A Photovoltaic Cell Based Dc-Dc Converter for Dc Motor

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ABSTRACT: In recent years, power generation utilizing solar power or wind power has been being great attractive for effective utilization of electrical energy. In Order to protect the natural environment on the earth, the development of clean energy without pollution has the major representative role in the last decade. By dealing with the issue of global warming, clean energies, such as fuel cell (FC), photovoltaic, and wind energy, etc., have been rapidly promoted.Standalone photovoltaic (SAPV) systems are widely used in remote areas after development of photovoltaic cell industry in recent years. A PV cell has an exponential relationship between current and voltage, and the maximum power point (MPP) occurs at the knee of the curve. In this paper a photovoltaic array is used to run a DC motor using a dc-dc converter. The gating signal to the dc-dc converter is giving using soft switching technique. The simulink model of the PV array connected to dc motor using a dc –dc converter is developed in MATLAB and the outputs are observed.

KEYWORDS: Photovoltaic array, Soft Switching, ambient temperature, irradiation level**.**

I.INTRODUCTION

 In recent years the population of India is being increased rapidly. The utilization of power has become very important in every humans life. Any work a human does is directly or indirectly related to power. And people now a days are developing many equipments and machines in order to make their work more easier. And hence there is a great demand for electrical energy. The power generating stations are unable to meet the demand, due to which the people are facing a great power crisis. In addition to it there are many remote places where the electrical power cannot be transmitted. Hence there is great need to utilize the non-renewable energy resources(like fuel cell, wind energy, solar energy etc.,) for power generation.

 In this paper an efficient attempt is made for using the non-renewable energy resource(solar energy) as an voltage source input i.e. the output voltage of the photovoltaic array is used as an input to run the load. In this paper the load and the source are separated by a dc-dc converter. The gating signals to the converter are giving using soft switching technique which has the advantage of reducing are eliminating the commutation losses. The converter used here has an efficiency of about 93 percent. In this paper the simulink model of the pv array connected to dc motor separated by a dc –dc converter is developed in Matlab and the outputs are presented. The block diagram shown below gives a basic idea of the paper:
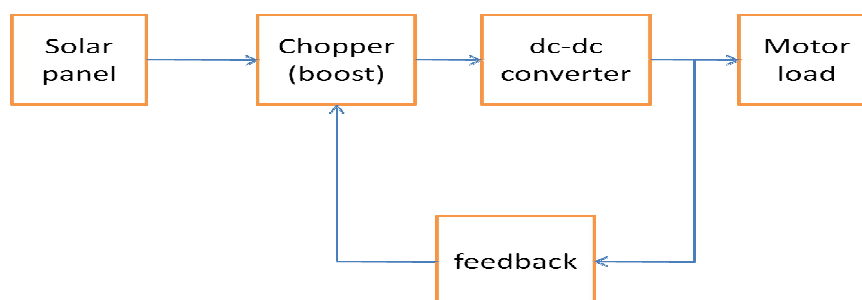

Fig.1: Basic block diagram

The above figure shows the basic block diagram of the project. The small output voltage of the PV array is given to the boost chopper where the voltage is boosted. This voltage is fed to the dc to dc converter where the efficient conversion is made at high efficiency. This improved dc voltage is fed to the dc motor which makes the motor to run.

II.PHOTOVOLTAIC ARRAY MODELING

PV arrays are built up with combined series/parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model as shown below.
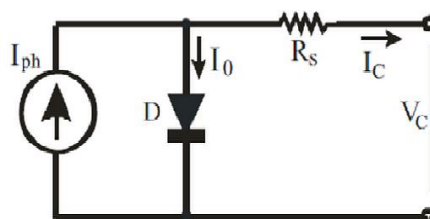

Fig 2: Simplified-equivalent circuit of photovoltaic cell.

The output voltage of PV cell is a function of the photocurrent that mainly determined by load current depending on the solar irradiation level and is given by:

$$V_c = \frac{AkT_c}{e} \ln\left[\frac{I_{ph} + I_0 - I_c}{I_0}\right] - R_s I_c \qquad (1)$$

Where

e : electron charge (1.602×10^{-19}C).
k : Boltzmann constant(1.38×10^{-23} J/^{o}K).
I_c : cell output current, A.
I_{ph} : photocurrent, function of irradiation level and junction temperature (5 A).
I_o : reverse saturation current of diode (0.0002 A).
R_s : series resistance of cell (0.001 Ω).
T_c : reference cell operating temperature (20 °C).
 V_c : cell output voltage, V.

The above gives the voltage of a single solar cell, the full array voltage is obtained by multiplying the voltage of single solar cell with the number of cells connected in series.

The operating temperature of the solar cell as a function of solar irradiation level and ambient temperature. The cell output voltage and cell photocurrent are affected by the ambient temperature T_a. These affects are represented in the model by temperature coefficients C_{TV} and C_{TI} for cell output voltage and cell output current, respectively, as:

$$C_{TV} = 1 + \beta_T (T_a - T_x) \qquad (2)$$
$$C_{TI} = 1 + \frac{\gamma_T}{S_c}(T_x - T_a) \qquad (3)$$

where, $\beta_T = 0.004$ and $\gamma_T = 0.06$ for the cell used and $T_a = 20^oC$ is the ambient temperature during cell testing.

A change in solar irradiation level causes a change in the value of cell photocurrent and cell operating temperature ,which in turn affects the cell output voltage. Thus the change in operating temperature and photocurrent due to the change in the solar irradiation level can be given via two constants, C_{SV} and C_{SI}, which are correction factors for the change in the cell voltage and cell current respectively:

$$C_{SV} = 1 + \beta_T \alpha_S (S_x - S_c) \qquad (4)$$
$$C_{SI} = 1 + \frac{1}{S_c}(S_x - S_c) \qquad (5)$$

Where S_C is the standard solar irradiation level during cell testing and S_X is the new level of solar irradiation. The change in temperature, ΔT_C occurs because of the change in the solar irradiation level and is obtained using the equation

$$\Delta T_c = \alpha_S (S_x - S_c) \qquad (6)$$

Using the above correction factors the new values of the cell output voltage and the photocurrent are obtained for the new temperature T_x and solar irradiation S_x as follows:

$$V_{cx} = C_{TV}C_{SV}V_C$$
$$I_{phx} = C_{TI}C_{SI}C_{ph}$$

Where V_C and I_{ph} are the benchmark reference cell output voltage and reference cell photocurrent respectively.

III. PVA MODELING FOR SIMULINK

The general block diagram of the PVA model for simulink is shown below.
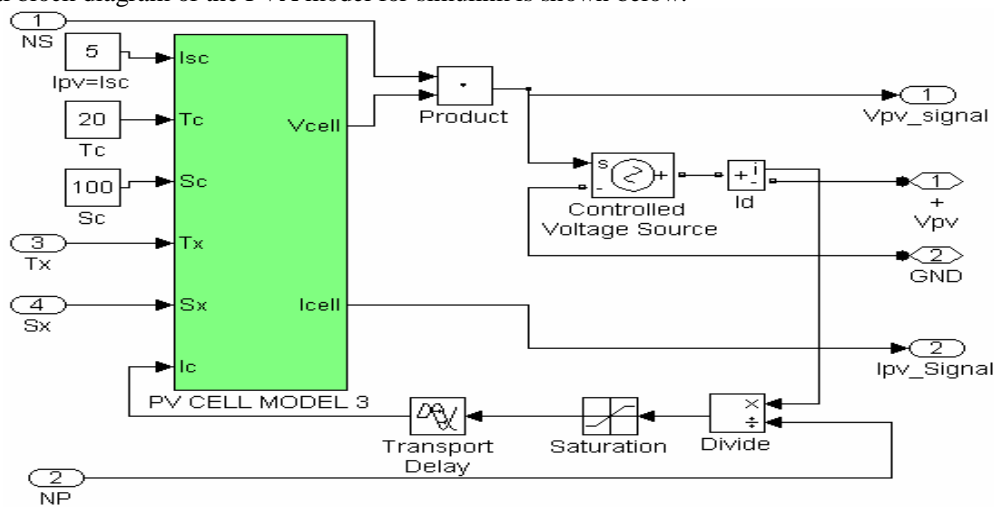

Fig 3: Simulink model of photovoltaic array

The figure above shows the simulink model of the PV array whose output after simulation is obtained as 83volts.

IV.DC-DC CONVERTER

A bidirectional dc to dc converter is used for the better performance of the load. The isolated bidirectional dc to dc converter consists of a boost chopper circuit and a full bridge type LLC converter for isolation. The boost chopper is used to boost the output voltage of the photovoltaic array.

The bidirectional boost chopper circuit consists of a input capacitor C_{chop}, input inductor L_{chop} and two IGBT switches Q_{chop1}, Q_{chop2}. The full bridge type LLC converter consists of a DC link capacitor C_1, four switches for full bridge in primary side, resonant capacitor C_r, and inductor L_r, transformer, four switches in the secondary side and a smoothing capacitor C_{bus}.

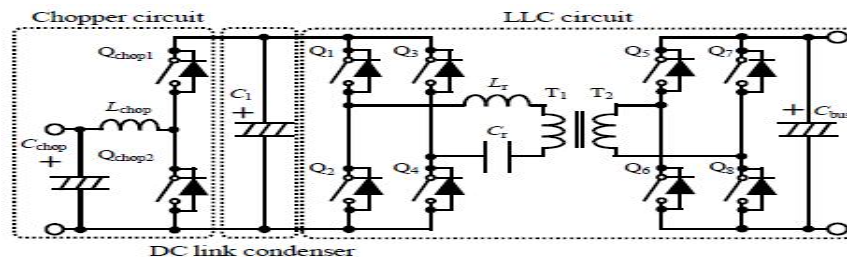The isolated bidirectional dc –dc converter used is shown below.

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Fig 4:Bi-directional dc to dc converter.

In general the switching of the bidirectional dc – dc chopper circuit shows hard switching and in order to prevent from short circuit there is dead time for on and off of switch Q_{chop1} and Q_{chop2}. The pulse width modulation (PWM) control is adopted for the bidirectional boost chopper circuit. The isolated bidirectional dc to dc converter is driven with duty of nearly 50% to attain best efficiency. Dead time for the switches Q_1,Q_4,Q_5,Q_8 and Q_2,Q_3,Q_6,Q_7 is set up. If the duty of isolated bidirectional dc to dc converter is fixed, the current and voltage control isn't required.

The operation principle for the isolated bi-directional DC-DC converter is discussed below. The operation of the isolated bi-directional dc to dc converter can be explained in six modes as follows:

Mode 1: The switches Q1, Q4, Q5, and Q8 are on. The resonant voltage of the capacitor Cr is positively charged in this moment and then resonant capacitor Cr starts to discharge. After that, the resonant voltage of capacitor Cr crosses zero and completes to charge negatively. The current of inductor Lr is approximately zero.

Mode 2: The switches Q1, Q4, Q5, and Q8 turn on since the resonant current of the inductor Lr is zero. For that reason, the ZCS operation is realized due to no current switching. Each of the switches turns off. After that, they are in the dead time period.

Mode 3:The beginning of this mode starts from the dead time period. All switches are in the off state. After finishing the dead time period, the switches Q2, Q3, Q6, and Q7 turn on. At this time, the ZCS operation is achieved since the switch current gradually rises up by the resonant capacitor Cr and inductor Lr. In this moment, the resonant voltage of the capacitor Cr shows the negative voltage.

The figures below (fig5 and fig 6) show the operation stages for discharge and each of the voltage and current waveforms in discharging time for the isolated bi-directional dc to dc converter.
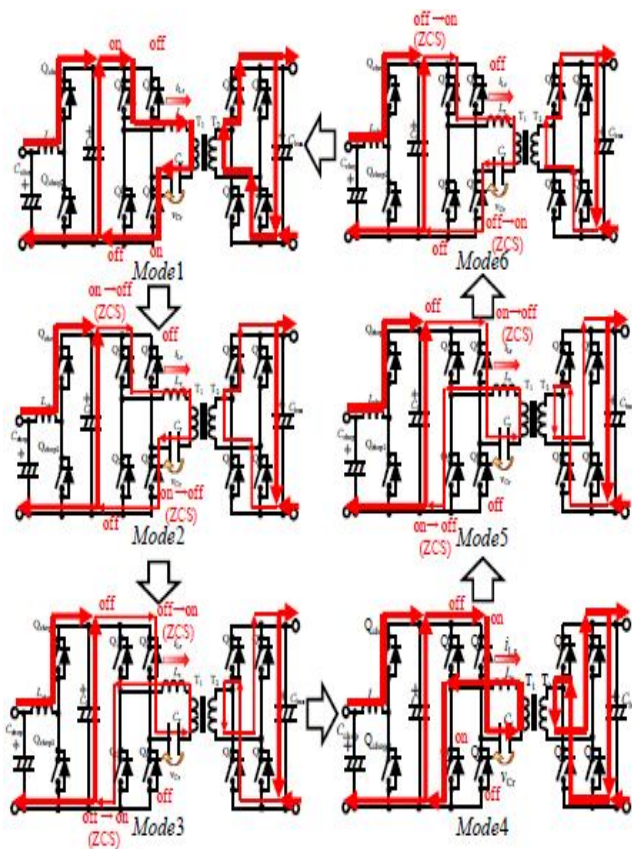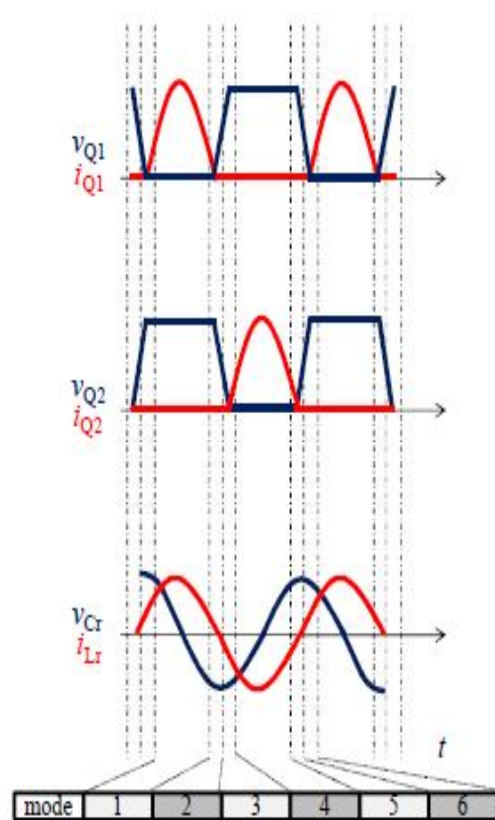

Fig 5:operation stages for discharge

Fig 6:Waveform of voltage and current during discharge

Mode 4: The switches Q2, Q3, Q6, and Q7 turn on and then the resonant capacitor Cr starts to discharge with resonant. After that, the resonant capacitor Cr charges positively due to the resonant. In other words, the current and voltage of the resonant capacitor Cr and inductor Lr change in contrast to Mode1.

Mode5: The resonant current of inductor Lr becomes approximately zero, and then the switches Q2, Q3, Q6, and Q7 turn on. Accordingly, the ZCS operation is realized. After that, each of the switches turns off and the mode moves to next mode.

Mode6: In the beginning of this mode, all switches are in the off state. Finishing the dead time period, the switches Q1, Q4, Q5, and Q8 turn on. At this moment, the ZCS operation is realized since the current gradually rise up with the resonant. After turning on,the mode moves to Mode1.

A output voltage of the converter is given to the motor and the output is observed. The output is given back for the required operation of the motor. The error voltage is given to the pi duty controller where the duty cycle is obtained. The obtained duty cycle is given to the PWM generator which in turn provides the gating signal for the boost chopper and thus the cycle repeats.

V.SIMULATION AND RESULTS

The simulation circuit for a dc to dc converter connected to a motor load fed by a photovoltaic cell is shown below:
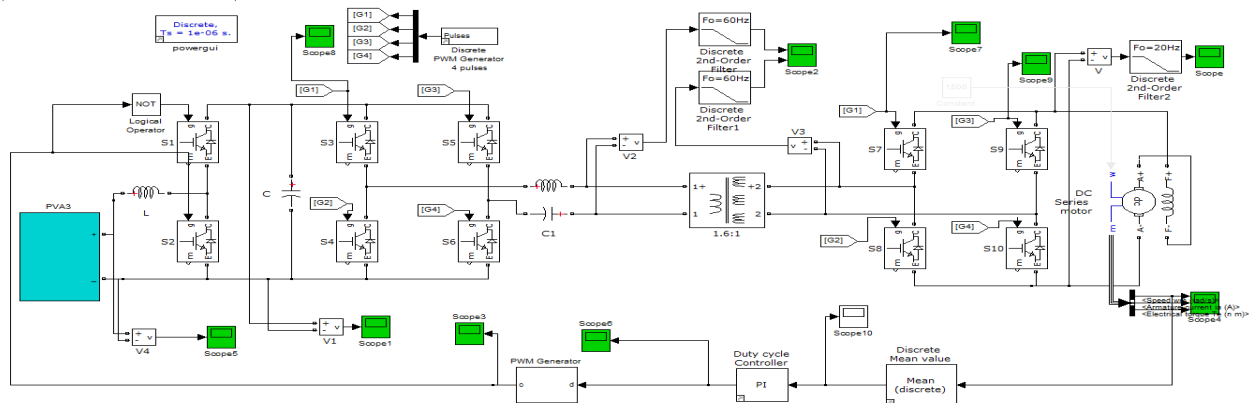

Fig : simulink model

The simulink diagram shown above is the complete model of a PV array connected to a dc motor through a dc to dc converter.
The figure shown below represents the output waveforms of the dc motor. The first waveform represents the speed of the motor for the time(t).
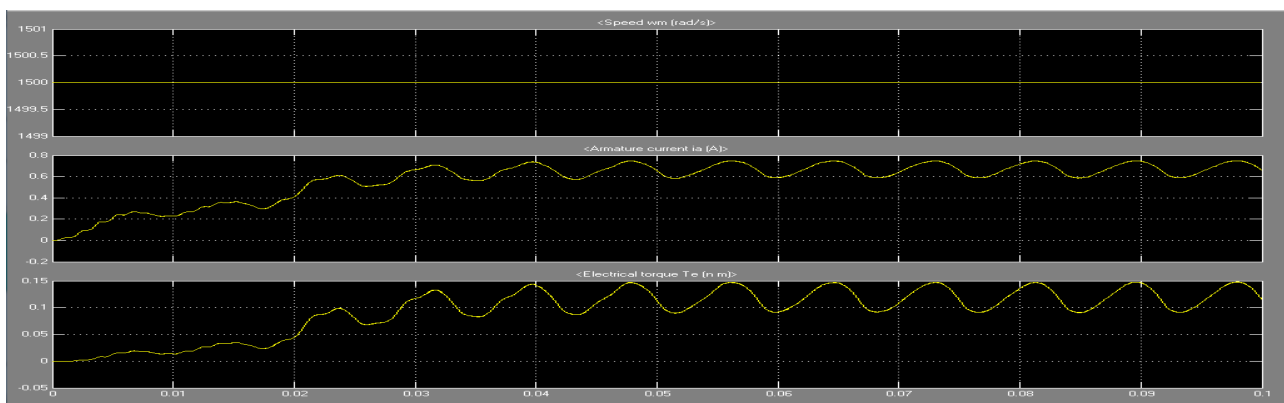

Fig : Output waveforms for speed ,armature current and torque Vs time.

The second waveform represents the armature current of the dc motor for a particular time(t). And the third waveform represents the torque of the dc motor for a particular time(t).

VI.CONCLUSION

The simulation of the isolated bi directional dc to dc converter connected to a motor load fed by a photovoltaic cell is carried. This is an efficient way of utilizing the non renewable energy resources for domestic appliances where there is no availability of power supply.

Here the use of the bidirectional dc to dc to converter is advantageous as it enhances the signal and helps in boosting the voltage obtained from the output of the photovoltaic array. The output of the PV array is a low voltage which can be boosted up to a required level using the converter. This is the great advantage of this project as the appliances can be run with less number of solar cells. This work can be extended to even ac motors by introducing an inverter circuit at the load side. Hence this can be best option at the remote places where there is no way to transmit the power.

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BIOGRAPHY

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