Design and analysis of PV powered PMSM drive using SMC control technique

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***Abstract*—This project presents the PV (Photo Voltaic) provided PMSM (Permanent Magnet Synchronous Motor) drive for refrigerator compressor system and PV provided grid connected system. Refrigerator compressor may be a universal would like for agriculture and therefore the use of PV panels may be a natural selection for such applications. The high speed photo voltaic (PV) hopped-up static magnet electric motor (PMSM) drive is investigated in one case and in alternative case the facility is transferred to Grid. 3 part VSI- one (Voltage supply Inverter) is controlled to produce PMSM, to manage discharge of VSI-2 is controlled to produce power to the grid through PLL (PHASE secured LOOP).Vector management is employed for the sleek operation. PV -refrigerator compressors extremely competitive compared to ancient energy technologies and best fitted to remote website applications that have little to moderate power necessities and may yield revenue for provision power to the grid. PV refrigerator compressor system using PMSM drive with associate degree optional power offer to the grid is modeled in MATLAB/SIMULINK setting victimization the sim-power system toolboxes. The performance of the projected system is obtained separately.**

Keywords- DC-DC Boost Convertor, PMSM Drive, Electrical Phenomenon, Vector Management, Refrigerator Compressorsystem, Part Secured Loop, PIC-Proportional Integral Controller, SMC-Sliding Mode Controller.

I. INTRODUCTION

Solar energy is free, inexhaustible, and clean; it's an excellent potential to be a really enticing provide choice for industrial and domestic applications, particularly in remote areas, like pumping, heating, and cooling, electrical phenomenon (PV) systems use the PV modules so as to convert the daylight into voltage. PV generation is gaining hyperbolic importance as a renewable supply thanks to its benefits that embrace few maintenance needs, the absence of fuel value, and lack of noise thanks to the absence of moving components [1]. PV refrigerator compressor systems area unit is receiving a lot of attention in recent years. Additionally, PV pumps have major developments within the field of electric cell material and technology. They're wide utilized in domestic and ethereal mammal provides and small-scale irrigation systems [2,3].For such PV systems, most electric receptacle trailing management is most popular for economical operation. All has conferred a MPPT system for PV system by utilizing steady state power reconciliation condition at DC link. It's any improved by Mikihiko for sensorless application. The PV system has found several potential applications like residential, vehicular, house air craft and refrigerator compressor system. PV -refrigerator compressors very competitive compared to ancient energy technologies and best suited to remote website applications that have tiny to moderate power needs. Most of the prevailing electrical phenomenon irrigation systems provide a mechanical output power from zero.85 kW up to a pair of.2 kW. The potency of Induction motors area unit less compared to static magnet motors, whereas DC machines aren't appropriate for submersible installations [12].the duty cycle of boost convertor.

II. SYSTEM DESCRIPTION

The PV system thought of during this paper contains single PV array as shown in Fig.1. During this paper a PV model is taken into account. The modelling is tried by (1), where, IPV, VPV are the PV array current and voltage severally. Rsh and Rs are the intrinsic shunt and series resistances of the array, Isc is being the short current of the array, G is that the irradiance (W/m2), q = 1.602 ×10−19 C being the negatron charge, Boltzmann's constant (K) =1.3806 ×10−23 J/K, p-n junction's quality issue (A) = a pair of , T is array temperature (in 0K), I0 is diode reverse saturation current, Tr is cell reference temperature and Irr is reverse saturation current at Tr.

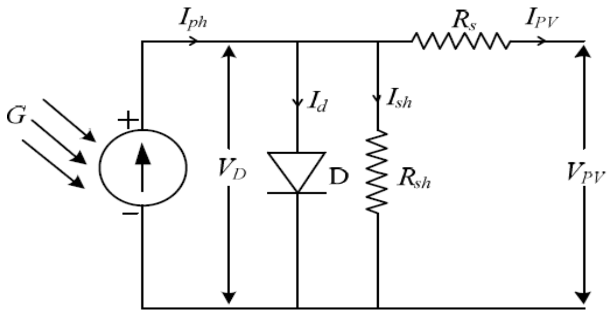
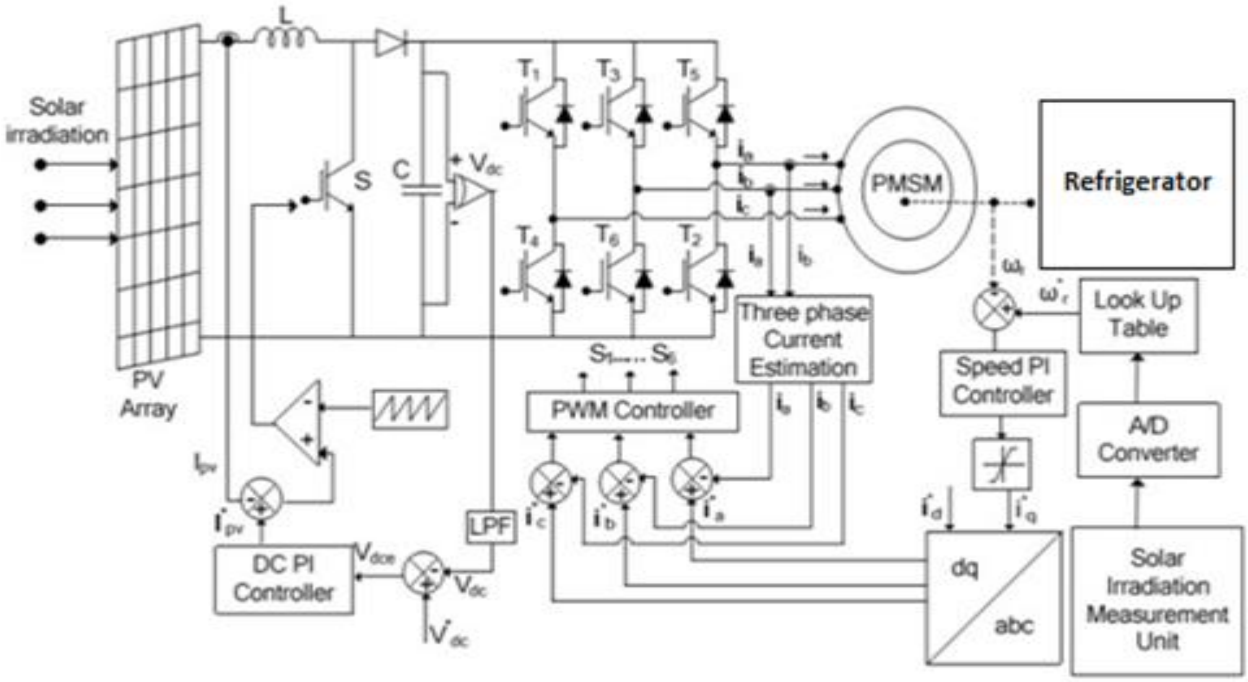


Fig 1. PV system

III. SYSTEM CONFIGURATION AND PRINCIPLE OF OPERATION



. Fig 2. Schematic diagram of solar PV based PMSM drive for refrigerator compressor system.

Fig.2 shows schematic diagram for the complete PV primarily based PMSM drive for refrigerator compressor system. The projected system consists of PV panel, a lift device, a 3 section VSI (Voltage supply Inverter) and a PMSM not to mention a centrifugal pump. A PV or cell is that the basic building block of a PV system a personal PV cell is typically quite tiny, usually manufacturing regarding one or 2W of power to extend the ability output of PV cells, these cells square measure connected serial and parallel to assemble larger unit referred to as PV module. The PV array is connected to the DC to DC boost device to extend the output voltage level associate degree IGBT (Insulated Gate Bipolar Transistor) primarily based VSI is employed for DC to AC conversion and connected to the PMSM drive. The constant DC voltage is regenerate to the AC output employing a VSI.

IV. DESIGN OF PV BASED PMSM DRIVE

The design of a PV based mostly PMSM drive consists of PV array, a DC to DC device, a DC link electrical device and a VSI. Ratings of elite parameters are given in Appendix. The styles of varied parts of drive system are as follows, DC motor driven PV pumps are used overall the planet as a result of they will be directly connected to the PV generator and an adjustable DC drive is simple to attain. However, this method suffers from multiplied motor price and maintenance issues thanks to the presence of a switch and brushes [3–5]. Hence, a refrigeration system supported brushless motors represents a gorgeous various thanks to its deserves over DC motors. Brushless static magnet DC motors are planned [4]; but, this resolution is restricted to solely low- power PV systems many studies have investigated AC systems victimization either current supply or voltage supply inverters [1]. The PV pumping system supported AN induction motor (IM) offers another motor for additional reliable and maintenance-free systems the most blessings of IMs are reduced cost, ruggedness, brushless rotor construction, and easy maintenance [1, 3, 6].

The static magnet electric motor (PMSM), conjointly referred to as the brushless DC motor, coupled to a pump is found to be appropriate for PV pumping systems [7, 8]. In recent years, the employment of PMSM (Permanent Magnet Synchronous Motors) are multiplied for drives applications thanks to its high potency, giant torsion to weight quantitative relation, longer life and up to date development in static magnet technologies [9]-[10]. It would like power processor for effective management. PMSM become a heavy contender of induction motors in hybrid electrical vehicle applications. This paper deals with PV equipped PMSM drive for refrigeration system and PV equipped grid connected system. AN interlink Boost device is employed between PV panel and DC bus The DC bus voltage of PMSM drive is maintained constant by dominant

A. DESIGN OF BOOST CONVERTER

The boost device is employed to feed the active power from PV array to the DC link capacitance connected VSI fed PMSM. Considering Vpv=198.99V, Δi=10% of PV current and fsw= 15 kilocycle per second, the worth of L is obtained as two.67 mH. the most current through boost device IGBTs is obtained as one.25 (ipp+ Ipv) wherever ipp is peak to peak ripple current considering 100 percent ripple twenty five A, 600 V IGBT is employed for boost device.

B. VOLTAGE SOURCE INVERTER

The apparent power rating of a VSI is given as, SVSI= √ p2+q2 it's obtained as 1500 VA. The rms current through a VSI is given as, IVSI=2.165 wherever Vrms mechanical device voltage of PMSM. The maximum current through IGBTs is obtained as one.25 (ipp+ IVSI). Considering seven.5% peak-peak ripple current, 25 A, 600 V IGBTs are utilized in a VSI.

i. Control theme:

Fig.2 shows the excellent management theme for a standalone PV primarily based PMSM drive. The management theme is mentioned in 2 elements, i.e. management of boost device to keep up constant DC link voltage and management of VSI in vector oriented mode to realize quick dynamic response beneath amendment in irradiances and cargo conditions. Basic Eq. utilized in management algorithms are as follows,

ii. Control of Boost device:

The DC bus voltage and therefore the output of the DC PI controller is employed to estimate the DC voltage error at the kth sampling instant wherever Vdc and V*dc are detected and reference DC bus voltages severally. The output of the DC PI controller at the kth sampling instant wherever kpa and kia are the proportional and integral gain constants of the PI controller. Vdce (k) and Vdce (k-1) are the DC bus voltage errors within the kth and (k-1)th sampling instant and I*pv (k) and I*pv (k-1) are output of DC PI managementler within the kth and (k-1)th instant required for voltage control. The reference and actual PV bus current are wont to estimate the PV bus current error at the kth sampling instant as,

The PV bus current error (Ipve) is amplified victimization gain K and compared with mounted frequency carrier signal to get shift signals for IGBT utilized in boost device.

iii. Management of VSI:

For the VSI, a VOC (Vector oriented Control) theme is employed. 2 Hall impact current sensors are wont to sense 2 section motor currents Iowa , ib and third section supply current ic is calculable considering that fast total of three-phase Currents is zero. Reference motor speed (ω*r) is that the operate of irradiation and wont to track the utmost power. Irradiation device electrical device offers the output within the kind of voltage signal that is fed to the planning up table. Reference speed is compared with the measured rotor speed (ωr) and it provided speed error ωe. The speed error at the kth sampling instant is given as, Speed error is processed victimization the speed PI controller, which offer the reference magnetic force (T*ref). The reference force (T*ref) is employed to get reference axis current (i*q) as follows, Here kpa and kia are the proportional and integral gain constants of the PI controller. ωe (k) and ωe (k-1) are the speed errors within the kth and (k-1)th sampling instant and i*q and i*q (k-1) is that the output of speed PI managementler within the kth and (k-1)th instant required for speed control. Similarly, from the detected rotor speed of the PMSM, magnitude of d-axis PMSM current (i*d) is obtained that is contemplate zero below rated speed. For the estimation of 3 section PMSM currents the transformation angle (θre) is obtained as, wherever P is that the range of poles of the PMSM. Three-phase reference PMSM currents (i*a, i*b, i*c) are obtained victimization i*d and i*q and therefore the rotor position in electrical rad/sec by inverse park transformation. Three section reference currents (i*a, i*b, i*c) square measure compared with perceived PMSM currents (ia, ib, ic) and ensuing current errors square measure fed to the PWM current controller for generating the change signals.

iv. Boost:

Basic Principle of Boost The boost may be a widespread non- isolated power stage topology, typically referred to as a increase power stage. Power offer designers opt for the boost power stage as a result of the specified output is usually beyond the input voltage. The input current for a lift power stage is continuous, or non-pulsating, as a result of the output diode conducts solely through out some of the change cycle. The output electrical condenser provides the complete load current for the remainder of the change cycle.

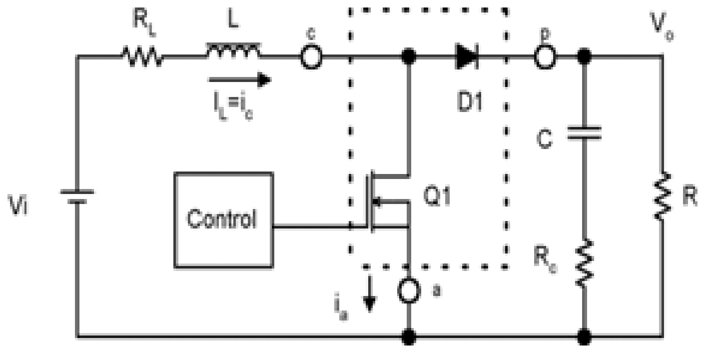


Fig.3. Boost Power Stage Schematic

Fig.3 shows a simplified schematic of the boost power stage inductance L and capacitance C structure the effective output filter. The capacitance equivalent series resistance (ESR), RC, and also the inductance, dc resistance, RL, area unit enclosed within the analysis electrical device R represents the load seen by the facility offer output an influence stage will operate in continuous or discontinuous inductance current mode. In continuous inductance current mode, current flows unceasingly within the inductance during the whole change cycle in steady-state operation. In discontinuous inductance current mode, inductance current is zero for some of the change cycle. It is at zero, reaches peak worth, and come to zero throughout every change cycle. it's fascinating for an influence stage to remain in exactly one mode over its expected operative conditions as a result of the facility stage frequency response changes considerably between the 2 modes of operation.

v. Phase Locked Loop:

Within grid-connected device management rule it's necessary to accurately and exactly verify the grid voltage point (θ) so as to attain freelance management of active and reactive power flow between the device input facet and therefore the grid. This task is performed by grid synchronization unit as shown in Fig.4.

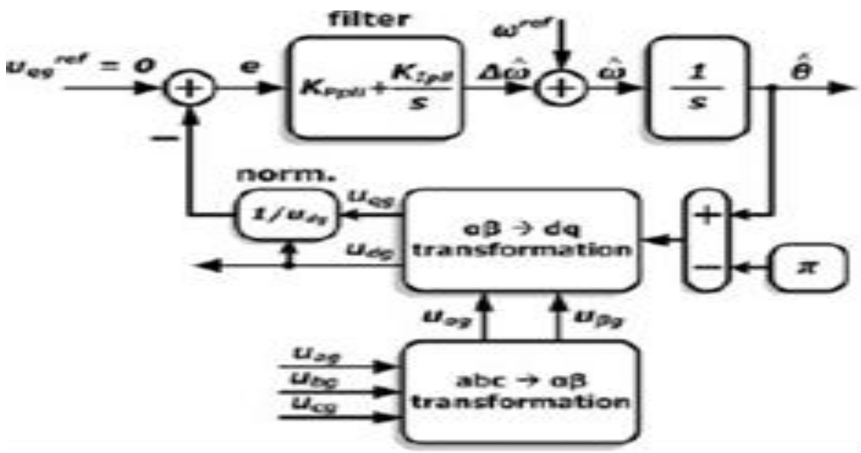


Fig.4. PLL Schematic

vi. Sliding Mode Control:

Sliding mode control (SMC) could be a nonlinear control technique that includes exceptional properties of accuracy, robustness, and simple standardization and implementation. SMC systems are designed to drive the system states onto a selected surface within the state space, named slippery surface. Once the slippery surface is reached, sliding mode control keeps the states on the shut neighbourhood of the sliding surface. Therefore the sliding mode controls a two half controller style. The primary half involves the planning of a slippery surface so the sliding motion satisfies style specifications.

The second is bothered with the choice of a control law which will build the shift surface engaging to the system state. There are two main blessings of slippery mode control. Initial is that the dynamic behavior of the system is also tailored by the actual selection of the slippery perform secondly the closed-loop system response becomes altogether insensitive to some explicit uncertainties. This principle extends to model parameter uncertainties, disturbance and nonlinearity that are delimited. From a sensible purpose SMC permits for dominant nonlinear processes subject to external disturbances and serious model uncertainties.

V. MATLAB/SIMULINK RESULT

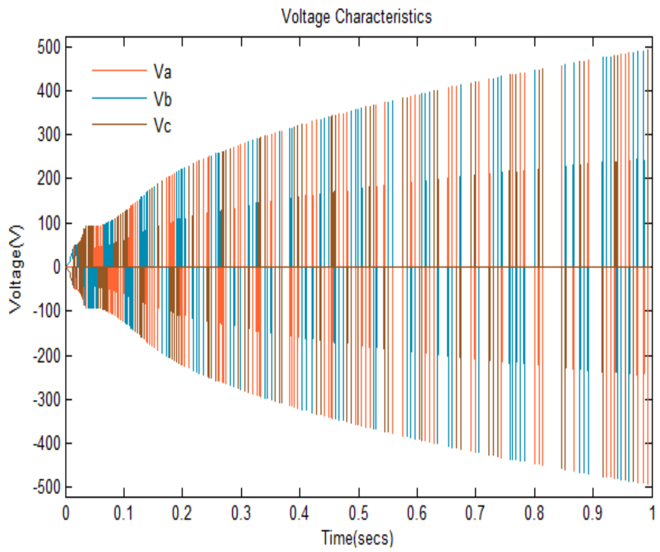


Fig 5(a).Inverter Output Voltage for PIC

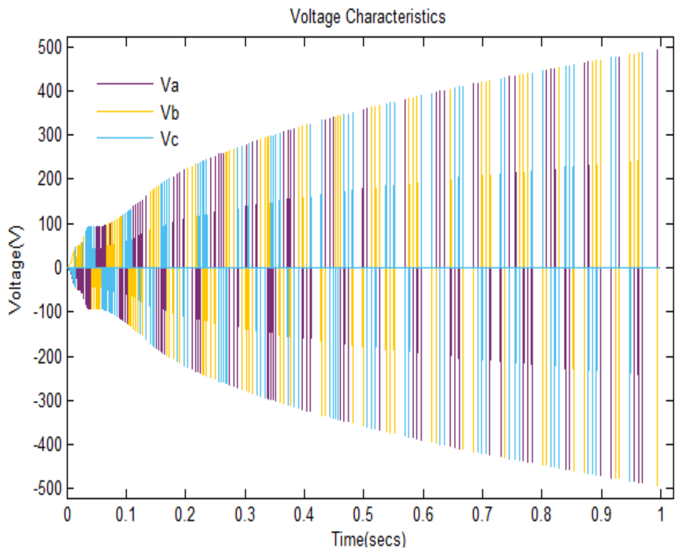


Fig 5(b). Inverter Output Voltage for SMC

In figure 5(a)&(b) shows that the output of the inverter voltage. PWM inverter is used for the conversion of DC to AC. Comparing these two graph width (voltage value) of the inverter using PIC is higher than the SMC.

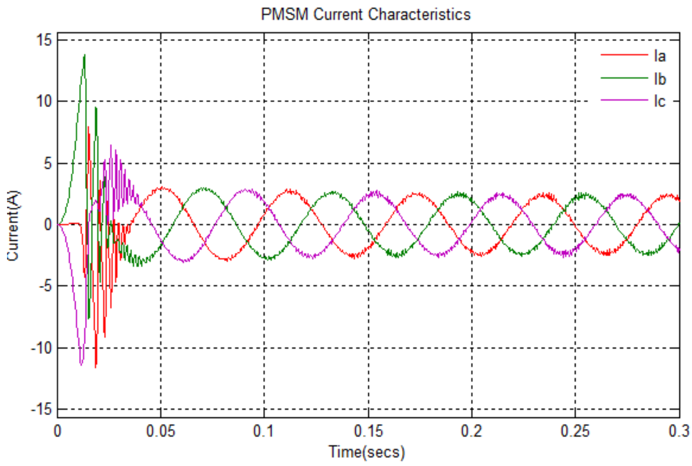


Fig 6(a).Motor Current Characteristics for PIC

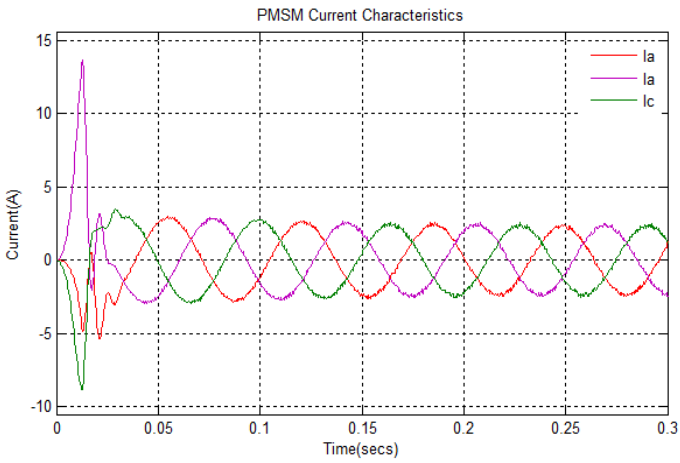


Fig 6(b). Motor Current Characteristics for SMC

Comparing figure 6(a) and 6(b) the oscillation time of the current reduced in usage of sliding mode control. Oscillation reduction time is .03s in PIC and .02s in SMC. Current maximum value without oscillation is 3.125 A and 3.1 A using PIC and SMC respectively.

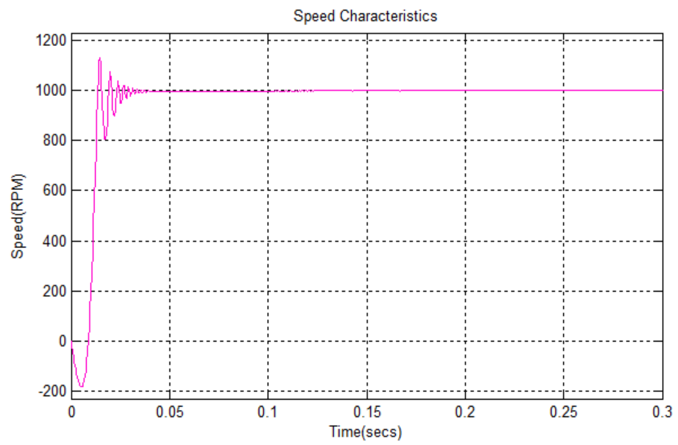


Fig 7(a).Speed Characteristics of PMSM for PIC

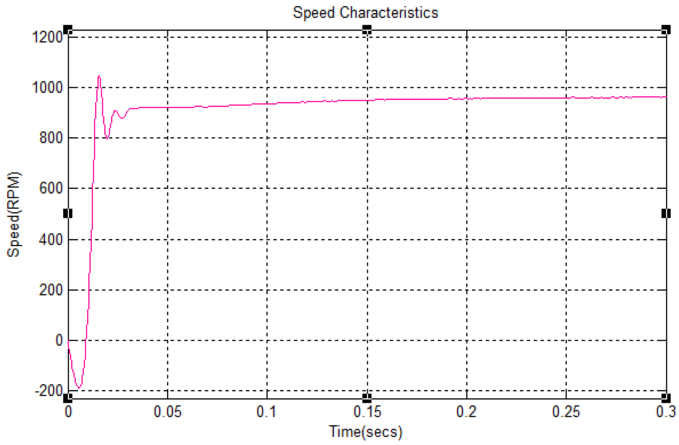


Fig 7(b).Speed Characteristics of PMSM for SMC

Comparing figure 7(a) and 7(b) the oscillation time of the speed reduced in usage of sliding mode control. Oscillation reduction time of PIC and SMC are .037s and .027s respectively. The maximum value of speed without oscillation is 1000rpm and 950rpm using PIC and SMC respectively

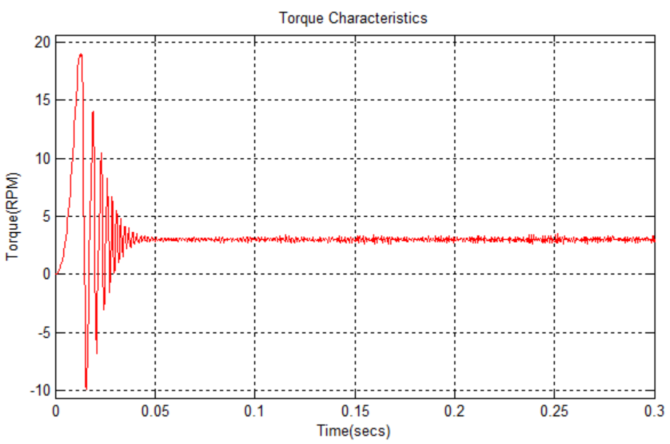


Fig 8(a). Torque Characteristics of PMSM for PIC

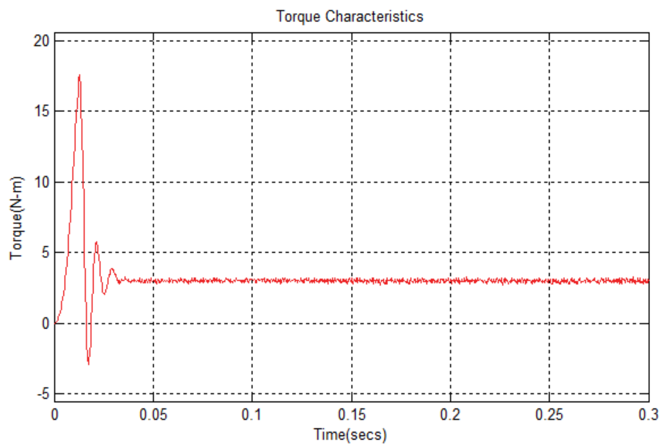


Fig 8(b). Torque Characteristics of PMSM for SMC

The figure 8(a) and 8(b) shows that the output electrical torque (Te) of the motor using PIC and SMC respectively. The torque is not varied after the reduction of oscillations. The time taken to reduce the oscillation is .04 applying Proportional Integral controller and .03 for applying Sliding Mode Controller.

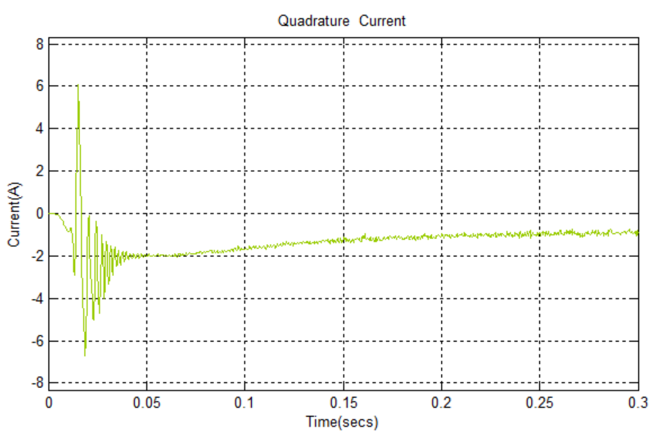


Fig 9(a).Iq Characteristics of PMSM for PIC

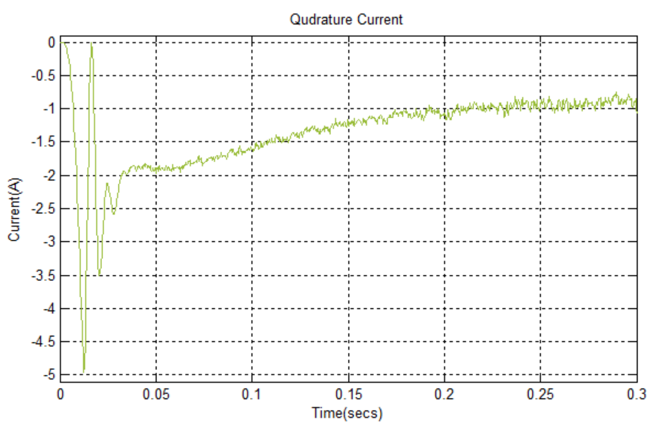


Fig 9(b).Iq Characteristics of PMSM for SMC.

From the figure 9(a) and 9(b) the current is oscillated highly in usage of PIC and also oscillations are varied only in the negative values in usage of SMC.

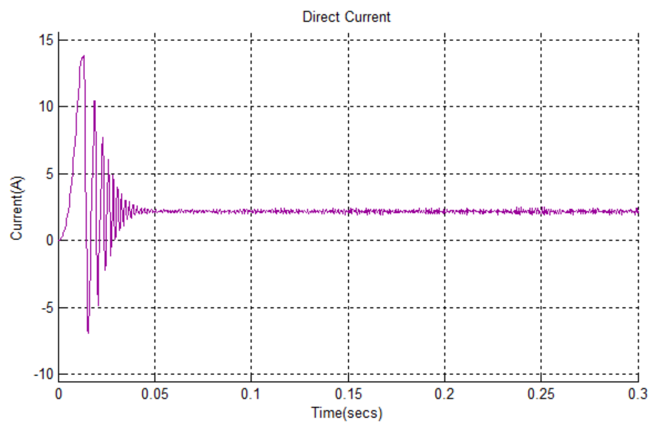


Fig 10(a). Id Characteristics of PMSM for PIC

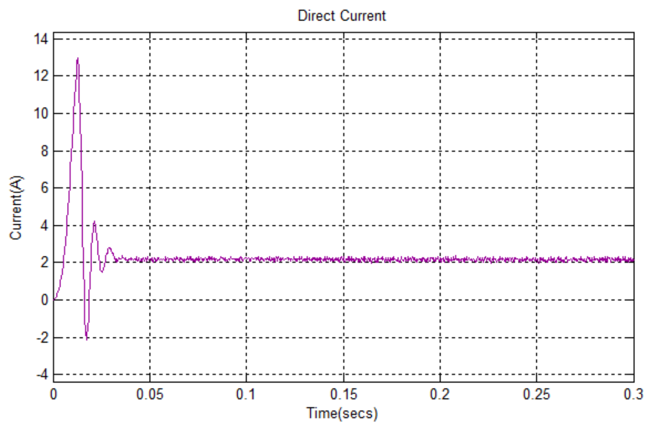


Fig 10(b). Id Characteristics of PMSM for SMC

In figure 10(a) has more number of oscillation than 10(b). The graph 10(a) represents the direct current of PMSM using PIC and10 (b) represents the output parameters of PMSM using SMC. The current value is same using both SMC and PIC. The time taken to attain the stability of current is 0.04 for PIC and 0.03 for SMC.

VI. CONCLUSION

A PV system has been sculptured for the PMSM drive is employed in white goods mechanical device system. PV white goods mechanical device systems are straightforward, reliable, conserve energy and want less maintenance. It has been incontestable that projected system offer satisfactory management on motor speed for white goods mechanical device and simulated results were shown. The PV system is employed to transfer the facility to the grid, once motor is off. The controller should act to keep up the DC bus voltage constant as attainable and improve the steadiness of the entire system. Grid-connected electrical phenomenon power systems that have a capability over one kilowatts will meet the standards. They will feed power to the grid. The energy created by the panels will yield revenue by commerce it to the grid. Looking on their agreement with their native grid energy company, in some cases, money incentives are paid from the grid operator to the buyer. The performance of developed approach of SMC is better than PIC.

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