Simulation of Solar Powered PMBLDC Motor Drive

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***Abstract* - Recent global developments lead to the use of renewable energy sources as main energy source. There are several sources of renewable energy sources, but among them the photovoltaic system appears to be the most promising one. This is because it is environmentally clean in nature & it directly converts the solar energy into electrical energy. This paper presents the speed control of BLDC motor using solar energy as main energy source. The boost converter is used to boost the voltage, required to drive the motor. The speed is regulated by a PI controller. A three phase voltage source inverter is used as an electronic commutator to operate the PMBLDC motor. The proposed system is designed, modeled & its performance is evaluated in Matlab- Simulink environment. Simulink is utilized with MATLAB to get a reliable and flexible simulation. This drive has high accuracy, robust operation from near zero to high speed.**

***Keywords* - PMBLDC motor (Permanent magnet Brushless DC motor), Photovoltaic (PV), Boost converter, PWM (Pulse width modulation), VSI (Voltage source inverter), Hall position sensors, PI controller**

I. INTRODUCTION

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy. Solar power has two big advantages over fossil fuels. The first fact is that, it is renewable; it is available in adequate amount. The second is its effect on the environment. While burning of fossil fuels introduces many harmful pollutants into the atmosphere and contributes to environmental problems like global warming and acid rain, whereas, solar energy is completely non-polluting. While many acres of land must be destroyed to feed a fossil fuel energy plant while, solar energy plant need less area. Solar energy is a large, inexhaustible source of energy & it is capable to supply all the present & future energy needs of the world. This makes it as one of the most promising of the unconventional energy sources.

Usually, the BLDC motor is driven from ac main supply through DBR (Diode Bridge Rectifier) & VSI circuit. The various converters like SEPIC (Single Ended Primary-Inductor Converter) [1], half bridge converter [2], buck DC-DC converter [3], & dual boost converter [4] & cuk converter [5] are used as PFC (Power factor correction) converter between DBR & VSI circuit to reduce the problems like THD (Total harmonic distortion), crest factor, poor quality & poor power factor at ac mains. Even though these converters are used still there will be little problems due to THD, poor power factor, ripple torque & poor quality, etc at ac mains. So to overcome all these problems the solar energy is used as main energy source to drive the BLDC motor where there is no conversion of ac to dc, instead we directly obtain dc electrical energy from solar panel & it is independent from ac mains.

Photovoltaic is a technology in which the radiant energy from the sun is converted to direct current (DC). Solar panels are the devices which are used to convert the solar radiation/light into electricity. In order to achieve the required voltage to run the BLDC motor, the PV module may be connected either in series or parallel, but it's costlier. Thus to make it cost effective; power converters & batteries are used. Batteries are used to store the DC voltage obtained from solar panel & this voltage is not sufficient to run the BLDC motor, hence boost converter is used which boost the voltage & provides the required voltage needed to run the BLDC motor.

Recent advance in permanent magnet materials, solid state devices and microelectronic have resulted in new energy efficient drives using permanent magnet brushless DC motors (PMBLDCM). Brushless DC motors are very popular in a wide array of applications in industries such as appliances, automotive, aerospace, consumer, medical, industrial automation for its reliability, high efficiency, high power density, low maintenance requirements, lower weight and low cost. As the name implies, BLDC motor do not have brushes for commutation, instead they are electronically commutated. BLDC motor have many advantages over brushed DC motor and induction motors, like better speed torque characteristics, high dynamic response, high efficiency, noiseless operation and wide speed ranges [6]. BLDC motors are synchronous motors with permanent magnets on rotor & armature windings on stator. Electronic commutation of stator windings is based on rotor position with respect to the stator winding [7]. In motor control applications, open-loop control is used to control the speed of the motor by directly controlling the duty cycle of the PWM signal that directs the motor-drive circuit. The duty cycle of the PWM signal controls the ON time of the IGBTs in the motor-drive circuit and this in turn controls the average voltage supplied across the armature of the motor. In a closed loop control system, the state of the output directly affects the input condition. In this method the speed is controlled in a closed loop by measuring the actual speed of the motor. The error in the set speed and actual speed is calculated. A proportional plus integral (PI) controller is used to amplify the speed error and dynamically adjust the PWM duty cycle [8]. When using PWM outputs to control the six switches of the three phase inverter bridge, variation of the motor voltage can be controlled by varying the duty cycle of the PWM signal. For low-cost, low-resolution speed requirements, the Hall signals are used to measure the feedback speed. Closed loop control is efficient than open loop. Fig 1 shows the basic structure for closed loop control of the PMBLDC motor drive.

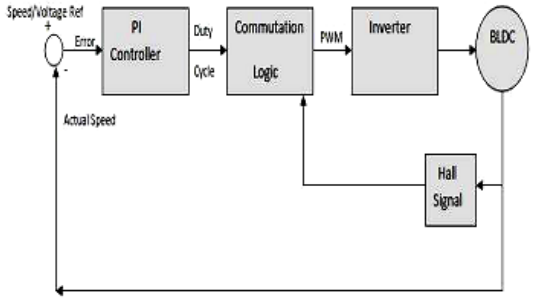

Fig 1: Close loop speed control system

II. SPEED CONTROL OF BRUSHLESS DC MOTOR

The speed of the BLDC motor is directly proportional to the applied voltage. The commutation logic specifies the coils that need to be energized for every 600 of electrical revolution based on Hall inputs. The Pulse Width Modulation logic specifies the time intervals during which the switches should be ON and OFF to average the DC Bus voltage applied thereby controlling the speed. If the switches are ON for the complete duration of the commutation period, then the DC bus rated voltage is directly fed to the phase windings of the motor. Hence the motor will run at the rated speed. To operate at any speed below this level, the commutation pattern applied at either the High-side or Low-side switch should be pulse-width modulated with the PWM Pulses at a specified frequency [7].

Voltage source inverter (VSI)

The VSI fed BLDC motor is shown in fig 2. In order to get constant output power & consequently constant output torque, current is driven through a motor winding during the flat portion of back emf waveform. At a time, only two switches are turned ON, one in a high side & the other in a low side. Thus for a star connected motor winding, two phases are connected in series across the DC bus, while the third winding is open. The switches are operated such that each phase carries current only during 1200 period when the back emf is constant. Thus there is a commutation event between phases for every 600 electrical. Effectively it means that there is a current transisition every 600. Appropriate commutation therefore requires knowledge of BLDC motor of rotor position, which can be directly, detected using the hall sensors in this paper. The three phase VSI has 6 IGBT switches.

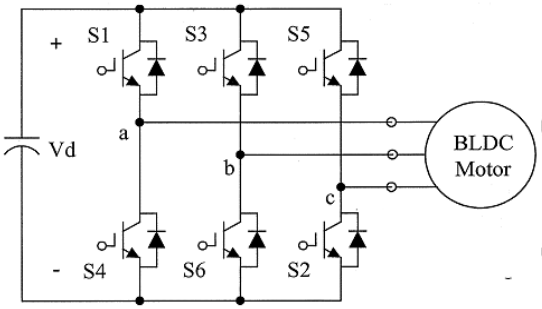

Fig 2: Three phase VSI

Speed control in BLDC motor involves changing of applied voltage across the motor phases, which is obtained by PWM (Pulse width modulation) method in this paper.

Hall sensors: The sensor feedback is carried out by hall-effect sensors. Energizing the appropriate phase coils based on hall effect sensors input is known as commutation logic. Whenever a new hall signal change is detected, the new drive switching pattern is applied. In hall sensor technique, 3 hall sensors are placed inside the motor, spaced 1200 apart. Whenever hall sensor faces north pole of rotor it produces '1' & produces '0' whenever it faces south pole of rotor. The rotor position signals are used to generate the switching sequence for VSI.

III. MATLAB/ SIMULINK

MATLAB is a high level language & its interactive environment helps us to perform intensive tasks faster than the traditional programming languages such as C, C++ and FORTRAN. Another important feature of MATLAB is it helps in modeling, simulating & analyzing dynamic systems. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows in solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program.

SIMULINK is a toolbox extension of the MATLAB program. It is a program for simulating dynamic systems. Simulink has the advantages of being capable of solving complex dynamic system simulations, graphical environment with visual real time programming and broad selection of tool boxes. The simulation environment of Simulink has a high flexibility and expandability which allows the possibility of development of a set of functions for a detailed analysis of the electrical drive. Its graphical interface allows selection of functional blocks, their placement on a worksheet, selection of their functional parameters interactively and description of signal flow by connecting their data lines using a mouse device. System blocks are constructed of lower level blocks grouped into a single maskable block. Simulink simulates analogue systems and discrete digital systems.

Modelling and simulation is usually used in designing PM (Permanent magnet) drives compared to building system prototypes because of the cost. Having selected all components, the simulation process can start to calculate steady state and dynamic performance and losses that would have been obtained if the drive were actually constructed. This practice reduces time, cost of building prototypes and ensures that the requirements are achieved.

In this work, the simulation of a BLDC motor drive system is developed using Matlab/Simulink 7.10 R2010a. The simulation circuit includes all realistic components of the drive system. This enables the calculation of currents and voltages in different parts of the inverter and motor under transient and steady conditions.

IV. SIMULINK MODEL

In servo applications position feedback is used in the position feedback loop. By varying the voltage across the motor, we can control the speed of the motor. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be obtained by varying the duty cycle of the PWM signal. The speed and torque of the motor depend on the strength of the magnetic field generated by the energized windings of the motor, which depend on the current through them. Commutation ensures only proper rotation of the rotor. The motor speed depends only on the amplitude of the applied voltage. This can be adjusted using PWM technique. The required speed is controlled by a speed controller. This is implemented as a conventional proportional-Integral controller.

The close loop speed control of BLDC motor is verified using software "MATLAB". This gives the expected waveforms when simulation is done. Fig 3 shows the close loop speed control of BLDC motor. In fig 3 solar panels are provided by two inputs i.e, temperature & intensity. The obtained voltage from solar panel is given to the boost converter. Boost converter is used to boost the voltage required to run the BLDC motor. The obtained voltage from boost converter is given to the three phase inverter, from inverter it is given to the three phase V-I measurement block. The voltage is then applied to the BLDC motor.

In case of closed loop control the actual speed is measured and it is compared with the reference speed to find the error speed. This difference is supplied to the PI controller, which in turn gives the duty cycle which is applied to the VSI. PMBLDC motor is popular in applications where speed control is necessary and the current must be controlled to get desired torque. It consists of an outer speed control loop, an inner current control loop for speed and current control respectively. Speed loop is relatively slower than the current loop.

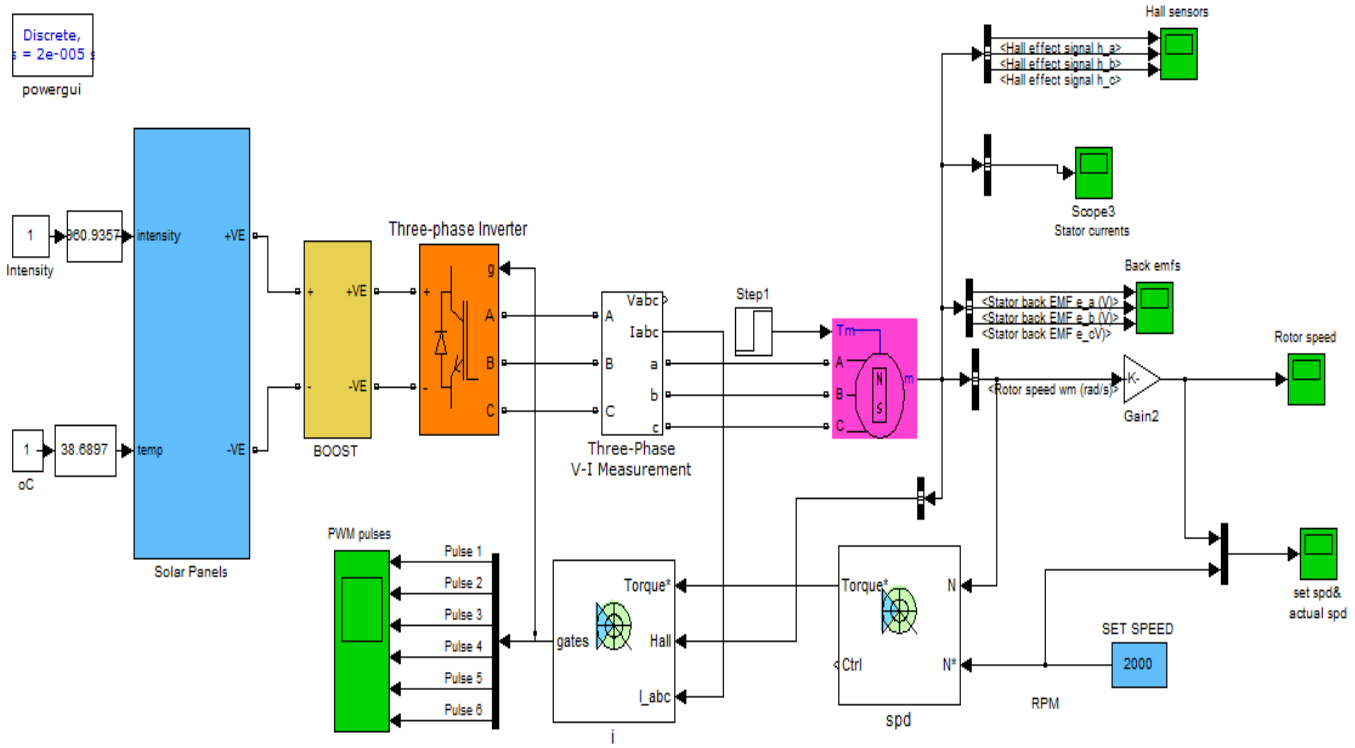

Fig 3: Simulation of close loop speed control of BLDC motor

V. SIMULATION RESULTS

The simulation results of hall sensors A, B & C are shown in fig 4. Fig 5 shows the stator currents of BLDC motor & fig 6 shows the back emfs of phase R, Y & B. Fig 7 shows the PWM pulses applied to the VSI circuit. Fig 8 shows the variation of reference speed with respect to actual speed at 2000rpm.

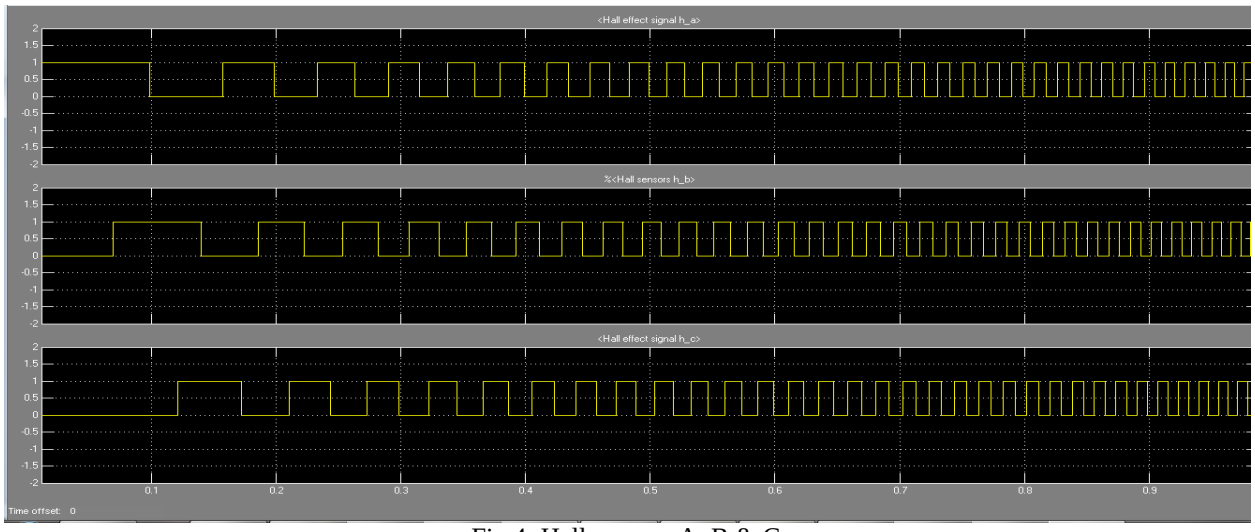

Fig 4: Hall sensors A, B & C

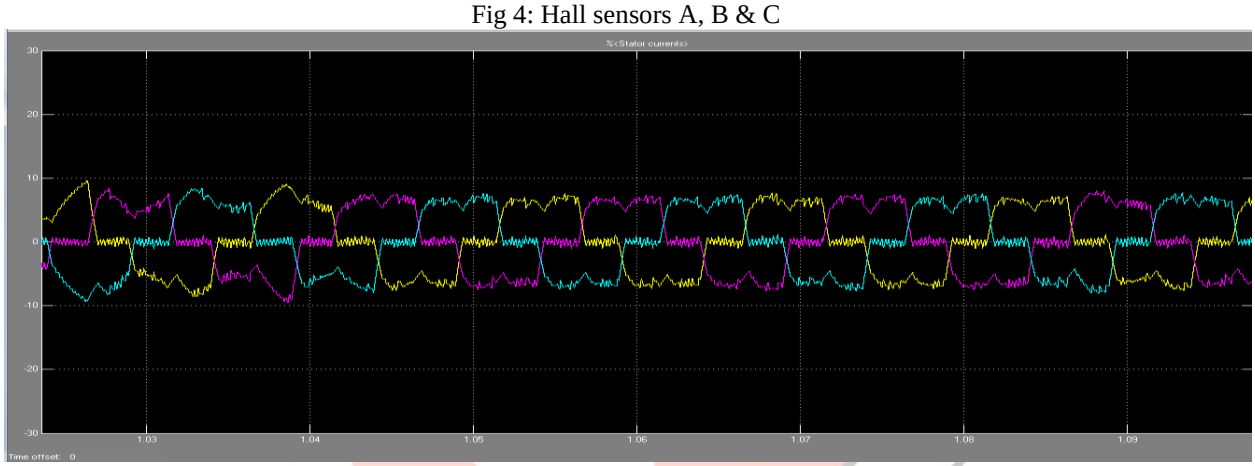

Fig 5: Stator currents

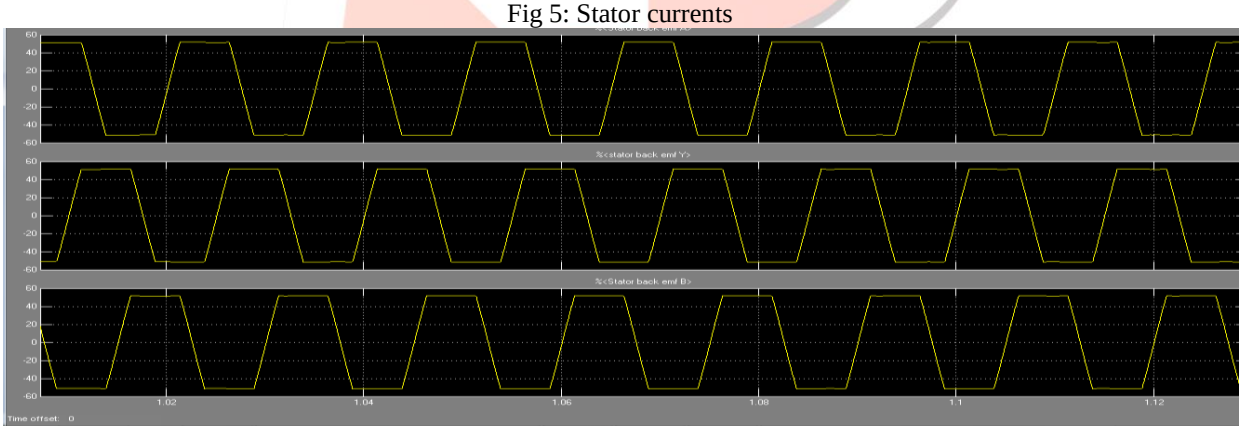

Fig 6: Back emfs of phase R, Y & B

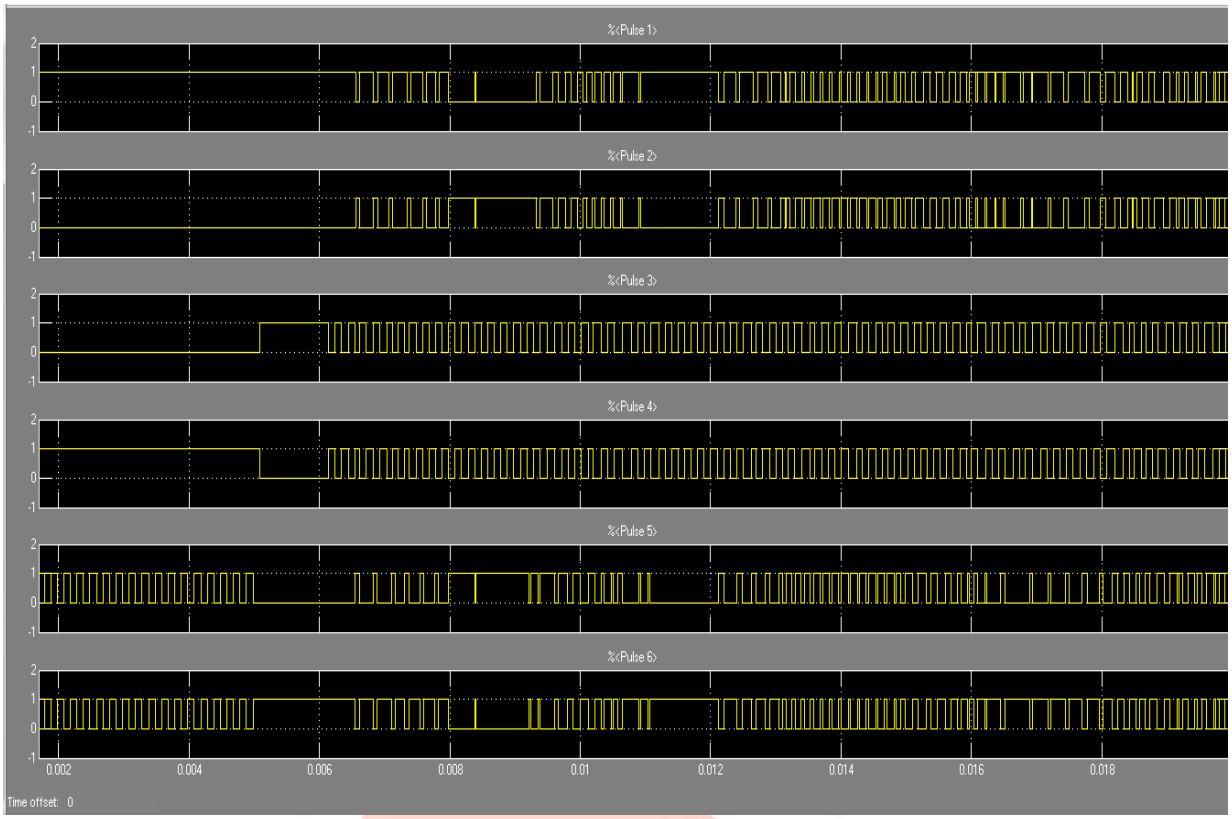

Fig 7: PWM pulses applied to VSI

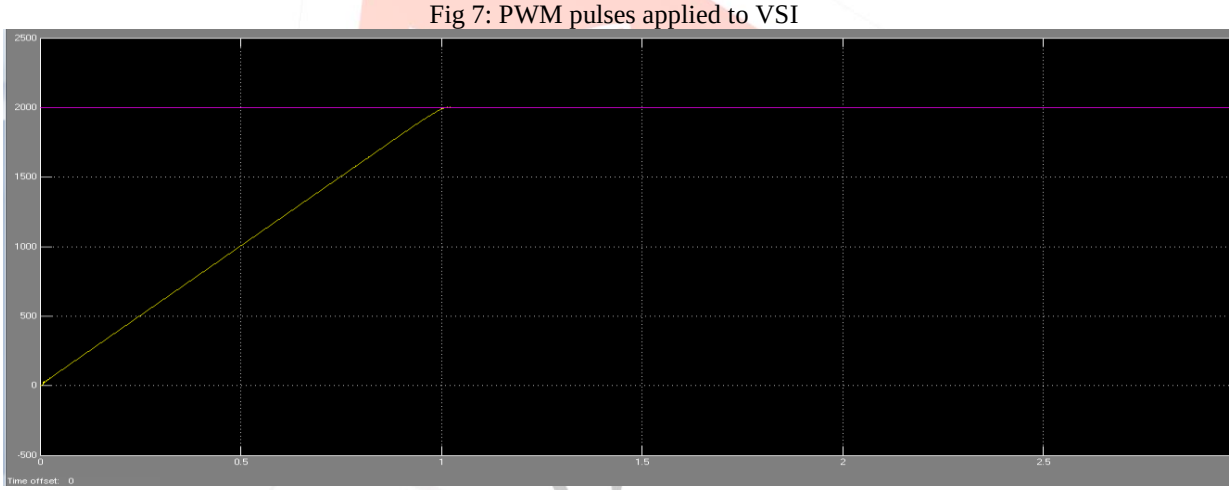

Fig 8: Variation of rotor speed at 2000rpm

VI. CONCLUSION

The importance of making shift in the source of energy which is made cost effective has been put forth, and utilization of solar power in driving & speed control of BLDC motor is implemented. It is independent of supply as the BLDC motor is driven by solar energy & hence can be used in solar powered electric vehicle, compressor of Air-conditioner, PV water pumping system & airplanes. Closed loop controlled VSI fed PMBLDC motor using PWM control is modeled and simulated. Feedback signals from the PMBLDC motor representing speed and position are utilized to get the driving signals for the inverter switches. The simulation results can be used for implementation of PMBLDC drive.

REFERENCES

[1] Sanjeev Singh and Bhim Singh "Single-Phase SEPIC Based PFC Converter for PMBLDCM Drive in Air-Conditioning System"

[2] C. Umayal, B. Janani and S. Rama Reddy "Digital implementation of pfc half bridge converter fed PMBLDC motor using microcontroller" ARPN Journal of Engineering and Applied Sciences VOL. 7, NO. 2, FEBRUARY 2012

[3] Sanjeev Singh and Bhim Singh "PFC Bridge Converter for Voltage-controlled Adjustable-speed PMBLDCM Drive" by Journal of Electrical Engineering & Technology Vol. 6, No. 2, pp. 215~225, 2011

[4] Mrs. Sindhuja.G, Dr. Shankar.C.B & Dr. R.Prakash "Power factor correction controller for PMBLDC motor using Dual boost converter" International Journal Of Advance Research In Science And Engineering IJARSE, Vol. No.2, Issue No.6, June, 2013

[5] Sanjeev Singh, Member, IEEE , and Bhim Singh "A Voltage-Controlled PFC Cuk Converter-Based PMBLDCM Drive for Air-Conditioners" IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 48, NO. 2, MARC H/APRIL 2012

[6] Padmaraja Yedamale "Brushless DC (BLDC) Motor Fundamentals" Microchip Technology Inc, 2003 Microchip technology

[7] Hamid A. Toliyat (Texas A&M University) and Tilak Gopalarathnam (Texas A&M University) "AC Machines Controlled as DC Machines (Brushless DC Machines/Electronics)"

[8] Microsemi "Speed control of Brushless DC motors- Block Commutation with Hall sensors"