STANDALONE BLDC BASED SOLAR AIR COOLER

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Abstract- In the present scenario, due to the unavailability of power grid in rural areas as well as depleting fossil fuel sources, it causes us to implement newer technologies which rely on renewable energy resources like solar energy, wind energy, etc. As we know solar energy is abundant in the supply and is available during day time in all countries. In this project we are designing and developing a standalone BLDC based solar air cooler. As we know numerous researches has been carried out on irrigation and automotive systems which are power by a PV array and it formed by combining various converters mainly DC-DC and other motor drives, but as the statistics shown, very low work has been carried out in the field of home-appliances. The main challenge while implementing this project is the maintenance of constant speed of the motor. The system consists of the Photovoltaic array which is connected to the sepic dc-dc converter which in turn helps in feeding the VSI and finally supplying the required voltage to the BLDC motor which is coupled to cooling fan of the air cooler. The speed of motor is controlled according to the measured room temperature and switching pulses to the sepic converter is varied according to the temperature changes. BLDC motor is employed due to its high efficiency, high torque to weight ratio and high reliability. The evalution of the proposed system for various temperatures is carried out by simulating the proposed system using MATLAB/Simulink.

Keywords: BLDC, solar.

1. INTRODUCTION

The abundant use of fossil fuels has led to the emission of greenhouse gases and increase of pollutants in air and the uneven distribution of power between the rural and urban areas. People living in rural area employ the technique of using fossil fuels or wood from tree for their cooking purpose. It results in increase of cutting down of trees and depletion of fossil fuels. Hence in the current scenario, renewable energy resources can be a solution to all the constraints. As we know already the use of renewable energy resources have numerous advantages. The term renewable itself means that resource won't run out. They are cost effective as they are mostly natural sources and it's easy to harness renewable energy. Their maintenance costs are low and they

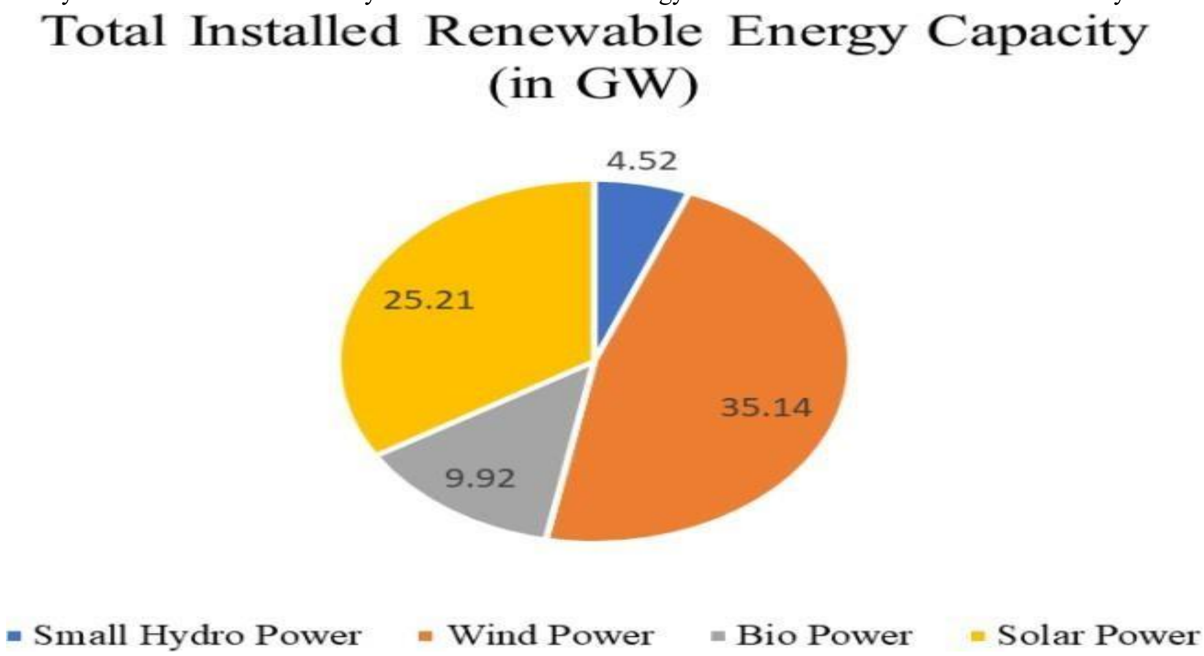

Fig.1.1 Distribution of Renewable Energy Resources in India

provide numerous health and environmental benefits. The main renewable energy resources are solar energy, wind energy, tidal energy, nuclear energy etc. The distribution of renewable energy resources is shown in the pie chart.

As seen from the pie chart it is evident that we still rely on the small hyrdo power by 35.2 percent whereas we only 25 percent of the energy is being extracted from the solar energy. Comparing it with the global scenario, India ranks third largest installed capacity of concentrated solar power. India plans to achieve an ambitious target of 175GW of renewable power by 2022 out of which 100 GW is extracted from the sun 60 GW from wind energy, 10 GW from Biomass and the rest 5 GW from small hydro power. Out of these sources the most used ones are solar and wind energy as they are the most efficient. Solar energy is the energy being radiated out from the sun in the form of sun light. Sunlight is present throughout the earth and available at all times throughout the year. Solar cells are semi-conductor devices which use sunlight to produce electricity. They are primarily made up of silicon which absorbs photons emitted by sun's rays. Solar power is pollution free and causes no greenhouse gases to be emitted after installation. Also it reduces the dependence on fossil fuels. It is one among the few renewable clean power that is available every day of the year; even cloudy days produce some power. Thus the energy extracted from the sun can be used to supply power for an air cooler whose speed varies according to the room temperature .[12]

1.1 Purpose of Study

In the present scenario the temperature variations is not predictable and also the climatic conditions are at end extremes. The use of air coolers is to maintain a temperature that can be adaptable and suitable to human life. The mode of supply of energy to the air cooler is from solar energy which helps in reducing the losses and making it cost effective. Hence by implementing this we can control the speed of a BLDC motor coupled cooling fan according to the sensed room temperature with the help of a sepic converter.

1.2 Objective

- The objective of this work is to control the speed of a BLDC motor coupled to a cooling fan based on varying room temperature.
- Secondary objective is to power the system using solar energy so as to make it energy efficient and reliable.

1.3 Existing System

Automatic controls are now used very frequently and are one of the important aspect in today's world. It is indeed a very vast area in terms of technology whose main aim is to improvise control strategies that helps in improving the performance of the system. As we know the fans are usually equipped with regulators which act as speed control. But the existing system consists of manual regulators in cooling fans which will be a resistive device to control speed. Coolers and fans will be consisting of DC motors or induction motors which has a comparatively low efficiency. There are temperature controlled cooling systems but are highly expensive and have limitations in installation.

2. LITERATURE REVIEW

2.1 Different Types of Motors

2.1.1 DC Motor

DC motors are capable of generating high torque at low speed and the torque-speed characteristics suits the traction requirements. Based on the excitation of field dc motors are classified as self-excited and separately excited. In self-excited it is again classified as series, shunt and compound based on the interconnection of armature and field windings. In dc series motor armature and field windings are connected in series. The same current flows through both windings. In such motors speed can be varied only by varying the supply voltage. On the other hand, armature and field windings are connected in parallel in shunt motor. Shunt motors have better controllability than series motor. Separately excited motors have field winding supplied separately. Such motors are more suitable for field weakening operation, because of decoupled flux and torque control characteristics. Therefore, controlling of dc motor is easier than other motors. The power electronic circuit required for its control is relatively simple, cheap and easy to design .[1] Different types of DC motors shown in the fig. 2.1.

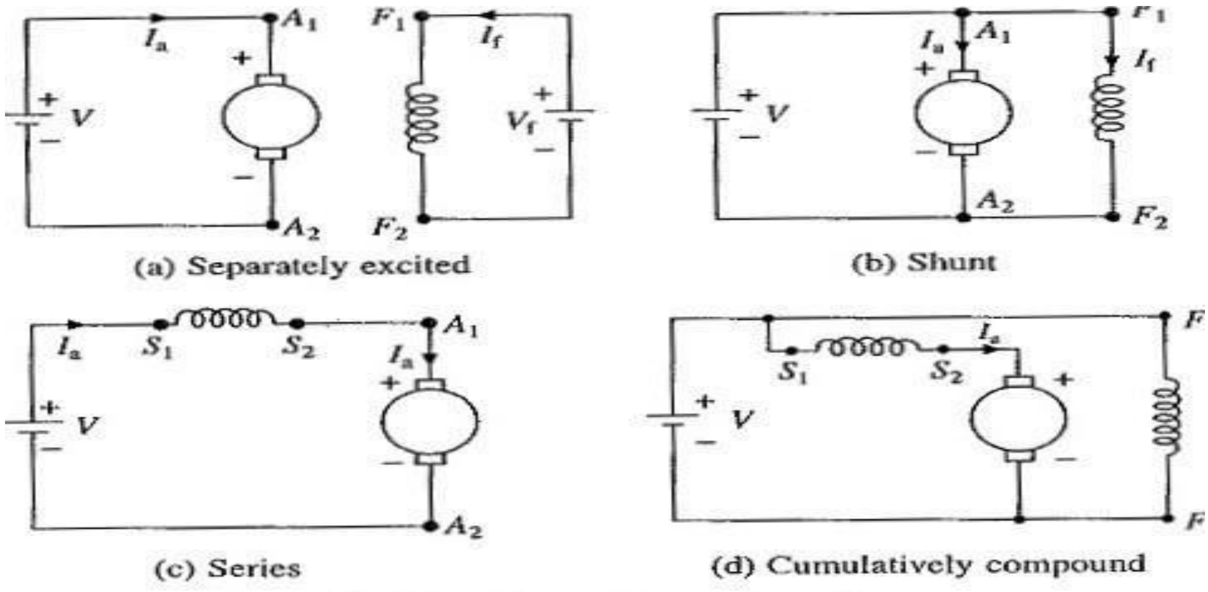

Fig. 2.1 DC Motor Types

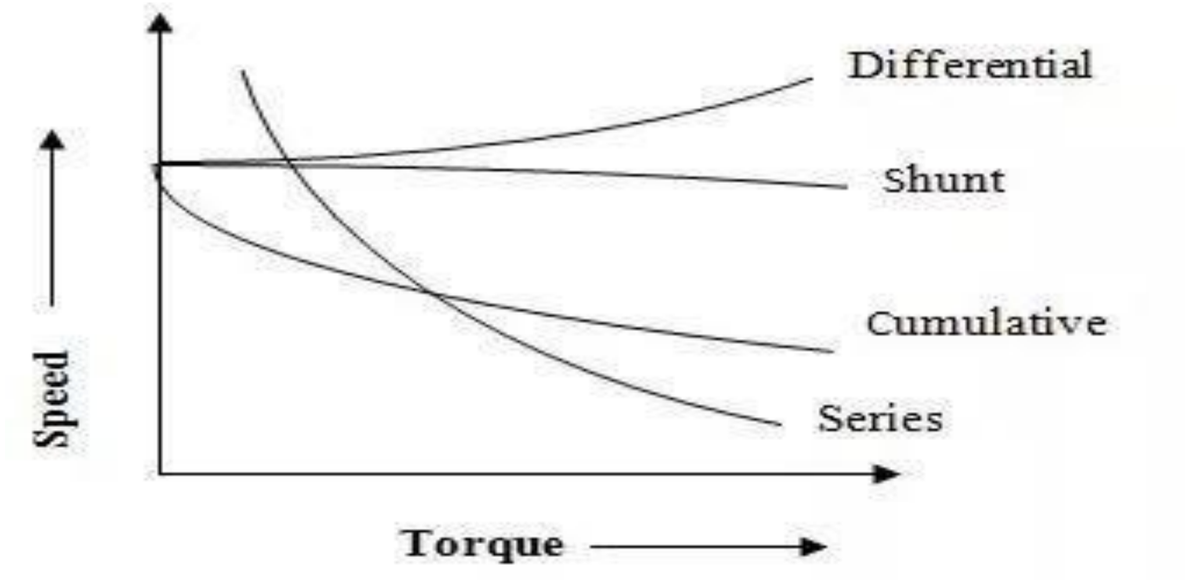

Fig. 2.2 Torque Speed Characteristics of DC Motor

2.1.2 Induction Motor

Induction motor (IM) are more commonly used now a days by the advancements made in the power electronic converters. IM can be classified into two based on the type of rotor, wound rotor and cage rotor. Wound rotor are high cost, requirement of more maintenance and lack of sturdiness. On the other hand, cage rotor IM are simple and extremely in construction, offers reliable performance, cheap and able to operate in hostile environments. As there is no brush friction it permits to raise the limit of maximum speed and higher speed ratings enables these motors to develop high output .[2]

Any endeavor to work the motor at most extreme current past this speed will slow down the engine. In spite of the fact that FOC may broaden steady force activity, it brings about expanded breakdown force in this manner bringing about oversizing of the engine. Furthermore, effectiveness at fast range may endure notwithstanding the way that IM productivity is innately lower than that of PM motors and SRM because of the absence of rotor winding and rotor copper loss. To extend the constant-power region without oversizing the motor (to solve the problem of breakdown torque), the use of a multiphase pole-changing IM drive has been proposed, especially for traction application .[2].Torque speed characteristics of Induction motor is shown in the figure 2.3

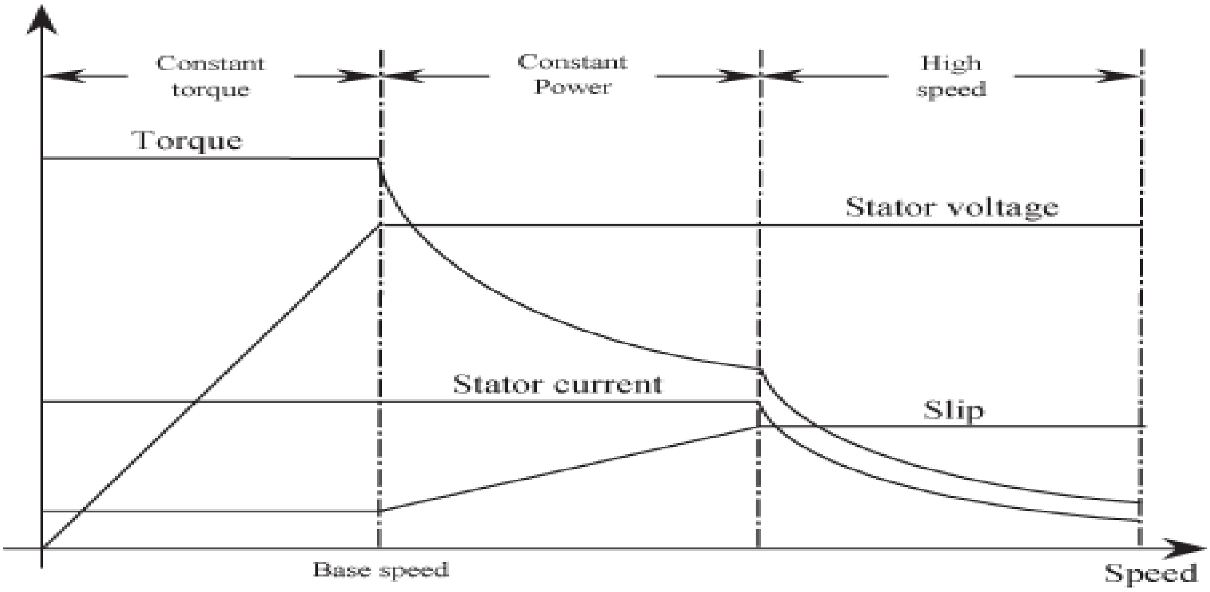

Fig. 2.3 Torque Speed Characteristics of Induction Motor

2.1.3 PM Synchronous Motor

In permanent magnet synchronous motor, PM is mounted on the rotor, therefore the electromagnetic field system, slip rings and brushes are eliminated which in turn eliminates field copper loss and brush friction loss. Thus a higher efficiency is achieved compared to induction motor. Also the overall size, weight and volume can significantly be reduced for a given output power, leading to high power density. Also the heat is dissipated from the winding more effectively as the winding is stationary, thus effective cooling is possible. However, PMSM have short constant power region because PM can provide only a fixed magnetic field and field wakening is not possible. In order to increase the speed range above base speed (about three to four times the base speed is possible), the conduction angle of the power converter can be controlled .[3]

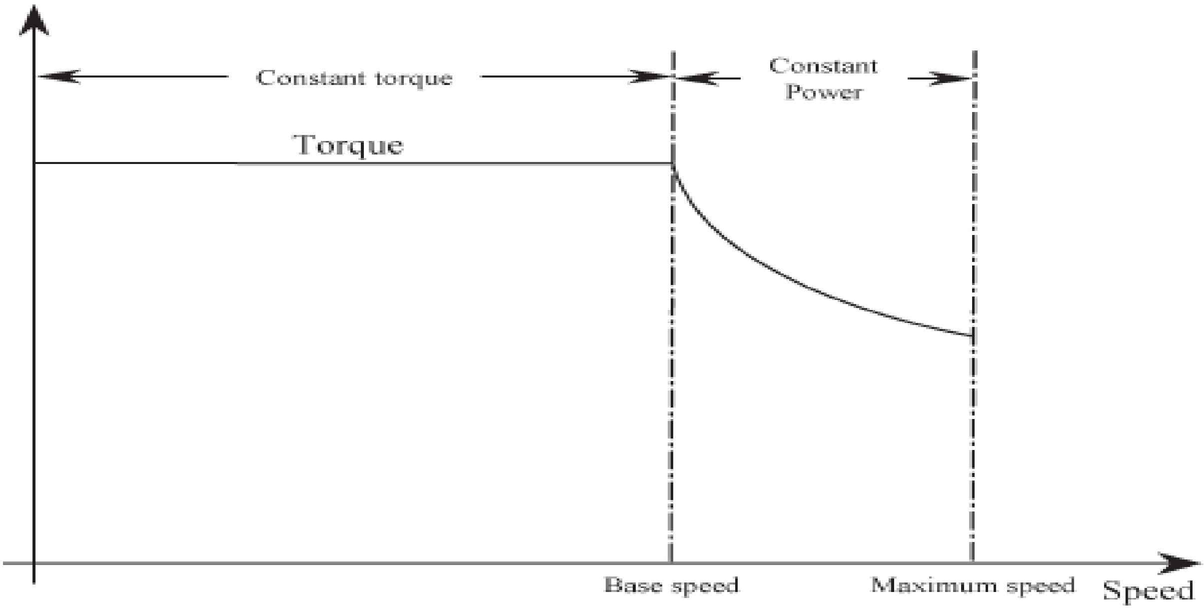

Fig. 2.4 Torque Speed Curve of PMSM

2.1.4 PM Brushless DC Motor

One more sort of motors in options to utilize is the PM brushless dc machine shown in figure 2.5. These are accessed by for all intents and purposes transforming the stator and rotor of the permanent magnet dc motor. Despite the fact that their setup is relative to the PMSM, the BLDC motors are fed by an AC supply that is rectangular in nature as opposed to a sinusoidal supply. Another benefit of PM BLDC motors is their capacity to deliver a greater torque when contrasted with other motors at similar apex amount of voltage and current. BLDC motors are simple to maintain, durable, smaller and lighter than same powered DC motor. In addition to that

BLDC motor has faster dynamic response and at higher operational speed. Also they are less prone to failure that a brushed motor experience because of the absence of commutator and brushes .[4]

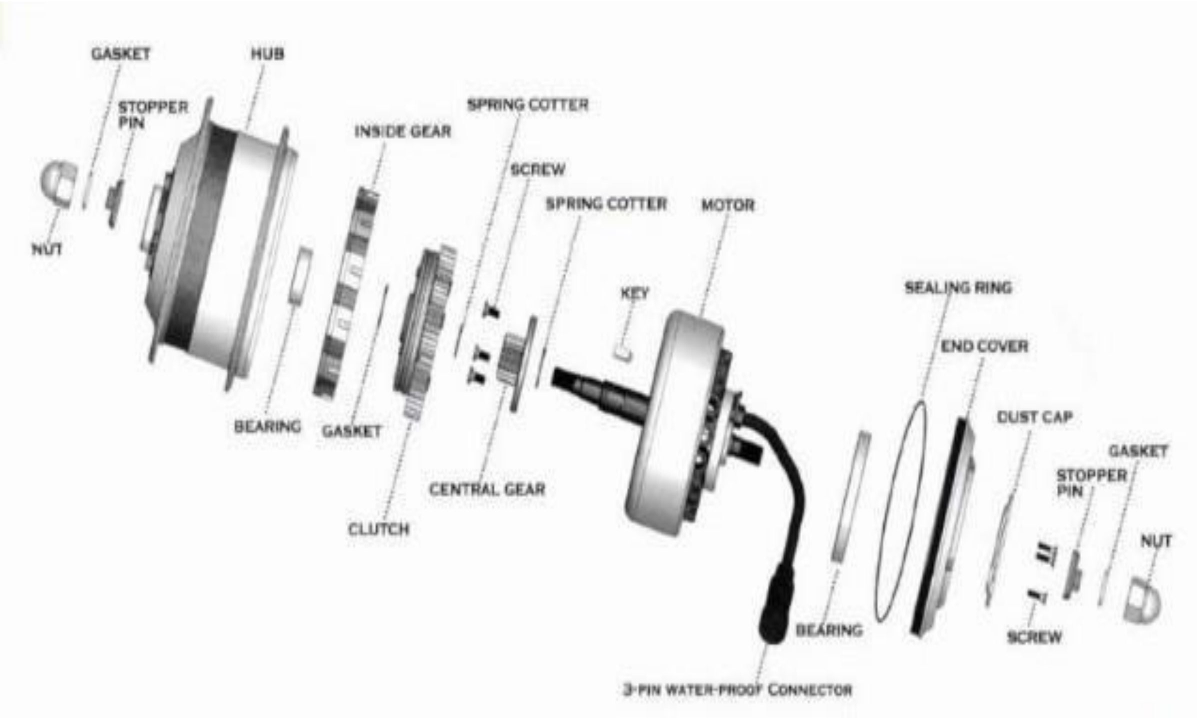

Fig. 2.5 BLDC Motor

However, BLDC motor is expensive because of the permanent magnets, there is temperature limit on rotor because of the magnets and demagnetization possibility also limits the input current of BLDC.

2.2 Speed Control of BLDC Motor

BLDC motor is a brushless motor. The name itself implies that there are no brushes and commutator. In BLDC Motor the commutation is performed with the help of electronic circuit, which reduces the mechanic losses and improves the efficiency. Different methods are available for speed control of BLDC motor, like Using PIC Microcontroller, PWM technique, DC Variable Voltage Converter etc .[11]

2.2.1 Speed Control of BLDC Motor using PWM Technique

R. M. Pindoriya , S. Rajendran , P. J. Chauhan proposed Speed Control of BLDC Motor using PWM technique[5]. These days distinctive PWM methods are accessible, as Sinusoidal, numerous sinusoidal and so on. Here, sinusoidal PWM procedure is utilized for controlling the speed of BLDC engine, since it is simple and less tedious. In this speed control of BLDC engine has been accomplished through variety of duty cycle.

BLDC is a brushless motor. The name itself says BLDC have no brushes and commutator. In BLDC engine the compensation is finished by help of electronic circuit. It diminishes the mechanical misfortunes and improves the proficiency the speed of the engine is legitimately relative to the applied voltage. By changing the normal voltage over the windings, the speed can be modified. This is accomplished by adjusting the obligation pattern of the base PWM signal. The utilization of PWM in power hardware to control high vitality with greatest productivity power sparing isn't new at the same time, fascinating is to create PWM signals utilizing HDL and executing it in FPGA. FPGAs are progressively being utilized in engine control applications because of their strength and adaptability .[5]

2.3 Solar PV Array Fed Water Pumping System using SEPIC Converter Based BLDC Motor Drive

Rajan kumar and Bhim Singh are the authors of Solar PV Array fed water pumping system using SEPIC converter based BLDC motor drive[8].In this the sepic converters are used in the water pumping set. The delicate beginning is accomplished by choosing the estimation of addition size appropriately in the MPPT calculation. Configuration of SPV array-SEPIC fed BLDC motor driven water pumping system is shown in the fig. 2.7.

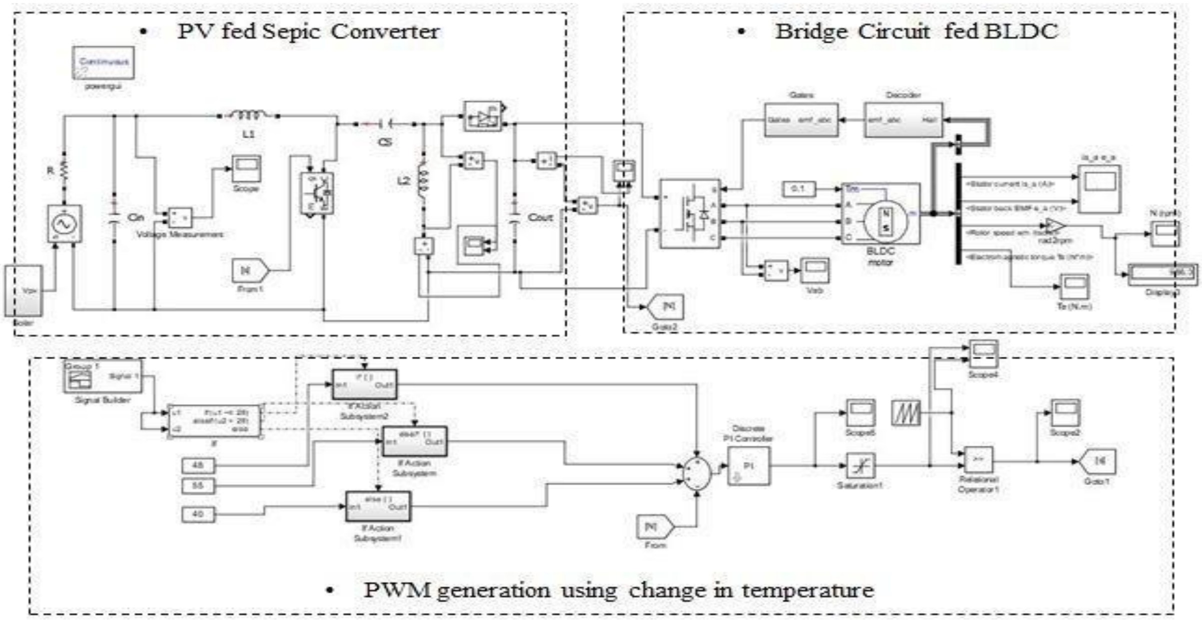

Fig. 2.7 Simulink Model of SPV array-SEPIC fed BLDC Motor

2.4 Modeling and Analysis of DC-DC SEPIC Converter with Coupled Inductors

These days, DC/DC converters are generally utilized in mechanical applications and sustainable power source frameworks. A SEPIC (single-finished essential inductance converter) DC-DC converter is equipped for working in either step-up or step-down mode and normally utilized in a battery charger framework. Every one of these converters has its focal points and weaknesses. The SEPIC isn't the best as a productivity and cost among these converters. Be that as it may, it has a few critical points of interest as to different converters.

As shown in the fig. 2.8 the SEPIC converter is consists of an active power switch , a diode, two inductors (L_1, L_2) and two capacitors (C_1, C_2). C_1 capacitor, which is between the inductors L_1 and L_2, ensure DC isolation which blocks any DC current path between the input and the output .[9]

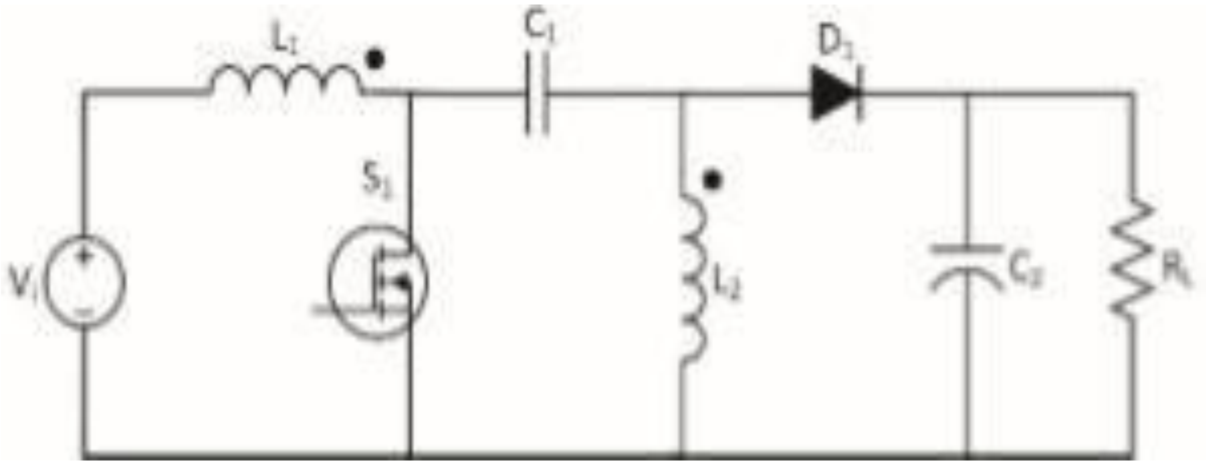

Fig. 2.8 Equivalent Circuit of SEPIC Converter

If the SEPIC converter is operating in the CCM, two switching modes are considered and the equivalent circuits belong to each mode. In Mode 1 (S_1 is turned on) L_1 and L_2 are charged by V_i =20v. In Mode 2, (S_1 is turned off) C_1 and 1 are discharged by L_2. The inductors L_1 and L_2 can be used uncoupled, which are separated or coupled which are wound on the same core[9]. The Perturb & Observe (P & O) based maximum power point tracking(MPPT) algorithm is used to control the DC-DC converter such that the solar power system always operate at its MPP .[10]

2.5 SPV Array Fed Water Pump Driven by Brushless DC Motor Using Landsman Converter

Rajan Kumar and Bhim Singh are the authors of Solar PV Array fed water pumping system using Landsman converter based BLDC motor drive. The proposed water pump framework utilizing a DC–DC Landsman converter is planned to such an extent that the activity isn't decayed by variety in irradiance level and misfortunes related with the converters and engine siphon. In addition, the Landsman converter is intended to work consistently in persistent conduction mode (CCM) regardless of the variety in irradiance level, bringing about a decreased weight on its capacity gadgets and parts. The VSI is worked with the heartbeats of essential recurrence by methods for electronic compensation, bringing about a diminished exchanging misfortune. The speed of BLDC motor is constrained by variety in the DC-link voltage .[12]

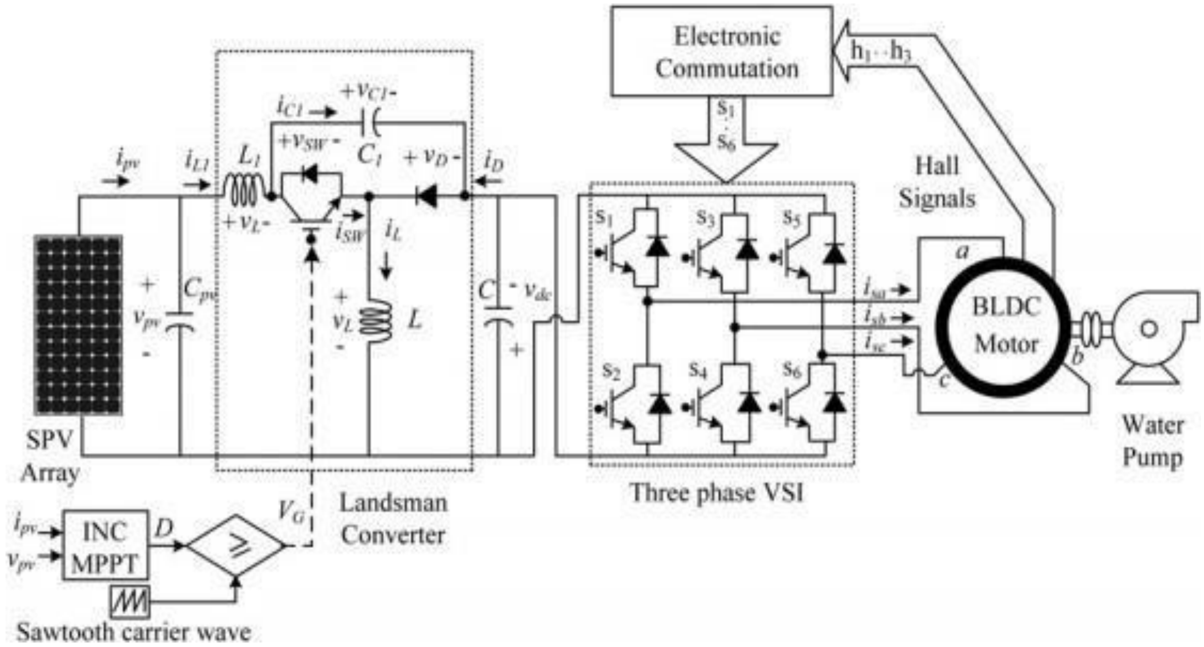

Fig. 2.9 Landsman Converter Fed BLDC Motor Driven Water Pumping System

The Landsman converter is designed to operate in CCM irrespective of the variation in irradiance level.
The circuit operation is divided into two modes . [12]

- Mode I – when switch is ON
- Mode II – when switch is OFF

The Landsman converter is intended to work in CCM regardless of the working conditions. Following the environmental variation, the converter consequently works either in buck mode or boost mode. A water pump is coupled to the pole of BLDC motor, going about as a load. There are two control procedures utilized in the framework at two unique stages, one for MPPT of SPV cluster and another for BLDC engine activity as expounded in the ensuing areas .[12]

2.6 BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter

Rajan Kumar and Bhim Singh are the authors of BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter. Zeta converter as an intermediate DC-DC converter in order to extract the maximum available power from the SPV cluster. A incremental conductance (INC) MPPT calculation is utilized to work the zeta converter with the end goal that the SPV exhibit consistently works at its MPP and the BLDC motor experience a diminished current at the beginning .[13]

The beat generator creates, through INC-MPPT calculation, the exchanging beat for the IGBT (Insulated Gate Bipolar Transistor) switch of the zeta converter. The INC-MPPT calculation takes the voltage and current factors as input from SPV cluster and returns an ideal estimation of obligation cycle. Further, the beat generator creates genuine exchanging beat by contrasting the obligation cycle and the high recurrence transporter wave. Along these lines, the greatest force extraction and henceforth the proficiency improvement of the SPV cluster is practiced.[12]

Then again, VSI changing over the DC power yield from the zeta converter into the AC power takes care of the BLDC motor to drive the radial siphon coupled to its pole. The VSI is worked by the basic recurrence exchanging profited by the alleged electronic substitution of BLDC motor helped by its implicit encoder. The high recurrence exchanging misfortunes are in this way wiped out, contributing in the powerful and expanded effectiveness activity of the proposed water siphoning framework. The benefits of both the BLDC motor and zeta converter can add to build up an ideal SPV exhibit took care of water pumping framework having the capability of working agreeably under the powerfully changing atmospheric conditions .[13]

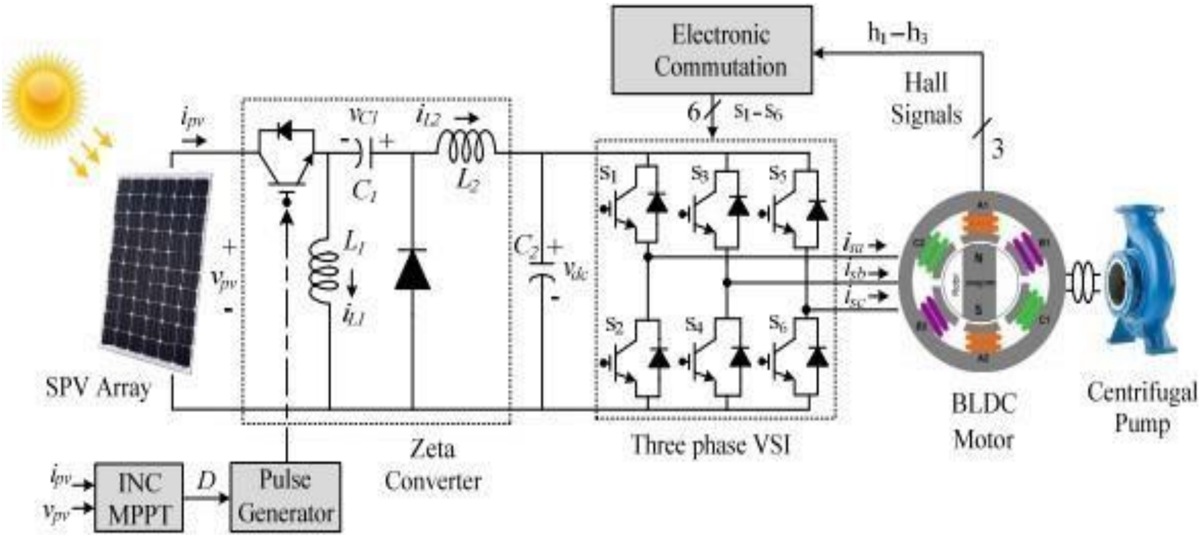

Fig. 2.10 SPV Array-Zeta Converter Fed BLDC Motor Drive for Water Pumping System

2.7 Analysis of Portable Solar Powered DC Air Conditioning System

Tehseen Ilahi,Abdul Moqeet,Hamza Mukhtar are the authors of Analysis of Portable Solar Powered DC Air Conditioning System. Air Conditioning System frameworks are introduced in homes and structures to give the inhabitants cool and tranquil situations. Significant measure of vitality is devoured and power misfortunes brought about in the activity of the wasteful traditional cooling frameworks, which prompts a few ecological issues that are identified with vitality creation just as the high paces of power units' utilization prompting a precarious ascent in power bills. In this idea the framework comprises of two wellsprings of influence supplies for example DC Power being created from the PV module and AC Power being utilized typically. These wellsprings of intensity supplies are being utilized to drive the cooling framework as delineated in the square graph underneath. So as to decide all the qualities and properties, every part was taken as a solitary unit of the considerable number of segments being utilized .[15]

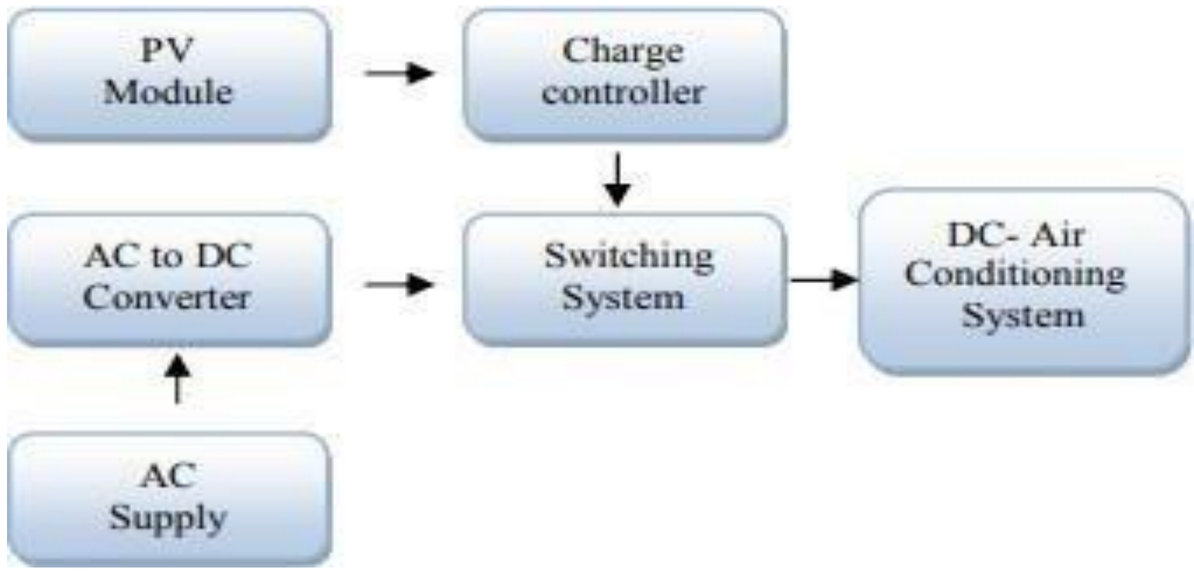

Fig. 2.11 Block Diagram of Portable DC Air Conditioning System

Based on air-conditioning unit capacity, an output of 12V and 60W is obtained from the solar panel which is then taken care of to the charge controller. The charge controller is utilized to shield our framework from voltage surges and spikes. This controlled DC supply is then used to drive the DC blower .[15]

2.8 Gist of Observations

- The challenging issue in designing the solar air cooler as compared to the solar pumps is to maintain the constant speed of the motor that drives air blower .[2]
- The BLDC contain hall effect position sensors for position control. It is done by changing the commutation angle .[4]

- MPPT algorithm ensures the extraction of maximum power from the PV source, the V/f control is used .[10]
- The primary function of a DC– DC Landsman converter is to optimize the power output of SPV array. It also provides the safe and soft starting of the BLDC motor with an appropriate control .[12]
- The speed of BLDC is controlled through a variable DC link voltage of VSI .[13]
- Speed controller is used to vary the speed of the air blower as per the user requirements and ensuring its ability to extract possible power from the PV system .[13]
- The Hall-sensor controlled BLDC motors are preferred in many applications due to their relative simplicity, low cost, and reliable operation in wide range of loading conditions and speeds .[14]
- The cooling and power consumption of Portable solar power DC air-conditioner system was studied and also the economical effectiveness of DC cooling system . [15]
- With all these points taken into consideration , the Standalone based BLDC fed air cooler provides a better way of cooling incorporating a temperature sensor which can be used to control the cooling levels according to the various temperature changes in the surroundings .[11]

2.9 Problem Statement

In the current scenario, mode of energy supplied for the working of air cooler is a major concern. The use of renewable energy can be a good option to solve this issue. Along with this, the inefficient motor used in the existing systems is to be replaced by a suitable motor which improves efficiency of the system is to be employed.

3. RESEARCH METHODOLOGY

3.1 Proposed System

The block diagram of standalone BLDC based solar air cooler is shown below (fig 3.1). The main components include solar panel from which the power is to be taken and a sepic converter along with a microcontroller and a temperature sensor. In this proposed system, with the temperature variations, the microcontroller is set to control the speed of the fan. The voltage from the PV panel is fed into a sepic dc-dc converter which acts as a boost converter, will boost the input voltage to a higher voltage required by the motor. The temperature sensor measures the change in temperature and produces the required output. Basically microcontroller acts as the backbone of the system controlling all the operations. The basic working principle is the room temperature is sensed by LM35 (temperature sensor that is commonly used) and by employing PWM technique the speed of the fan is controlled according to the room temperature change. For processing analog signals microcontroller has an inbuilt analog to digital converter which converts analog signals to digital ones. The temperature sensor gives 10mv for each 1^{0}C change in the temperature; this value is analog value and should be converted to digital. Any adjustment in the temperature will be sent to the microcontroller by means of information port. The microcontroller utilized in this framework has inbuilt PWM module which is utilized to control speed of the fan by fluctuating the obligation pattern of sepic converter along these lines changing the voltage. The readings from the temperature sensor are estimated and the obligation cycle is changed as per that consequently controlling the fan speed .

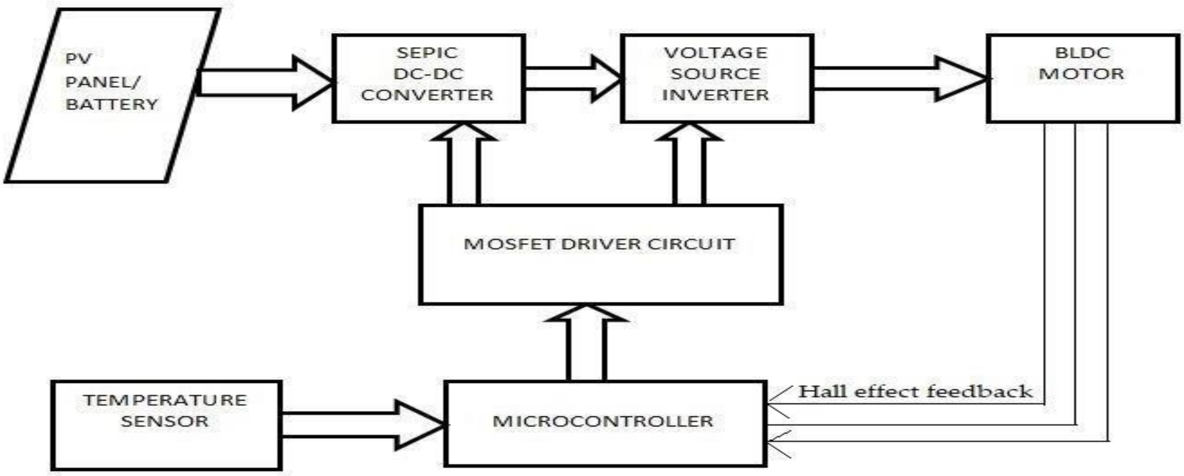

Fig. 3.1 Block Diagram of the Proposed System

4. RESULTS

4.1 Simulink model

The following simulink model shows the PV design. It consists of 36 solar cells connected in series. PV array delivering a maximum of 100kW at 1000W/m sun irradiance

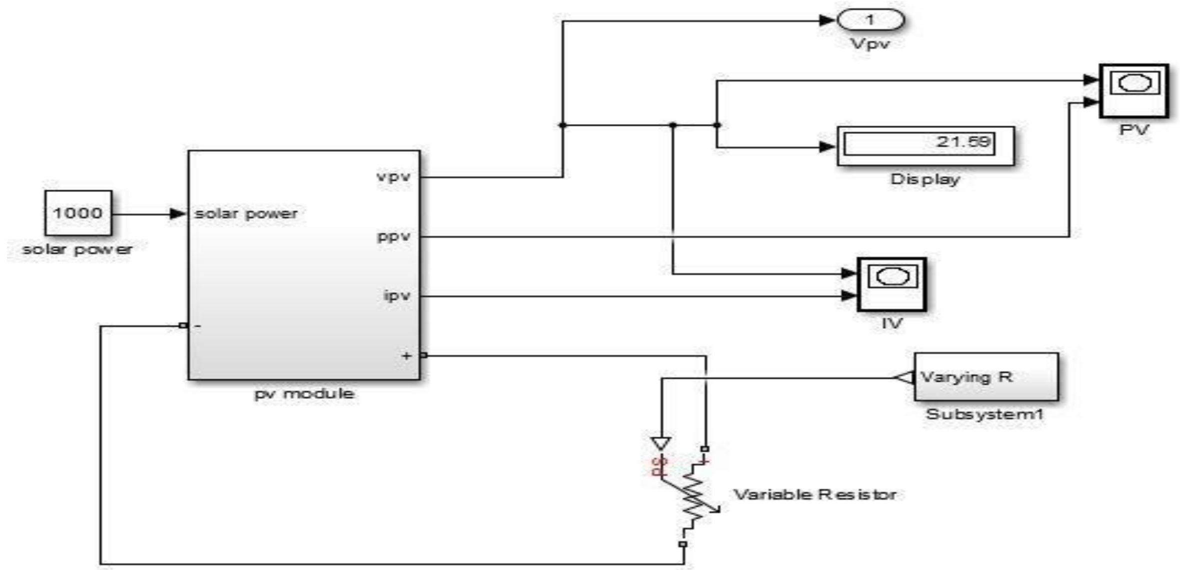

Fig. 4.1 Simulink Model of a PV Array

The PV and IV curves are obtained as shown below. From the graph it can be noted that the Open Circuit Voltage Voc=24V, Short Circuit Current= 0.7A. At maximum power point, the voltage Vmp=21.4V and the current Imp=0.57A.

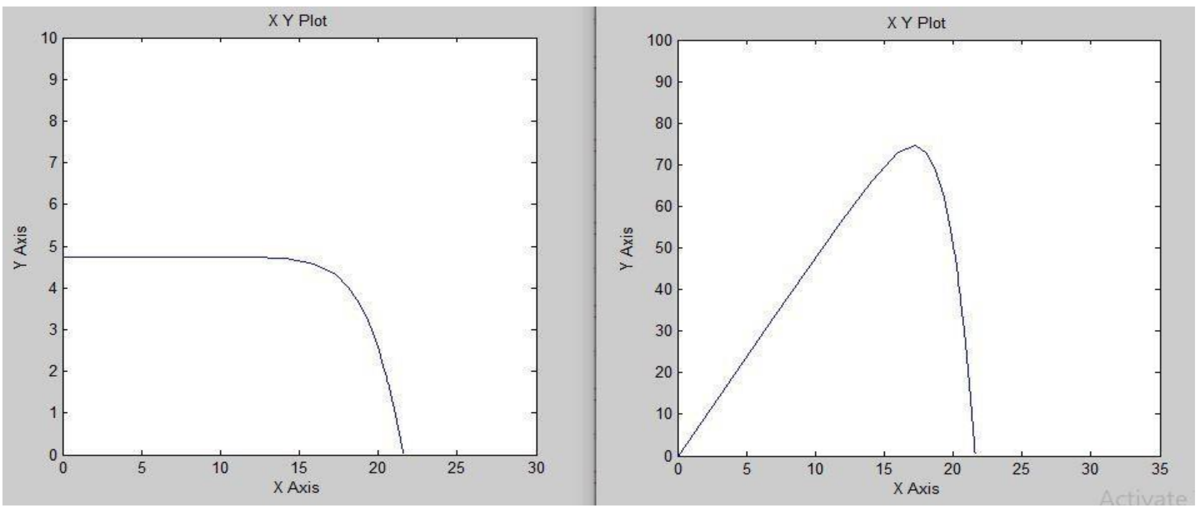

Fig. 4.2 P-V and I-V Curve of Solar Cell

4.1.1 Sepic Converter

Fig 4.3 shows the Simulink model of a Sepic Converter. Being a DC/DC converter, it allows the electrical potential to be less than or equal or greater than the input. The design of the sepic converter is done below and from that we get the duty cycle as 0.740.The values of inductance and capacitance are found to be 4.316mH and 0.084 µF.

$$D_m = \frac{V_{out}}{V_{in} + V_{out}}$$

$$V_{in} = 14V$$

$$V_{out} = 40V$$

Substituting these values in the equation, we have,

$$D_m = \frac{40}{14 + 40}$$

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$$I_o = 4.8A$$

$$L_1 = L_2 = \frac{V_{in(\min)} * D_m}{\Delta I_l * F_{sw}}$$

ΔI_l = Inductor ripple current = $0.1 * I_o$

F_{sw} = Switching frequency = 5kHz

$$L_1 = L_2 = \frac{14 * 0.740}{0.1 * 4.8 * 5} = 4.316mH$$

$$C_o = \frac{I_{out} * D_m}{V_{ripple} * F_{sw}}$$

$$C_o = \frac{4.8 * 0.74}{0.6 * 14 * 5} = 0.084\mu F$$

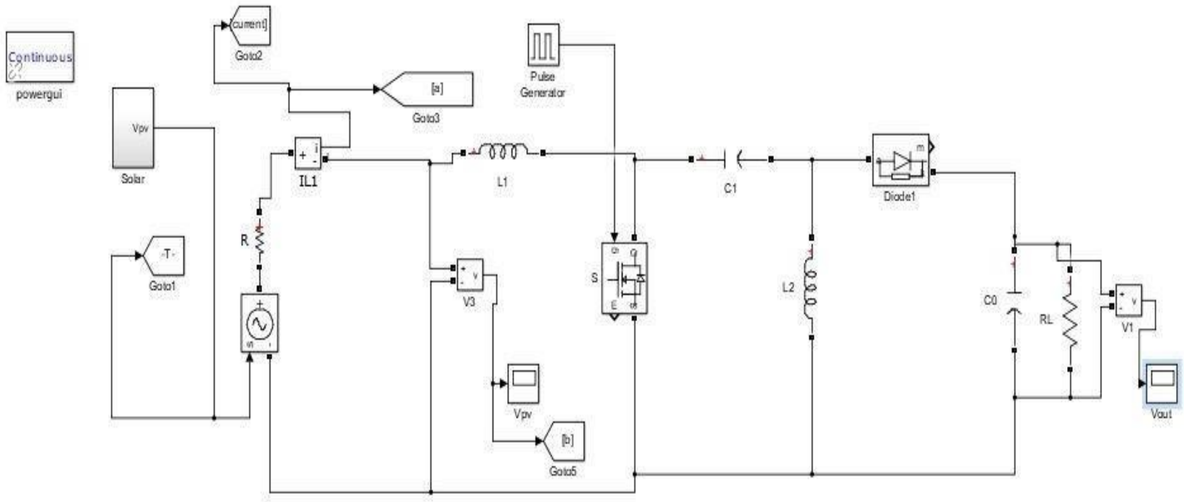

Fig. 4.3 Sepic Converter

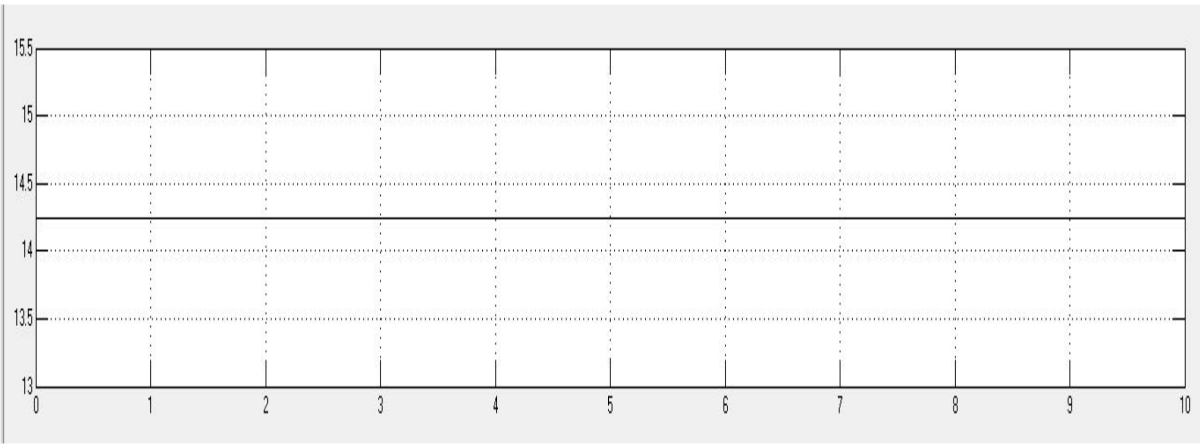

Fig. 4.4 Input Voltage V

The input voltage and current to the sepic converter is noted and the waveform is analyzed

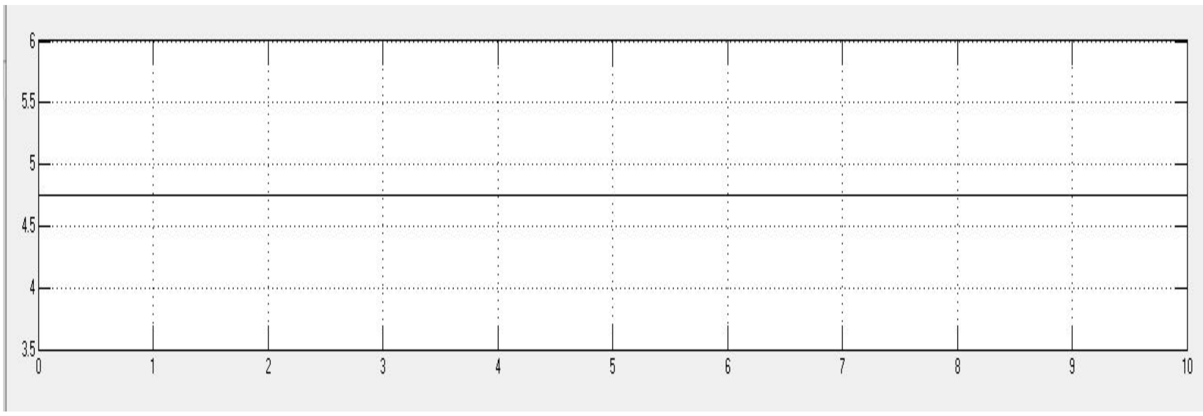

Fig. 4.5 Input Current I

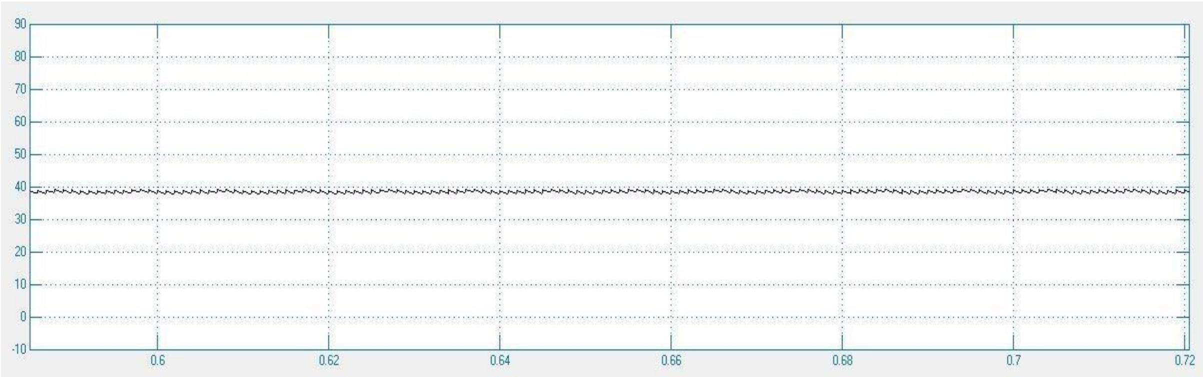

Fig. 4.6 SEPIC Output Voltage V

An average of 14V is given as input to the sepic converter which gives above 40V as its output performing a boost operation.

Fig. 4.7 shows the combined model incorporating the PV fed Sepic Converter, Bridge circuit fed BLDC and PWM generation using the change in temperature. From the graph shown in fig it is clear that speed of the BLDC varies from 400rpm at 0.6s to 960rpm at 0.7secwhich occurs due to change in temperature. The change in temperature is the raise of temperature from 28C to 32C and this change is depicted in the speed curve.

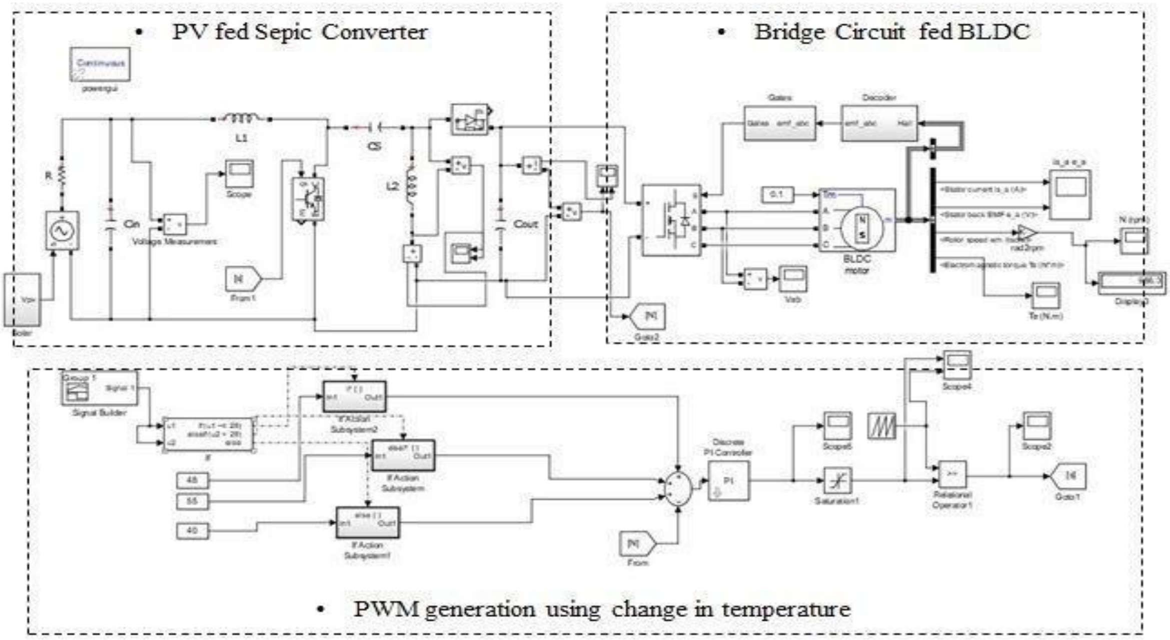

Fig. 4.7 Overall Model

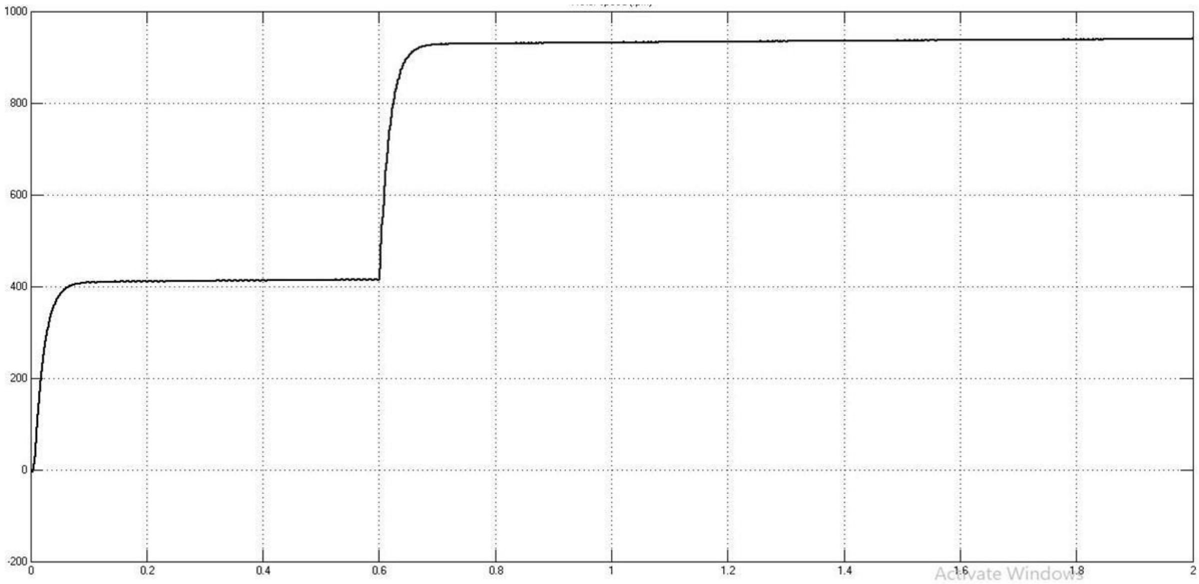

Fig. 4.8 Speed Characteristics

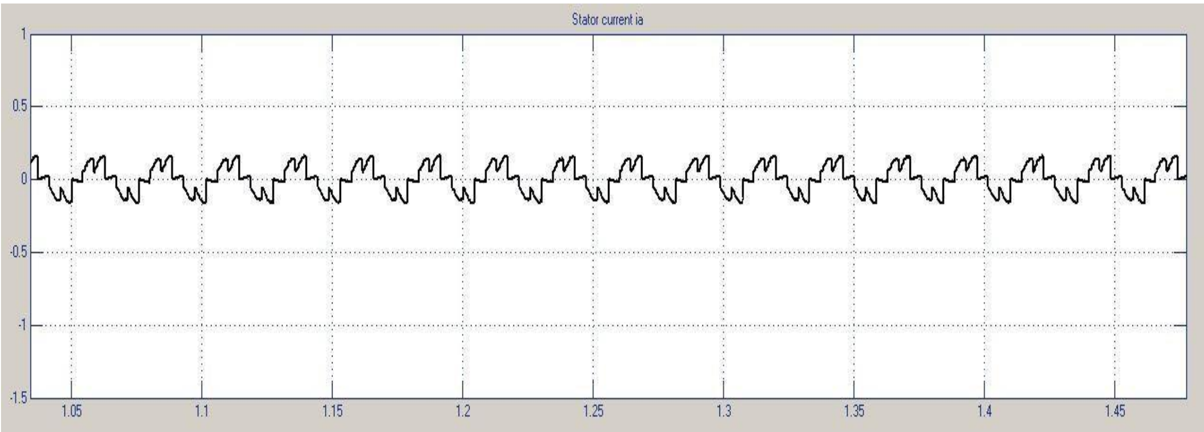

Fig. 4.9 Stator Current Isa

The stator current Isa (fig 4.9) and emf ea (fig 4.10) graphs are obtained from the bridge circuit fed BLDC. The emf graph is trapezoidal in shape as expected. The speed of motor is controlled according to the measured room temperature and switching pulses to the sepic converter is varied according to the temperature changes. Switching sequences for the VSI is generated by electronic commutation. Encoder provides the Hall Effect signals which are mounted on the BLDC motor. It is then converted into 6 pulses according to the switching of the VSI.

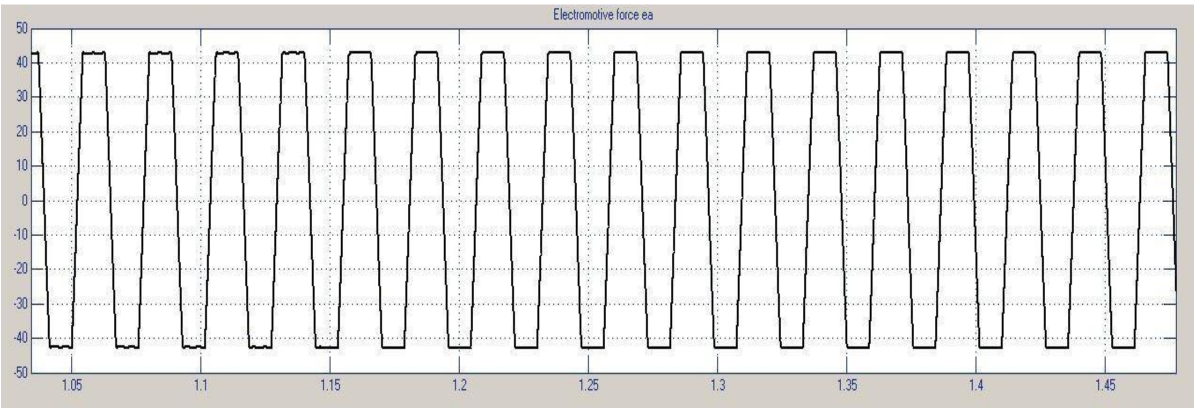

Fig. 4.10 Stator Back Emf ea

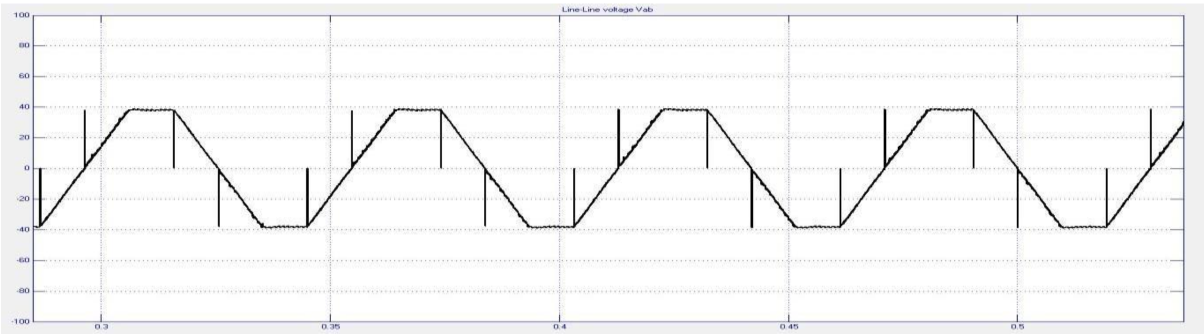

Fig. 4.11 Line Voltage V

CONCLUSION

The literature survey was conducted on the various topics such as BLDC Motor-Driven Solar PV Array-Fed System Employing Zeta Converter and the problems associated with the BLDC such as motor efficiency were identified. As a solution to the problem identified, a Simulink model was created for the speed control of BLDC motor based on the temperature variations. This type of control was then identified to be highly efficient on basis of continuous usage and the system was powered using a PV array.

The simulation was carried out and it's r results were obtained. It was found was that speed of the BLDC motor is varied in accordance with the temperature and from the simulink model ,PV and IV curves were also obtained.

FUTURE SCOPE

Hardware implementation of the Standalone BLDC fed air cooler can be done. The hardware implementation involves the use of PIC microcontroller as the main part which connects the Solar cell and the temperature sensor in the input part along with a sepic converter and a BLDC motor on the output part whose speed is varied in accordance with the temperature changes.

For further improving efficiency, various MPPT algorithms can be implemented onto the simulation.

A MPPT is employed so that it tracks the maximum power value that can be extracted from the panels any time during its operation, which is available for efficient conversion. The various MPPT algorithms like Perturb and Observe or Incremental Conductance can be used.

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