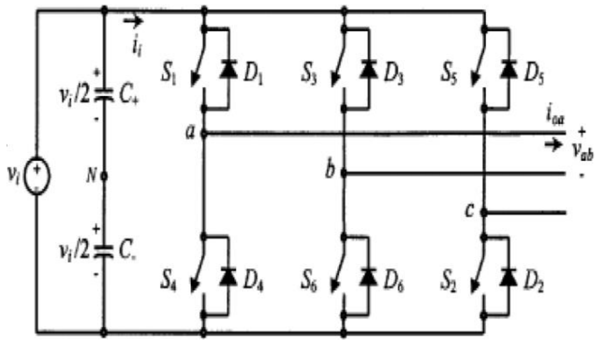

Figure 6. Three phase BLDC Switching topology

The closed loop operation of forward and reverse the direction of the motor the duty cycle will be varying automatically. Table 1 indicates the valid switch states of a three phase BLDC motor. Figure 7 shows the P & O Algorithm flow chart which shows the step by step process [12] of getting maximum power output from the PV array according to the variable irradiance level.

Table 1. Valid switch States of a three-phase BLDC Motor

Phase	HALL SENSOR			SWITCHES					
	H3	H2	H1	Q1L	Q1H	Q2L	Q2H	Q3L	Q3H
1	1	0	1	0	1	1	0	0	0
2	0	0	1	0	1	0	0	1	0
3	0	1	1	0	0	0	1	1	0
4	0	1	0	1	0	0	1	0	0
5	1	1	0	1	0	0	0	0	1
6	1	0	0	0	0	1	0	0	1

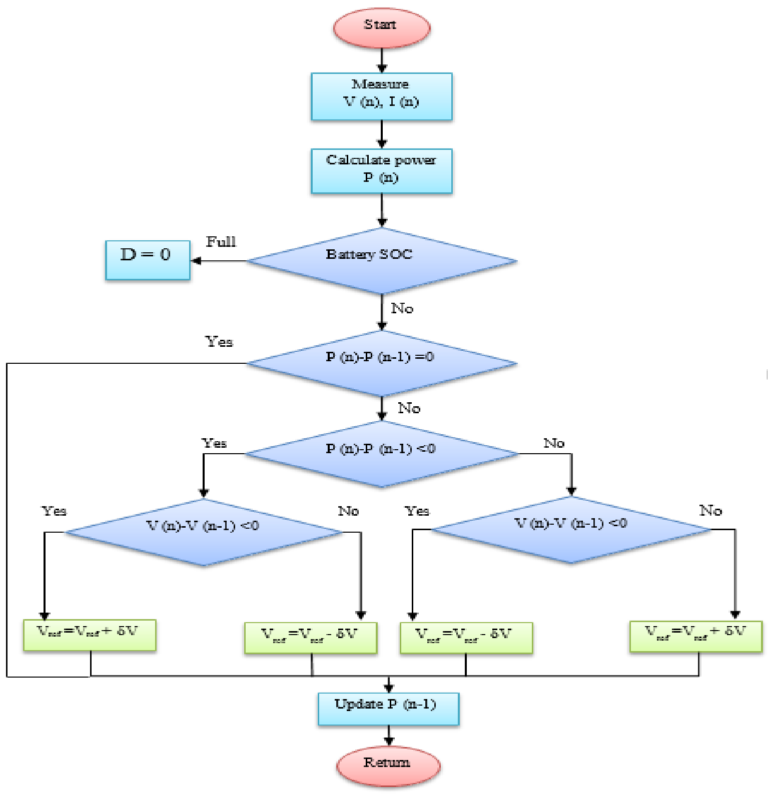

Figure 7. Flow chart perturb and observe method

9. CHARACTERISTICS OF PV CELL

Ideal PV is modeled by current source in parallel with diode. Whenever no solar cell is ideal and there by shunt and series resistance are added to model as shown in the PV cell diagram (Figure 8). RS is intrinsic series resistance whose value is very small. RP is the equivalent shunt resistance is very high value.

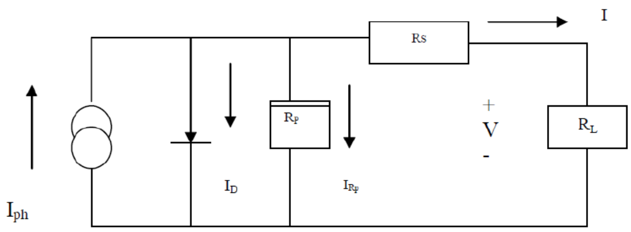

Figure 8. Photovoltaic Cell

Applying Kirchhoff's law to the node Iph, diode, Rp and Rs, we get

$$Iph=ID+IRp+I \quad (1)$$

We get the following equation for the photovoltaic current:

$$I=Iph-Irp-ID \quad (2)$$

$$I = I_{ph} - I_{o}.\left[exp\left(\frac{V+I.R_S}{V_T}\right) - 1\right] - \left[\frac{V+I.R_S}{R_p}\right] \quad (3)$$

where, Iph is the insulation current, I is the cell current, IO is the reverse saturation current, V is the cell voltage, Rs is the series resistance, Rp is the parallel resistance, VT is the thermal voltage, k is the Boltzmann constant, T is the temperature in Kelvin, q is the charge of an electron.

10. EFFICIENCY OF PV CELL

The efficiency of a PV cell is defined as the ratio of peak power to input solar power.

$$\eta = \frac{Vmp.Imp}{I\left(\frac{KW}{m^2}\right).A(m^2)} \quad (4)$$

where, Vmp is the voltage at peak power, Imp is the current at peak power, I is the solar intensity per square meter, A is the area on which solar radiation fall. The efficiency will be maximum if we track the maximum power from the PV system at different environmental condition such as solar irradiance and temperature by using different methods for maximum power point tracking.

11. MODELLING OF PV ARRAY

The current source Iph reprensents the cell photo current, Rj is used represent the non linear impdedance of the p-n junction, Rsh and Rs are used to reprensen the intrinstic series and shount resistance of cell respectively usually the value of Rsh is very large and that of Rs is very small, hence they may be neglected to simplify the analysis.

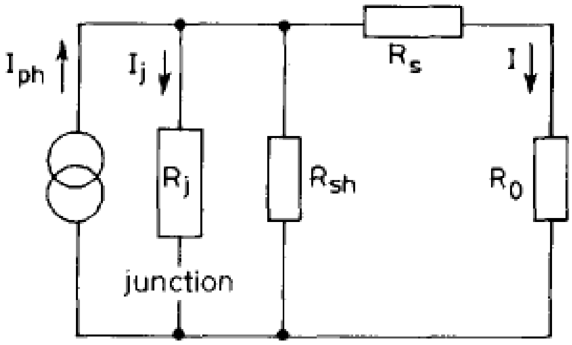

Figure 9. Modelling of PV Array

The PV mathematical model used to simplify our PV array is reprensented by the equation.

$$I=n_pI_{ph}-n_pI_{rs}[\exp(\frac{q}{KTA}*\frac{V}{n_s})-1] \quad (5)$$

where I is the PV array output current, V is the PV array output voltage, ns is the number of cells is series and np is the number of cells parallel, q is the charge of an electron, k is Boltzmann's constant; A is the p-n junction ideality factor; T is the cell temperature (K); Irs is the cell reverse saturation current. The factor A in equation determines the cell deviation from the ideal p-n junction characteristics; it ranges between 1-5 but for our case A=2.46 The cell reverse saturation current Irs varies with temperature according to the following equation:

$$I_{rs}=I_{rr}[\frac{T}{T_r}]^3\exp(\frac{qE_G}{KA}[\frac{1}{T_r}-\frac{1}{T}]) \quad (6)$$

where Tr is the cell reference temperature, Irr is the cell reverse saturation temperature at Tr and EG is the band gap of the semiconductor used in the cell.

The temperature dependence of the energy gap of the semi conductor is given by:

$$E_G= E_G(0)-\frac{\alpha T^2}{T+\beta} \quad (7)$$

The photo current Iph depends on the solar radiation and cell temperature as follows:

$$I_{ph}=[I_{scr}+K_i(T-T_r)]\frac{S}{100} \quad (8)$$

where Iscr is the cell short circuit current at reference temperature and radiation, Ki is the short circuit current temperature coefficient, and S is the solar radiation is mW/cm2. The PV power can be calculated using equation as follows:

$$P=IV= n_pI_{ph}V[(\frac{q}{KTA}*\frac{V}{n_s})-1 \quad (9)$$

12. CONCLUSION

This proposed system with solar based converter gives a efficient solution to overcome the problem of harmfulness to the society for using fossil fuel. Green energy based coupled inductor interleaved converter with MPPT technic for BLDC motor was implemented and verified with simulation. The BLDC motor is running with pv power as well as battery power has verified .The duty cycle of the Coupled inductor interleaved boost converter is varied and the BLDC motor speed is also controlled. Open loop and closed loop are verified. The simulation is done by MATLAB software.

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