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Design And Implementation Of PV Based Standalone Air Cooler

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Abstract

This paper is about designing and developing of PV based Air cooler without the access of grid system.it is mainly used for industrial and working areas where we can reduce the power usage. Air blower is coupled with PMDC motor and speed is controlled with Arduino UNO controller which is cost efficient and simple in programming. DC-DC buck converter is placed between PV panel and PMDC motor for step down of input voltage from PV panel. The performance of the proposed system is simulated in MATLAB/ Simulink environment and the result are validated.

Keywords: PV based air cooler, DC/DC Buck power converter; PMDC motor; MATLAB/Simulink.

I.INTRODUCTION

Due to rapid increase in population rate, energy consumption is rapidly increasing and at the same time fossil fuels are depleting enormously, thus result in requirement of alternative resource. This paved the way for available renewable resource in which solar is available in abundance and it can be effectively harvested to fulfil the requirement.

Though the initial cost is more, energy can easily be acquired compared to grid power system. In recent years, the usage of solar energy is increased due to the development of technology among industries and awareness among the people. Considering the environment condition several researches have been undergoing which is based on renewable energy in which majority of the project is based on the photovoltaic cell.

Even though several researches have been carried out on PV array combining DC-DC converter and motor drives only less work has been carried out on home application.

The application of PMDC is relatively high, efficient and easy control when compared to single phase ac motor. Controlling of PMDC motor is easier than controlling BLDC motor.

This paper is organized as follow. Section II gives the detailed account of Solar air cooler system. Section III describes the design procedure of individual components of solar air cooler and finally IV provides the conclusion of the paper.

II.Standalone Air cooler configuration

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The solar air cooler consists of PV panel, PMDC motor coupled to fan, DC-DC buck converter, diver circuit which is controlled by Arduino. Power from the PV panel is given to the buck converter and the driver circuit is connected to the fifth pin and ground pin of the Arduino and then output of the driver is connected to the gate and source of the buck converter, this converter is used for step down of voltage from PV panel and here optocoupler is used in driver circuit for providing gate signal to the buck converter finally the output of buck converter is given to the PMDC motor which is coupled to the fan blower and by varying the duty cycle the speed of the motor can be adjusted.

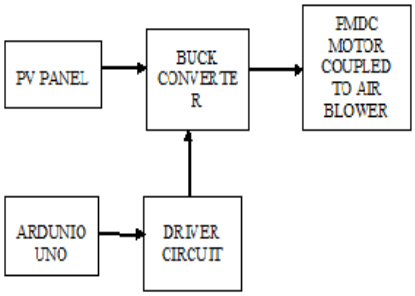

Fig 1 Elock diagram of the air cooler system

III. Layout of Solar air cooler system

For efficient development of air cooler system, design and development of each component is required. The design of each component such as the buck converter, PMDC motor driving the air blower are described as follows

A.Sizing of PV array

A PV array of peak power capacity of 200W is used which is higher than required by the motor so that system performance is not affected by the losses associated with the motor and the converter. The standard insolation of 1000W/m^2 are estimated for all parameter of the PV array. A PV module manufactured by Bosch solar energy c-Si M60-225-16 is used with Maximum Power Point of 225W, Voltage at Maximum Power Point of 28.3V and current at Maximum Power Point of 7.95A is considered for required capacity

Current at MMP, $I_{mpp}= i_{pv} = p_{pv}/v_{pv}=4A$

Numbers of modules connected in series are as, $N_s=V_{mpp}/V_m= 7.9V$
Number of modules connected in parallel are as, $N_p= I_{mpp}/ I_m= 1$

B.Design of DC-DC buck converter

Buck converter is a switch mode DC-DC electronic converter in which output voltage will be transformed to level less than the input voltage it is also called step down converter. The name step down converter comes from the fact that analogous to step down transformer tat is input voltage is stepped down to level less than input voltage. By Law of conservation of energy, the input power has to be equal to the output power. The circuit consists of an inductor, a capacitor, a diode and a switch. In which inductor in the input circuit resists sudden variation in input current. When the switch is ON the inductor stores the charges in the form of magnetic energy and discharges it when it is closed. The capacitor in the output circuit is assumed large enough that time constant RC circuit in the output stage is high. The large time constant output voltage this circuit can be operated in two modes based on OFF and ON states of switch.

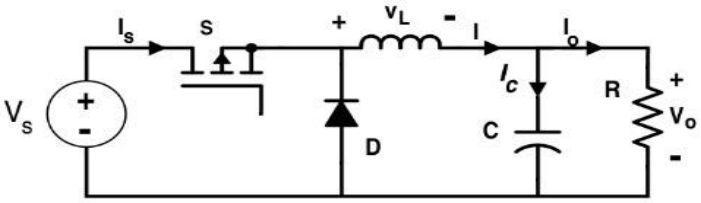

Fig. 2 Diagram of Buck converter

TABLE-1: Data sheet of the PV panel

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MODEL PARAMETER	VALUE
Input voltage	22.8V
Power	132W
Output voltage	12V
Switching frequency	8KHz
Inductor	1.071×10^{-3}H
Capacitor	2.1484×10^{-4}H

MODE I

when is switch is in ON state so the diode is reverse biased so that it is open circuited condition and in this state inductor is charged by Vin. Voltage and Current when switch is ON state

$V_L = L\, dI_L / dt$ (1)
$\Delta I_{LON} = (Vi - Vo) / L$ (2)

MODE II

Here the switch is in off state the diode is forward biased and now the inductor discharges through the diode and capacitor C

Voltage and Current when switch is OFF state

$V_L = L\, dI_L / dt$ (3)
$\Delta I_{LOFF} = - (Vo / L)$ toff (4)

The duty cycle of buck converter is given by

D=Vo / Vin = 0.4240 (5)

The inductor current of buck converter is given by
ΔIL=30% of IL load

= (30/100) *11=3.3A (6)

The inductor value is

L=V* (T/ΔIL)

= 1.0719*10^-3H (7)

The capacitor value is

C=ΔIL/(8*f*Vc)

Vc= 2% of Vo =0.2V

C=2.1484 *10^-4H (8)

TABLE-2: Design parameters of Buck converter

PARAMETER	VALUE
Peak Power	225 W_P
Open circuit voltage (V_{oc})	36V
Short circuit current (I_{sc})	8.7A
Voltage at maximum power (V_{mp})	28.3V
Current at maximum power (I_{mp})	7.95A

C.Design of Driver circuit

Driver circuit consists of optocoupler, three resistor and an input, output port. Optocoupler (TLP250) is an electronics component that transfer electrical signals between two isolated circuits by using lights. It also prevents high voltage from affecting the system receiving the signals. It is used for driving gate terminal of power switches. The major difference from other MOSFET driver is that its input is independent of output. It consists of GaAIAs (Gallium-aluminum-Arsenide) light emitting diode and the outside gets a driver signals through an integrated photodetector. The main feature is

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electrical isolation between low and high-power circuits and it is available as an 8 pin DIP package.

D.Design of PMDC motor

PMDC motor is designing to drive the blower, the rating of the motor is 132W. it acts as a load and to which supply is given through PV which acts a input source it is interfaced through buck converter. It is cost efficient and required less maintenanceand it is more efficient compare to single phase induction motor and more over by using PMDC motor the inverter stage can be avoided

E.Design of blower fan

The blower fan is based on the load torque -speed characteristics.These characteristics exabits similar torque speed relation which is given by

$T_x = K_x \omega_x^2$

T_x - blower fan load torque

ω - rotor mechanical speed (rad / sec)

value of K_x can be obtained using

$K_X = p_{x\,/}\, \omega_x^3$

F.Arduino UNO board

The Arduino is an open source microcontroller board based on has 8-bit ATmega328P controller. Is consists of crystal oscillator, voltage regulator series communication etc. and it is consisting of analog a digital pin in which it has 14 digital input/output pins and 6 analog pins a total of 20 pin. It is used instead of PID controller because it is less cost, versatile and easily programmable and its biggest advantage is that it can be connected to the pc through USB cable so that power supply to the Arduino and the computer. It provided with a voltage of 7 to 20 volts

IV. Result and Discussion

The buck converter part of the proposed scheme has been the simulated in MATLAB/SIMULINK environment and schematic of the proposed system is shown in figure 3.

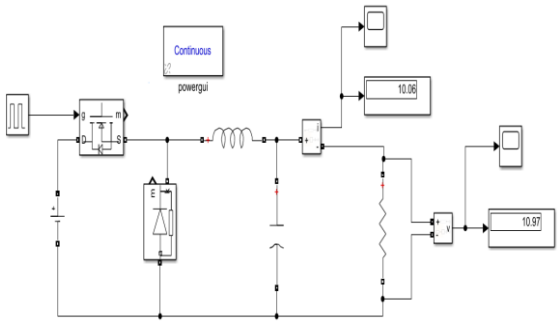

Fig .3 simulation of buck converter

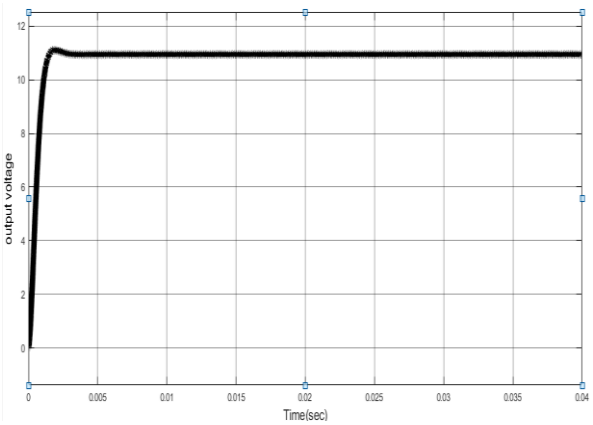

Fig .4 output voltage of buck converter

In fig 4, buck converter output voltage of magnitude 12 V is shown. Output voltage settles at 12V with slight peak overshoot. In fig 5, load current of magnitude 10A is shown

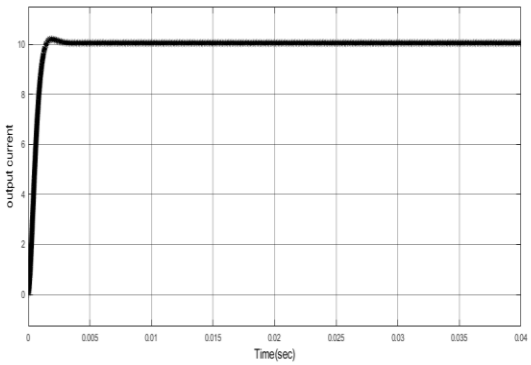

Fig. 5 output current of buck converter

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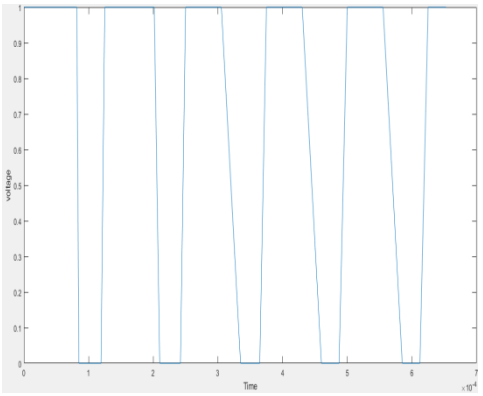

Fig 6. Pulse generator of buck converter

In fig 6, pulses of frequency 7.81KHz generated from Arduino microcontroller is shown. The pulses with duty cycle of 68% is given to the MOSFET of the buck converter

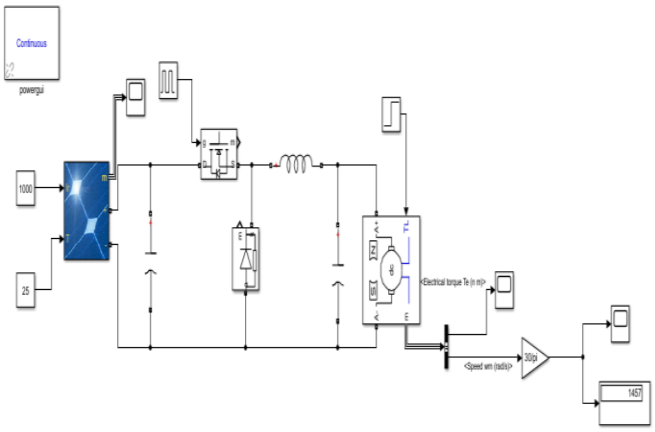

Fig .7 simulation circuit of proposed system

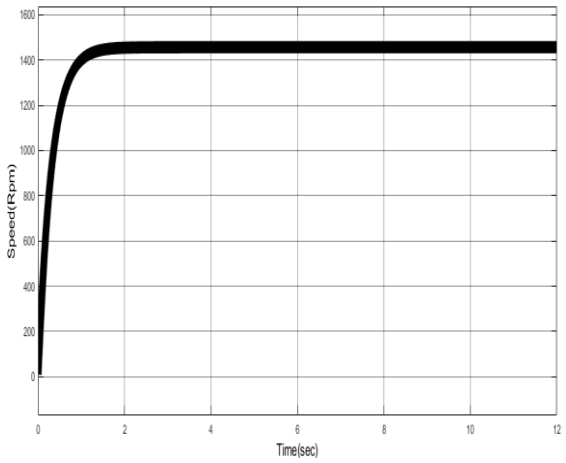

Fig .9 output speed of PMDC motor with PV source

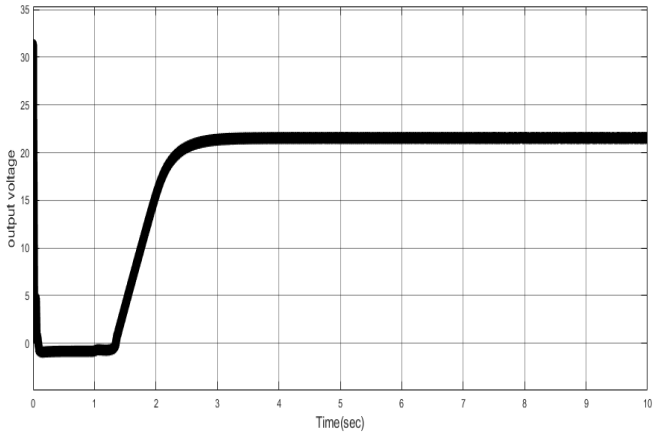

Fig 10. Output Voltage of PMDC motor using solar array

The circuit model of the proposed system is shown in fig 7. As per data sheet of the solar panel, solar panel voltage is around 21V as shown in fig 9 and current is around 5.5A as shown in fig 10 for duty cycle value of 68% of the buck converter.

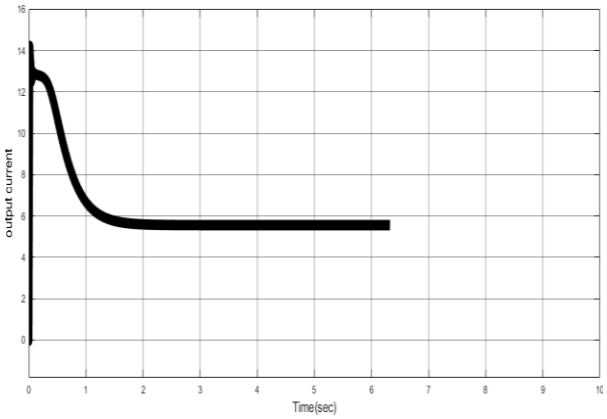

Fig 11. Output Current of PMDC motor using solar array

CONCLUSION

The proposed system has been simulated in the MATLAB/Simulink environment and the results have been presented. In commercial air cooler systems, single phase induction motors are still used whose efficiency is very poor. Since the proposed system uses PMDC motor for driving the air blower, efficiency of the overall system is greatly enhanced.

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Also, unlike the BLDC motor-based air cooler system, the proposed system does not require inverter stage and controlling of the PMDC motor-based system is rather easy. In addition to this, cost of PMDC motor is less than BLDC motor.

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