FABRICATION AND DEVELOPMENT OF EXPERIMENTAL SETUP OF SOLAR OPERATED AIR CONDITIONING SYSTEM

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ABSTRACT

In summer hot and humid condition feel uncomfortable , so it is necessary to maintain thermal comfort condition. The objective is to fabricate and develop the highly efficient solar operating air conditioning experimental setup. By using solar energy , VCRS system is used to operate air conditioner of 0.25 ton. The solar energy from sun is collected through solar panel. Solar energy is in DC(direct current) form, to convert this DC into AC(alternate current) inverter is used. Now this AC current is supplied to run the whole VCRS cycle. This will save high electricity consumption as compared to same setup running on 230 volt AC supply.

Keyword:-*solar energy, VCRS, experimental setup*

1. INTRODUCTION

With an ever-increasing energy demand we are now facing a global energy crisis. There is a continued dependence on fossil fuels, leading to high levels of greenhouse gasses which if not reduced will cause an increase in global temperatures and climate change. Renewable energy such as solar can reduce the need to burn fossil fuels and in turn reduce the amount of greenhouse gasses being released into the atmosphere. To promote the use of solar energy new innovative solutions must be created in both engineering and policy. Air conditioners are becoming more common and are a major strain on energy demands specially in vidarbha region where the temperature in summer goes above 45^0 C due to this people are using air cooler and air conditioners for their comfort. But due to day by day increase in temperature air coolers are not effective to cope up that temperature. Therefore, there is no option to buy air conditioner which are now easily available in market. After buying AC the main problem arises that is the high electricity consumption and emission of greenhouse gases. To avoid this problem our project aims to reduce this high electricity consumption by using solar energy. Solar energy is available in abundant form which can be utilized for several applications. One of the application we are focusing is to operate air conditioning system using solar energy. The experimental setup consists of solar panel, condenser, evaporator, compressor, expansion valve, inverter, battery and other external fittings required for taking readings. Air Conditioning system can be classified into three main categories:

1.1 AC air conditioning system:

The most common air conditioning systems are AC (alternating current) air conditioning systems and these are the systems that are used in both the classroom and the office. This type of system is the cheapest and most widely available type of air conditioner but it has its drawbacks as well. It uses alternating current (AC) only and has a large start up power. The large start-up power is a big disadvantage when trying to design a solar system to power the air conditioner. To meet the start-up power of the air conditioner the inverter will need to be strongly over-sized which will reduce the efficiency of the inverter. Over sizing the inverter will also increase the cost. If it is a system without batteries then the PV panels will also need to be strongly over-sized to meet the demand. These disadvantages are very significant but these systems are by far the most common in use today. If a viable low cost solar solution is to be designed then it has to be compatible with this type of system. A solar energy system used to power an AC air conditioner would typically have solar panels, charge controllers, batteries and inverter. we are using this type of system. As it is experimental setup, it requires less capacity inverter and battery and no. of solar panel depending on the overall power required to drive the system.

1.2 DC Air Conditioning System:

Direct current (DC) air conditioning systems have been in use for some time with industrial and commercial applications. All components in the DC air conditioning systems such as compressors, fan motors, solenoids, valves etc. are powered by direct current. Because solar panels produce direct current (DC) it can be fed directly to the air conditioner. This eliminates the use of an inverter, which can reduce cost and increase efficiency. The main component changes come from the compressor and the fan motors. The fan motors used are brushless DC (BLDC) motors which have a higher efficiency than AC motors especially at low speeds. These BLDC motors are variable speed which gives better control over airflow. The main component change is the compressor which uses the majority of the power consumed by an air conditioner. DC compressors are much more efficient than AC compressors and by using a "soft start" they greatly reduce the high start-up power that leads to inverter and PV over sizing. Direct current (DC) air conditioning systems are mostly used in off grid applications. While the air conditioning systems are efficient and the panel size can be reduced, large battery banks are needed to maintain the use of the system during the night or days of low PV production. Lead acid batteries are very expensive and usually need to be changed every 8 years depending on the number of cycles and depth of discharge, making the cost and maintenance level increase greatly.

1.3 Inverter Air Conditioning System:

Regular air conditioning units are fixed speed, meaning that the compressor motor is either on or off. The compressor will run until the set temperature is reached and will then turn off until the temperature rises above a certain level where the compressor will start again until the set temperature is reached again. This cycle is repeated over and over as long as the air conditioner is running. This stop start cycle means there is high energy usage in the air conditioner and high fluctuations in the temperature .An inverter air conditioning system has a variable speed compressor which can increase or decrease its speed to hold the set temperature. The compressor will be constantly running but mostly at slow speeds to maintain the desired temperature. Running the compressor at a constant slow speed is more efficient than having an AC compressor. This greatly reduces the number of start-ups required, thus reducing the energy needed to power the air conditioner. Because the inverter air conditioner holds the set temperature, it gives a greater level of comfort in the room being cooled (see Figure 1).An inverter air conditioner is similar to a DC air conditioner. The same direct current brushless motors and compressors are used but the inverter air conditioner uses a rectifier to convert the AC to DC whereas the DC air conditioner uses the DC directly.

2. Need For Utilization Of Solar Energy:

In Vidarbha region is a hottest region having almost 300 sunny days (Average temperature @30^{O}C) which is perfect climate for solar energy. Indeed, it would dump greenhouse heat to space for its power while producing biodiesel, electricity, fish, fresh water, salt and real estate - all in quantities demanded by developed-world populations - without adding to, and possibly even Sequestering, greenhouse gases. Solar updraft towers could thus help assure the economic and environ– mentally benign provision of energy in sunny regions. Today in Vidarbha many Power Plants mostly coal based-thermal power plants functioning which indeed leads to CO_2 emissions with scarcity of water, thus suffering poor people from use of fossil fuel for cooking with diseases due to ever increasing pollution of CO_2 emissions, dust, global warming. Solar radiations available in abundant can be utilized to solved this serious problem. Thus Vidarbha region can play vital role in utilizing solar radiation for power generation and helps in conserving the natural resources, water and preventing deforestation which reduces CO2 emissions –pollution. In recent years Government of India focusing on using renewable sources of

energy with subsidy for loan on development of infrastructure and land acquisition. This abundant available energy can change the scenario of Vidarbha in respect of financial development raising the region in National Development.

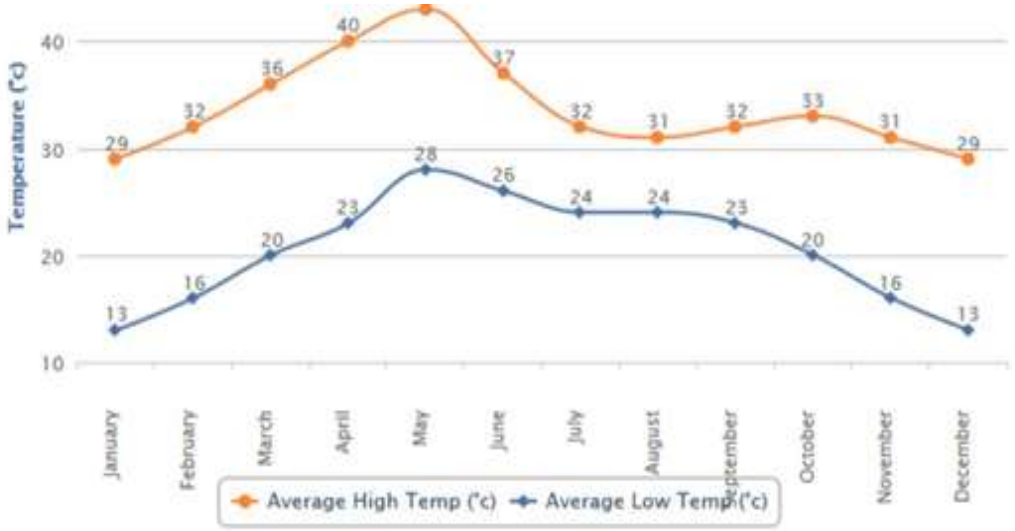

Fig-1: Average temperature graph for Nagpur region

3. COMPONENTS

3.1 Compressor :

The Function of a compressor is to increase the pressure and corresponding saturation temperature (boiling point) of the refrigerant vapour to high enough level so the refrigerant can condense by rejecting its heat through the condenser. It is heart of the refrigeration system as it circulates the refrigerant in the system like the heart of a human being circulating the blood in the body. Two different pressures exist in the refrigeration cycle. The evaporator or low pressure, and the condenser , or high pressure. These pressure areas are divided by the other two components. On one end, is the metering device which controls the refrigerant flow, and on the other end, is the compressor . There are three types of compressors namely reciprocating, rotary and centrifugal. The type of compressor depends on the pressure difference between the high pressure side (condenser) and low pressure side (evaporator) of the refrigeration system. This further depends on the refrigerant selected for the application under consideration.

Specification:
230V, 50Hz, 0.8Amp
Refrigerant used - R-134a

Fig- 3.1: Compressor

3.2 Evaporator:

Low pressure and low temperature refrigerant is pass to the evaporator. In evaporator, liquid refrigerant absorbs heat and converted into low pressure and low temperature vapour refrigerant. Its function is to absorb the heat from the space in order to cool by means of low pressure liquid refrigerant . Usually, a fan will move warm air from the conditioned space across the evaporator finned coils. The cooler refrigerant in the evaporator tubes, absorb the warm room air. The change of temperature causes the refrigerant to "flash" or "boil", and changes from a low pressure liquid to a low pressure cold vapour . Evaporators are two types i.e. flooded evaporators necessitating the use of accumulators to permit only vapors to the compressor and dry expansion type evaporators. Flooded types are used in industrial units whereas dry expansion types are used in domestic and commercial refrigeration units.

Piping materials**:** Pipe material should have high thermal conductivity, low cost, easy working and inertness with the refrigerant. Till date most commonly used pipe material is soft copper with all refrigerants except ammonia. The pipe material used with ammonia is mild steel as ammonia is highly corrosive to copper**.**

Specification :

Size 9*9 (one row)

Aluminium fin and Copper Tubing

Fig. 3.2- Evaporator

3.3 Condenser:

The condenser consists of coils of pipe in which the high pressure and high temperature vapour refrigerant is cooled and condensed by giving up its latent heat to the surrounding air or water. It is located in between compressor and receiver. To complete the refrigeration cycle, and thereby ensuring the refrigeration takes place continuously,

To complete the refrigeration cycle, and thereby ensuring the refrigeration takes place continuously, the following two functions are required:

1. To concentrate and liquefy the evaporated refrigerant vapor, which is generated in the high-pressure generator.
2. To supply the condensed water to the evaporator as refrigerant (water)

For these two functions a condenser is installed.

Specification :

10*10 (two row)

Aluminium fin and Copper Tubing

Fig. 3.3-Condenser

3.4 Solar Panel :

Solar panel use a special process of converting photons to electrons to generate a current by making use of a special type of cell known as photovoltaic cell. These cells are commonly found on the front of calculators and small gadgets. Photo voltaic cells are made up of semi conductive materials such as silicon. The semiconductor absorbs the light from the sun. when this happens, the photons in the sunlight knock some of the electrons in the semi conductive material loose which allows them to flow in an electrical current. Within each cell, there is an electric field which is used to streamline this flow of electrons in a particular direction. When these electrons meets the metal contact placed on the photo voltaic cell, it can be used to power device.

By affixing solar panels to the roof of a house, photovoltaic cells can be used to produce electricity which can be used directly by the power supply of the house or, increasingly , stored in large battries which can be used to power the house like generator.

fig 3.4-solar panel

3.5 Dimmerstat:

It is a device with ac input and ac output. It consists of variable transformer inside it so as to vary the output. Dimmers are the device use for controlling the intensity of electric current we can increase or decrease the RMS voltage.

Specification: -

Dimmerstat of 2 Amp.

Fig. 3.5- Dimmerstat

3.6 Energy Meter :

Energy meter is a device that measures the amount of electric energy consumed by a residence, a business or an electrically powered device. Electric utilities use electric meters installed at customers' premises to measure electric energy delivered to their customers for billing purposes. They are typically calibrated in billing units, the most common one being the kilowatt hour [*kWh*]. They are usually read once each billing period.

When energy savings during certain periods are desired, some meters may measure demand, the maximum use of power in some interval. "Time of day" metering allows electric rates to be changed during a day, to record usage during peak high-cost periods and off-peak, lower-cost, periods. Also, in some areas meters have relays for demand response load shedding during peak load periods.

Specification: -

1ph AC 230V

Amp – 50Hz

3200 Impl/ kWhr (Jaipur make)

Fig. 3.6- Energy Meter

3.7 Throttling valve :

In Throttling valve , pressure as well as temperature of liquid refrigerant is reduce keeping the enthalpy constant before supplying it to the evaporator. It maintains the desired pressure difference between high and low side of the system. This valve has the capability of controlling the refrigerant flow. If the load on the evaporator changes, the valve can respond to the change and increase or decrease the flow accordingly. Liquid can not be compressed and when a compressor tries to compress a liquid, mechanical failing can happen. The compressor can suffer mechanical damage in the valves and bearings. This is called" liquid slugging". The metering device tries to maintain a preset degree of superheat at the outlet openings of the evaporator. As the metering devices regulates the amount of refrigerant going into the evaporator, the device lets small amounts of refrigerant out into the line and looses the high pressure to low pressure.

Fig. 3.7- Throttling Valve

3.8 Inverter:

Inverter is an apparatus which converts direct current (DC) into alternating current (AC). The invertor does not produce any power, the power is provide by DC source. An inverter is used to control the speed of compressor motor, so as to continuously regulate the temperature. The drive converts the incoming AC current to DC and then through a modulation in an electrical inverter produces current of desire frequency. The inverter AC unit might be more expensive than the constant speed air conditioners, but this is balanced by lower energy bill, the payback time is approximately two years depending on the usage.

Fig.3.8- inverter

3.9 Batter:

Batteries are the storage device that stores energy so that it can be used when needed. In stand- alone power system, the energy stored in batteries can be used when energy demand exceeds the output from renewable energy sources like solar (e.g. on a cloudy day) and wind (e.g. on a still day). When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal

marked negative is the source of electrons that when connected to an external circuit will flow and deliver energy to an external device. When a battery is connected to an external circuit, electrolytes are able to move as ions within, allowing the chemical reactions to be completed at the separate terminals and so deliver energy to the external circuit. It is the movement of those ions within the battery which allows current to flow out of the battery to perform work. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to additionally include devices composed of a single cell.

Fig.3.9- battery

4. Mountings and Equipment's used :

4.1 Pressure Gauge:

It is used to measure the pressure lower than the atmospheric pressure. Gauges help to ensure there are no leaks or pressure changes that could affect the operating condition of the hydraulic system. Without pressure gauges, fluid power systems would be both unpredictable and unreliable. Pressure gauges are used for a variety of industrial and application-specific pressure monitoring applications. Pressure gauges use pounds per square inch (psi) as the unit of measure.

Specification: -
500 I (35 Kg/Sq.cm)

4.2 Compound Gauge:

It is used for displaying both positive and negative pressures on the gauge. A compound gauge is a device that can display both positive and negative (vacuum) pressures. You need to use a compound gauge when you are measuring a system that is exerting both positive and negative pressure on the gauge.

Specification: -

250 PSI (17.5 Kg/sq.cm)

Fig. 4.1- pressure and compound Gauge

4.2 Thermocouple:

Thermocouple is electrical device consisting of two dissimilar conductors forming electrical junctions at different temperatures. We have use PT 100 type thermocouple. A thermocouple is made from two dissimilar metal wires. The wires are joined together at one end to form a measuring (hot) junction. The other end, known as the reference (cold) junction, is connected across an electronic measurement device (controller or digital indicator). A thermocouple will generate a measurement signal not in response to actual temperature, but in response to a difference in temperature between the measuring and reference junctions. A small ambient temperature sensor is built into the electronic measuring device near the point where the reference junction is attached. The ambient temperature is then added to the thermocouple differential temperature by the measuring device in order to determine and display the actual measured temperature. Only two wires are necessary to connect a thermocouple to an electrical circuit; however, these connecting wires must be made from the same metals as the thermocouple itself. Adding wire made from other materials will create new measuring junctions that will result in incorrect readings.

Fig. 4.2-Thermocouple

4.3 Digital Temperature Indicator:

Digital Temperature indicator are designed for temperature monitoring and analysis. Temperature indicators either come equipped with an integral sensor, or require sensor input. Approximately 16% of all process instrumentation measures, indicates, or controls temperature. In many industrial applications it is necessary to

collect temperatures as a permanent record due to government or manufacturing requirements, or to provide historical data that may later be used to determine problems within a system.

Fig. 4.3- Digital Temperature Indicator

4.4 Miniature circuit Breaker (MCB) :

It is an automatically operated electrical switch design to protect an electrical circuit from damage caused by excess current typically resulting from an overload or short circuit. It's basic function is to interrupt current flow after a fault is detected. There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current. The thermal operation of miniature circuit breaker is achieved with a bimetallic strip whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts. But during short circuit condition, sudden rising of electric current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts.

Fig. 4.4- Miniature Circuit Breaker

4.5 Digital Ammeter And Voltmeter :

They are use to measure current flowing and voltage in the circuit.Digitized numbers are displayed on the display board.

Voltmeter :

A voltmeter is an instrument that measures the difference in electrical potential between two points in an electric circuit. An analog voltmeter moves a pointer across a scale in proportion to the circuit's voltage; a digital voltmeter provides a numerical display. Any measurement that can be converted to voltage can be displayed on a meter that is properly calibrated; such measurements include pressure, temperature, and flow.

Ammeter:

An ammeter measures the electric current in a circuit. The name is derived from the name for the SI unit for electric current, amperes (A). In order for an ammeter to measure a device's current, it must be connected in series to that device .This is necessary because objects in series experience the same current. They must not be connected to a voltage source -- ammeters are designed to work under a minimal burden, (which refers to the voltage drop across the ammeter, typically a small fraction of a volt).

Fig 4.5- Digital Ammeter And Voltmeter

5. EXPERIMENTAL SETUP

Fig 5-experimental setup of solar operated air conditioning system

Working :

Vapour Compression Refrigeration Systems

Vapour compression refrigeration systems are the most commonly used among all refrigeration systems. As the name implies, these systems belong to the general class of vapour cycles, wherein the working fluid (refrigerant) undergoes phase change at least during one process. In a vapour compression refrigeration system, refrigeration is obtained as the refrigerant evaporates at low temperatures. The input to the system is in the form of mechanical energy required to run the compressor. Hence these systems are also called as mechanical refrigeration systems. Vapour compression refrigeration systems are available to suit almost all applications with the refrigeration capacities ranging from few Watts to few megawatts. A wide variety of refrigerants can be used in these systems to suit different applications, capacities etc. The actual vapour compression cycle is based on Evans-Perkins cycle, which is also called as reverse Rankine cycle. Before the actual cycle is discussed and analysed, it is essential to find the upper limit of performance of vapour compression cycles. This limit is set by a completely reversible cycle**.**

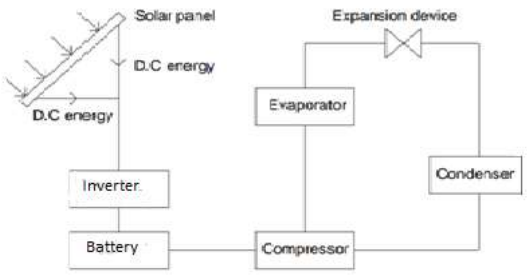

Fig. 5.1- Schematic of Experimental Setup

Figure shows working principle of solar operated air conditioning system. Sun rays are coming directly on the solar panel. Solar Panel are of silicon based crystalline material which will generate direct current(DC). That Direct current(DC) is Converted into Alternating current(AC) by means of inverter (240V) , Alternating current is stored in battery(12 Volt ,8 amp).

The vapour-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Figure 3.4.2 depicts a typical, single-stage vapour-compression system. All such systems have four components: a compressor, a condenser, a thermal expansion valve (also called a throttle valve or metering device), and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapour and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapour is then in the thermodynamic state known as a superheated vapour and it is at a temperature and pressure at which it can be condensed with either cooling water or cooling air flowing across the coil or tubes. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by either the water or the air (whichever may be the case). The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapour mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapour from the evaporator is again a saturated vapour and is routed back into the compressor.

6. ENERGY CALCULATION

Time taken by compressor for 10 blinks of energymeter = 52.06sec

Power required to drive compressor = $\frac{Number\ of\ blinks*3600}{Energy\ meter\ constant*time\ taken\ by\ compressor}$

$= \frac{10*3600}{3200*52.06}$

= 0.21 kw

= 210 watt

Now Energy Required = Power required to drive compressor * Time taken by compressor

= 210*52.06

= 10932.6 Joule

We know 1kwh = 3.6 * 10^6 Joule then how many units = 10932.6 Joule

Units Consumption for 52.06 sec = $\frac{1*10932.6}{3.6*1000000}$

= 0.030 units

Units Consumption for 1 hour = $\frac{Unit\ consumption\ for\ 52.06\ sec*3600}{52.06}$

$= \frac{0.030*3600}{52.06}$

= 0.207 units

We consider 10 hour energy consumption in a day, i.e. for 10 hour

= 0.207 * 10

= 2.07 units

Now for one month units consumption = Unit consumption for 10hour * 30

= 2.07 * 30

= 62.14 units

Cost for consumption of units = Number of units * Tarrif rate

= 62.14 * 6.94

= 430.974 Rupees

Area required for cooling 1ton of AC = 10*10*10 feet

Area required for cooling 0.25ton of AC = 5*5*5 feet

7. Objectives:

1. To control room temperature in an efficient way.
2. To save electricity by using solar power
3. To increase use of Non-conventional energy sources.
4. To develop effective air conditioning system by using Solar Energy.
5. To minimize the operating cost

8. FUTURE SCOPE

We have made Ac of 0.25 ton capacity, in upcoming years there is a possibility of installing solar Ac of higher capacity in institutions, offices, etc.

9. RESULT

Table 1- analysis result

Sr.no.	Parameter	Setup running on 230V AC	Setup running on solar
1	Electricity Consumption in a month	62.14 units	No units
2	Initial Cost	15000	55000
3	Operating cost	430Rs./month	0Rs./month

10. CONCLUSION

From above table , We can conclude that the electricity consumption for AC which is operated at 230V is 62.14 units per month & for solar operated AC there is no electricity consumption. That means it is profitable for long

run, initial cost of ac expeimental setup is low as compare to solar operated experimental setup but operating cost is high.

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