

Performance Analysis of a Solar Powered BLDC Motor

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ABSTRACT: This paper proposes a photovoltaic system by using BLDC motor without the use of Chemical storage space elements such as batteries. The DC-DC boost converter is considered to drive BLDC motor directly since a photovoltaic energy. Evaluate the BLDC motor PV system a superior solution of the DC and Induction motor PV system. The PV system of BLDC motor more reliable and efficient. During this work, it is advance improved with the use of non isolated improvement snubber along with a MPTT controller and the use of constant PWM control to improve its efficiency. The method is excepted high life time, due to the BLDC motor and the total cost is reduced. The method is improved solution to be used non isolated location and to send water for poor country.

KEYWORDS: Solar power generation, Photovoltaic array, DC-DC boost converter, DC-AC three phase inverter, BLDC motor.

I. INTRODUCTION

The PV systems [1] in DC motors have low efficiency, low speed range, high maintain, high electric noise as compared to BLDC motor and output power is moderate dynamic response is lower compared to BLDC motor [2]. The DC-DC boost converter [3] have high efficiency, low cost, high life span, easy operation. The total diagram of the PV system is shown below. The aim of this thesis is to improve, analyse and test, via simulation control algorithm for MPTT technique, BLDC motor. These BLDC motors are fast in advance status. These motors frequently used in industries, aerospace, medical and instrumentation.

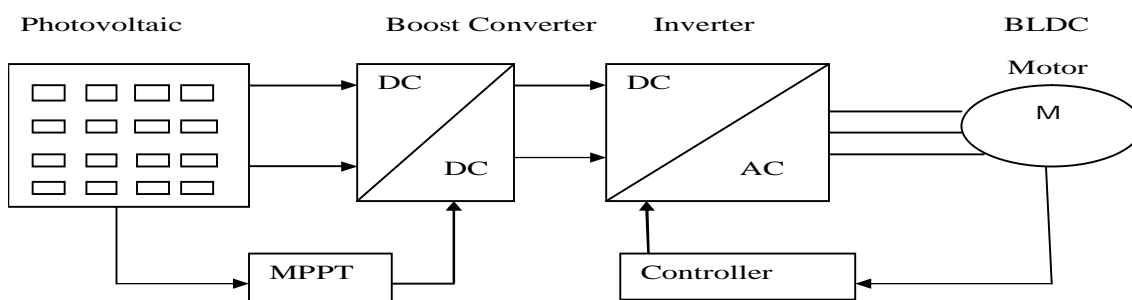


Fig.1: Block diagram of PV system

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II. PHOTOVOLTAIC SYSTEM

A photovoltaic cell [4] is a particular semiconductor diode to converts observable light into direct current. The simplest model of a PV cell [5] consists of an ultimate current source in parallel by ideal current source in parallel among an ideal diode. The current source represents the current generated by photons, and its output is constant under constant temperature and constant incident radiation of light. The PV current is shown in below equation [6].

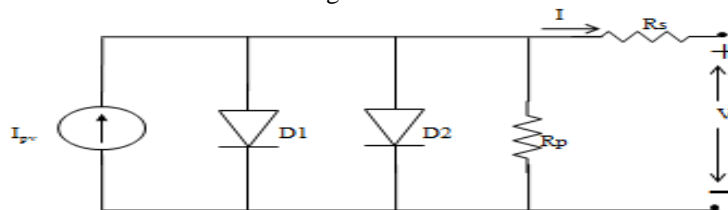


Fig 2: Two-diode model of PV solar cell.

$$I = N_{pp} \times I_{pv} - N_{pp} \times I_{ol} \left[\exp \left(\frac{q \times \left(V + IR_s \left(\frac{N_{ss}}{N_{pp}} \right) \right)}{N_{ss} A k T} \right) - 1 \right] - N_{pp} \times I_{o2} \left[\exp \left(\frac{q \times \left(V + IR_s \left(\frac{N_{ss}}{N_{pp}} \right) \right)}{N_{ss} A_2 k T} \right) - 1 \right] - \left(\frac{V + IR_s \left(\frac{N_{ss}}{N_{pp}} \right)}{R_p \left(\frac{N_{ss}}{N_{pp}} \right)} \right) \quad (2.1)$$

2.2 Maximum Power Point Tracking:

Maximum Power Point Tracking [7], commonly referred to as MPPT, is an electronic system with the aim of operates the Photovoltaic (PV) modules in a way that allows the modules to generate all the power they are able of. MPPT is not a mechanical tracking system that “physically move” the modules to make them point more honestly at the sun [8].

2.3 Perturb and observe (hill climbing method) [9]

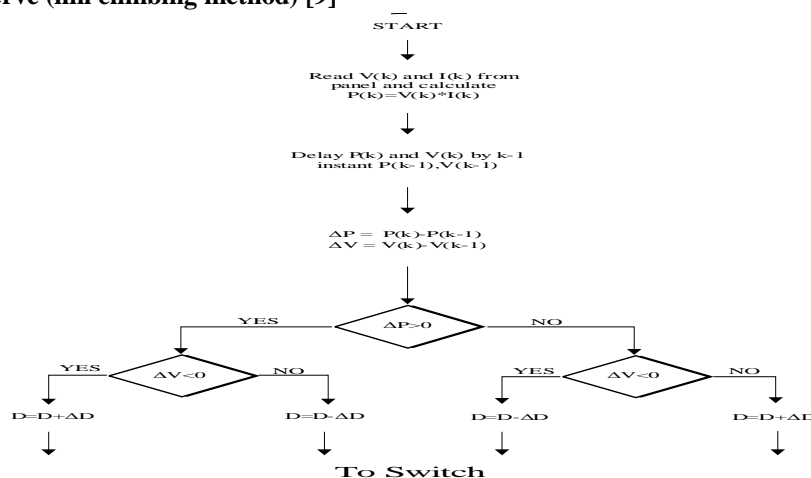


Fig.3: Flowchart of the perturb and observe algorithm

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III. BLDC MOTOR

A BLDC motor [10] is operate by way of an electronic six step communication. In its place, the electromagnets inside the motor remain stationary beside with armature, while encased permanent magnets rotate, generating torque. The BLDC motor is synchronous, mutually the stator and the magnetic field generate the same frequency, therefore avoid any type of slip. Six step commutations is a cost effectual means of electronic commutation [11]. In six step commutation, only two out of the three BLDC motor windings are use at a time steps are the same 60 degree, so six steps makes a full, 360 degree rotation. One full 360 degree round is able to control the current, suitable to the fact that there is only one current path. Six step commutations are typically helpful in application require high speed and Commutation frequencies. A six step BLDC motor regularly has lesser torque efficiency than a sine wave commutated motor [12].

3.1 Modeling Equations of BLDC Motor [13]

$$V_a = R_a I_a + \frac{d}{dt}(L_{aa} I_a + L_{ab} I_b + L_{ac} I_c) + \frac{d\delta_{ar}}{dt}(\theta) \quad (3.1)$$

$$V_b = R_b I_b + \frac{d}{dt}(L_{ba} I_a + L_{bb} I_b + L_{bc} I_c) + \frac{d\delta_{br}}{dt}(\theta) \quad (3.2)$$

$$V_c = R_c I_c + \frac{d}{dt}(L_{ca} I_a + L_{cb} I_b + L_{cc} I_c) + \frac{d\delta_{cr}}{dt}(\theta) \quad (3.3)$$

$$J \frac{d\omega_r}{dt} + B\omega_r = T_e - T_l \frac{d\theta}{dt} = \frac{P}{2} \omega_r \quad (3.4)$$

$$\dot{X} = AX + BU \quad (3.5)$$

$$X = \begin{bmatrix} I_{as} \\ I_{bs} \\ I_{cs} \\ \omega_r \\ \theta \end{bmatrix} \quad (3.6)$$

$$T_e = \gamma_p [F_{as}(\theta) I_{as} + F_{bs}(\theta) I_{bs} + F_{cs}(\theta) I_{cs}] \quad (3.7)$$

$$A = \begin{bmatrix} \frac{-R_s}{L_1} & 0 & 0 & \frac{\gamma_p F_{as}(\theta)}{L_1} & 0 \\ 0 & \frac{-R_s}{L_1} & 0 & \frac{-\gamma_p F_{bs}(\theta)}{L_1} & 0 \\ 0 & 0 & \frac{-R_s}{L_1} & \frac{-\gamma_p F_{cs}(\theta)}{L_1} & 0 \\ \frac{\gamma_p F_{as}(\theta)}{J} & \frac{\gamma_p F_{bs}(\theta)}{J} & \frac{\gamma_p F_{cs}(\theta)}{J} & \frac{-B}{J} & 0 \\ 0 & 0 & 0 & \frac{P}{2} & 0 \end{bmatrix}, B = \begin{bmatrix} \frac{1}{L_1} & 0 & 0 & 0 \\ 0 & \frac{1}{L_1} & 0 & 0 \\ 0 & 0 & \frac{1}{L_1} & 0 \\ 0 & 0 & 0 & \frac{-1}{J} \\ 0 & 0 & 0 & 0 \end{bmatrix}, U = \begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \\ T_l \end{bmatrix} \quad (3.8)$$

IV. PULSE WIDTH MODULATION

Pulse width modulation (PWM) [14] is a method in which a series of digital pulses is use to be in command of an analog circuit. The length and frequency of these pulses determine the total power deliver to the circuit. PWM signals are mainly usually used to control DC motors, but contain many other applications ranging from controlling valves or pumps to adjusting the intensity of an LED.

The main benefit of PWM is that power failure in the switching devices is very low. When a switch is off there is basically no current, and when it is on and power is being transfer to the load, there is approximately no voltage drop across the switch. Power loss, being the produce of voltage and current, is thus in equally cases close to zero. PWM also works well with digital controls, which, since of their on/off nature, can simply set the required duty cycle. Pulse-width modulation use a [rectangular pulse wave](#) whose pulse width is modulate follow-on in the variation of the

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average value of the waveform. If we consider a pulse waveform $f(t)$, with period T , low value y_{min} , a high value y_{max} and a duty cycle D , the average value of the waveform is given by

$$\bar{y} = \frac{1}{T} \left(\int_0^{DT} y_{max} dt + \int_{DT}^T y_{min} dt \right) = \frac{y_{max} \cdot D \cdot T + T(1-D)y_{min}}{T} \quad (4.1)$$

$$= y_{max} \cdot D + (1 - D)y_{min} \quad (4.2)$$

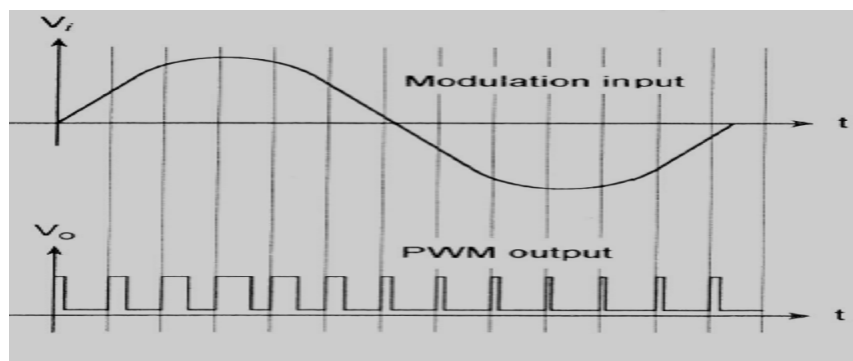


Fig.4: Waveform of Pulse Width Modulation

4.1 MPPT Control

The MPPT [15] is a approach used to guarantee that the operating point of the system is kept at the MPP of the PV panel. In this work the perturb and observation method is used because it is a true MPPT, and its implementation complexity is low and it requires no periodic tuning, also independent of PV array. The MPPT block is shown in Fig 5.



Fig.5: MPPT block

The MPPT building block as shown in Fig.5 has two input signals one is photovoltaic voltage V_{pv} and other one is photovoltaic current I_{pv} and it has one output signal i.e. the duty cycle D which is specified to the MOSFET gate of a boost converter.

4.2 BOOST CONVERTER:

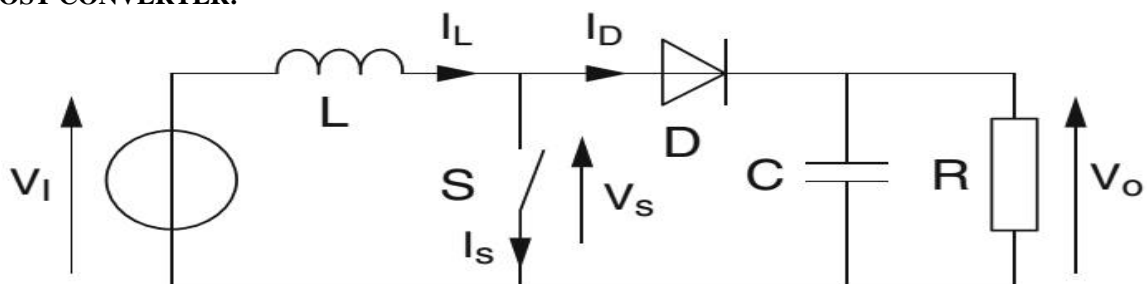


Fig.6: Circuit diagram of boost converter

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The fundamental dc-dc boost converter circuit which can generate an output voltage greater than the source input voltage The DC-DC boost converter is use as an adapter between the PV generator and the motor-pump group.

1. Duty cycle, $D = 1 - \frac{V_s}{V_o}$
2. Inductance, $L = \frac{V_s * D}{\Delta I * f}$
3. Capacitance, $C = \frac{I_o * D}{\Delta V * f}$

4.3 System Parameters:

Filter resistance	R_f	0.001Ω
Filter inductance	L_f	4.7mH
Phase voltages	V_p	300V
Voltage frequency	F	50Hz
Dc input from PV array	V_{dc}	300V
Sampling period	T_s	50μs
Capacitance	C	15mF
Inductance	L	0.1mH

V. EXPERIMENTAL RESULTS

1. The source voltage V_s ,

Where $V_s=152V$.

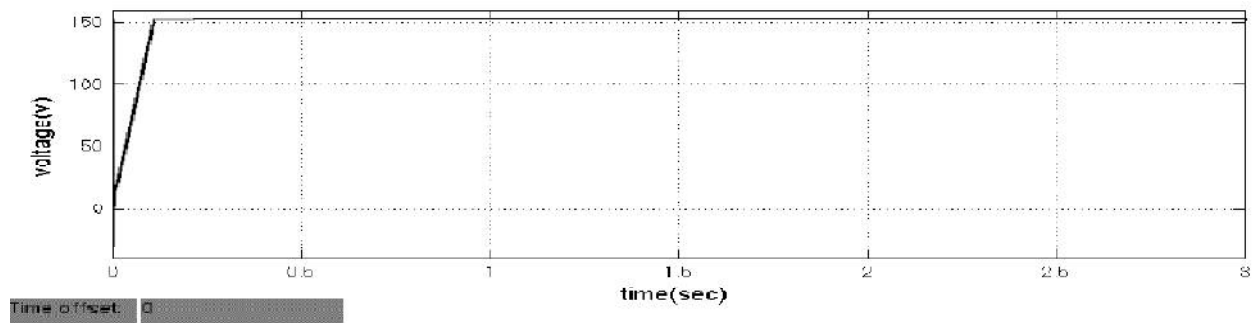


Fig.7: Source voltage V_s from PV array

2. Photovoltaic current ($I_{pv}=84.5A$)

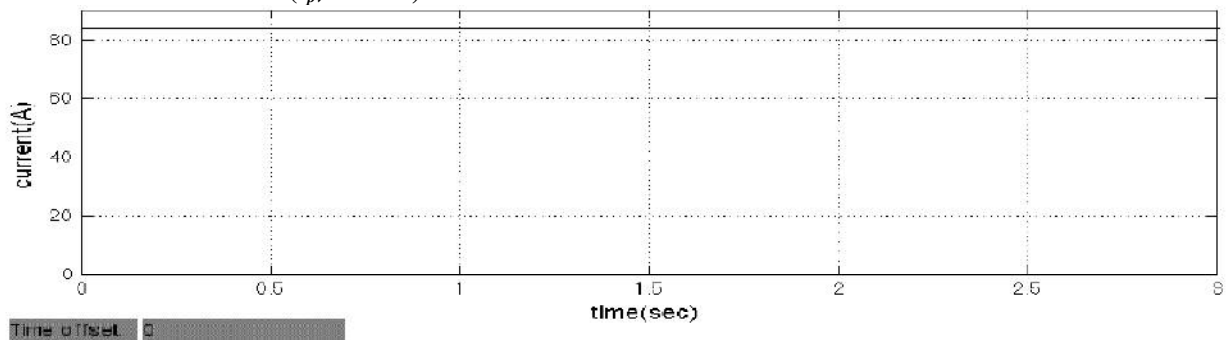


Fig. 8: Photovoltaic current

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Based on simulations of solar PV module drawn their various characteristics and presented them in the above figures (Figure 7: solar voltage versus time, Figure 8: solar PV module Current versus time). By seeing these output voltage and current waveforms it is clearly observed that solar PV module producing variable natured DC quantities under varying atmospheric conditions. Hence perturb and observe mode MPPT is designed to make these quantities constant at the optimum operating point of solar PV module with the help of DC-DC converter.

3. The output voltage of DC-DC boost converter ($V_o=300V$)

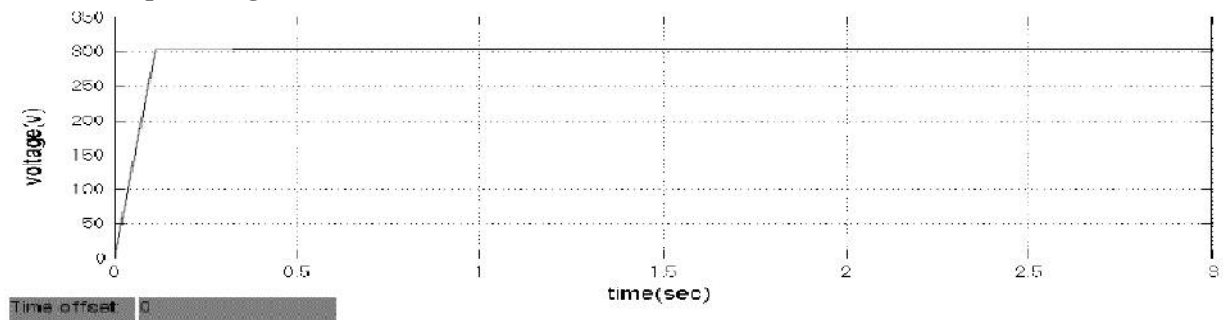


Fig. 9: Dc link voltage (Vdc) output of DC-DC boost converter

The output voltage of DC-DC boost converter is shown in above figure 9 and output voltage is 300V.

4. Gate signal of inverter

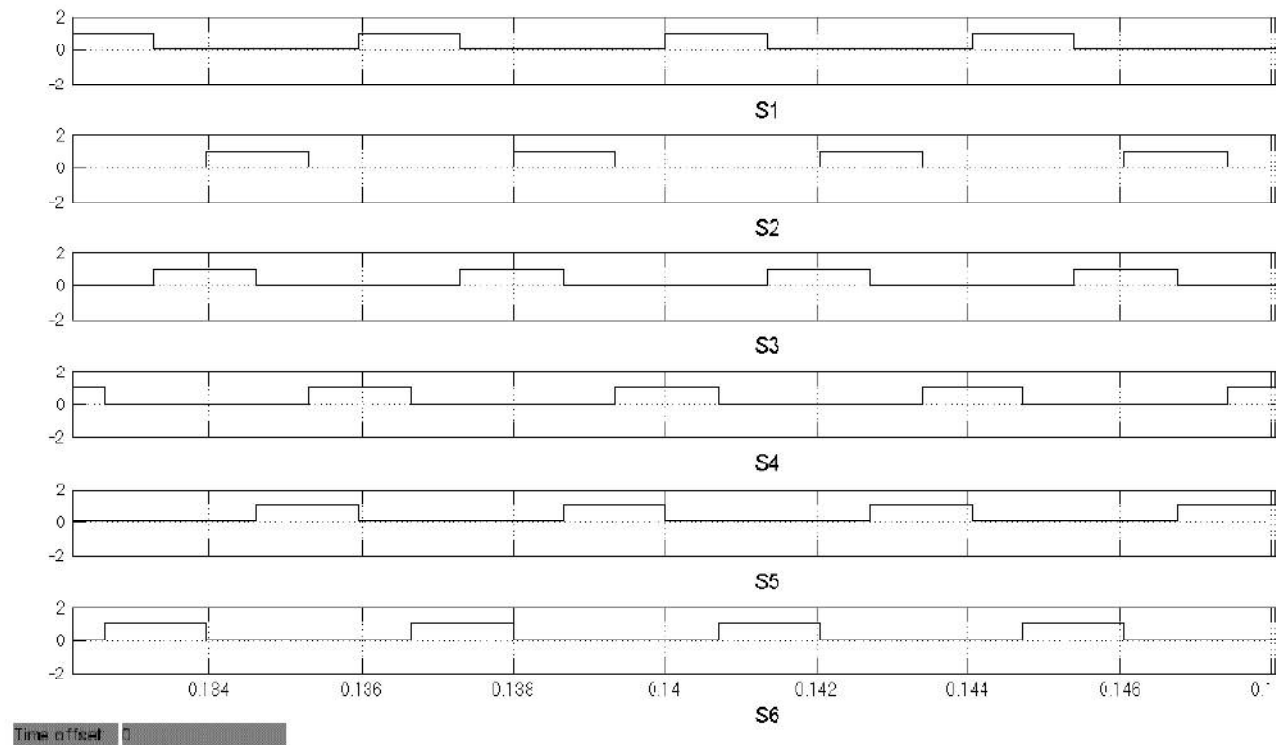


Fig. 10: Gate signal of inverter

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The gate signal of inverter is shown in above fig 10. PWM controller is used for generating pulses, which is to be fed to the inverter. Apart from isolating it also isolates the power circuit part and the control (PWM) circuit part. The operation of power supply circuits built using filters, rectifiers, and then voltage regulators. Starting with an AC voltage, a steady DC voltage is obtained by rectifying the AC voltage, then filtering to a DC level, and finally, regulating to obtain a desired fixed DC voltage. The gate signal across S1, S3, S5, S2, S4, S6 are shown in figure 10.

5. Line to line voltages of inverter (V_{ab})

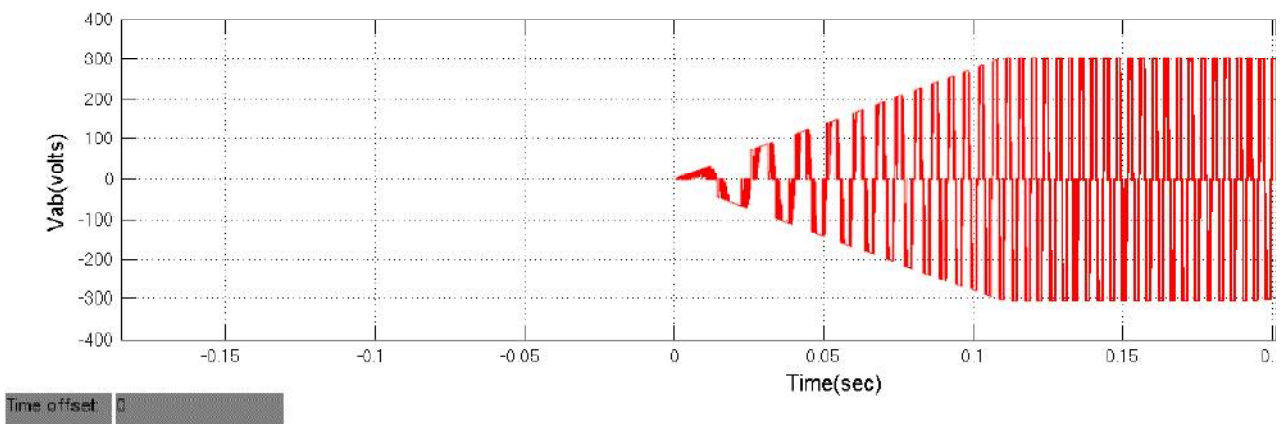


Fig. 11: Line to line voltages of inverter (V_{ab})

6. Line to line voltages of inverter (V_{bc})

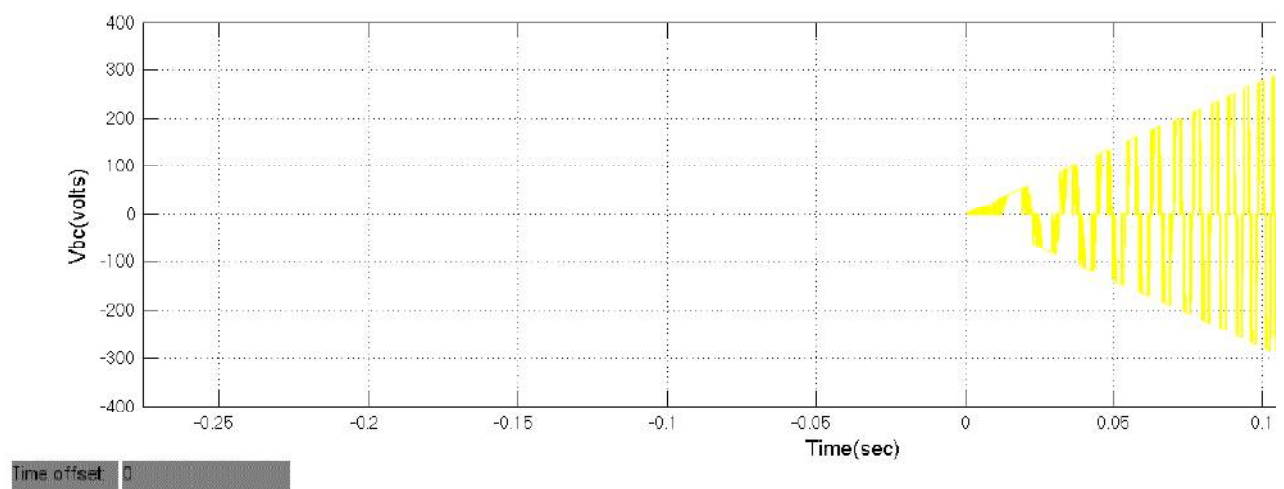


Fig.12: Line to line voltages of inverter (V_{bc})

7. Line to line voltages of inverter (V_{ca})

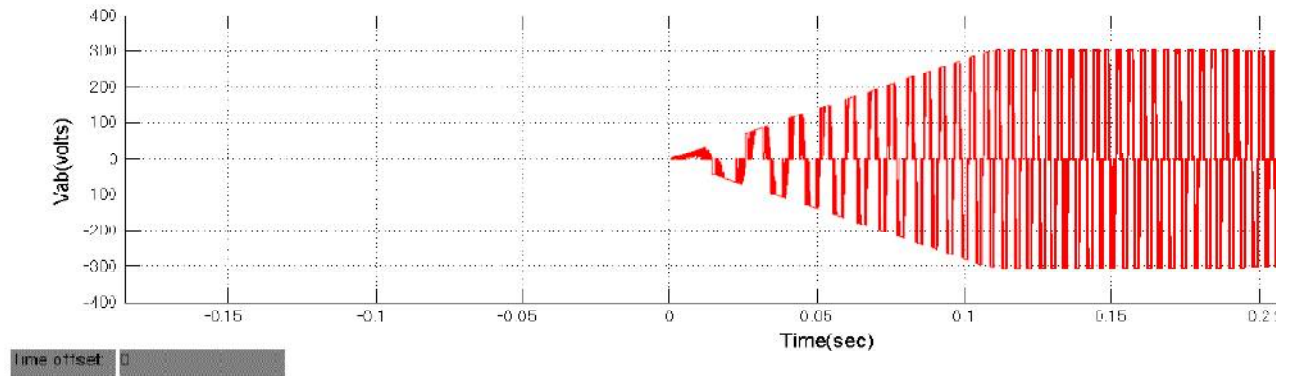


Fig. 13: Line to line voltages of inverter (V_{ca})

The line to line voltages of inverter as shown in above figure 11, 12 and 13. The line voltage is 300V.

8. Stator current of BLDC motor

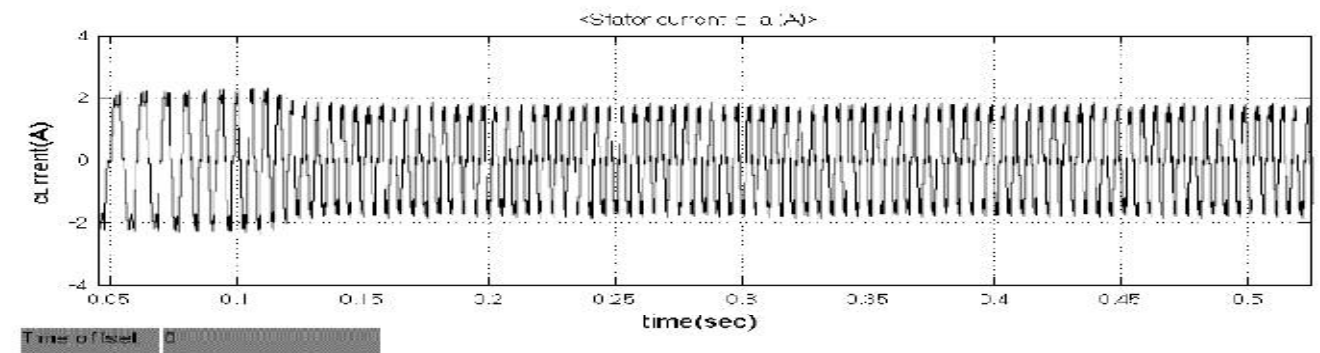


Fig. 14: Stator current of BLDC motor

9. Speed of BLDC motor

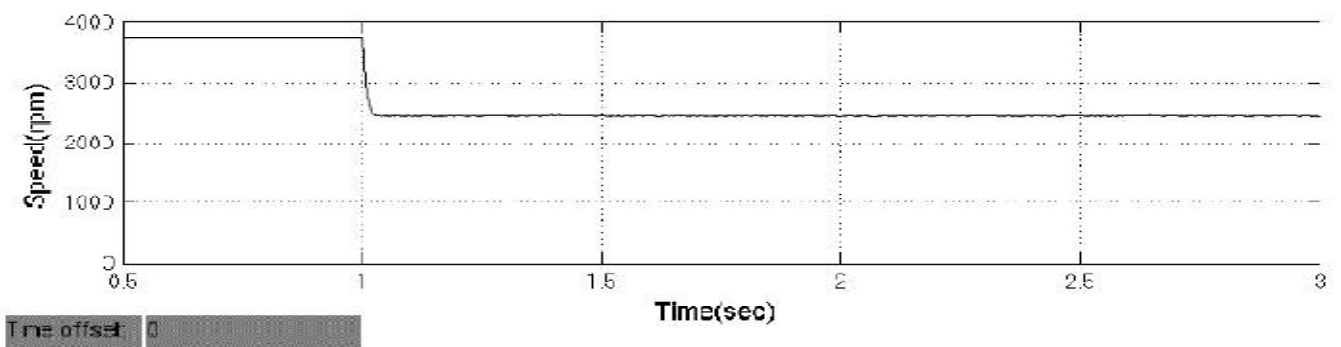


Fig. 15: Speed of BLDC motor

10. Torque of BLDC motor

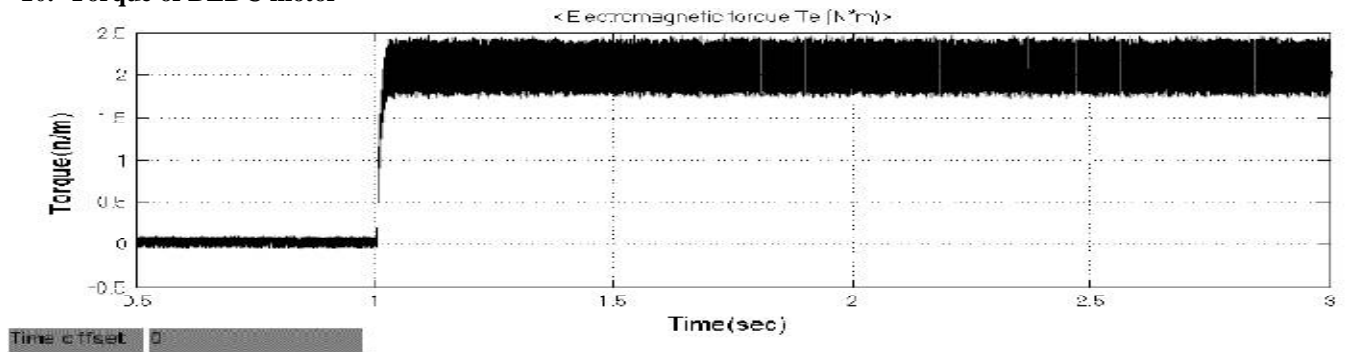


Fig. 16: Torque of BLDC motor

- I. BLDC motor is connected to the PV system and input signal of BLDC motor is step signal. Speed of the BLDC motor 3800 rpm at initial Torque is zero. By applying the step signal at the time constant of one and decreasing the speed of BLDC motor is 2500.

11. Stator current of BLDC motor

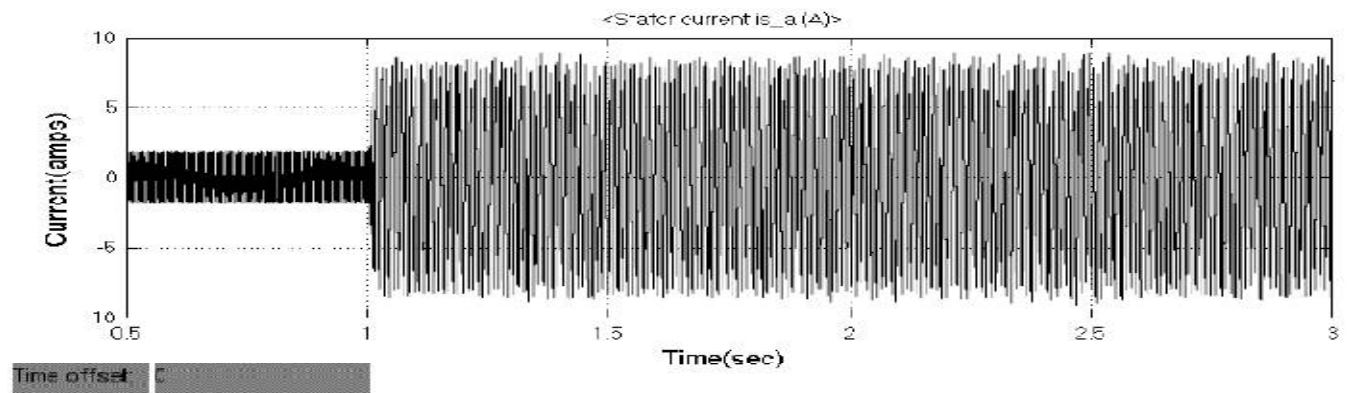


Fig. 17: Stator current of BLDC motor

12. Speed of BLDC motor

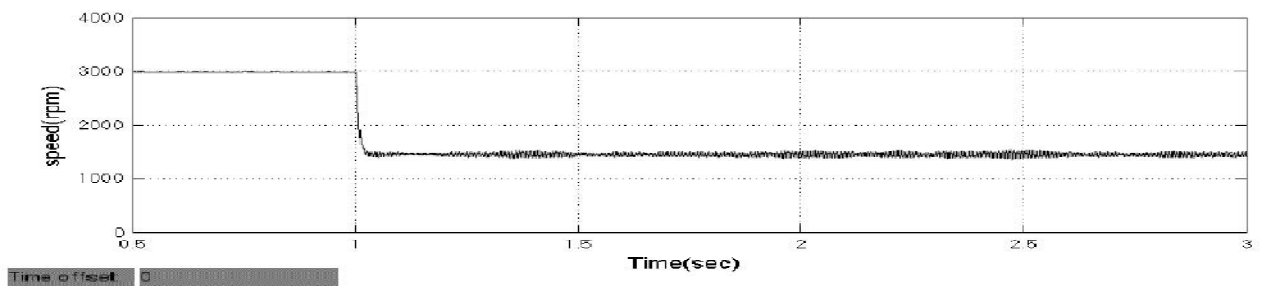


Fig. 18: Speed of BLDC motor

13. Torque of BLDC motor

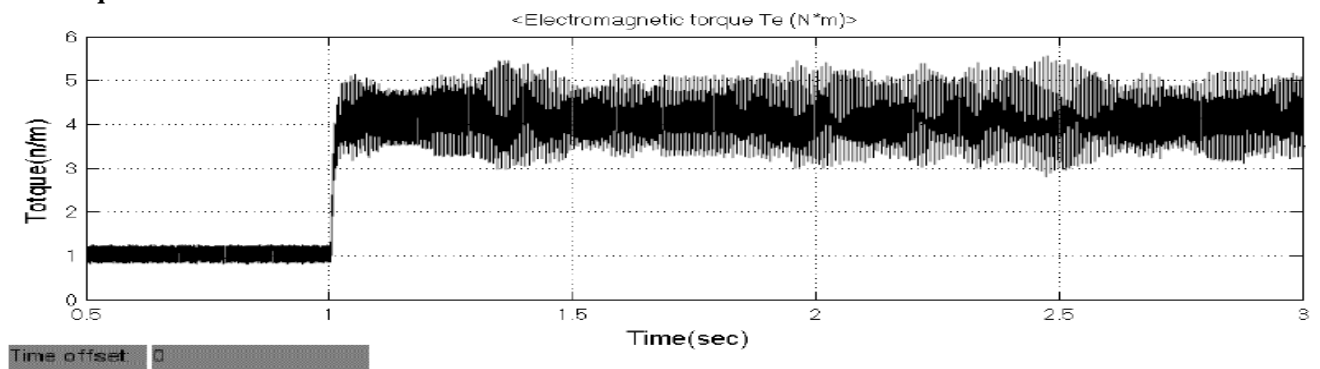


Fig. 19: Torque of BLDC motor

- II. BLDC motor is connected to the PV system and input signal of BLDC motor is step signal. Speed of the BLDC motor 3000 rpm at initial Torque is one. By applying the step signal at the time constant of one and decreasing the speed of BLDC motor is 1500.

VI. CONCLUSION

We have implemented a PV system using BLDC motor. Firstly, design of system happening with the design of BLDC motor by in view of the load to it, after that drawing of solar PV array is completed to meet the order of BLDC motor fed load. considered solar PV array consists of 7 solar PV models with module base MPPT charge controllers and these boost converter base MPPT charge controllers are controlling with the help out of P&O method MPPT to extract maximum power from the modules. And all the solar PV modelled base MPPT charge controllers are connected in parallel to meet the current demand of the load. The load be supposed to have a torque-speed curve that increase as rapidly as probable in the operating region, which provide a good match between the uniqueness of the PV array and the electromechanical system. Also, the load must have low starting torque. The performance investigation of the PV system using BLDC motor will be of use to select the suitable motor and load for PV system application in isolated area.

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