Performance Analysis of Domestic Refrigeration System with Thermoelectric Module

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ABSTRACT— Thermoelectric refrigeration is one of the best alternative technologies to the conventional refrigeration system. TER system works on the principle of the Peltier effect. P&N-type of semiconductors are used as charge carrier in the thermoelectric module. Thermoelectric refrigeration system has wide application in all the cases. It is compact in size and has long life. Major advantage of TER system is it does not use any refrigerant. The heat is pumped from one side to the other side of the module which results as cold and hot side of the thermoelectric module. The temperature difference of the hot and cold side of the module has major effect on the performance of the module.
The COP of the TER system is very low as compare to the conventional refrigeration system. The combination of both conventional refrigeration and thermoelectric refrigeration cycle can help to increase the cooling rate of the system. This also helps to reduce the power consumption of the system.

Keywords— Thermoelectric Refrigeration (TER), Peltier Effect, P&N-type Semiconductor, etc.

I. INTRODUCTION

Refrigeration & air conditioning is the basic need of the human being. More than 40% of energy used is utilized for refrigeration and air conditioning system. Lots of research is going on in the particular field. Though the conventional refrigeration systems fulfill all the requirements, it has harmful effect to the environment. The use of refrigerant in the conventional refrigeration system has bad effect on ozone layer. Thermoelectric refrigeration system is best option for the refrigeration system. R&AC deals with the techniques to control the environments of the living and non-living subjects and thus provides comfort enabling them to perform better. Air conditioning is the heating, cooling, dehumidification, humidification, ventilation, and sterilization of air. Heat is removed from enclosed space which reduces and maintains the temperature for content of that space. In large buildings air conditioner is used to regulate the air temperature. Refrigeration is generally used for small space. These innovations make human life more comfortable and happy.

II. LITERATURE SURVEY

The following literature survey includes research papers and journals surveyed with goal of understanding the various refrigeration processes.

Gajendra S. Pache, has stated that TE R&AC technology will overcome all the disadvantages of existing R&AC system. Conventional R&AC system has many disadvantages like use of hazardous refrigerants, bulky system, orientation problems, etc. The new R&AC system using thermoelectric couple which shall overcome all the disadvantages of existing R&AC system which gives advantages like environment friendly, precise temperature control, spot cooling, compact, high reliability, electrically quiet operation, ability to heat and cool with the same module. [7]

S.B. Riffat, (December 2002), has stated that TE R&AC systems are environment friendly as CFC gas or any other refrigerant gas is not used, due to which they have many potential applications. Bismuth telluride$(Bi,Sb)_2(Te,Se)_2$ is widely used thermoelectric material having temperature range of 120 to 230 ^{0}C. Hot and cold side maximum temperature difference for normal thermoelectric devices is 70 ^{0}C. Multistage series is used for large temperature difference. Due to lack of moving parts system maintenance is less. Life of these devices exceeds 100,000hrs of steady state operation. [9]

Manoj Kumar Rawat, (Feb 2013), Achieved the cooling rate for system having refrigeration space of 1 liter with the help of four thermoelectric modules (Qmax=19W). With respect to ambient conditions the temperature difference for no load and load of water is taken. The calculated COP of the system was 0.1. [10]

Gao Min, 2006,has found out that the typical COP range of thermoelectric module is 0.3 - 0.5. He had developed different thermoelectric refrigerators with different heat exchanger. COP for different combination is found out. COP of the module can be increased with the improvement in module resistance and heat exchanger effectiveness. [3]

Onoroh Francis, Chukuneke Jeremiah Lekwuwa, and Itoje Harrison John give idea about the working principle of the thermoelectric module. COP of the thermoelectric system is function of temperature. It varies with the temperature difference on hot and cold side of the module. [2]

Gao Min, D.M. Rowe stated that improvement in COP is possible through improvements in module contact resistances, thermal interfaces and the effectiveness of heat exchangers. The coefficient-of-performance of a thermoelectric refrigerator is found to be around 0.3–0.5 for a typical operating temperature at 5 ^{0}C with ambient at 25 ^{0}C. [3]

S.B. Riffat , GuoquanQiu have studied the various type of refrigeration systems namely the vapour compression air-conditioner (VCAC), the absorption air-conditioner (AAC) and the thermoelectric air conditioner (TEAC) and have given the result for the same. Comparative results show that VCAC have advantage of high COP and low cost but it have bad effects on environment. AAC are bulky and have low cost but it have low COP as compare to VCAC, as it works on thermal energy. TEAC are environment friendly and simple. Their low COP is limiting factor domestic refrigeration system. [5]

D. Astrain, A. Martinez, A. Rodriguez has combined the vapour compression system and thermoelectric system for domestic refrigerator. This is an attractive alternative to current domestic refrigerators. This reduces the power consumption.[1]

Problem Statement

R&AC has vast scope in our day-to-day lives. The heat carrier fluids in the conventional R&AC systems deplete the ozone layer and increase global warming. Decrease in concentration of the ozone layer results in increased amount of UV light reaching the earth due to which the incidences of skin cancers, eye cataracts and interference with photosynthesis in plants increase. This could potentially have harmful effects on both plant and animal life on the earth. The use of refrigerants in space cooling applications may lead to out gassing and orientation problems. In cooling of mines, any minor leakage of toxic & flammable refrigerants can prove to be a big problem. Submarine needs an electrically quiet & compact AC system. In Industries, where localized temperature control is needed even the smallest vapour compressor system would provide much more cooling than necessary.

Looking at these perpetual threats, an alternate R&AC technology has become a necessity which leads to thermoelectric refrigeration system. TE R&AC technology provides cooling without the use of refrigerant. This technology overcomes all the disadvantages of existing R&AC system and gives advantages of precise temperature control, spot cooling, compact, high reliability, electrically quiet operation, ability to heat and cool with the same module.

Only problem with thermoelectric technology is its efficiency. The efficiency of thermoelectric refrigeration system is 0.3-0.5, which do not satisfy the cooling requirements. To overcome this thermoelectric system can be connected with conventional refrigeration system to improve efficiency. This will lead to reduce the power consumption of the system and work of conventional refrigeration system can be also reduced.

Methodology

The project methodology comprises of the following steps:

1) Selection of Thermoelectric (Peltier) module
2) Design and construction of experimental set up
3) Experimentation
4) Result analysis and Discussion

Selection of thermoelectric module

In project for the experimentation purpose we have taken midrange thermoelectric module TEC1-12706. It is having maximum heat removal capacity of 50-60 watts. Thermoelectric module works on Peltier principle i.e. when dc current is passed through two semiconductor one junction will get hot and one will get cool. Heat will be removed from cold surface to the hot surface with the help of semiconductor material.

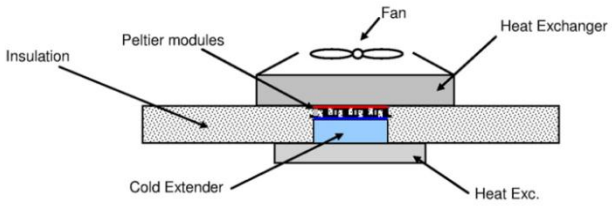

Fig 1: Working Principle of Thermoelectric module

The current supplied for the Peltier element is actively regulating the temperature of a given object or case. This is done without acoustic and electrical noise, vibrations and mechanical moving parts. Changing from cooling to heating is possible by changing the direction of the current, without making any mechanical changes.

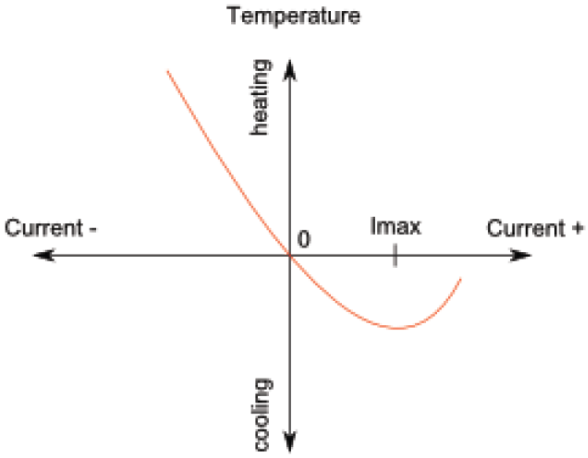

Fig 2:Effect of current on TE module [13]

Experimental set up

Domestic refrigerator having volume 165 liters is taken for the experimentation process. Two number of thermoelectric module is placed in the side wall of the refrigerator. One surface of the module is inside the refrigerator which will carry the hot air and will be taken away from other side of the module. The hole is made in the side wall of the refrigerator to place the thermoelectric module, which are properly sealed with the help of non-conductive material. SMPS is used for power supply as the module require DC power source. Energy meter is used to measure the power consumption by the refrigerator. Multi meter is used to measure the dc power supply given to the module.

Fig.3: Actual experimental set up

Experimentation

Experimentation is done on the set up in the college itself. The temperature pattern is observed during the experimentation. The temperature of the refrigerator after each 10 minutes is note down. This process is done first without thermoelectric module and then with the help of thermoelectric module. Power consumption during each set of readings is calculated with the help of energy meter. Time required for cooling of refrigerator is calculated. The load is placed inside the refrigerator and the same readings are taken for comparison. The temperature of refrigerator is maintained at 5 0C approximately and time required for cooling of the water is calculated. Also the power consumption by refrigerator is calculated.

Calculations

The COP of the thermoelectric module is found out by the following method [12]:
The theoretical equations for the thermoelectric module performance include:
The voltage equation,
$V = \alpha(T_H - T_L) + IR$
The input power equation,
$P = \alpha I\ (T_H - T_L) + I^2R$
The cooling capacity equation,
$Q_L = I\alpha T_C - K\ (T_H - T_L) - 0.5I^2R$
The total heat rejection equation,
$Q_H = I\alpha T_W - K\ (T_H - T_L) + 0.5I^2R$
And COP is given by,
$COP = Q_L/P$

Result and Discussion

The use of thermoelectric module along with conventional refrigeration cycle will increase the cooling rate of the system. Thermoelectric module has long life and can be used for precise temperature control. To maintain minimum the temperature difference of hot and cold side of module is the challenging work as the performance of the module depends on the temperature difference. From this it is seen that the cooling rate of the system increases effectively when modules are connected to the refrigeration system.

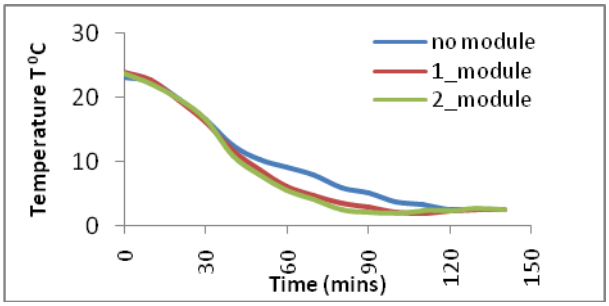

Fig.4: Comparison of temperature with respect to time for no load condition

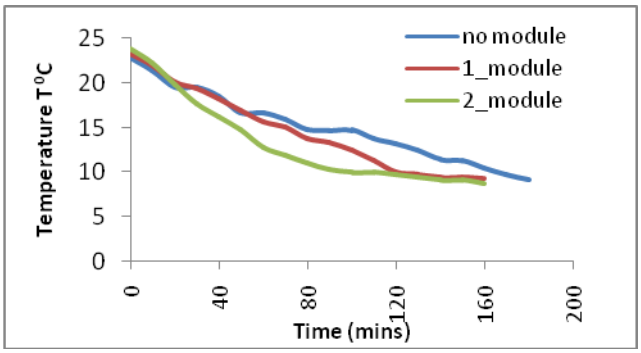

Fig.5: Comparison of temperature with respect to time for load condition

Drawbacks of TER

1) COP of the TER cycle is very low of the range 0.5
2) There are limitations of this system for large volume.
3) Hot side heat dissipation is the challenging task.
4) Effective heat sink is required on both sides for more effective cooling.

III. CONCLUSION

Thermoelectric module can be used with refrigeration system to get more cooling rate. When it is used with the conventional refrigeration cycle following conclusion can be made.

1) Time required for cooling of the refrigeration reduces by 25 minutes for no load condition when two numbers of thermoelectric modules are connected to the refrigeration system.

2) As time reduces, it helps to reduce the power consumption of the system. Further as we go with constant temperature the compressor work reduces which helps to reduce energy consumption by 0.083kWHr per day.
3) The overall COP of the system increases by 0.3.

IV. REFERENCES

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