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PV Connected BLDC Motor Drive by Employing P&O MPPT Controller

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ABSTRACT: In this paper Brushless DC motor drive is utilized as the load of a Photovoltaic system with Maximum Power Point Tracking (MPPT) controller. Perturbation and Observation (P&O) based approach for MPPT controller is presented. A brushless DC motor that unites a motor controller with Proportional Integral (PI) speed control loop is effectively instigated. MATLAB/Simulink is used to construct the dynamic model and simulate the system. The solar Photovoltaic system uses MPPT controller where the output signal is used to govern the DC-DC boost converters to accomplish the MPPT. This proposed MPPT controller produces an average power increase and this unit provides rapid achievement of the MPPT and current control of the BLDC motor drive.

I. INTRODUCTION

A photovoltaic system converts sunlight into electricity. The central device of a photovoltaic system is the photovoltaic cell. Cells are grouped to form panels or modules. Panels are grouped to form large photovoltaic arrays. The term array is usually employed to describe a photovoltaic panel (with several cells connected in series and/or parallel) or a group of panels. The term array used henceforth means any photovoltaic device composed of several basic cells [1]. The output voltage, current and power of PV array vary as functions of solar irradiation level, temperature and load current. Therefore the effects of these three quantities must be considered in the design of PV arrays so that any change in temperature and solar irradiation levels should not adversely affect the PV array output to the load/utility, which is either a power company utility grid or any stand alone electrical type load. Solar energy has many advantages such as readily available, abundant, and low carbon emission etc.

The coupling between the motor load and the PV module is implemented via a maximum power point tracking (MPPT) controller to operate the PV system at its maximum output power for any temperature and solar radiation level. In principle, this controls the output voltage of a PV panel automatically so that it can operate continuously on the maximum power points irrespective of load variation, solar radiation and temperature changes. The purpose of this paper is to study the execution, efficiency of Perturbation and Observation (P&O). P&O can track the Maximum Power Point (MPP) all the time, irrespective of the atmospheric conditions, type of PV panel, and even aging, by processing actual values of PV voltage and current. Since the cost of the required circuitry for implementing on-line MPPTs is higher, they are usually employed for larger PV arrays [2].

II. PV MODELING

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. Figure1 shows Single diode model of a PV cell it has its own series and parallel resistance.

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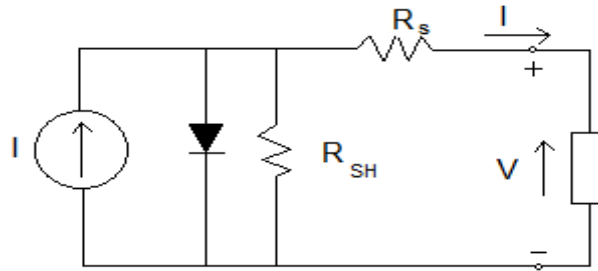


Figure 1 Single diode model of a PV cell

Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current. In this model we consider a current source (I) along with a diode and series resistance (R_s). The shunt resistance (R_{sh}) in parallel is very high, has a negligible effect and can be neglected [3].

The output current from the photovoltaic array is

$$I = I_{sc} - I_d \dots \dots \dots (1)$$

$$I_d = I_0 (e^{qV_d/kT} - 1) \dots \dots \dots (2)$$

where I_0 is the reverse saturation current of the diode, q is the electron charge, V_d is the voltage across the diode, k is Boltzmann constant (1.38×10^{-19} J/K) and T is the junction temperature in Kelvin (K)

$$I = I_{sc} - I_0 (e^{qV_d/kT} - 1) \dots \dots \dots (3)$$

Using suitable approximations,

$$I = I_{sc} - I_0 (e^{q(V+IR_s)/nkT} - 1) \dots \dots \dots (4)$$

where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor . Figure 2 I-V characteristics of a solar panel.

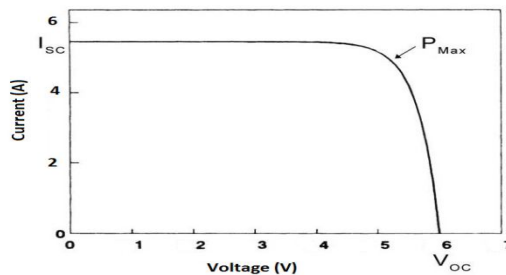


Figure 2 I-V characteristics of a solar panel

When the voltage and the current characteristics are multiplied we get the P-V characteristics as shown in Figure 3. The point indicated as MPP is the point at which the panel power output is maximum.

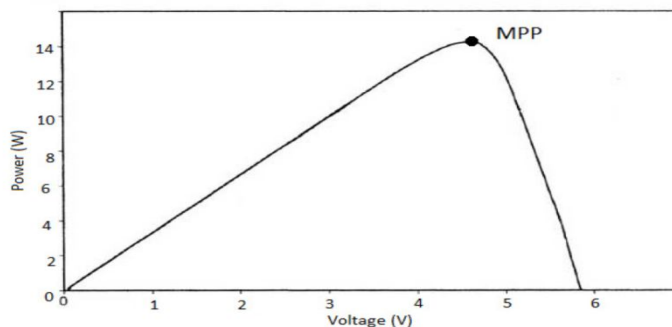


Figure 3 P-V characteristics curve of photovoltaic cell

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III. PERTURB & OBSERVE ALGORITHM

The Perturb & Observe algorithm states that when the operating voltage of the PV panel is perturbed by a small increment, if the resultant change in power ΔP is positive, then we are going in the direction of MPP and we keep on perturbing in the same direction. If ΔP is negative, we are going away from the direction of MPP and the sign of perturbation supplied has to be changed [4].

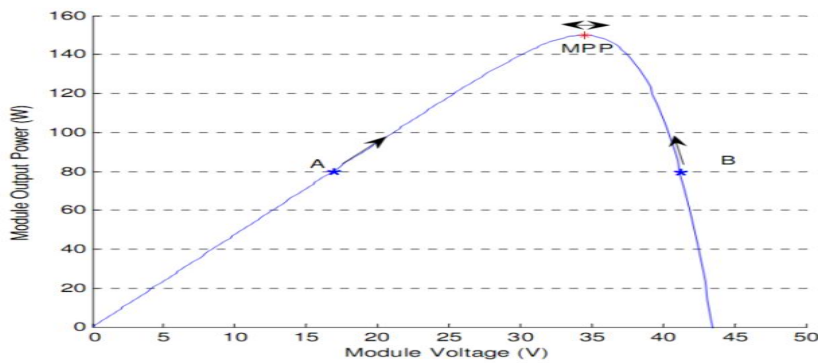


Figure 4: Solar panel characteristics showing MPP and operating points A and B

Figure 4 shows the plot of module output power versus module voltage for a solar panel at a given irradiation. The point marked as MPP is the Maximum Power Point, the theoretical maximum output obtainable from the PV panel. Consider A and B as two operating points. As shown in the figure above, the point A is on the left hand side of the MPP [5]. Therefore, we can move towards the MPP by providing a positive perturbation to the voltage. On the other hand, point B is on the right hand side of the MPP. When we give a positive perturbation, the value of ΔP becomes negative, thus it is imperative to change the direction of perturbation to achieve MPP [9]. The flowchart for the P&O algorithm is shown in Figure 5.

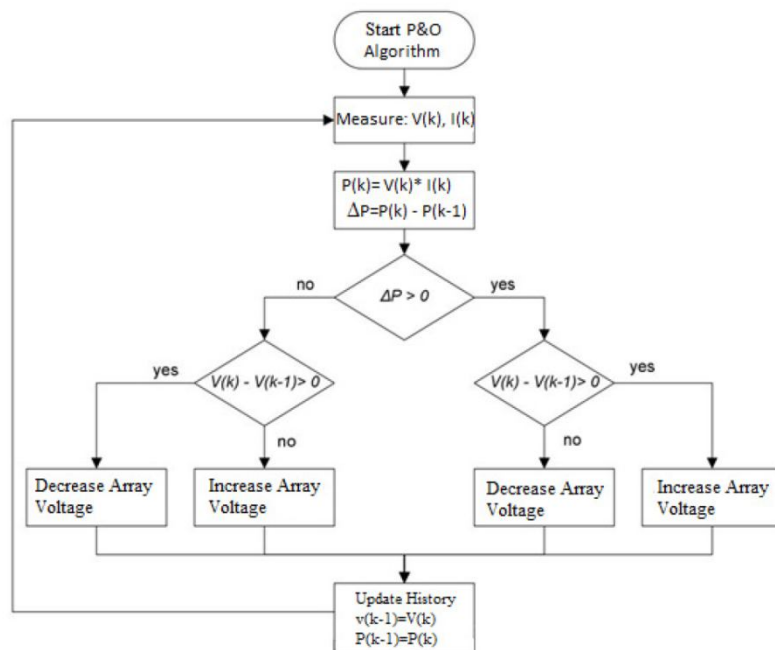


Figure 5: Flowchart of Perturb & Observe algorithm

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IV. PROPOSED BLOCK DIAGRAM

The total block diagram of the realised system is shown in Fig. 6. In the MPPT controller, P&O is utilized to track the MPP. The BLDC motor controller [5] is utilized to sense the position of rotor from the Hall Effect sensors and generate their corresponding switching signals for three phase inverter AC power to electronically commutate the motor. The speed controller also incorporates a simple proportional integral (PI) control loop. BLDC motors are different from synchronous machine in that the former incorporates some means to detect the rotor position or magnetic poles to produce signals to control the power electronic switches. The most common position/pole sensor is the Hall element; but some motors are using optical sensors. BLDC motor drives necessitate variable voltage, variable frequency (VVVF) that is usually provided by a three phase full bridge inverter. In this system consists of Proportional Integral (PI) speed controller, reference current generator, PWM controller, Hall sensor, three phase bridge inverter and the load. The speed of the motor is matched with its reference value, and the error is managed in the PI speed controller. The reference current generator makes the three phase reference currents based on the controller and the position sensor. The motor currents are compared with the reference currents, and based on that switching pulses are generated to drive the three phase bridge inverter [8]. Due to its simplest arrangement and ease implementation the PI controller is mostly used in electrical drive systems.

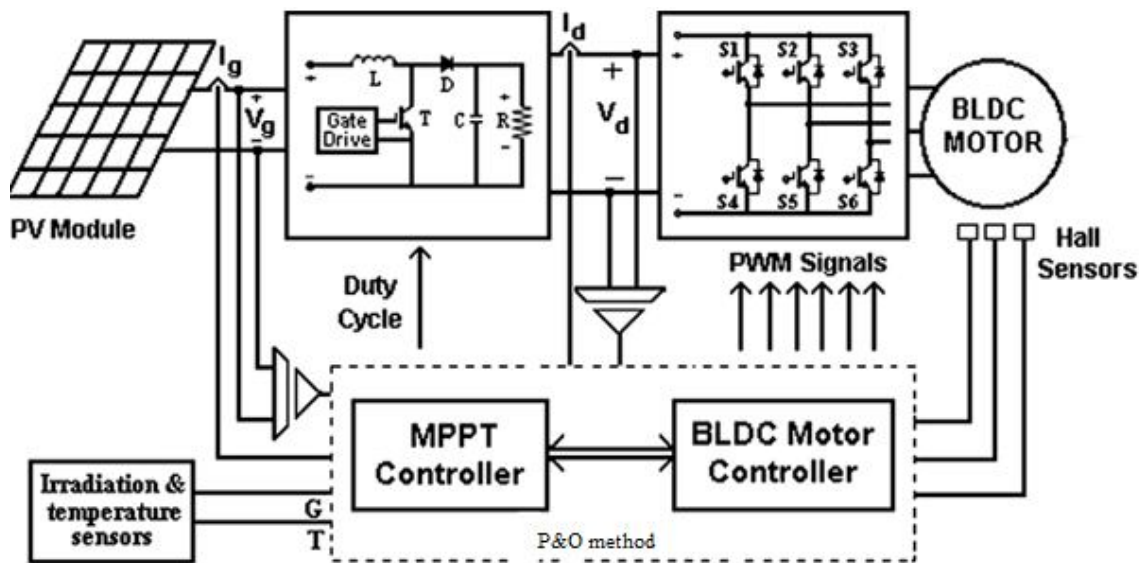


Figure.6 – Block diagram showing the proposed work

It seems that not enough attention has been given to PV systems feeding brushless DC (BLDC) motor loads, despite these motors' favourable features such as high reliability, high efficiency, less maintenance requirements and reduced environmental effects [7]. In various contributions, brushed DC motor or induction motor loads are considered. The output from the MPPT controller is given to interleaved converter which sets the maximum power by changing the duty cycle. The converter is characterized by a low input current ripple and low conduction losses; it is suitable for high power applications. The electrical parameters of BLDC motor is shown in table.

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Table I: Electrical Parameters of BLDC Motor

BLDC Motor Details		
Number of poles	P	2
Assigned power rating	W	1.2
Nominal voltage	V	6.0
No load speed	RPM	47130
Stall torque	mNm	0.50
No load current	mA	60
Terminal resistance	Ohm	12.50
phase to phase	mH	0.091
Terminal inductance	mNm/A	1.05
phase to phase	gcm ²	0.005
Torque constant	Nm. s	1.38. 10 ⁻⁸

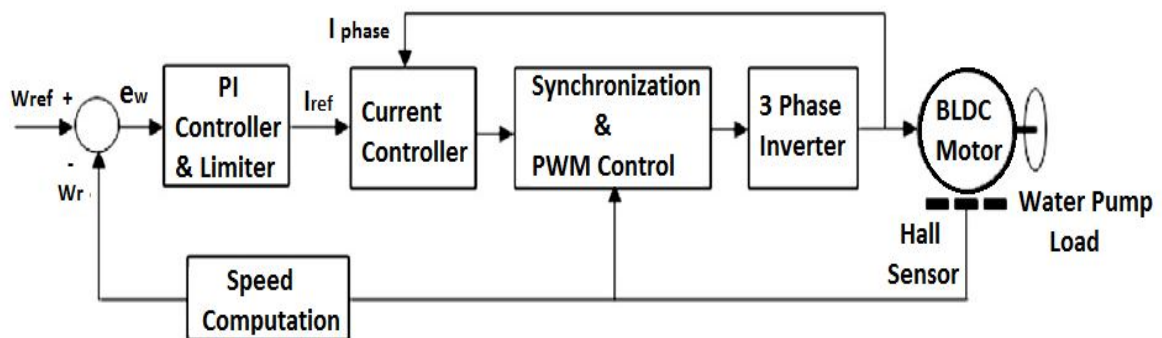


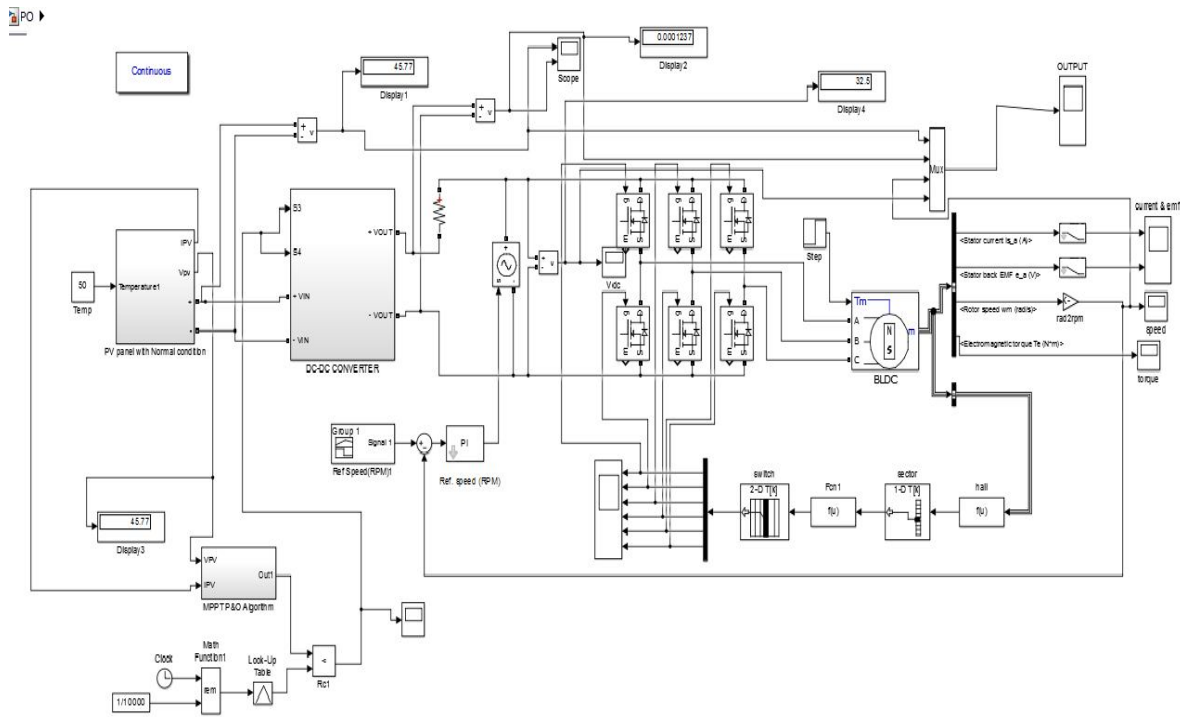
FIG.7. Block diagram of BLDC motor drive system

In this system consists of Proportional Integral (PI) speed controller, reference current generator, PWM controller, Hall sensor, three phase bridge inverter and the load [11]. The speed of the motor is matched with its reference value, and the error is managed in the PI speed controller. The reference current generator makes the three phase reference currents based on the controller and the position sensor. The PWM controller controls the winding currents (i_a , i_b , i_c) within a small band about the reference currents. The motor currents are compared with the reference currents, and based on that switching pulses are generated to drive the three phase bridge inverter [12]. Due to its simplest arrangement and ease implementation the PI controller is mostly used in electrical drive systems [13]. Fig.7 shows the Block diagram of BLDC motor drive system.

V. SIMULATION RESULT

Model For Perturb & Observe Algorithm

Figure 8: Model For Perturb & Observe Algorithm



The simulation model for perturb & observe algorithm for MPPT controller with BLDC motor as a load is shown in figure 8. The PV modelling is been discussed above. To MPPT controller (based on P&O algorithm) inputs are given from PV array and the temperature [10]. The figure.9 shows the PV and converter output voltage in P&O method and Fig: 10 the motor speed and figure: 11 show the stator current, electromotive force of BLDC motor. The converter output voltage will vary based on the speed of the rotor. The rotor speed is sensed by the sensor. The rotor speed and reference speed is given to PI controller. The settling time is 1.0 sec and the tracking of MPPT is quick and the steady state error is less compared to conventional method.

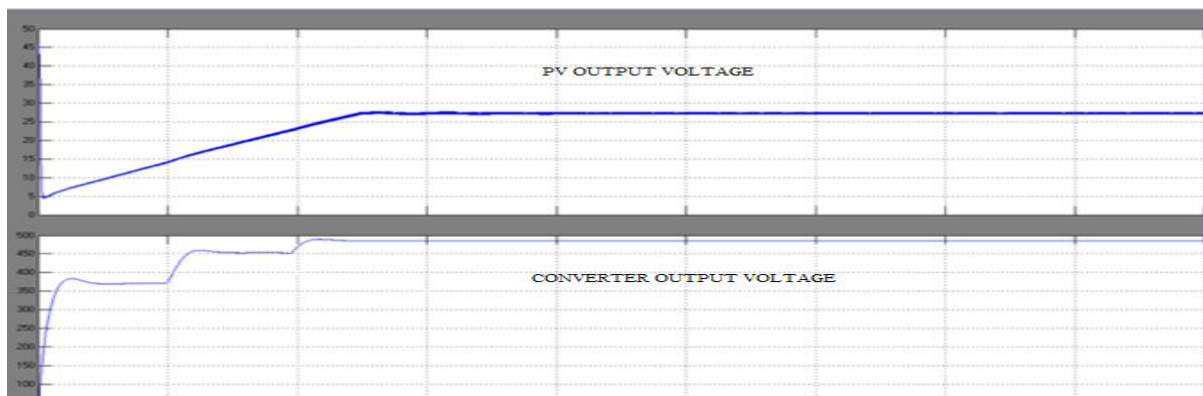


Figure: 9 PV output voltage and converter output voltage in P&O method

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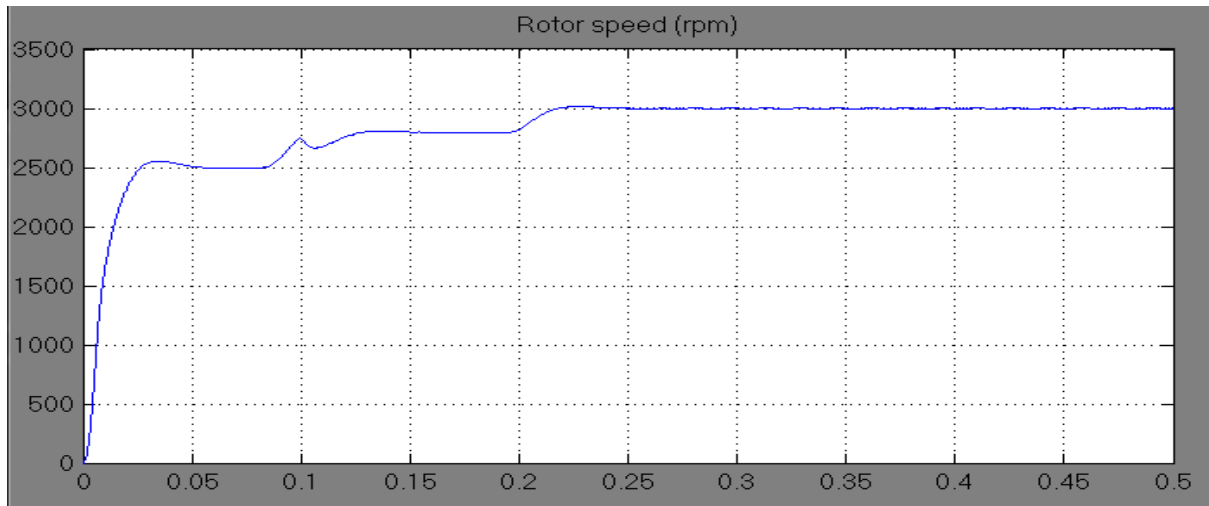


Figure 10: Motor speed of BLDC motor

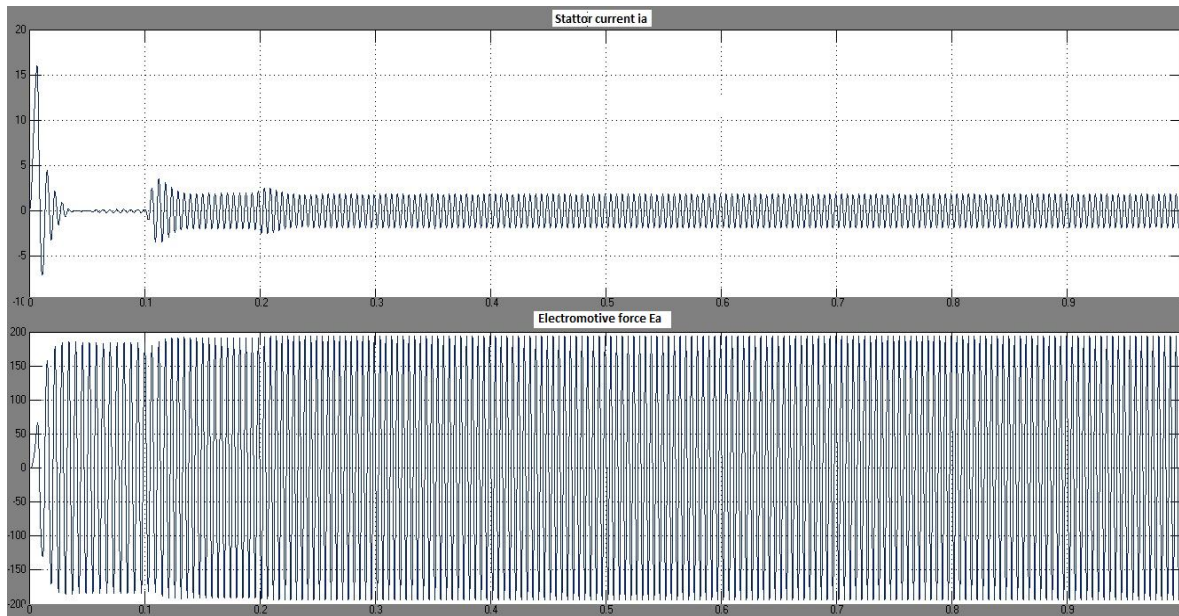


Figure 11: stator current, electromotive force of BLDC motor

VI CONCLUSION

In this paper, the MPPT algorithms which can find the real MPP were reviewed. For simplicity and effectiveness reasons, P&O is selected. A simplified model of the PV system was developed. It is found that the P&O technique is the most extensively used in commercial MPPT systems because it is straight forward, accurate, and easy to implement. Its accuracy and tracking time depend on perturbation size.

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The main part of the work was involved in the development of the interaction with BLDC motor. The aim was to make a model that would be simple, accurate, and easy to modify and fast running. The settling time of the motor is also reduced. It is believed that the goals have been reached parameters of a real BLDC motor were used and it was verified that the model performed according to the information.

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