Solar powered air conditioner using BLDC motor

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Abstract. This paper presents a load compressor fed Brushless DC motor for solar power air conditioner under variable air conditions. At current scenario, air conditioners are manufactured according to room size and space with available objects present in the room. The output of the air conditioner cannot be alternatively changed. This problem is overcome by modifying the fixed output of the air conditioner using BLDC motor. The BLDC motor performance is superior when compared to other motors. Solar power is used as the main source which is a renewable energy and readily available and also very useful for the future generation. This work deals with the output of the air conditioner can be alternatively changed according to the size of the room by varying the speed of Brushless DC motor.

1. Introduction

Air temperature varies according to climate and place, to control the temperature of air, air can be conditioned. It can be conditioned in two ways. They are
1. Forcing of air, e.g.: forced air network
2. Conditioning of air, e.g.: air conditioner. Air conditioning introduced by maintaining the temperature of air at standard medium by circulating the air at closed space or room. In this project, air conditioning is done by varying gas compressor or open drive compressor, the gas used in this is proposed work is R134Aa i.e. tetrafluromethane gas which is a coolant gas mainly used in air conditioning. Since, it has high boiling point and low melting point and it turns into crystal at very low temperature. The compressor is driven by Brushless DC motor using belt drive. The compressed R134Aa gas has raised its temperature and pressure which is given as the input of condenser where its temperature pressure is reduced and the output of condenser is given to evaporator through drier and capillary tube and the cool air with 18 degree Celsius to 200 Celsius is given as output of air conditioner. The source for Brushless DC motor supplied from solar panel or photovoltaic cell which is a renewable energy [1, 2, and 3]. BLDC motor is suitable to produce flat torque characteristic than the other motor because of no brush fiction to reduce the torque and it relatively as a high speed range for supporting the torque. The BLDC motor also supports the design it varying character by producing low noise, since the design is based on room appliance.

2. Proposed System
The proposed work block diagram shown in figure 1. It consists of Solar panel, Charge controller, Battery, Boost converter, BLDC motor and Air conditioner.

**Figure 1** Block Diagram of Proposed system

### 2.1 Solar Panel

The photovoltaic cell Conversion of light energy in electrical energy is created on a portent called photovoltaic effect. When semiconductor materials are bare to light, the some of the photons of light ray are immersed by the semiconductor crystal which origins significant number of free electrons in the crystal. This is the basic reason of creating electricity due to photovoltaic effect. Photovoltaic cell is the basic unit of the system where photovoltaic effect is employed to harvest electricity from light energy. Silicon is the most extensively second-hand semiconductor material for creating photovoltaic cell. In this design, 24V, 500W, 4 panels is used to 1500W.

### 2.2 Charge Controller

A solar charge controller is fundamentally a voltage or current controller to charge the battery and keep electric cells from overcharging. Here we use Pulse Width Modulation controller. This is the traditional type charge controller, for instance anthrax, Blue Sky and so on. These are essentially the industry standard now. The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascents to a certain level. More charge controllers utilized a mechanical relay to open or shut the circuit, halting or beginning power heading off to the electric storage devices. In this design, we are going to use 24V, 50A PWM type. Since solar panel and battery voltage is 24V [4].
2.3 Battery
In this paper, lead acid battery with the capacity of 24V, 72Ah can be used. Since, it is lower in cost it can be used in home appliances. It is capable to tolerate the overcharging. It can deliver high current.

2.4 Boost Converter
The low input DC voltage is converted into high output DC voltage using Boost converter. This project Boost converter given 48V from 24V .Its output is connected to the BLDC motor. [5, 6]

2.5 Brushless DC Motor
The Brushless DC motor is powered up by a DC electric source from a battery which is charged by the photovoltaic cell. Since, the rotor parts of BLDC motor consist of permanent magnet which rotates around a fixed armature develops a maximum torque when stationary, linearly decreasing when velocity increases. It has high efficiency and lower mechanical veer [7, 8]. Compared to other motors, BLDC motor is more efficient is to transfer electrical energy into mechanical energy. Hence, BLDC motor is applied in this concept with 2 hp, 48V, 33A, 8 pole, and Single phase with a driver

2.6 Compressor
The Varying compressor consists of a cylinder with a reciprocating piston of 1ton with 31.3 bar pressure. The forward and backward movement of the piston is conducted by the bearings according to the rotation of the snap ring which is rotated by the belt drive from the BLDC motor. When the piston takes its backward movement the R134Aa i.e., Tetrachlorofluoro Methane gas enters the compressor and during the forward movement the entered R134Aa gas is compressed. The compressed gas with high temperature and pressure is passed through the outlet of the compressor.

2.7 Condenser
The outlet of the compressor is connected to the inlet valve of the condenser where the gas with high temperature and pressure is condensed by cooling the condenser with reduction of heat by a suction fan. During condensation the hot gas with high temperature and pressure is converted into liquid and partial vapour. After condensation both the temperature and pressure of the gas drops to a certain temperature from the room temperature and the outlet of the condenser is passed through the drier.

2.8 Drier
The outlet of the condenser is passed through the drier which is in the form of liquid and partial vapour. The drier filters the vapour and just allows the liquid to pass through. The vapour filtered liquid is then passed through the capillary tube.

### 2.9 Capillary Tube

The liquid outlet from the drier is passed through the capillary tube. The capillary tube works on the principle of Avogadro which states that when a liquid of certain temperature is passed through a pipe or valve which has a constant volume throughout the length will lose its temperature below the atmospheric temperature. Hence, the outlet of the drier which is passed through the capillary tube will lose its temperature below the atmospheric temperature at maximum level.

### 2.10 Evaporator

The liquid with low temperature from the outlet of the capillary tube is passed through the evaporator. When the liquid travels inside the evaporator it is blown with the atmospheric air by the blower. Hence, heat reduction takes place. According to the thermodynamics principle, when a hot and cold body gets in contact heat exchange takes place. Hence, by the thermodynamics principle the atmospheric air obtains the temperature of the liquid inside the evaporator and the liquid obtains the temperature of the atmospheric air and partially converted into vapour. The liquid which has been increased in temperature is passed through the accumulator.

### 2.11 Accumulator

Accumulator is storage or collecting tank that stores the outlet of the evaporator which is in the form of hot vapour and liquid. The vapour is again passed through the compressor by suction method. Hence, it is a cyclic process the compressor again compresses the outlet of the accumulator.

### 3. Circuit Diagram

![Circuit Diagram](image)

**Figure.3 Circuit Diagram**

### 4. Working of Air Conditioner Using BLDC Motor

The working of air conditioner is based on the principle that when air with definite temperature is circulated inside a closed room will lose its temperature to a certain level. The air inside the room can
be cooled by using R134Aa which as high boiling point and low melting point, which is ecofriendly and it, is present in liquid state before it reaches the compressor. The working stages of the air conditioner consist of

1. Power source.
2. Driving unit.
3. Compression.
4. Condensation
5. Evaporation.
6. Cooling.

4.1 Power Source
Here, the power source obtained from the solar panel which is a variable source that depends on the climatic condition. The power source from the solar panel is given to the charge controller to give a regulated voltage, this output is given to the battery since charge controller has 6 terminals two for input two for battery where the regulated voltage is stored for many hours and other two terminals for boost converter because battery and charge controller are 24V but the load need 48 V. so, the output of charge controller is given as the input to boost converter where 24V is converted into 48V and 33 A . The output of boost converter is fed to BLDC motor.

4.2 Driving Unit
The driving unit in this setup is the BLDC motor. The BLDC motor drives the compressor with a belt transmission which leads to the working of overall setup. When the input source is given to the BLDC motor the electronic controller controls the charge controller output amplitude and waveform which is transmitted to the permanent magnet by means of boost converter[10,11,12]. The permanent magnet which rotates around a fixed armature connects the current to the moving armature. The electronic controller continuously switches the face to the windings to run the motor, which produces a uniform torque. The resultant torque and speed of the driving unit is enough to run the compressor with belt drive.

4.3 Compression
The compression process takes place inside the compressor when motor drives at high speed with required torque. Inside the compressor setup consist of cylinder with piston when the motor drives the compressor the piston moves in a reciprocating motion. The R134Aa gas is compressed by the forward and backward motion of the piston during backward movement the suction of gas takes place and during the forward motion compression of gas takes place which increases the temperature and pressure of the gas. Here, the load on the compressor depends upon the temperature of the atmospheric air. If the temperature of the atmospheric air increases, the temperature of the R134Aa gas increases. Hence, the load of the compressor increases and the power unit of the motor also increase with increase in torque.

4.4 Condensation
The condensation process is carried out in the condenser. According to the air conditioning principle, a condenser must be 0.5 ton higher than the capacity of the compressor. Since, our project is based on varying compressor the highest range of the compressor 0.9 ton i.e., approximately 1 ton. So, the condenser is of 1.5 ton capacity is used the condenser is of two row single pass type since it has a single passage for input and output transmission. Condenser consist of 32 fins arranged in a row by
folded mode with vast face between one fold to another when compared to evaporator, the condenser fins in this manner for the fast reduction of heat by the suction fan. Since, the compressed gas entering into the with high temperature and pressure by heat reduction and changes into liquid state and passed through the condenser.

4.5 Evaporation
The evaporation takes place in the evaporator with the help of the blower. According to the air conditioning principle, the capacity of the evaporator depends upon the capacity of compressor where it varies between 0.2 to less than the compressor. The evaporator is also of two row single pass type with 35 fins arrangement. Here fins are folded in a row and closely packed than the condenser for forcing the air that passes through the evaporator with the help of the blower. Hence, evaporator of the air conditioner is takes place by the atmospheric air.

4.6 Cooling
Cooling is conditioning the air inside the room temperature. The cooled air or the air with reduced temperature compared with the room temperature is the output of the air conditioner. When the evaporator consisting of the cold liquid gets in contact with the atmospheric air heat transfer takes place. Therefore, the liquid gets heated up by the temperature of the atmospheric air and the atmospheric air gets the temperature of the liquid and spreads over the room as cooled wind.

5. Design Calculation For The Air Conditioner

5.1 Calculation for Charge Controller
\[
\text{Ampere} = \frac{\text{DC Connected Watts}}{\text{DC System Voltage}} = \frac{1100}{24} = 45.83 \text{A (approx.)}
\]

5.2 Calculation for Battery
\[
\text{Power} = \frac{1100}{24} = 45.83 \text{Ah}
\]

5.3 Calculation for Solar Panel
\[
\text{Battery Capacity} = 72 \text{Ah}
\]

\[
\text{Sunrise-sunset= 5 hours}
\]

\[
\text{Power} = \frac{(72 \times 24)}{5} = 432 \text{Watts= 500 W (approx.)}
\]

5.4 Calculation of Compressor

*To convert kg/cm^2 to MPa
For higher side: 1 kg/cm^2 = 0.98 MPa
The higher side ranges from 28 – 32 kg/cm^2
Assuming higher side value, 32 kg/cm^2 = 3.13 MPa

*To convert MPa to bar 1 MPa = 10 bar
= 3.13*10 = 31.3 bar

*To convert bar to ton 1 bar= 10.19 tonnes per meter
= 31.3*10.19= 318 tonnes per meter

*Room size = 318/1000 = 0.31 ton

*To convert ton to Kilowatts 1 ton = 3.516KW= 0.31* 3.516=1.05 KW
*To convert kilowatts to horsepower 1KW = 1.32hp = 1.32 * 1.05 = 1.38hp

So, the BLDC motors need 1.38hp for a closed room, since the ac in open space in practical we need minimum 2hp, 1.5kw motor because R134a gas temperature varies according to the atmosphere, so temperature increases. Therefore, weight increases it need high torque with high horse power.

5.5 Calculation of BLDC Motor
Since, we need high torque, so current must be high in 2 hp motor we can get about 33amps motor
So, I = 33A, V = P/I = 1500/33 = 48V
*So, the BLDC motor with 48V, 33A, 8 poles, with driver need for this design

5.6 Calculation for Compressor
The thumb rule is condenser must be 0.5 ton greater than the compressor. So, the compressor varies till 0.9 ton i.e., 1 ton. Therefore condenser is 1.5 ton.

5.7 Calculation for Evaporator
The thumb rule is evaporator must be 0.2 ton lesser than the compressor. So, evaporator is 0.8 ton.
Experimental Setup

6. Working Of Brushless DC Motor
The BLDC motor replaces the brushes of the conventional motor by employing an electronic commutator. The system consist of three coils of the motor arranged in a y formation i.e., a microchip PIC microcontroller, an insulated gate bipolar transistor (IGBT) driver, and a three phase inverter comprising of 6 IGBT’s. MOSFET (Metal Oxide Semiconductor Filed Effect Transistors) can also be used for the high power switching. When the input current is given to the motor the electronic commutator transmits it to the microcontroller [13, 14]. The output from the microcontroller comprises pulse width modulated signals (PWM) that determines the average voltage and average current to the coils.

![Constructional Diagram of Brushless DC Motor](image)

**Figure.5** Constructional Diagram of Brushless DC Motor

The motor practices three Hall Effect sensors to specify the rotor locations.

![Brushless DC Motor](image)

**Figure.6** Brushless DC Motor

The rotor themselves uses two pairs of permanent magnets two make the magnetic flux. Conferring to Lenz’s law, it gives growth to a current in the winding with a magnetic field that faces the unique change in magnetic flux. Henceforth the electric motor produces a voltage potential due to the instant of the windings done the related magnetic field. This potential is recognized as EMF (Electromotive Force). Meanwhile the motor consist of six step commutation arrangement for all electrical revolution
with the assistance of two pairs of magnets, two electrical revolutions are compulsory two spin the motor once. Hence, the electrical response is converted into mechanical energy and this mechanical energy is transferred through belt drive to ride the compressor.

7. Conclusion

The output of the air conditioner can be varied by varying the speed of the motor. The BLDC motor also supports the design it varying character by producing low noise, since the design is based on room appliance. The speed is constant even at high load and torque at low speed also high. The BLDC motor is very suitable to run the setup. This work can be implemented in hardware also. Based on the result, it has better thermal performance and withstand at high temperature. In BLDC motor the voltage drop on the electronic device which improves the efficiency of the motor compared to other. As the BLDC motor is free from brushes and commutator their maintenance is less with efficient life time. Hence it is confined that the BLDC motor is more suitable for this design compared to other motors.

7. References

[1] Arora and Domkundwar, Refrigeration & Air Conditioning, Dhanpatrai& Company.
[2] Solar Electricity Handbook – 2014 Edition: A Simple Practical Guide to Solar Energy – Designing and Installing Photovoltaic Solar Electric System
[3] Solar Powered Variable Speed Power Factor Corrected BLDC Motor Drive, Muhammed Rajees.P.P
[4] C. L. Xia, Permanent Magnet Brushless DC Motor Drives and Controls, Hoboken, NJ, USA: Wiley, 2012.
[5] Comparison of Basic Converter Topologies For Power Factor Correction. Huai Wei, IEEE Member, and IssaBatarseh, IEEE Senior Member, University of Central Florida Orlando, FL 32816.
[6] H.Wei,I.Batarseh,”Comparison of basic converter topologies for power factor correction,”inProc.IEEE,pp 348-353, Apr.24-26 1998
[7] SanjeevSingh,BhimSingh,”Voltage controlled PFC zeta converter based PMBLDC drive for an air-conditioner,”in Proc.ICIS,pp.550- 555,Jul./Aug. 2010
[8] Rajan Kumar and Bhim Singh, “Buck boost converter fed BLDC motor drive for PV array based water pumping,” IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), pp.1-6, 16-19 Dec. 2014.

[9] S. Veeraraghavan, M. Kumaravel, Krishna Vasudevan, and Ashok Jhunjhunwala, “Experimental studies and performance evaluation of Solar PV powered BLDC motor drive with an integrated MPPT in fan applications,” 40th IEEE Photovoltaic Specialist Conference (PVSC), pp.3713-3718, 8-13 Jun. 2014

[10] Solar powered speed control of Brushless DC motor drive using PID FUZZY Controller, Volume 8, Issue 8, August 2017, pp. 1135–1147, Article ID: IJMET_08_08_113

[11] Simulation of Solar Powered PMBLDC Motor Drive, © 2014 IJEDR | Volume 3, Issue 1 | ISSN: 2321-9939

[12] 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

[13] PadmarajaYedamale “Brushless DC (BLDC) Motor Fundamentals” Microchip Technology Inc, 2003 Microchip technology

[14] 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