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Solar PV-Powered BLDC Drive for EVs to achieve Flexible Energy Control Functions using Tri-port converter

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Abstract.

The paper presents a TriPort converter coordinated between Brushless DC drive and solar PV, battery to increase the driving distance of electric vehicles. The assurance on battery of the EV's can be reduced. In this system, A BLDC drive is used along with solar PV for better traction characteristics i.e., more starting torque and more efficiency. BLDC motor is suitable for EV's because of its better traction characteristics and for more power density. The main module of this is to control the energy flow from PV panel, battery, grid to BLDC motor. This can be done using Matlab/Simulink to know the efficient working of TriPort converter. For the flexible energy flow to control driving and charging, six modes of operation are developed.

Keywords: Brushless DC motor; tri port converter; PV panal; Matlab/Simulink.

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1 Introduction

Electric vehicles (EV's) are most eloquent in lowering the relay on fossil fuels. This made a significant upswing towards advancements on different motors, converters, batteries and some energy management systems to enhance the driving distance. For high performance permanent magnets are used for which large amount of rare earth materials are required which limits the wide application of electric vehicles.

In electric vehicles, they cannot sustain high temperatures, which violate the usage of SRM drives [1]. The most disadvantage of using SRM drives are high noise, vibration, and torque ripple. To overcome such drawbacks BLDC is implemented in this project. A BLDC drive is used along with solar PV to reduce the cost and for better traction characteristics i.e., high starting torque and more efficiency. BLDC motor is suitable for electric vehicles because of its better traction characteristics and for high power density

A Photovoltaic fed Electric Vehicle and hybrid electrical vehicle have similar structure in which ICE is reintegrated with solar PV. The PV-fed Electric Vehicle system is illustrated in Fig. 1.A power converter, a PV panel, batteries, and an off board charging station are the main components to incorporate. A BLDC drive is used along with solar PV to reduce the cost and for better traction characteristics i.e., high starting torque and more efficiency. BLDC motor is suitable for electric vehicles because of its better traction characteristics and for high power density

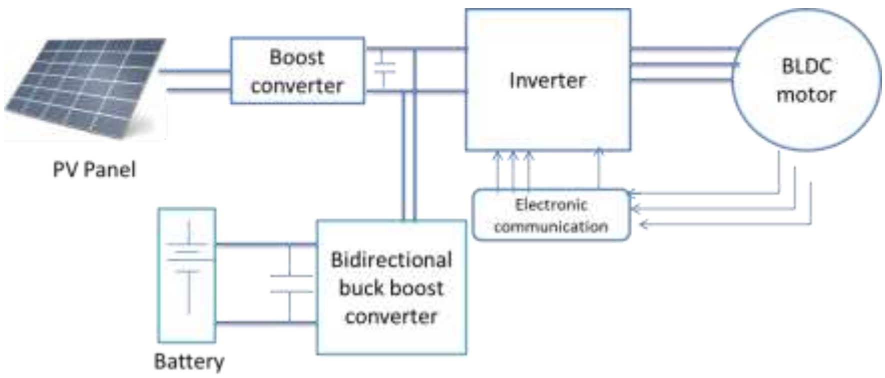

Fig 1. Block Diagram

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J1 AND J2 ACTIONS UNDER DIFFERENT MODES

Mode	J1 and J2
1	J1 turn-off; J2 turn-on
2	J1 and J2 turn-on
3	J1 turn-on; J2 turn-off
4	J1 and J2 turn-on
5	J1 and J2 turn-on
6	J1 turn-off; J2 turn-on

Table 1.different operational modes

In mode 1, Power from PV turned on, battery power flow is idle to drive the BLDC. PV panel can act as energy source for BLDC and excess energy can be used to charge battery .In mode 2,Both the battery and solar PV can act as energy sources for driving BLDC motor. In mode 3, the solar PV can act as driving source for BLDC whereas the battery inactive. In mode 4, the battery can be driving source for BLDC whereas solar PV is inactive. In mode 5, the battery will be charging from grid whereas BLDC and solar PV are idle. In mode 6, the battery can be charged using solar PV whereas BLDC is inactive or standstill condition

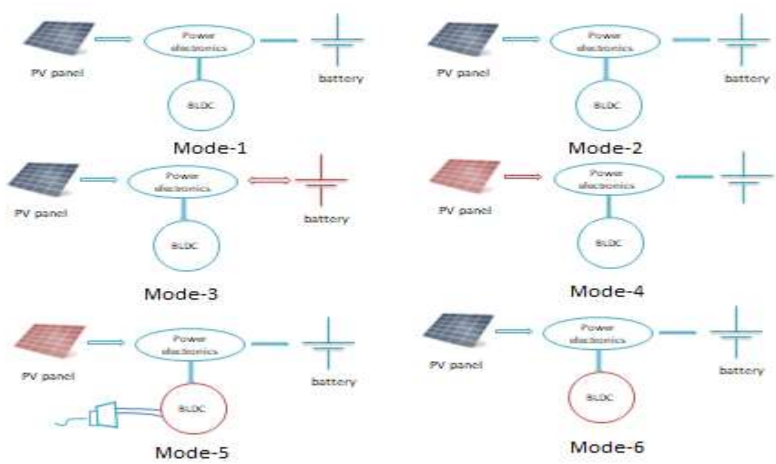

Fig 2. Different modes of operation

2 Modes of operation and Topologies

2.1 working modes and functions

The TriPort converter connects solar PV, battery, and BLDC drive together using different converter which includes four switching devices and diodes along with two relays for switching By controlling strategies of relay operation , six modes of operations are implemented , compatible modes actions shown fig.2. First four modes are driving modes and

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mode 5 and mode 6 are charging modes.In mode 1, Power from PV turned on, battery power flow is idle to drive the BLDC. PV panel can act as energy source for BLDC and excess energy can be used to charge battery .In mode 2,Both the battery and solar PV can act as energy sources for driving BLDC motor. In mode 3, the solar PV can act as driving source for BLDC whereas the battery inactive. In mode 4, the battery can be driving source for BLDC whereas solar PV is inactive. In mode 5, the battery will be charging from grid whereas BLDC and solar PV are idle. In mode 6, the battery can be charged using solar PV whereas BLDC is inactive or standstill condition

2.2 Boost and bidirectional buck-boost converter modeling

2.2.1 Solar PV - boost converter-Inverter

Solar voltage Vs=24V, inverter required voltage Vo=230V

Required output voltage Vo=(D/1-D)Vs (1)

Duty Cycle D=0.9

Minimum inductance value Lmin=(1-D)^2xR/2f (2)

Minimum capacitace value C=D/rRf (3)

R=0.1Ohms(assume) Ripple voltage=1.5%

Switchingfrequency=50KHZ

value of capacitor: C2=0.012F

L=Lmin+25% of Lmin (4)

L=1.25 Lmin

Value of inductor: L1= 0.0125micro H

2.2.2. Battery-Bidirectional Buck boost-Inverter

Battery voltage Vs=350 , inverter required voltage Vo=230

Output volatge Vo=(D/1-D)Vs

Duty cycle D=0.3

Minimum inducatnce value Lmin=(1-D)^2xR/2f

capacitance value C=D/rRf

R=0.1Ohms(assume)

Ripple voltage=1.5%

Switchingfrequency=50KHZ

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value of capacitor: C1=4.166mF

Lmin=5.9Micro H

Inductance L=Lmin+25% of Lmin

L=1.25 Lmin

Value of inductor: L2=7.37 micro H

3 Control Statergies of different modes of operations

3.1 Driving mode with single source

Due to the switching of the power sources, there are solar PV alone used for driving i.e. PV-driving, battery alone used for driving i.e. battery-driving, and both PV and battery together parallel fed as single source. For high load requirements, the power from single source cannot support the Electric Vehicle in such case mode 2 can be implemented for supporting sufficient power and makes efficient usage of solar energy. As solar PV is connected parallel to battery, the voltage of PV panel will be clamped to voltage of battery. Both the battery and solar PV can act as energy sources for driving BLDC motor. Mode 3 is PV driving mode where energy from PV panel is taken. In Mode 4 battery driving mode where is taken from battery.

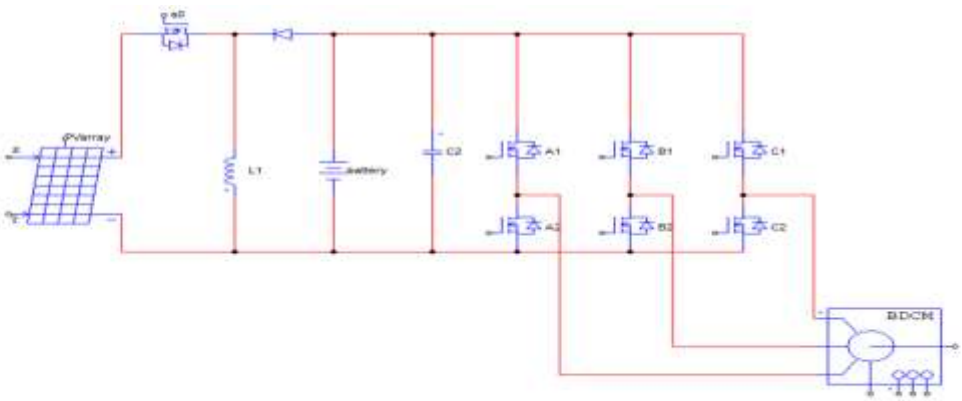

Fig.3.1 Driving mode with single source

As solar PV is connected parallel to battery as shown in fig 3.1, the voltage of PV panel will be clamped to voltage of battery. Both the battery and solar PV can act as energy sources for driving BLDC motor

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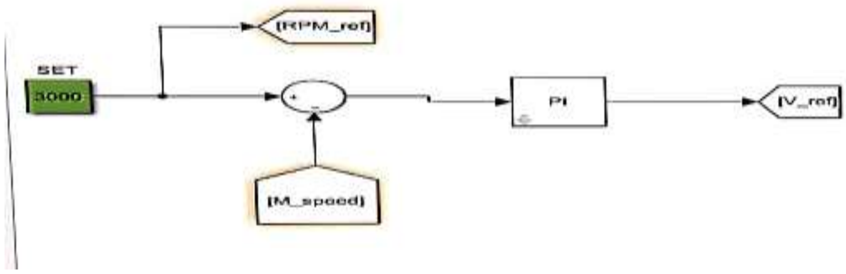

Fig.3.2 Speed control in single source driving

3.2 Charging mode control strategy

For a charging mode control strategy, solar PV will act as driving source and the battery is for charging using current from freewheeling action, as implemented in driving mode 1.The speed of the BLDC is controlled and monitored using PI controller. That can be used for charging the battery with battery reference voltage. When there is requirement of two sources in high load condition then from mode 3 i.e PV driving source, it switches to Mode 1. At initial step, speed of BLDC will be controlled at a reference speed in PV driving mode. Here J2 relay will be turned on and J1 relay will be turned off to change to mode 1.

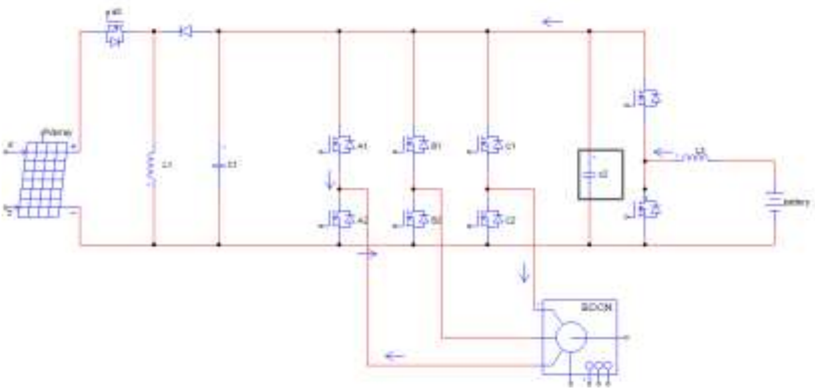

Fig.3.3 charging mode control strategy

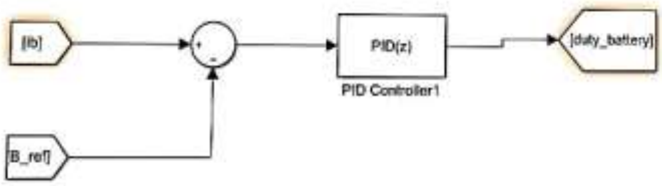

Fig.3.4 PID controller for battery reference voltage

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3.3 Grid connected Control Strategy

Grid connected control strategy is similar to single-phase connected grid charging.

- Vgrid-Voltage from grid which Charge the phase winding
- I_{ref_grid}- Amplitude of Grid Current
- To implement the changes in Inductance Hysteresis control is employed to realize grid current [1].
- Grid Connected Controlling Stability
- Vgrid > 0 – Inductance is La
- Vgrid <0 –Inductance is paralleled

3.4 Solar PV for Charging Control Strategy

In PV charging control, the PV panel used to charge battery directly from the driving strategy. The windings of phases in BLDC are incorporated in inductors, and For each phase there are going to be two states, when the switches A1,A2 and B1,B2 the PV panel directly charges the phase inductance.[1 when the switches A1,A2 and B1,B2 turns off the battery is charged when the phase inductance discharges. To maintain battery health condition and to use full energy generated by solar three stages are employed according to state Of Charge (SOC). At stage1 the State Of Charge corresponding to the battery is extremely lac of charge during stage 2 the constant voltage is obtained by using the state of charge. In stage 3 the state of charge of battery will be 100%[2].

4 Simulation

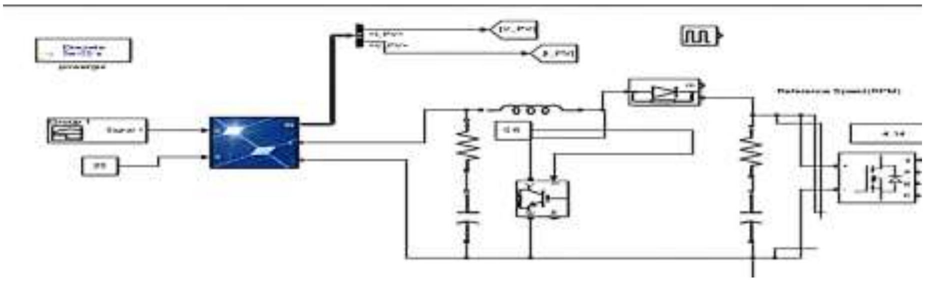

Fig 4.1 PV Panal combined with boost converter

In this part we are going to connect The PV panel to the boost converter and the boost converter is connected to the Inverter. A pulse signal is given to the PV panel and one of the output is given to the scope. In this part we used boost converter because as the output voltage that is from the PV panel will not be enough to rotate the BLDC motor. So that the

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voltage that we get from the PV panel will be send to the boost converter so, that the boost converter boosts the voltage and gives it to the inverter. The input to the PV panel is given by Square wave which triggers the Photovoltaic panel and the output voltage that we get from the PV panel is 24v. The outputs of the Photovoltaic panel given to the scope which measures V-PV and I-PV. The PV panel will give a voltage of 24v to the boost converter. The boost converter the boosts the voltage and gives an output voltage of 230v to the inverter. The inverter gives the voltage to the BLDC motor and the motor starts rotating. When it comes to the case of mode1 the voltage will be given to the battery to charge the battery.

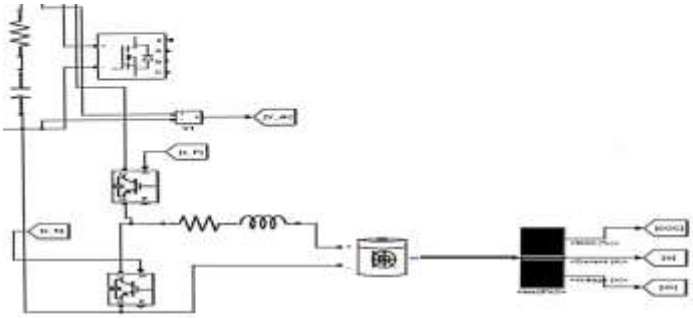

Fig 4.2 Parallel connection from inverter to battery combined with bidirectional converter

The output of the PV panel and inverter which are connected in parallel is given to the battery through Bi-Directional converter. The bi-directional converter acts as both buck and boost converter.

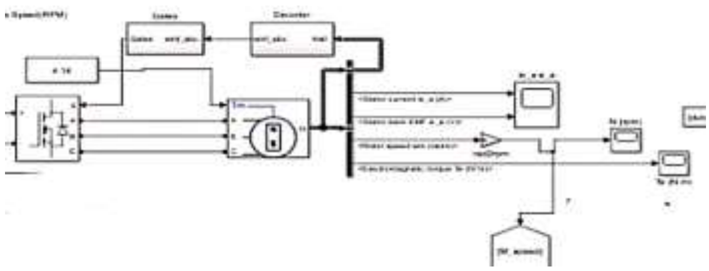

Fig 4.3 Inverter connected to BLDC

Inverter Parameters

Input Voltage	230 TO 440
Output Voltage	220-440
Rated Power(Watts)	1-10000

Table 2 Inverter ratings

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Motor Parameters

Speed	3000 RPM
Power	3000 watt
Rated current	67A
Voltage	48v/60v
No of Poles	8

Table 3 BLDC motor ratings

Simulation Parameters

S.NO	PARAMETER	VALUE
1	PV Panel	24V
2	Reference Voltage	310V
3	Battery voltage	350V
4	Constant current control reference current	1A
5	Speed reference	1250
6	Charging Current	60A

Table 4 simulation Parameters

5 Results

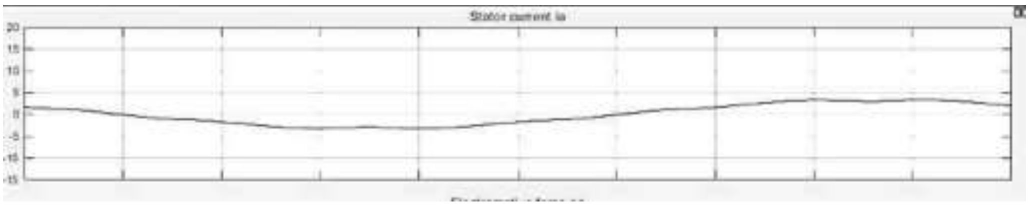

Fig 4.2.1 Stator Current

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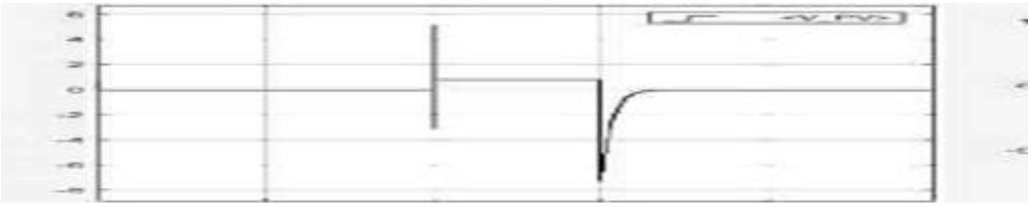

Fig 4.2.2 solar output voltage

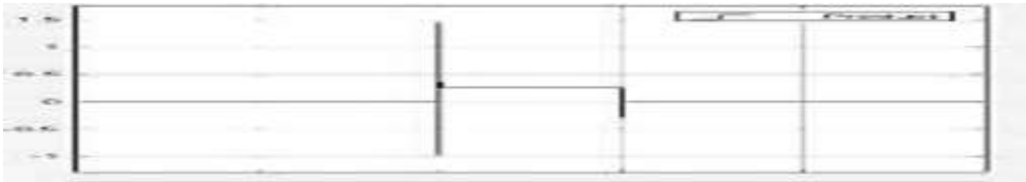

Fig 4.2.3 solar output power

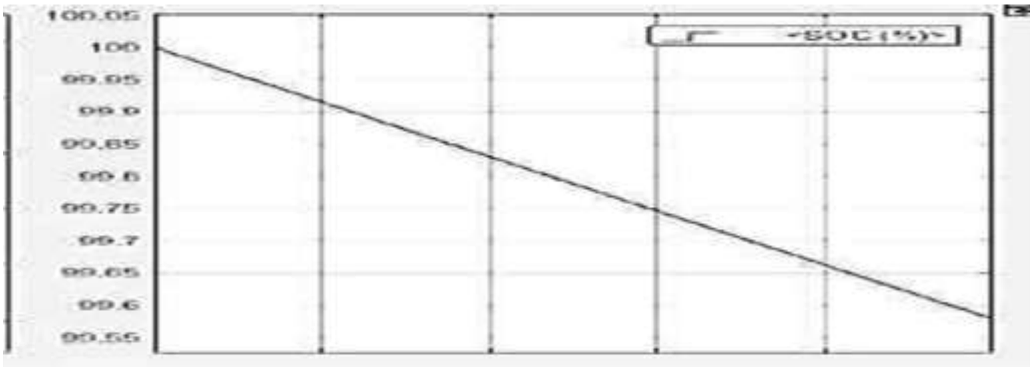

Fig.4.2.4 battery state of charge(SoC)

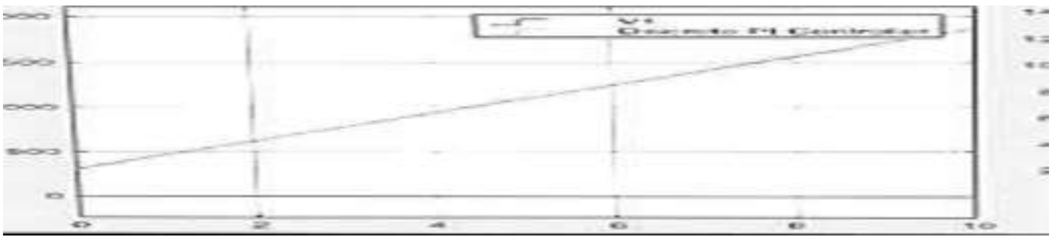

Fig 5.5 constant voltage reference voltage control

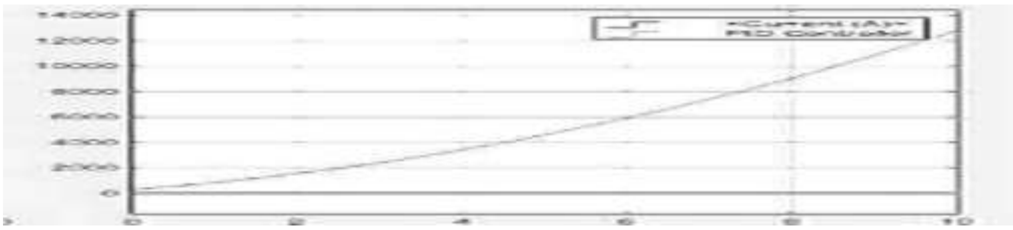

Fig 4.2.6 constant current reference current control

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6 Conclusion

To address the various concerns of using electric vehicles and reduce system costs, PV panel and BLDC are combined in a EV driving system. The main objectives of this paper are

1) The solar PV panel, battery, and BLDC are coordinated using TriPort converter.

2) The six modes of operations are designed to gain the dynamic flow of energy control for driving and charging control.

3) The grid charging is built for avoiding electrical power devices connecting externally.

4) Control of PV-powered battery charging was developed for improvement of solar energy use. In addition, the proposed technology can also be applied to similar applications such as electric vehicles. Electrical cells are very powerful and therefore better suited to applications for electric vehicles. This can be advanced by using multiport converter.

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