Design and Implementation of a Low Power Consuming Air Cooling System for Remote Hospitals to Preserve Essential Medicine and Vaccines

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Abstract - A solar assisted Air Conditioner (SAC) can be made using components like compressor, condenser, expansion valve and the evaporator. The power can be supplied using grid and also from the solar panel. This work gives a proof of concept of use of solar energy for saving electricity and for places where electricity is not available but AC is need. The targeted room temperature was 16 Degree Celsius to 25 Degree Celsius. A model air conditioner was designed and constructed locally. It was installed and tested to get the required temperature. An AC compressor was used, and therefore, an inverter has been used to convert the DC power to AC power. The model was tested in a 10 feet by 12 feet room for a period of one weeks in August 2018. Wind speed, ambient temperature and solar radiation intensity data were monitored and collected from scientific weather station using internet. By monitoring the temperatures and compressor current power consumption and the performance were determined. The overall performance was measured and it was normal. For the refrigerant R-22 all the necessary data has been taken and calculated practically. It is observed that the SAC is performed well for the most used refrigerant R-22. The temperature profile and pressure profile has been made using digital thermocouple and highly accurate pressure gauge to determine the room temperature and suction and discharge pressure respectively. Total power consumption per day by the SAC has been calculated. It was thus proved that a suitably sized PV system could be designed and implemented at rural areas and the areas where electricity is not available at all. This could be a great thing for a country like Bangladesh where electricity is main problem.

Index Terms – Air Cooling System, R-22, Solar Air Cooling System, Rural Area, outdoor Unit, Indoor Unit, Solar Powered Air Conditioning System

1 Introduction

The demand and the cost of energy is thriving swiftly over the world, particularly in Bangladesh. Because of the change of climate condition and for the global warming, the using of Air conditioner (AC) is significantly increased. In fact, more than 30% of energy is used for cooling or heating of domestic and commercial buildings and it is rising rapidly [1]. To accomplish that increasing demand more fossil fuel is needed and that raising the environmental pollution and global warming. In this respect, international research is moving in two main directions. The first focuses on the building itself, aiming to minimize heat gains through the building envelope and to simultaneously maximize the use of natural heat sinks. Whereas the second is concerned by the development of technologies that can offer reductions in energy consumption, peak electrical demand and energy costs without lowering the desired level of comfort conditions [2]. Solar AC is an excellent alternative of fossil fuel to accomplish the heating and cooling needs. In Bangladesh there are many rural areas where electricity is not attainable to conduct AC, but in hospitals and govt. offices it is essential. In urban areas, national grid is unable to supply continuous electricity and it creates huge problem for banks, offices, residential areas, hospitals etc. So, using of solar AC in every places can replace all these problems and it can reduce the pressure on national grid, hence the load shedding problem also. People don't have to pay a large amount of electricity bill for AC, as the solar AC will be powered from solar cell. In remote and tourist areas such as saint Martains, Bandarban, Sundarban where there is no grid connection and foreign tourists are facing a lot of problem because of electricity and also for the AC. So, there hotel, motel, resorts can be standardized by Solar AC. This research is analysing in many countries such as, A solar-powered Adsorption air-conditioning system was designed and installed in the green building of Shanghai Research Institute of Building Science [3] X.Q. Zhai 21 Dec. 2007, another one is at Hong Kong, A solar-powered Adsorption air-conditioning system was designed and successfully constructed on campus of the University of Hong Kong [4] M.R. Yeung, 1992. So, for Bangladesh Solar AC can be a great beneficial and time relevant.

2 Methodology

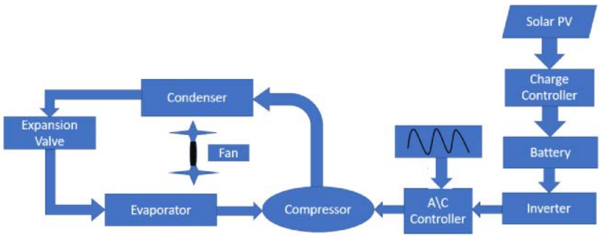

Fig. 1 Block Diagram of Solar AC

In Bangladesh there is a huge prospect of solar thermal and photovoltaic applications. The average solar irradiation in Bangladesh is about $5kwh/m^2/day$ and the highest is about $6.4kwh/m^2/day$ [5]. So, to begin with solar AC at first, solar energy is absorbed by photovoltaic cell. Then a charge controller used to store the energy on a battery. Battery stores the energy as direct current. But to conduct AC the direct current needs to convert into alternating current. An inverter converts direct current to alternating current for compressor. As, it is a hybrid solar AC so, it is also connected to supply current though a controller. When the sun will not available the AC can operate from the grid supply. Now, the basic principle of refrigeration cycle will show below:

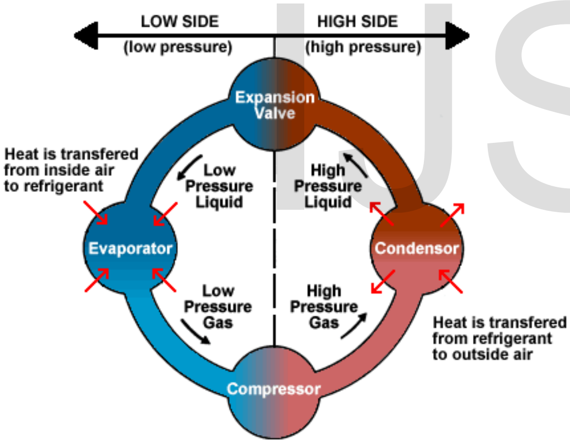

Fig. 2 Refrigeration Cycle [6]

To operate an air conditioning system with economy, the refrigerant must be used repeatedly. So, to cool an area all the air conditioners use the same cycle of compression, condensation, expansion, evaporation.

At first the low pressured refrigerant comes to the compressor and the compressor compressed them. Then the refrigerants moves out of the compressor as a high-pressure gas. After that the gas moves though the condenser. Now, the gas condenses into liquid and releases its heat to outside air. The high pressure liquid then moves to the expansion valve. It restricts the flow of the fluid and also make its pressure low when it leaves the expansion valve. The low-pressure liquid then moves to the evaporator, where heat from the inside air is absorbed and changes it from liquid to gas. The refrigerant moves to the compressor as a hot low-pressure gas. Where the entire cycle is repeated [7].

There are three basic areas in electrical circuitry of an AC. There are-

- High voltage source
- High voltage controls and motors
- Low voltage controls

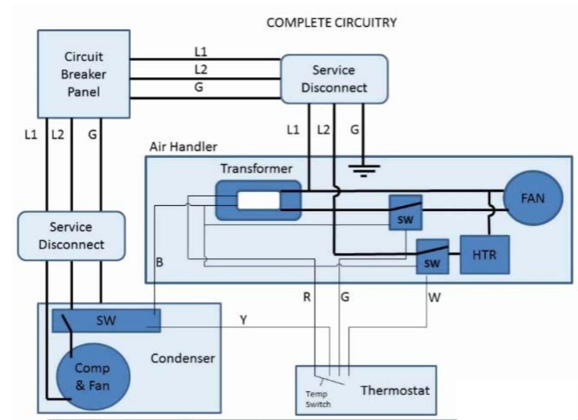

Fig. 3 Basic Electrical circuit

The electrical connection starts from the high voltage supply outlet of the house. The circuit breaker serves the current for the outdoor and indoor unit through the service disconnect.

The high voltage at outdoor unit is used to turn on the compressor and the outside fan motor.

The high voltage at indoor unit powers the cooling fan motor and creates the low voltage through the transformer. The low voltage is used for controlling the AC and for the thermostat to turn on the compressor and fans.

3 Calculation

3.1 Power Calculation

The room width 10 feet and length 12 feet and height 10 feet.

$$v = w \times l \times h$$

Here,

v= Volume, w= Width, l= Length, h= Height.

So, $v = 15\,feet \times 12\,feet \times 10\,feet = 1800\,feet^3$

Multiply this volume by 6.

$$C1 = v \times 6 = 1800 \times 6 = 10800$$

Let, Four person in room (N = 4) and for one person need 500 $BTU/hour$

Now,

$$C2 = 4 \times 500 = 2000\,BTU/hour$$

Add $C1$ and $C2$ together and we will get a very simplified cooling capacity needed for the desired room.

Estimated Cooling Capacity = $10800 + 2000\,BTU/hour$

$=12800\,BTU/hour$

As 1 HP ($746\,watt$) $= 9000\,BTU/hour$

So, require output in watt = $(746 \div 9000) \times 12800$

$= 1061\,watt$

3.2 Solar Cell Calculation

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Efficiency = 18%
$Vmax$ = 0.47
Power require for AC = $1200w$
System voltage = $12v$
Maximum irradiance for June 21, $Pin = 812.7791$
So,
$Pmax = 0.18 \times 812.7791 = 146.3w$
$Imax = 146.3 \div 0.47 = 311.277$
$Area = 1200w \div 146.3 = 8.20\, m^2$
$I = Imax \times cell\ Area = 311.277 \times 232.26cm2 = 7.23$
Power per cell = $Vmax \times I = 0.47 \times 7.23 = 3.398w$
Total number of cell require = $1200w \div 3.398 = 353.15$
No. of cells in series = $12v \div 0.47 = 25.53 = 26$
No. of cells in parallel = $353.15 \div 26 = 13.58 = 14$
So,
Power output from solar pv = $26 \times 14 \times 3.398 = 1236.9w$
Here, $250w$ is achieved by a single solar PV. So, there need five single parallel PV for achieving total require power for AC.
Power required for AC is achieved by solar PV.
C. Battery Calculation
12-volt 200-amp battery was used for storing charge, so total power can be store in one battery = $12 \times 200 = 2400W$
So, by one battery the solar AC can run for two hours. For 6 hours it requires 2 more batteries.

4 DESIGN AND IMPLEMENTATION

TABLE I
LIST OF COMPONENTS

Outdoor	Indoor
1. Steel Casing	1. Plastic Casing
2. Compressor	2. Evaporator
3. Condenser	3. Cooling Fan
4. Outdoor Fan	4. Louvers
5. Magnetic Contacts	5. Swing Motor
6. T-joint	6. Controller

4.1 Implementation Process

Step-1: Outdoor Unit

Fig. 4 Outdoor Casing, Cooling Fan, Copper tube Aluminium sheet

Fig. 5 Installed Compressor, Full Condenser, after Installation of cooling fan

The casing of outdoor unit is used to keep all the equipment in a particular box. Panasonic (2P21T225AZB) Compressor is used. The main function of the compressor is pumping the coolant gas from a low pressure to high pressure state.
Condenser is made of copper tube and huge number of Aluminium sheet. Diameter of copper tube is ¼ inch and 50 feet of tube was used. The main function of the cooling fan is to cool down the condenser chamber as well as the whole outdoor unit.

Step-2: Indoor Unit

A plastic made casing was used to pack all the component in a box. Evaporator is made of a huge number of small sheet of aluminium. Blower rotates and provides the cool and clean air.
T-joint is mainly used to connect the pressure gauge with the indoor and outdoor unit. Cooling motor helps the blower to rotate and swing motor helps the louver to change angle.

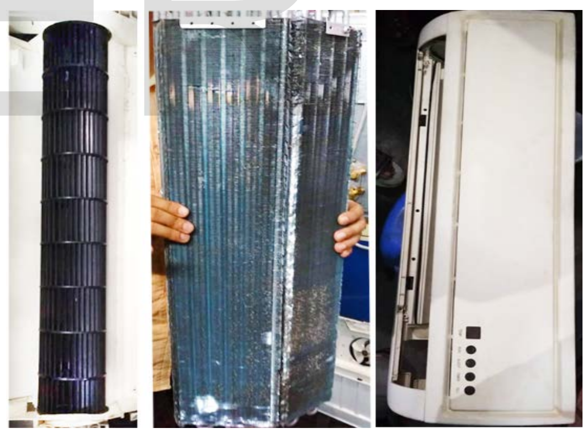

Fig. 6 Blower, Evaporator & Casing

Fig. 7 T-joint, Cooling & swing motor

Step-3: Solar Unit

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Fig. 8 PV cell, Battery, Converter

Solar PV panel, Battery and converter is used to provide the power supply to the AC. As, the AC compressor needs alternating current so the converter is used.

4.2 Overall Design

Fig. 9 Complete Design of AC

5 Cost Analysis

TABLE II
CONSTRUCTION COST

Name	Price (in USD)	Name	Price (in USD)
Compressor	83	Plastic casing	24
Condenser	71	Blower	9
Casing	36	Evaporator	52
Outdoor fan	18	Swing motor	4
Magnetic contacts	3	Cooling motor	12
T-joint	2	Converter	154
Controller	13	Battery	142
PV panel	300	**Total**	923

6 Result and Analysis

The AC was set in a 10 feet by 12 feet room for a period of one week at August 2018. Mostly used refrigerant in Bangladesh is R-22 and that refrigerant is used to measure the performance of solar AC. Pressure gauge is used to measure suction and discharge pressure and a 4 channel thermocouple is used to measure the room temperature at different point.

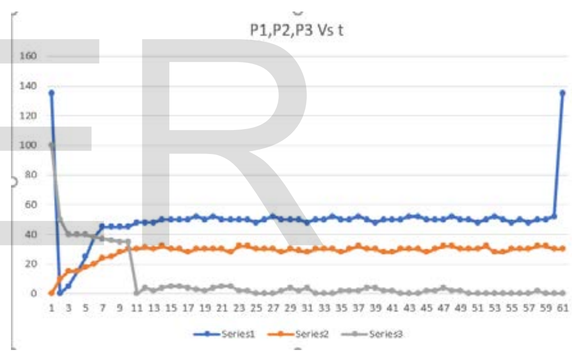
Pressure and temperature Data

Two pressure gauge was used to measure the pressure at indor units suction and discharge point and another one pressure gauge was used to measure the outdoor units discharge point. The data was obserbed for 1 hour and the data graph is shown below:

Fig. 10 pressure graph

Here the series-1 is outdoor units discharge pressure, series-2 is indoor units discharge pressure and series-3 is indoor unit's suction pressure. Series-1, 2, 3 running pressure was respectively 50psi, 30psi and 0psi. Which is normal for an AC. The temperature is also measured for different set temperature at AC.

Here four curves shows the temperature for four different point at room. T1 was very closed to AC, T2 was at normal distance and T3,T4 was at far distance form AC. Temperature at T1 decreases faster and was lower than the desired temperature. But, at T2 desired temperature was obtained



within 5 minutes. However, T3,T4 takes more time to achieve the desired temperature. From the temperature and pressure profile, it is observed that the AC was performed well when it was powered by solar.

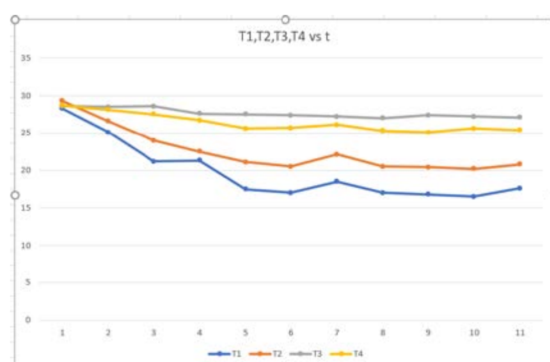


Fig. 11 graph for 18^0C

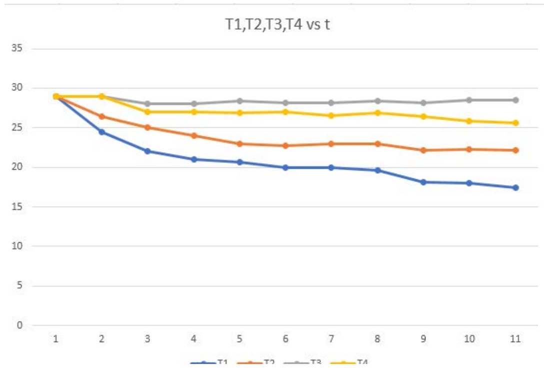


Fig. 12 Graph for 22^{0}C

7 CONCLUSION

This experiment was started depending on the demand of air cooler and how to reduce the consumption of electricity and also thinking about the remote and rural area where electricity is not available. By using this solar air conditioning system people do not have to pay more bill. It is portable that is why people can transport it easily. In Bangladesh there are some remote and rural areas where electricity is not available in those area it is highly recommended to use this solar AC. It was thus proved that a suitably sized PV system could be designed and implemented at rural areas and the areas where electricity is not available at all. This could be a great thing for a country like Bangladesh where electricity is main problem.

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