

# Analysis of PV Powered BLDC Drive using SMC Control Technique

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**Abstract**— This paper presents a detailed speed control analysis of PV powered BLDC (Brushless DC Motor) motor equipped electric vehicles using sliding mode control. The performance of the BLDC motor is compared with PI and sliding mode control. The parameters like torque, speed, direct current and quadrature currents are considered for analysis. The test results of SMC method gives better performance than the existing control method. The results of the proposed system have been validated using MATLAB/SIMULINK.

**Keywords** -- Boost Converter; Brushless DC motor; Electric Vehicles; Photo Voltaic; Proportional Integral Controller; PWM technique; Sliding Mode Controller.

## I. INTRODUCTION

Solar strength is loose, inexhaustible, and smooth; it's an great capability to be a virtually engaging provide choice for industrial and home programs, in particular in far flung areas, like pumping, heating, and cooling, electric phenomenon (PV) structures use the PV modules to convert the daylight hours into voltage[1]. Additionally, PV vehicle have most important developments within the subject of electrical cellular material and era. They're extensive utilized in domestic and ethereal mammal provides and small-scale irrigation systems. For such PV structures, most electric powered receptacle trailing control is maximum famous for within your budget operation. All has conferred a MPPT system for PV machine by using utilizing consistent country electricity reconciliation condition at DC hyperlink. The PV gadget has found numerous capacity applications like residential, vehicular, residence air craft and refrigerator compressor system [2]. PV vehicles are very competitive compared to historical energy technologies and first-class ideal to far flung website programs that have tiny to mild electricity needs. The potency of Induction

motors vicinity unit much less as compared to static magnet automobiles, while DC machines are not appropriate for submersible installations [3],[4]. The performance of single-phase induction motor with the control of single phase Z-source inverter using Simple boost controller is given in the reference [5]. In this paper a detailed speed control analysis of PV powered BLDC motor used for electric vehicles has been explained.

## II. SYSTEM DESCRIPTION AND PRINCIPLE OF OPERATION

The PV system considered for this study is shown in fig.1. The modelling is tried via (6), wherein,  $I_{PV}$ ,  $V_{PV}$  are the PV array cutting-edge and voltage severally.  $R_{sh}$  and  $R_s$  are the intrinsic shunt and series resistances of the array,  $I_{sc}$  being the quick present day of the array,  $G$  is that the irradiance ( $W/m^2$ ),  $q = 1.602 \times 10^{-19} C$  being the negatron price, Boltzmann's regular ( $K$ ) =  $1.3806 \times 10^{-23} J/K$ , p-n junction's excellent issue ( $A$ ) = a pair of ,  $T$  is array temperature (in  $0K$ ),  $I_0$  is diode reverse saturation contemporary,  $T_r$  is cellular reference temperature and  $I_{rr}$  is opposite saturation contemporary at  $T_r$  [7].

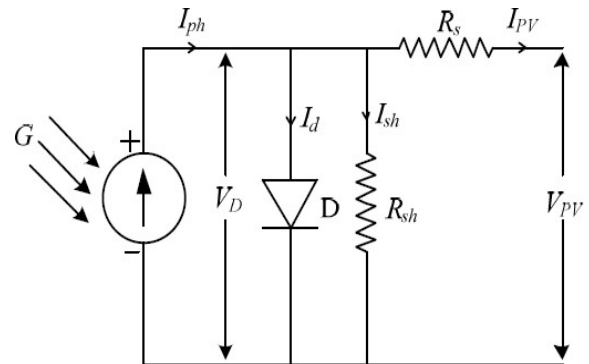


Fig 1. PV device

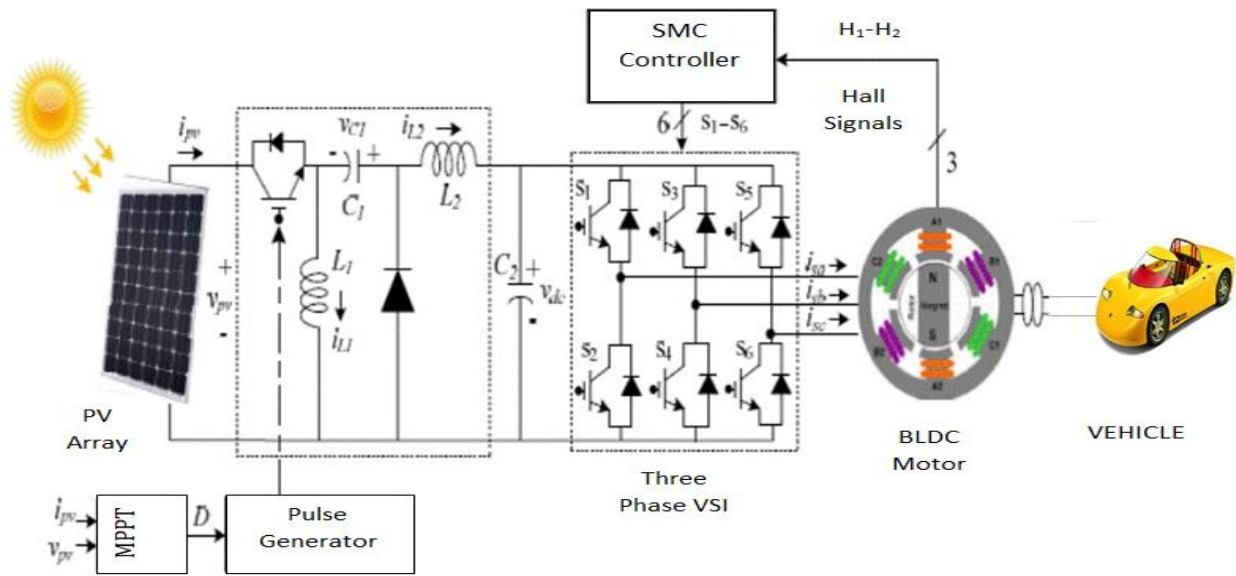


Fig 2. Schematic diagram of solar PV primarily based BLDC for vehicles

The fig.2 suggests schematic diagram for the complete PV primarily based BLDC for vehicles. The projected system includes PV panel, a lift device, a three phase VSI (Voltage supply Inverter) and a BLDC. A PV or cell is that the fundamental constructing block of a PV system non- public PV cellular is commonly pretty tiny, commonly manufacturing concerning one or 2W of electricity to extend the ability output of PV cells, those cells square degree related serial and parallel to assemble larger unit referred to as PV module. The PV array is hooked up to the DC to DC boost device to extend the output voltage stage associate diploma IGBT (Insulated Gate Bipolar Transistor) based VSI is hired for DC to AC conversion and connected to the BLDC pressure. The constant DC voltage is regenerated to the AC output employing a VSI.

### III. DESIGN OF PV BASED BLDC DRIVE

The vehicle industry is rapidly evolving. With many different aspects coinciding which includes depletion of fossil fuels, international warming, air pollution, carbon emission reduction legislation and new up and coming battery technology there may be a sluggish growth in demand for electric automobiles. With new era and a growing market, there are many new types of electric vehicle topologies developing. There also are many vintage car topologies such as bicycles and scooters that are being electrified. The high efficiency of electrical force systems which on average is 85 % as compared to the regular force systems with an internal combustion engine which has an average efficiency of 12-20 % , make it possible to design and construct lots lighter vehicles with an identical electricity rankings as the heavier automobiles with an internal combustion engine. there are numerous different electric powered motor kinds with different capabilities to be had. For the application of using mild electric cars there are two very similar motor kinds that

stick out from the others due to their high strength versus size and weight characteristics, those are the Brushless DC (BLDC) Motor[8]. The battery is best capable of presenting a DC voltage, whilst the BLDC vehicles require a three segment voltage. The conversion is made by a three phase inverter which additionally provides the capability to govern the motor by using having the ability to modify the voltage input to the motor.

By means of certain voltage across the motor, the speed of the motor can be controlled. Use of PWM outputs to control the six switches of the three-phase bridge, version of the motor voltage may be performed without difficulty through changing the responsibility cycle of the PWM sign[9]. The three-phase-section BLDC pace manages is executed with the aid of using both open loop and closed loop configurations. Open-loop manage is used to manipulate the rate of the motor with the aid of at once controlling the obligation cycle of the PWM sign that directs the motor-power circuitry[10]. The responsibility cycle of the PWM signal controls the ON time of the energy switches inside the half bridges of the motor-pressure circuit and this in flip controls the average voltage furnished across the motor windings. Closed loop manage regulates the velocity of the motor by means of at once controlling the obligation cycle of the PWM signals that direct the motor-pressure circuitry[11]. The most important distinction among the two control systems is that the open-loop manipulate considers simplest the rate manipulate enter to replace the PWM obligation cycle, whereas, the closed-loop control considers both velocity-input control and real motor speed (remarks to controller) for updating the PWM obligation cycle and, in flip, the motor speed. A PI controller is a closed-loop controller which manipulates the implementation that is extensively used and is maximum commonly used as a remarks controller. A selective harmonic elimination PWM technique with the help of Bee

algorithm is implemented for single phase DC-AC multilevel inverter [12].

#### IV. DESIGN OF BOOST CONVERTER

A boost converter is a DC-DC power converter that steps up voltage from its input to its output. To reduce voltage ripple filters made of capacitors are normally added to such a converters output and input. Boost converters can increase the voltage and reduce the number of cells [13].

Basic Principle of Boost The raise may be a widespread non-isolated strength degree topology, normally called a growth electricity stage. Power offer designers choose the increase strength stage because of the desired output is normally beyond the enter voltage. The input modern for a lift energy level is non-stop, or non- pulsating, due to the output diode conducts entirely through out some of the exchange cycle. The output electric condenser offers the whole load present day for the rest of the change cycle.

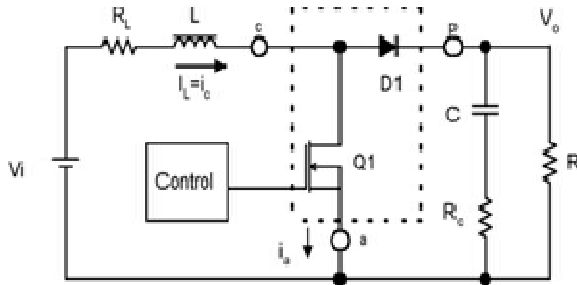


Fig.3. Boost Power Stage Schematic

Fig.3 shows a simplified schematic of the boost strength level inductance L and capacitance C structure the effective output filter. The capacitance equal collection resistance (ESR), RC, and also the inductance, dc resistance, RL, location unit enclosed inside the analysis electric tool R represents the burden visible by way of the power provide output an influence degree will function in non-stop or discontinuous inductance contemporary mode. In continuous inductance current mode, cutting-edge flows unceasingly within the inductance at some stage in the entire exchange cycle in steady-kingdom operation. In discontinuous inductance contemporary mode, inductance current is zero for some of the trade cycle. It is at zero, reaches height well worth, and available to zero during each alternate cycle. It is fascinating for a power degree to stay in exactly one mode over its anticipated operative situations.

#### V. SLIDING MODE CONTROL

Sliding Mode Control (SMC) could be a nonlinear manipulates technique that includes great houses of accuracy, robustness, and simple standardization and implementation. SMC structures are designed to pressure the system states onto a specific floor within the state space, named slippery surface. Once the slippery floor is reached, sliding mode manipulate keeps the states at the shut neighborhood of the sliding surface. Therefore the sliding mode controls a two half controller style. The primary half includes the making plans of

a slippery floor so the sliding motion satisfies style specifications.

The second is concerned with the choice of a manipulate regulation which will build the shift surface attractive to the system state. There are important blessings of slippery mode control. Initial is that the dynamic behavior of the system is also tailored with the aid of the real selection of the slippery perform secondly the closed- loop gadget reaction becomes altogether insensitive to some express uncertainties. This precept extends to model the parameter uncertainties, disturbance and nonlinearity which can be delimited. From a practical reason SMC lets in for dominant nonlinear approaches situation to external disturbances and extreme model uncertainties.

An ideal sliding mode exists only when the system rate satisfies the dynamic equation that governs the sliding mode for all time. This requires an infinite switching, in general, to ensure the sliding motion. The sliding mode control approach is recognized as one of the efficient tools to design robust controllers for complex high-order nonlinear dynamic plant operating under uncertainty conditions. Sliding mode controller design provides a systematic approach to the problem of maintaining stability and consistent performance.

The continuous part of the controller is obtained by combining the process model and sliding condition. The discontinuous part is nonlinear and represents the switching element of the control law.

#### VI. THE PROPOSED SYSTEM RESULTS

The proposed system is validated using MATLAB/SIMULINK software. The BLDC motor current characteristics for PIC have been depicted in fig. 4 and SMC in fig. 5.

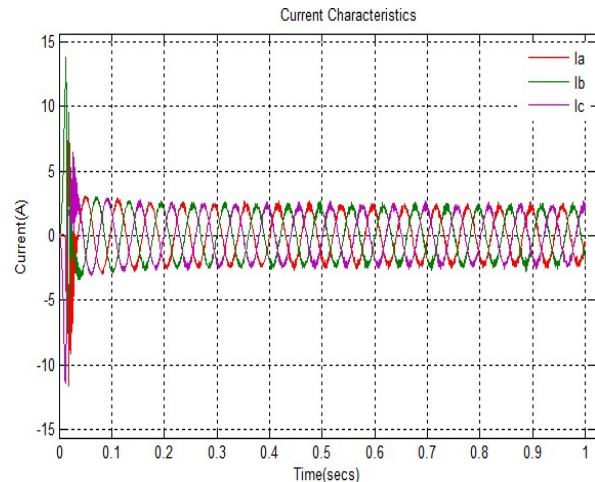


Fig 4 Motor Current Characteristics for PIC

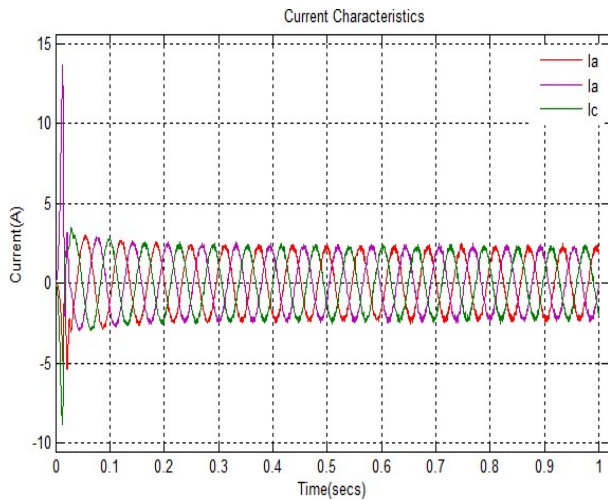


Fig. 5. Motor Current Characteristics for SMC

Comparing fig. 4 and fig. 5 the oscillation time of the current is reduced in sliding mode control. Oscillation reduction time is 0.03s in PIC and 0.02s in SMC. Current maximum value without oscillation is 3.125 A and 3.1A for PIC & SMC respectively.

The fig. 6 and fig. 7 shows the BLDC Motor speed characteristics of for PIC as well as for SMC.

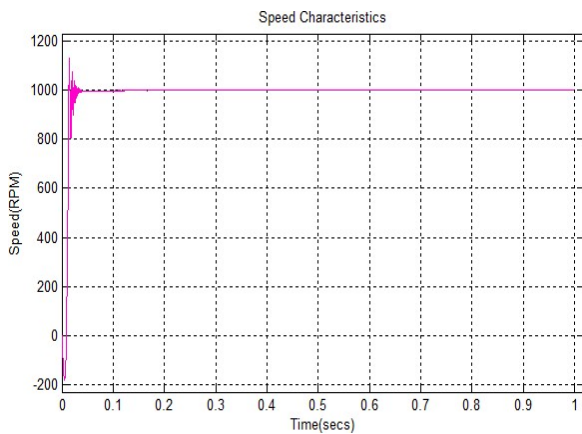


Fig. 6. Speed Characteristics of BLDC for PIC

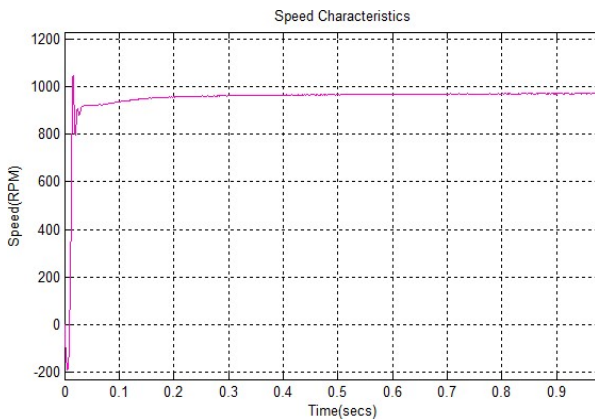


Fig. 7. Speed Characteristics of BLDC for SMC

Comparing the speed characteristics of both PIC and SMC control method, the oscillation time of the speed reduced in sliding mode control. Oscillation reduction time of PIC and SMC are 0.037s and 0.027s respectively. The maximum value of speed without oscillation is 1000 rpm and 950 rpm using PIC and SMC respectively

The BLDC motor torque characteristics for PIC and SMC are depicted in fig. 8 and fig. 9 respectively. The torque is not varied after the reduction of oscillations. The time taken to reduce the oscillation is 0.04 applying PIC and 0.03 for applying SMC.

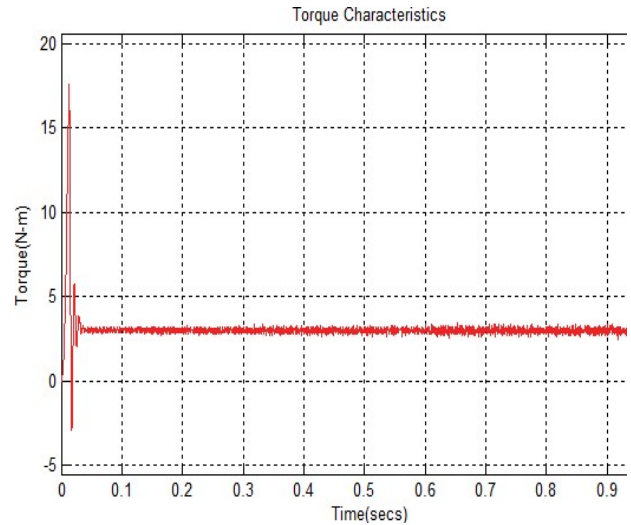


Fig. 8. Torque Characteristics of BLDC for PIC

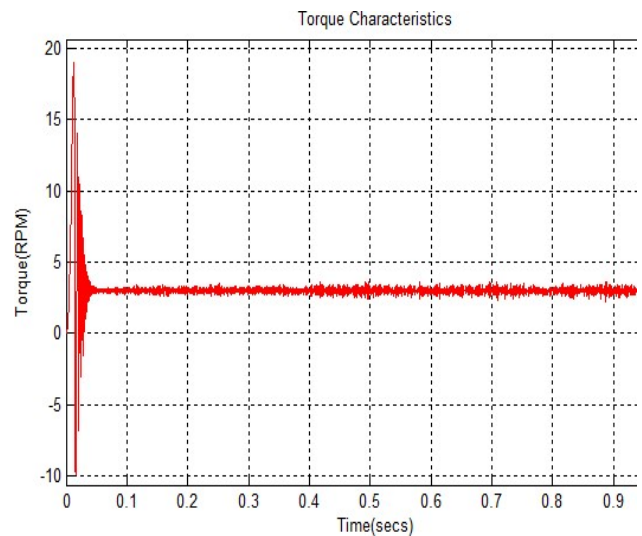


Fig. 9. Torque Characteristics of BLDC for SMC

The Id Characteristics of BLDC motor for PIC have been depicted in fig. 10 and SMC is depicted in fig. 11 respectively. Similarly the Iq Characteristics of BLDC motor for PIC and SMC have been depicted in fig. 12 and fig. 13 respectively.

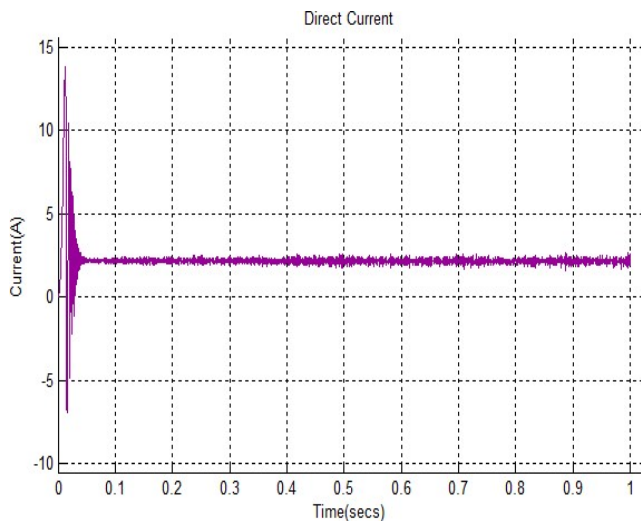


Fig. 10. Id Characteristics of BLDC for PIC

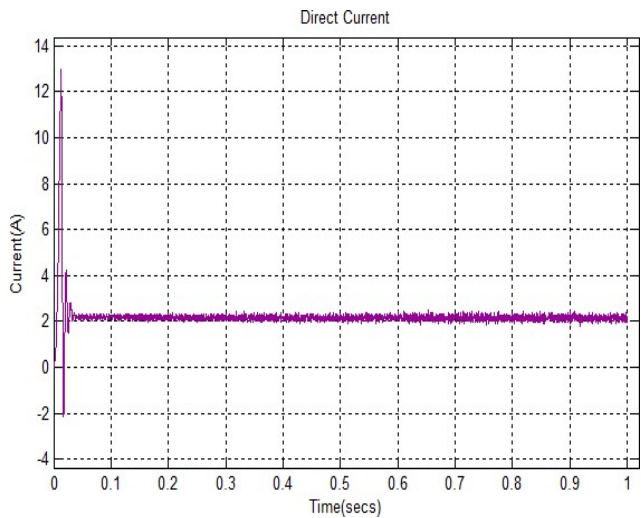


Fig. 11. Id Characteristics of BLDC for SMC.

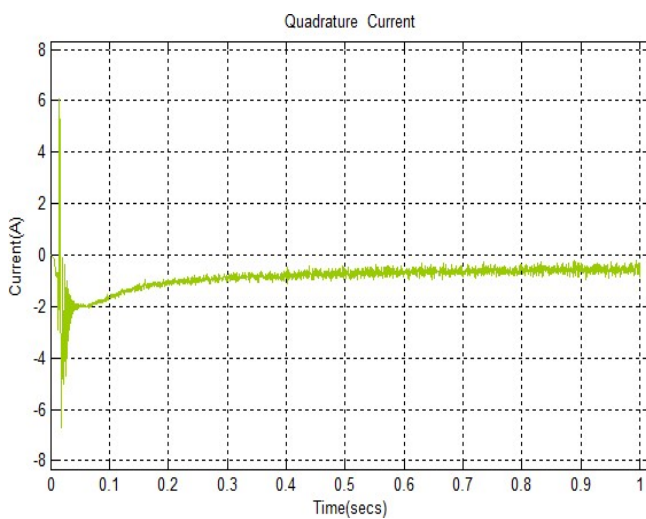


Fig. 12. Iq Characteristics of BLDC for PIC

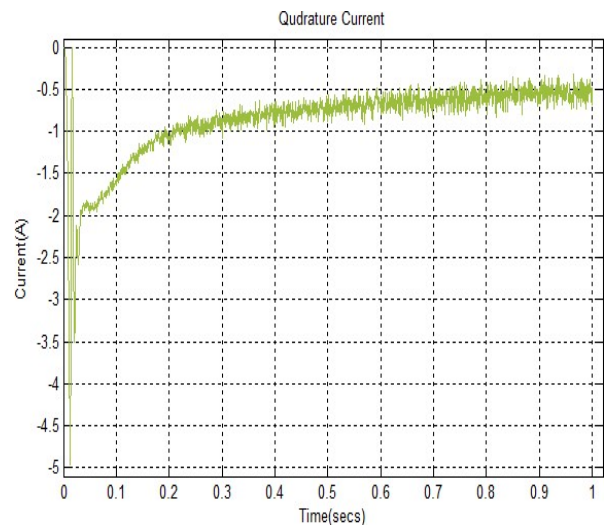


Fig. 13. Iq Characteristics of BLDC for SMC

From the figures 10, 11, 12 and 13 the current is oscillated highly in usage of PIC but the oscillations are varied only in the negative values in usage of SMC.

## VII. CONCLUSION

A PV device has been sculptured for the BLDC stress is hired in white items mechanical device tool. PV mechanical tool structures are trustworthy, reliable, hold energy and need a good deal much less preservation. It has been incontestable that projected system offer notable manipulated on motor pace, mechanical device and simulated outcomes were shown. The PV device is employed to interchange the ability to the grid, as quickly as motor is off. The controller must act to hold up the DC bus voltage steady as capability and decorate the steadiness of the whole machine. Grid-related electric phenomenon structures, that have a functionality over one kilowatts will meet the requirements. The overall performance of developed method of SMC is higher than PIC.

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