An Experimental Analysis on COP of Solar Refrigerator by Changing the Profile of Condenser with Axial D.C. Fans – A Review

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Abstract

In the refrigerator a problem is faced that the food items cool slowly, the reason behind is that dirt accumulates on the condenser after some time of uses. This causes the less heat transfer through the condenser thus reducing its coefficient of performance (COP). This can be eliminated by using fan which increases the heat transfer and keeps free from dirt for longer period of time. In this work an experimental analysis will be done on the coefficient of performance (COP) of solar refrigerator. A solar refrigerator is a refrigerator which is powered by solar electricity and is eco-friendly to the environment. The profile of the condenser is changed in such a way that it has more surface area to exchange heat (coming from compressor in the form of heated refrigerant). Then three DC fan is attached in the back panel of the refrigerator which is used to cool hot refrigerant by means of forced air cooling. In this experiment electricity is used by solar panel which has very low efficiency around 20% and it works only in day hours of sun light which is approximately around 6 to 7 hours generally. For the heat exchange minimum of 10 degree centigrade of temperature difference is needed, so when this difference is increasing more heat transfer occurred which then leads to more cooler refrigerant at the exit of condenser. Thus increases the coefficient of performance (COP).

Key Words: COP, air cooled condenser, axial DC fan, refrigerator, VCRS cycle, solar panel, solar electricity.

1. Introduction

A refrigerator is an appliance or compartment which is artificially kept cool and used to store food and drinks which runs by electricity. Now a day with increasing demands of energy or we can say electricity, we are moving towards alternative scope of electricity like solar energy, geothermal energy, wind energy and many more. Due to limited amount of fossil fuels which is majorly used to produce electricity, so we are focused on using solar energy, a renewable energy source.

In India the total electricity generation (utility and non utility) was 1,443.4 TWh in the fiscal year 2016-17. The electricity consumption was 1,122 TWh. 59.43% electricity generation is by coal fired power plant which is nearly two third of all electricity generation. So, the government has invested huge in renewable energy. The National Electricity Plan of 2018 prepared by the Government of India states that the country does not need additional non-renewable power plants in the utility sector until 2027, with the commissioning of 50,025 MW coal-based power plants under construction and achieving 275,000 MW total installed renewable power capacity. In 2016-17 fiscal year solar electricity generation is 12,086 GWh. It contributes 1% of total electricity generation. India set a target of achiving

40% of total grid capacity generation from non- fossil fuel sources by 2030, where it is 36 GW which is 13% as of 2015.

Solar electricity is generated by solar panel. Solar panels are those devices which are used to absorb the sun's rays and convert into the electricity or heat. A solar panel is actually a collection of solar (or photovoltaic) cells, which can be used to generate electricity through photovoltaic effect. Most solar panels are made up using crystalline silicon solar cells. Installation of solar panels in homes helps in combating the harmful emissions of greenhouse gases and thus helps reduce global warming. Solar panels do not lead to any form of pollution and are clean. They also decrease our reliance on fossil fuels (which are limited) and traditional power sources.

1.1. Vapor compression refrigeration system (VCRS) cycle:

Vapor compression refrigeration system in which the refrigerant undergoes phase changes, is one of the many refrigeration cycles and is the most widely used method for refrigeration and air-conditioning of buildings and automobiles. It is also used in domestic and commercial phase refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial and industrial services, Oil refineries, natural gas processing plants are among the many types of industrial plants that often utilize large vapor compression refrigeration systems. Refrigeration may be defined as lowering the temperature of an enclosed space by removing heat from that space and transferring it elsewhere. The vapor 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.

These VCRS systems have four components: a compressor, a condenser, a thermal expansion valve (also called a throttle valve or metering device), and an evaporator. The refrigerant which circulates into the system enters the compressor in the thermodynamic state known as a saturated vapor and is compressed to a higher pressure, resulting in a higher temperature. The hot, compressed vapor is then in the thermodynamic state known as a superheated vapor 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 the air. It is then goes to the throttle valve and reduced it to the lower temperature and pressure. Then it goes to the evaporator where it absorbs heat and it again goes to the vapor state.

1.2. Basic Working Cycle Procedure:

Compression:

The refrigerant being sucked to the compressor through the suction line. Afterward the refrigerant compressed into the compressor and the compressed refrigerant being discharged to the condenser unit through the discharge line.

Condensation:

When the high pressure refrigerant vapor enters into the condenser heat flows from condenser to cooling medium and thus allowing the vaporized refrigerant to return to liquid state.

Expansion:

After coming out from condenser the liquid refrigerant is stored in the liquid form. From the receiver end it then passes through an expansion value where the high pressure is reduced sufficiently to allow the vaporization of liquid at a low temperature of about - 10 degree centigrade.

Vaporization:

The low pressure refrigerant vapor after expansion in the expansion valve enters the evaporator on refrigerated space where a considerable amount of heat is absorbed by it and refrigeration is furnished.

1.3. Components of simple VCRS cycle:

1. Gas Compressor
2. Throttle Valve
3. Evaporator
4. Condenser

1.4. Condenser:

A condenser is a device or unit used to condense a substance from its gaseous to its liquid state, by cooling it. In so doing, the latent heat is given up by the substance and transferred to the surrounding environment. Condensers can be made according to numerous designs, and come in many sizes ranging from rather small (hand-held) to very large (industrial-scale units used in plant processes). For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemical process-ses such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers.

1.4.1. Types of condenser:

1. Air cooled condenser
2. Water cooled condensers
3. Evaporative condensers

1. Air Cooled Condenser:

The simplest air-cooled condenser consists of a plain tube containing the refrigerant, placed in still air and relying on natural air circulation. An example is the condenser of the refrigerator, which may also have some secondary surface in the form of supporting and spacer wires. Above this size, the flow of air over the condenser surface will be by forced convection, i.e. fans. The high thermal resistance of the boundary layer on the air side of the heat exchanger leads to the use, in all but the very smallest condensers, of an extended surface. Flow of the liquefied refrigerant will be assisted by gravity, so the inlet will be at the top of the condenser and the outlet at the bottom. The flow of air may be vertically upwards or horizontal and the configuration of the condenser will follow from this. Small cylindrical matrices are also used, the air flowing radially inwards and out through a fan at the top.

2. Water Cooled Condensers:

The higher heat capacity and density of water make it an ideal medium for condenser cooling and, by comparison with the 350 kW plant, the flow is only 9.8 litre/s. Small water-cooled condensers may comprise two concentric pipes (double pipe), the refrigerant being in either the inner tube or the annulus. Configurations may be straight, with return bends or headers, or coiled. The double-pipe condenser is circuited in counter flow (media flowing in opposite directions) to get the most sub cooling, since the coldest water will meet the outgoing liquid refrigerants. Larger sizes of water-cooled condenser require closer packing of the tubes to minimize the overall size, and the general form is shell and-tube, having the water in the tubes.

3. Evaporative Condensers:

Evaporative condensers are a combination of water cooled and air cooled condensers. In these condensers the hot refrigerant flows through the coils. Water is sprayed over these coils. At the same time the fan draws air from the bottom side of the condenser and discharges it from the top side of the condenser. The spray water that comes in contact with the condenser coil gets evaporated in the air and it absorbs the heat from the condenser, cools the refrigerant and condenses it. Evaporative condensers have the benefits of water cooled as well as air cooled condenser, hence it occupies less space. However, keeping the evaporative condenser clean and free of scale is very difficult and requires lots of maintenance.

1.5. Fan:

A fan is a piece of electrical or mechanical equipment with rotating blades that creates a current of air for cooling, ventilation or any other purposes.

1.5.1. Types of fan:

- Axial and/or propeller fans
- Centrifugal (radial) fans
- Mixed flow fans
- Cross flow fans

Axial and/or Propeller Fans:

In an axial fan the air flows in parallel to the shaft. The axial fan, the function of which is similar to a propeller, moves the air axially, parallel to the revolving motor shaft.

It Is Classified In Following Types:

C-wheel - Blades can be adjusted when running. High efficiency, small dimensions, variable air volume

A-wheel - Blades can be adjusted only when the fan is standing still. High efficiency, small dimensions, adaptive to recommended air volume

K-wheel - Blades cannot be adjusted. It is simple and having small dimensions.

2. Literature survey

M.Z. Sharif et al. investigated on "Mechanism for improvement in refrigeration system performance by using nanorefrigerants and nanolubricants", in this paper they presents a review on mechanism for improvement in VCRS performance by using nanorefrigerants and nanolubricants by the heat transfer augmentation, the refinement of refrigerant-oil mixture characteristic, and the tribology properties enhancement are among the major mechanisms that affect the VCRS performance, by this study we come to know that the use of nano refrigerants and nanolubricants were increased the heat transfer performance of VCRS especially in pool boiling and nucleate boiling heat transfer and the utilization of nanolubricants and nanorefrigerants were increased the overall performance of VCRS which related to the cooling capacity and coefficient of performance (COP) of the system.[1]

Jatinder Gill et al. analysed on "Performance analysis of vapor compression refrigeration system using an adaptive neuro-fuzzy inference system", in this paper an experimental investigation is carried out with R134a and LPG refrigerant mixture (composed of R134a and LPG in the ratio of 28:72 by weight) as an alternative to R134a in a vapor compression refrigeration system. Performance tests were performed with different evaporator temperatures under controlled ambient conditions and by this paper we come to know that R134a/LPG system demanded lengthening of capillary tube and reduction in refrigerant charge by about 64.4 % and 49.45 % respectively in comparison with R134a to achieve maximum COP and also COP of the vapor compression refrigeration system working with R134a/LPG compared with R134a improved by 15.28 %.[2]

D. Azzouzi et al. analysed on "Parametric study of the wire-on-tube condenser sub cooling effect on the performance of vapor compression refrigeration system", in this paper the condenser sub cooling effect on the performance of vapor compression refrigeration system is presented and Variation in sub cooling temperature and pressure ratio for all three refrigerants is taken in all stages of this study, by this we come to know that the COP increases with the increase of the sub cooling temperature for all three refrigerants.[3]

Jai kishor Verma et al. investigated on "Techno-economic sizing analysis of solar PV system for Domestic Refrigerators" this paper is about finding the optimum size of the photovoltaic system for refrigeration system and by this paper we come to know that to meet the requirement 1.3 modules of 100W PV module are required, a 150W PV module which is available in commercial market may be employed for the same and the inverter size on the basis of calculation is found to be 462.3W.[4]

F. Illán-Gómez et al. investigated on "Experimental assessment of the replacement of a conventional fin-and-tube condenser by a mini channel heat exchanger in an air/water chillers for residential air conditioning" this paper analyses the performance of an air/water chillers typically used for residential air conditioning when a mini channel condenser is used in replacement of a conventional fin-and-tube condenser and by this paper we come to know that In almost all cases studied the total mass of refrigerant is lower using a mini channel coil as condenser and Sub cooling is clearly the parameter that has the stronger influence on the refrigerant mass reduction obtained when replacing a fin-and-tube condenser by a mini channel condenser.[5]

Zhenya Zhang et al. investigated on "Effect of airflow field optimization around spiral wire-on-tube condenser (SWTC) on a frost-free refrigerator performance", in this paper they optimized airflow field by putting the condenser, fan and compressor are placed in a line and inside the refrigerator bottom, by this we come to know that More airflow contacted and exchanged heat with SWTC after optimization, though the overall airflow rate will drop by some extent.[6]

Wen-long Cheng et al. studied on "Analysis of energy saving performance for household refrigerator with thermal storage of condenser and evaporator", in this paper for enhancing heat transfer of the condensers and evaporators, a novel dual energy storage (DES) refrigerator with both heat storage condenser (HSC) and cold storage evaporator (CSE) is proposed and the performance comparison of three kinds of energy storage refrigerators: HSC refrigerator, CSE refrigerator and DES refrigerator is analyzed by establishing dynamic simulation models, by this we come to know that The DES refrigerator has the best heat transfer and operational performance, which can increase the vapor pressure and evaporator temperature so as to increase the cooling capacity and enhance the refrigeration efficiency.[7]

K. Harby et al. investigated on "Performance improvement of vapor compression cooling systems using evaporative condenser: An overview", in this paper they presents an extensive review of the state of the art of evaporative condensers used in residential cooling systems refrigeration, air-conditioning, and heat pump systems, by this we come to know that It was also found that by using evaporative condenser instead of air-cooled condenser, the power consumption can be reduced up to 58% and the COP can be improved by about 113.4%.[8]

Rahul Rawat et al. analysed on "A review on modeling, design methodology and size optimization of photovoltaic based water pumping, standalone and grid connected system" in this paper, a comprehensive designing process of solar photovoltaic water pumping system, standalone V system and grid connected PV system is presented. The modeling of PV modules, cell temperature, water pumping system and battery state of charge is tabularized so as to facilitate their utilization for proposing a PV system based on the techno-economic variables and environmental parameters by this paper we come to know that The motor torque, load management and efficiency curve of inverters are major factors for optimum sizing of SWPS, standalone and grid connected PV systems respectively.[9]

J.G. Bustamante et al. investigated on "Achieving near-water-cooled power plant performance with air-cooled Condensers", in this paper a model of a representative air-cooled condenser (ACC) system is developed to explore the potential to mitigate this penalty through techniques that reduce the air-side thermal resistance, and by raising the air mass flow rate and by this paper we come to know that wet-cooled power-plant efficiency levels could be achieved with enhanced ACCs if air flow rates are significantly increased (+68%), convection resistances significantly reduced (−66%), and pressure losses maintained close to conventional levels (+24%).[10]

G. Sonnenrein et al. investigated on "Reducing the power consumption of household refrigerators through the integration of latent heat storage elements in wire-and tube condensers", this paper evaluates the influence of latent heat storage elements on the condenser temperature of a commercial household refrigerator, by this we come to know that a significant impact of heat storage on the condenser temperature and consequently on power consumption. This effect is much more pronounced for latent than for sensible heat storage. By integrating a copolymer compound heat storage, power consumption was reduced by up to 10%.[11]

B.L. Gupta et al. analysed on "Optimum sizing of PV panel, battery capacity and insulation thickness for a photovoltaic operated domestic refrigerator" In this paper, a parameter study is carried out to find out the best combination of the PV panel wattage, battery capacity and insulation level to operate the refrigerator stand-alone on solar power. The transient simulation software (TRNSYS) is used to simulate the PV based refrigeration system. The system consists of a refrigerator with 50 l capacity, 24 V battery bank, 1 kVA inverter, and PV panels with charge controller by this paper we come to know that a system with a refrigerator having 25 mm insulation thickness, minimum 320W panel capacity along with 50Ah battery capacity.[12]

Fatemeh Ghadiri et al. investigated on "The effect of selecting proper refrigeration cycle components on optimizing energy consumption of the household refrigerators" this paper presents experimental results of hot-wall condenser removal, condenser air cooling increment, capillary tube diameter effect, compressor cooling capacity effect, changes of R134a charge amount and ambient temperature effect on a commercial bottom mounted freezer to decrease energy consumption and production cost and by this paper we come to know that elimination of hot-wall condensers has a little effect on the energy efficiency and by increasing condenser heat removal capacity, the energy consumption truly reduced.[13]

Vahid Vakiloroayaa et al. studied on "A comparative study on the effect of different strategies for energy saving of air-cooled vapor compression air conditioning systems", this paper investigates and compares the energy saving potential of air-cooled vapor compression air conditioning systems by using liquid pressure amplification (LPA), evaporative-cooled condenser (ECC)and combined LPA and ECC strategies, by this paper we come to know that by allowing temperature and pressure to fluctuate within the condenser, condensing pressures were reduced and the system consumed less electricity.[14]

Tzong-Shing Lee et al. investigated on "An improvement of airflow and heat transfer performance of multi-coil condensers by different coil configurations" this study is an attempt to investigate the effects of different included angles between the coils of the condenser. It has been found in this study that it can be a mean to improve the performance of multi coil condensers without using larger heat transfer surfaces by this paper we come to know that changing the configuration of the included angles of the coils has significant effects on the airflow distribution and consequently the heat transfer performance. It was found that the air flow rate can be increased by 7.85% by changing the included angle of the multi-coil condenser, in comparison with a commercial multi-coil condenser.[15]

3. Objectives

1. To increase the heat transfer from condenser.
2. To increase the surface area of condenser for better heat transfer.
3. To increase the coefficient of performance (COP) of the refrigerator.
4. To increase the refrigeration effect.

4. Methodology

This paper is about solar refrigeration in which a refrigerator will be operated using solar electricity. For this whole experiment a set-up will be constructed. For the set-up, first two types of solar panel are framed and it is then placed in an open environment where direct sun rays can incident on the panel fully. The electricity generated by the solar panel is then connected to the charge controller. After that it goes to the battery and then to the inverter. Inverter is used to convert the direct current to the alternating current (since refrigerator compressor is worked on alternating current). And after that alternating current is used for the refrigerator. For increasing the heat transfer of the condenser it is forced air cooled by means of DC fan. Profile of the condenser is will be changed for the increased heat transfer rate. This profile change increases the area of the condenser so that more space is there for heat exchange. The condenser is bent on both sides (left and right) at 15 degree. The space created in the condenser is used for the fans. Then DC fans are welded or fasten to the back panel and are attached to the battery directly. These fans are then circulate the air and force cool the condenser. Then calculation of COP of refrigerator is done by experimental data.

5. Conclusion

In recent time much research and development was made and many more is going on in the near future on the renewable energy like solar energy. The solar energy is used in many ways, solar panel is one of those, but it has a less efficiency. So in this paper a review on effect of forced air cooled condenser on the coefficient of performance (COP) is presented which runs on solar electricity. This review paper is discussed about when the condenser is modified with fan cooled heat exchanger then how the performance of refrigerator is affected. This work is on the renewable energy which gives no any harmful impact on the environment. So any improvement in the performance of refrigerator will lead to less consumption of electricity. This will save energy. If any change in performance of refrigerator is increased, it will increase the life of solar panel then it is a good for the energy saving. Because the energy is saved by less compressor work and thus less energy consumption so the electricity generated by solar panel is used for longer time. In recent time more research is going on for the saving on energy. A little bit energy saved for a single appliance will lead to a major energy save when we compare it to a large level. This work is also save electricity and thus energy by increasing heat exchange in the condenser of the refrigerator. So it is very useful for us, thus for our society.

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