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Solar Powered BLDC Fed Air Cooling System

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Abstract: In the present scenario solar energy is at its booming stage. Compare to other resources, the use of solar energy creates great differences in day to day life. This paper proposes a solar-powered BLDC fed air cooling system. With the isolation of solar energy and temperature, the characteristics of the PV module may also change. For every PV system, Maximum Power Point Tracking (MPPT) should be included. The solar tracker added a modified perturb and observe (P&O) MPPT algorithm to double-check the efficiency of the system. Here in the paper a simple and efficient solar Photovoltaic (PV) air cooling system fed with BLDC motor drive. This SPV air cooling system consists of power conversion stages. In the first stage, extracts the maximum power from an SPV array by controlling the duty ratio of a DC-DC boost converter. The duty cycle of the boost converter, which maintains the output voltage of the inverter to control the Brushless DC (BLDC) motor to drive the system. A scalar controlled Voltage Source Inverter (VSI) serves the operation of the BLDC motor. The VSI is operated at the fundamental frequency, which minimizes the switching loss. The proposed air cooling is designed to obtain system performance even under dynamic conditions. The effectiveness and performance of the system are evaluated and verified using MATLAB /Simulink platform.

Keywords: Photo Voltaic (PV), Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O), Boost converter, VSI, BLDC motor drive.

I. INTRODUCTION

A man has been in a constant search for energy since the dawn of existence. Now, after thousands of years, he has turned his ingenuity, finally, to the least exhaustible, most plentiful, and almost infinite source of sustainment, the sun. For the past few years, a man is facing a grave threat to his extinction itself, due to the significant decline in the conservative sources of energy. But this indeed can be considered as a blessing in disguise, as it has led to the exploration of one of the most indigenous sources of energy the solar energy "The solar energy". Renewable energy is coming as an advanced technology for meeting the demands of energy consumption to reduce pollution and to reduce the use of fossil fuels. They are also called eco- friendly technology due to sustainability and pollution-free nature. Hence the need of the hour is to switch over to solar energy for a considerable decrease in the pollution level and electricity bills. Thus we see a change in the mindset of man towards renewable energy. Efficient energy management is one of the prime requirements of the photovoltaic system. The solar-powered system is often considered for use in developing countries instead of other forms of alternative energy because they are durable and exhibit long term economic benefits.

A solar powered air-cooling system designed for remote areas, which can be operated to determine the performance and reliability of the system. The output of the solar power system varies throughout the day and with changes in weather conditions. A properly designed air-cooling system is efficient, simple and reliable [1] concerns about sustainability resulting from natural resource consumption global warming, climate change and increasing global energy use have brought renewable energy sources to the fore. Because of the possibility of shortly depleting fossil fuels, the use of clean and renewable energy sources has become inevitable.

Carbon emission due to the fuel cell and make more pollution than the solar cell. This is why solar energy is widely accepted. Because of these reasons, it has vast applications. The higher efficiency of the solar photovoltaic array is obtained based on the MPPT algorithm using the DC-DC converters. Various DC-DC converters topologies employed for MPPT in different Solar Photo Voltaic based applications. In most of the case, the electrical converter topologies have a greater value of reactive components, which result in high-cost weight and size. So, the proposed system a boost converter has good switching utilization, low stress on semiconductor devices, high conversion efficiency and a minimal number of reactive elements is selected [6],[7].

The three-phase inverter is operated at fundamental frequencies to reduce the switching losses and the electronic commutation is adopted for the control of the BLDC motor drive. The gate pulse of the inverter is getting from the electronic commutator and which control the stator current pattern of the brushless DC motor drive. The speed control along with the inner hysteresis current controller which is adapted to controlling the speed of the BLDC motor which will help to drive the air-cooling system. In the system, a battery is provided along with a charge controller is used to increase the reliability of the system during the truancy of power. So, the system designed under satisfactory performance under any variation in the solar irradiance level.

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The PMDC motors are widely used in various applications because of their low-cost construction, inexpensive control and simple and no need for an external controller. In some case the PMDC motor, which makes it unsuitable for Solar Photovoltaic array-based appliances due to higher speeds, brush friction increases, there reducing useful torque and other demerit which includes a higher reaction of the armature, a lower speed range due to mechanical limitations on the brushes and since the field in the air gap is permanent and limited which cannot be controlled outside. But in the case of BLDC motor, this has been gaining popularity in a plethora of applications in recent years. The BLDC motor is far more efficient than any other motor because of the use of an electronic switch as a replacement for a mechanical switch. Some of the advantages of BLDC motor over a DC motor are improved speed versus torque characteristics, reliability, longer life, noiseless operation and higher efficiency, eradication of switching ionizing sparks and a complete EMI trim. Due to the paramount advantages listed above, we choose the BLDC motor to build the SPV fed air cooler [2] in the proposed system.

The paper is oriented in different sections. Section I provides a brief introduction to the paper. Section II describes the working of the topology description, Section III deals with the control of the entire arrangement. Section IV discusses the simulation results and the last Section V deals with the conclusion.

II. TOPOLOGY DESCRIPTION

SPV- fed air cooling system is as shown in figure1. It is composed of the solar PV array, a DC/DC converter, a Three-phase inverter, BLDC motor, air cooling system.

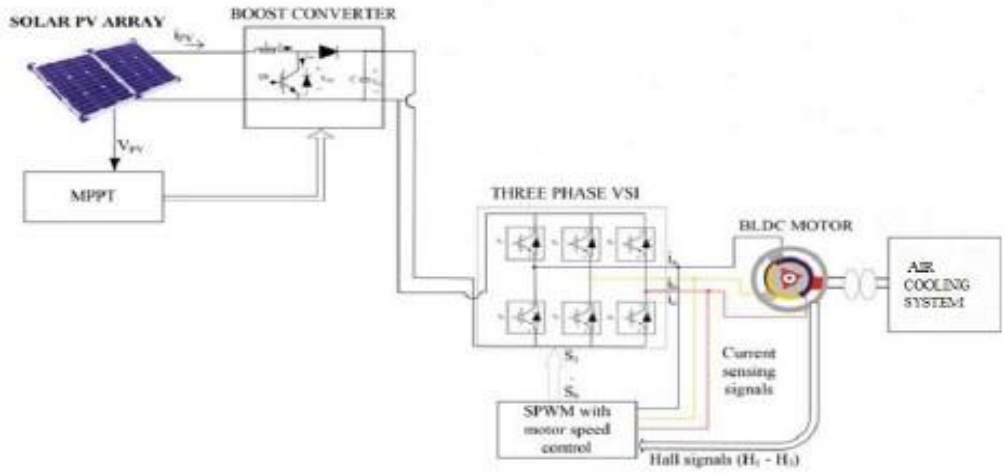

Fig.1. SPV-fed air-cooling system.

The circuit diagram is given below in fig: 2. The circuit consists of a PV panel, a boost converter, a voltage source inverter, a BLDC motor drive, air cooling system. The proposed configuration has a PV array that converts sun powered vitality to electrical vitality. The solar panel is the power source of all photovoltaic installation. For tracking of maximum power, MPPT algorithms use. In my system, an efficient, ease of implementation and simplicity, the P&O MPPT algorithm is better. It boosts the in voltage and produces higher output and it's a medium of power exchange to perform energy absorption and injection from PV module to inverter. The power- voltage characteristics of the PV module are found using this technique and hence elevate the maximum power from the solar panel under any conditions. The output of MPPT is fed as the switch driver for the boost converter, which converts DC to AC uses a three-phase voltage source inverter. The inverter output is fed to BLDC motor to drive the mechanical load.

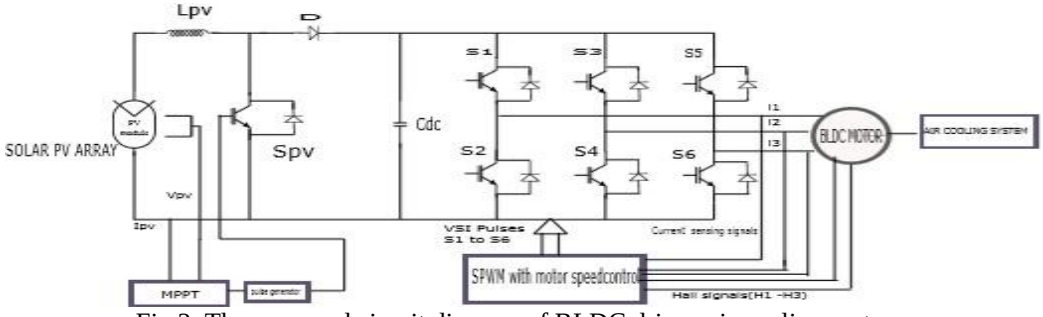

Fig.2. The proposed circuit diagram of BLDC driven air cooling system.

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Solar irradiance captured by the panel convert it into electrical energy which is fed to the boost converter. The power from a PV array is regulated using the P&O algorithm to attain its maximum value with available radiation. The voltage and current of the PV array are sensed and fed to the P&O algorithm. Based on the change in voltage, current, and power, this algorithm decides the duty ratio of the boost converter. The boost converter output voltage is maintained to a constant value using a proportional-integral (PI) controller.

An inbuilt encoder appended in the BLDC motor encodes has three Hall Effect sensor which generates hall signals. The signal generated thus converted by the encoder depends on the position on the rotor and hence the required gate pulse is generated to monitor the stator currents of the BLDC motor. Here the electronic commutator takes these signals and hence controls the inverter gate pulses. The speed of the fan blower coupled with the BLDC motor is controlled using the speed controller. The BLDC motor VSI's operated at the fundamental frequency and hence eliminating the high-frequency switching losses and the brush losses and contributing high efficiency and reliable operation of the proposed air cooler system. The Harmonics on the supply voltage can be reduced by using an RC ripple filter. The purpose system is to provide air cooling systems to the remote areas where power supply is not possible.

A. *DC-DC BOOST CONVERTER*

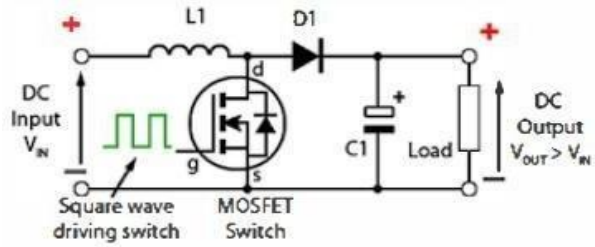

Fig.3. Equivalent circuit of a three-phase inverter.

When the MOSFET / switch is closed current flows through the inductor and stores some energy. When the switch is open, though initially the inductor shows some hindrance to flow the current stored in it, the current flows to the capacitor through the diode with the inductor polarity being reversed. The output voltage hence becomes greater than the input voltage which is given by;

$$V_O = \frac{1}{1-D} V_{IN}$$

B. DC-AC INVERTER

Solar panels may be on the top, but it is the inverter that does all the real work. Thus choosing the inverter topology is of prime importance. The topology selected over here is a voltage source inverter as explained in[2]. This topology produces an output voltge higher than the input voltage depending on the instantaneous cycle. The full bridge inverter is considered as two half bridge inverter.

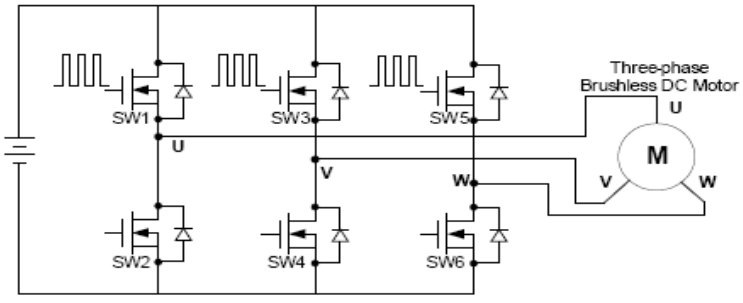

Fig.4. Equivalent circuit of a three-phase inverter.

III. CONTROL OF PROPOSED SYSTEM

A. P&O -MPPT Algorithm:

The MPPT controller is used under all possible conditions, to extract the maximum power. They match the load and the source property for the maximum power abstract and by increasing the efficiency of the system. In my system, an efficient, ease of implementation and simplicity, the P&O MPPT algorithm is better. This method is one of the direct and simplest methods for finding the maximum power from a solar panel.

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Perturb and Observe algorithm was implemented in MATLAB Simulink and the MPPT controller inputs are:

- Voltage and Current from the PV array.
- Maximum, minimum, Increment value and the initial value for the duty cycle.

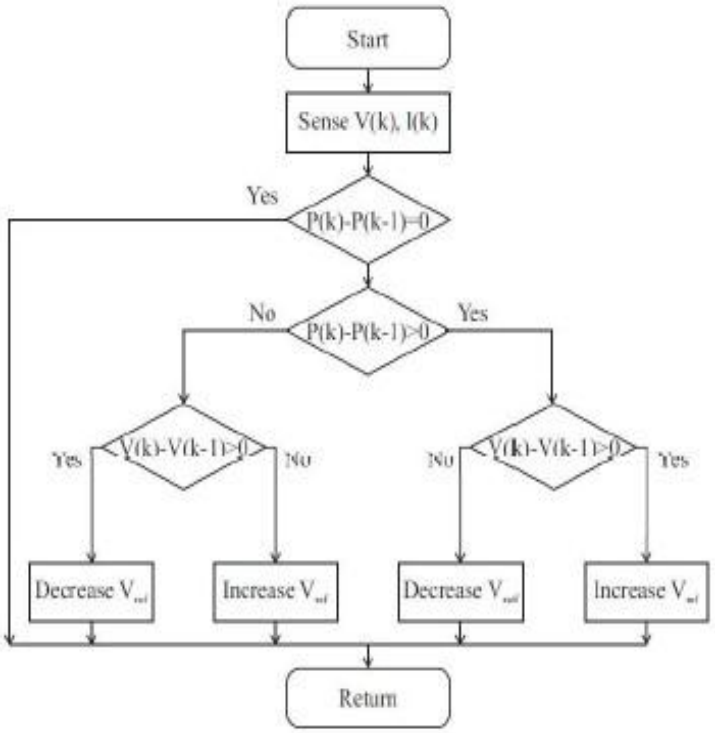

Fig.5. Flow chart of the P&O algorithm.

B. Electronic Commutation

VSI switching signal is produced by the electronic commutation of BLDC motor and three Hall Effect signals which are produced by the inbuilt encoder is decoded depending on the angular position of the rotor. For reducing the consumption of energy and cost, BLDC motor should operate more efficiently. To ensure increases in efficiency the correct Hall-effect sensors need to be selected for the electronic commutation. Six switching pulses are obtained by converting the Hall Effect signals and that is further used for the operation of the 6 IGBT's switches of the voltage source inverter.

0°	Hall Signals			Switching States					
	H_1	H_2	H_3	S_1	S_2	S_3	S_4	S_5	S_6
NA	0	0	0	0	0	0	0	0	0
0-60	1	0	1	1	0	0	1	0	0
60-120	0	0	1	1	0	0	0	0	1
120-180	0	1	1	0	0	1	0	0	1
180-240	0	1	0	0	1	1	0	0	0
240-300	1	1	0	0	1	0	0	1	0
300-360	1	0	0	0	0	0	1	1	0
NA	1	1	1	0	0	0	0	0	0

Fig.6. Switching states for electronic commutation of BLD Motor.

Preset speed is obtained by using a hysteresis control method in the fan blower. By comparing the reference speed and original speed of the BLDC motor generate a torque reference which when divided by constant Kb results in current reference magnitude. To get the current reference, the magnitude of current reference and current pattern generated through hall signal are multiplied. The produced 3 current references are compared with actual current flowing in the stator and the error signal is passed through the proportional-integral controller which generates two pulses each. The BLDC motor acquires the desired speed when the 6 pulses generated are given to the gate of VSI switches. Through the DC link voltage, the speed of BLDC motor for the water pump is regulated and speed is fixed without the need for any external controlling circuit. Therefore by maintaining the power balance, the DC link voltage remains within limits.

C. DC-Link Voltage Controller

The DC-Link voltage increases gradually due to the lack of power balance; for the case of air blower only operates there is no use of the controller. Power imbalance should be maintained by restricting this. That is generated power is the sum of power

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consumed and the losses. The voltage of the dc-link should be maintained, hence it can be achieved by the SPV should operate below MPP if the voltage reference to voltage controller is other than Vmppt. so, less power is obtained but this not a problem as the mechanical load required to be driven now is also diminished.

IV. SIMULATION

Simulation of the converter and the complete system were done using MATLAB/SIMULINK software. BLDC motor is controlled by three-phase VSI. The switching pulse is given to the VSI using SPWM technique. Simulation for the designed system had been done under some operating conditions such as 1000W/m^2 Irradiance and constant temperature of 25 ^{0}C.

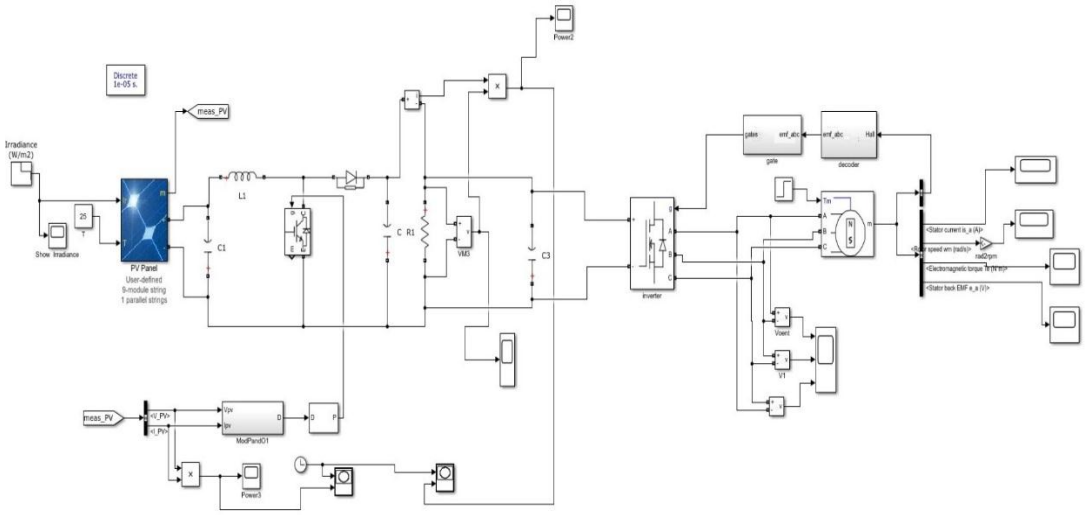

Fig.7. Solar PV based air cooling system using BLDC motor drives.

Figure 7 shows the simulation diagram of the entire topology. Here boost converter with PV panel, boost converter, Three-phase inverter and BLDC motor are connected. The DC-link capacitor which is connected in between the boost converter and inverter.

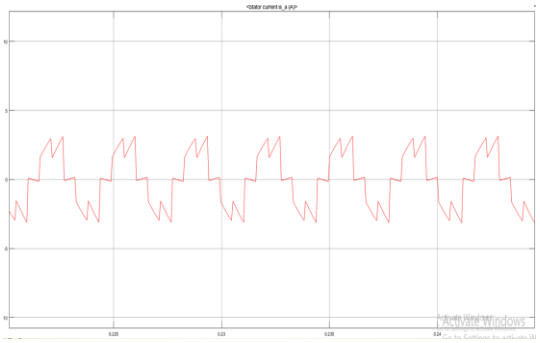

Fig.8. Armature current of BLDC motor drives.

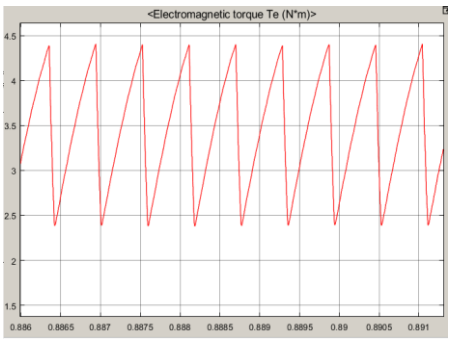

Fig.9. The torque of BLDC motor drives.

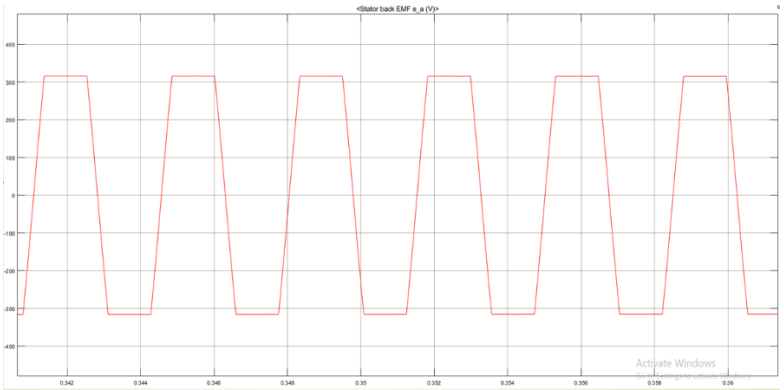

Fig.10. Back emf of the BLDC motor drives.

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V. CONCLUSION

There are several different types of cooling devices available to remove the heat from industrial enclosures, but as the technology advances, cooling is emerging as a truly viable method that can be advantageous in the handling of certain small to medium applications. This paper presents a solar-powered BLDC fed air cooling system, and the proposed system is simulated in MATLAB /Simulink platform. The main aim of the proposed system is to attain comfort level during summer for the people living in rural areas where it is difficult to depend on the electricity all the time. The boost converter, having the advantage of very good conversion efficiency is found to be more suitable for the proposed air cooling system. The VSI has operated under fundamental frequency which improves the efficiency of the system and reduces the switching loss. The further losses can be reduced by using high-frequency signals and using the protection circuit which is given in paper [2]. The designed air cooling system is reliable, efficient and good in all aspects as compared with any other existing system. Therefore, the proposed configuration converts sun powered vitality to electrical vitality efficiently.

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BIOGRAPHIES

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KN Chandra Bose received B.Tech. Degree in Electrical and Electronics Engineering from College of Engineering, Thiruvanathapuram and M.Tech (Power systems) from NIT Warangal, AP in 1995 and 2007 respectively. He served as Software Engineer in Infosys and Asst. Engineer in KSEB in 1998 and 1999 respectively. Currently working as Associate professor in Govt. Engineering College, Kerala from 2000 onwards. He is pursuing Ph.D in Combined AC-DC integrated transmission. His research interests include HVAC, HVDC, FACTS and Green Energy.