International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Solar Refrigeration System

Subbarao Chamarthi[1], Aditya Saxena[2], Siddhant Ratna[3]

[1]Assistant Professor, SRM University, India

[2, 3]UG Student, Department of Mechanical Engineering, SRM University, Ghaziabad, India

Abstract: ***In present world fossil fuel reserve of the world is continuously decreasing & use of nonconventional energy resources is gaining high importance. Solar energy is considered best nonconventional energy available free. Also the time of the day when the heat energy is maximum of the solar energy the utilization solar energy in air-conditioning will be more effective. Ozone layer depletion potential (ODP) is considered a very high threat to the environment. Under these circumstances ODP of solar driven vapor absorption system is zero. This gives us tremendous environmental benefits vis a vis refrigerants. Also global warming & Carbon dioxide emission are producing very big environmental hazards. Using solar energy instead of fossil fuels in case of vapor absorption system provides with big environmental benefits in terms of the above mentioned effects Looking at the advantages of solar driven vapor absorption system(VAS) in modern day environment ,we are motivated to work towards the system because a large part of solar driven VAS remains unexplored which has tremendous potential in the future of Refrigeration & Air-conditioning. A large number of people in developing countries still live in Rural and Remote area like India where the grid electricity is yet unavailable or not envisaged by the people. Vaccine preservation has become an important issue and the basic needs in rural areas. Solar power refrigeration is the one of promising option to resolve such burning problem.***

Keywords: Solar energy, solar panel, refrigeration system, generator, battery, COP, concentration difference

1. Introduction

In the current situation the energy demand is increasing with increasing in the population and improvement in the living standard. Energy is the crucial input to the social, economical, industrial and technological development of any country. A rational use of energy brings both economic and environmental benefits, by reducing consumption of fossil fuels, electricity and pollutant emissions. The International Institute of Refrigeration in Paris (IIF/IIR) has estimated that approximately 15% of all the electricity produced in the whole world is employed for refrigeration and air-conditioning processes . In a tropical country, like India, refrigeration is most widely used and generally the most energy consuming process. In general, refrigeration is defined as any process of heat removal from a place for preserving foods and medicines by enhancing their shelf life . Immunization prevents illness, disability and death from vaccine preventable diseases including diphtheria, measles, pertussis, pneumonia, polio, rotavirus diarrhea, rubella and tetanus. Immunization currently averts an estimated 2 to 3 million deaths every year but an estimated scrap water dispenser. 22 million people from remote area of developing country worldwide are still missing out their routine vaccination programs due to the lack in availability of the safe vaccine. According to WHO guidelines, vaccine should be kept in the temperature range of 0-8 o C. For the storage of life saving drugs or vaccines in the innumerable area of the developing country where the power supply is still irregular renewable has to be a central part of energy solution. Out of the various renewable sources of energy, solar energy proves to the best candidate for cooling because of the coincidence of the maximum cooling load with the period of greatest solar radiation input . Cooling from solar energy has great potential for lower running costs, greater reliability and a longer working lifethan other conventional cooling systems where as it may also contribute in the reduction of global warming. The review covers solar electric cooling, solar thermal cooling and solar combined power cooling. Comparison between these different technologies is also described with individual COP value. Application of solar power for producing refrigeration effect is discussed.

Possible solar power refrigeration system as discussed are – absorption cycle, adsorption cycle, desiccant cycle, ejector cycle, solar mechanical and solar PV (photovoltaic) operated refrigeration system.

Cooling system based on solar thermal technologies are having less thermodynamic efficiency as compare to Vapor solar refrigeration system because it is very difficult to keep the solar thermal system operating at steady condition throughout the day. Solar thermal based cooling systems are commercially available but mostly having capacity of more than 20TR because solar collector can't scale down in size. Further the small capacity of cooling system, solar photovoltaic vapor compression refrigeration system is deemed to be the most viable route.

Therefore the principle objective of this paper is to describe the result of thermodynamic test conducted on the developed solar vapor compression refrigeration system.

Figure 1: Installed solar panel used for experiment

Figure 2: Battery bank & UPS system

2. System Description

The solar photovoltaic based refrigeration system was designed and developed under no load and full load conditions. A PV panel consisting of three modules (125 Watt peak each) connected in series was used to obtain the desired voltage and current, respectively. Three 12 V, 7 Ah sealed lead acid battery was used to supply the power at starting time and ensure for the smooth operation. The refrigerator operates on an alternative current based compressor, a compressor used in the common domestic refrigerators. Technical specification of solar refrigeration is given in table 1

Table 1

S.No.	Parameters	Specifications
1.	Storage capacity	20 liters
2.	Door	Front opening
3.	Type of refrigeration	Vapor compression refrigeration
	Compressor	
4.	Power consumption	90W
5.	Refrigerant	R134a
6.	Operating voltage	230V AC
7.	Maximum &Minimum internal temperature	-4°C to 4°C
8.	Thermostat	3 setting
9.	Cut in temperature	9°C
10.	Cut out temperature	2°C
11.	Insulation	PUF, 2.5 cm thick

3. System Performance

Coefficient of Performance

The coefficient of performance is an index of performance of a thermodynamic cycle or a refrigeration system. COP is used instead of thermal efficiency. For the vapour compression refrigeration cycle, COP is defined as the amount of cooling produced per unit work supplied on the refrigerant. For a reversible or Carnot refrigeration cycle it is expressed as :

$$COP_{carnot} = \frac{T_e}{T_o - T_e}$$

T_e = Evaporator temperature
T_o = Ambient/room temperature
But all the real processes are irreversible process. The actual COP of the refrigeration system was calculated with the help of pressure enthalpy curve. The COP can be evaluated by using the formula-

$$C.O.P = \frac{Refrigeration\ effect}{Input\ compressor\ work}$$

$$C.O.P = \frac{h_1 - h_4}{h_2 - h_1}$$

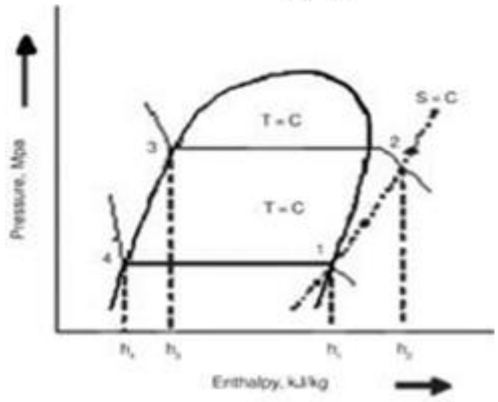

Figure 3: Pressure enthalpy diagram of operating system

Photovoltaic Efficiency

The efficiency of the solar panels, defined as the ratio of the electrical power produced to the incident radiation.

$$\eta_{pv} = \frac{P_{max}}{S \times A_{pv}}$$

where
h_{pv} = efficiency of photovoltaic system
P_{max}: Maximum power from photovoltaic system (W)
S = Solar irradiance (W/m^2)
A_{pv} = Area of the photovoltaic system (m^2)

Exergy Analysis

Exergy is defined as the maximum amount of work that can be done by a system. Unlike energy, exergy is not subject to a conservation law; exergy is consumed or destroyed, due to the irreversibility's present in every real process.

Photovoltaic Exergy

The energy of a PV module depends on two major components--electrical and thermal. While electricity is generated by the PV effect, the PV cells are also heated due to the thermal energy present in the solar radiation. The electricity (electrical energy), generated by a photovoltaic system, is also termed "electrical exergy" as it is the available energy that can completely be utilized in useful purpose. Since the thermal energy available on the photovoltaic surface was not utilized for a useful purpose it is considered to be a heat loss to the ambient.

Therefore, due to heat loss, it becomes exergy destruction. The exergy output of the photovoltaic system can be calculated as:

$$Ex_{out} = V_m I_m - \left(1 - \frac{T_0}{T_{cell}}\right)\left[h_c \times A_{pv}(T_{cell} - T_0)\right]$$

Where
V_m = maximum voltage
I_m = current of the photovoltaic system h_c = convective heat transfer coefficient from the photovoltaic cell to ambient
A= area of the photovoltaic surface
T_{cell} = cell temperature
T_O = ambient temperature (dead state temperature)

Exergy input of the photovoltaic system which is the exergy of solar energy can be calculated approximately as:

$$Ex_{in} = Ex_{solar} = A_{pv} \times S \times \left[1 - \frac{4}{3}\left(\frac{T_o}{T_{SUN}}\right) + \frac{1}{3}\left(\frac{T_o}{T_{SUN}}\right)^4\right]$$

where T_{SUN} = temperature of the Sun taken as 5760 K

Exergy efficiency of the photovoltaic system is defined as the ratio of total output exergy (recovered) to total input exergy (supplied). It can be expressed as

$$\psi_{PV} = \frac{Ex_{out}}{Ex_{in}}$$

4. Conclusions

Energetic and Exergetic techniques helps to evaluate the performance of the SPV refrigerator with a view to get better information about useful work and lost work and design some remedial techniques in future to overcome on these losses. The installed system of solar photovoltaic refrigerator system is capable for cooling the vaccine for 7 hour in a day. The pull down test indicates that 375Wp photovoltaic capacity and 21Ah battery bank is the least possible configuration required for this converted system. The average COP during no load and full load tests were found high as 3.37. Second law efficiency of the refrigerator system remains close to 55% at no oad full load conditions. The photovoltaic conversion efficiency and exergy efficiency found nearer to 10% and 8.5% respectively in both no load and full load condition. This indicates that the product load condition does not affect the PV system. The reason for low of overall efficiency and exergy efficiency of the PV system is low so that it can be said that exergy are destroyed highly in PV. The payback period of the proposed system was found 6 months. It is suggested that the design procedure may be improved by a variable speed compressor to cope with the variation of the refrigeration load due to different modes of operations. The performance curves are shown :

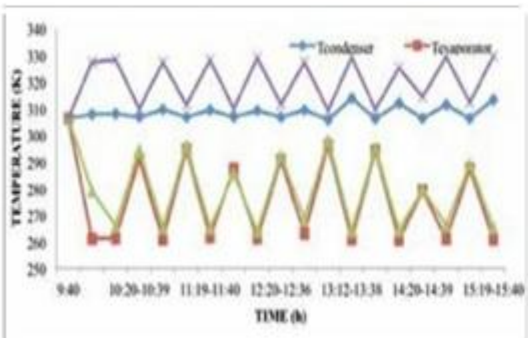

Figure 4: Cool down and warm characteristics of the refrigerator at no load condition

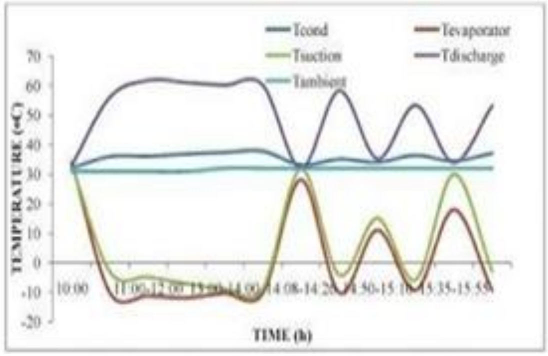

Figure 5: Cool down and warm characteristics of the refrigerator at full load condition

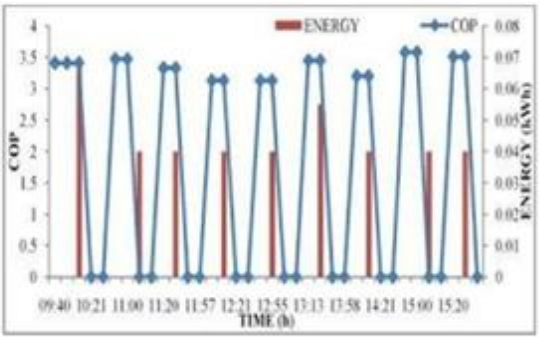

Figure 6: Variation of energy consumption and COP with time during no load

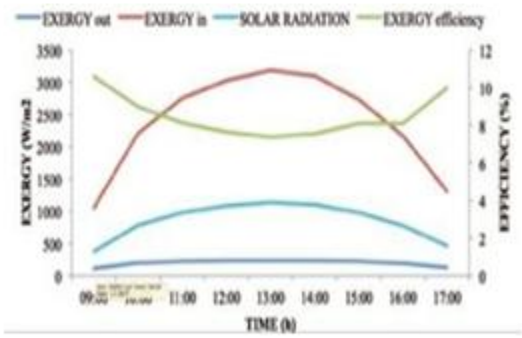

Figure 7: Variation of solar photovoltaic exergy efficiency with time & solar intensity during no load

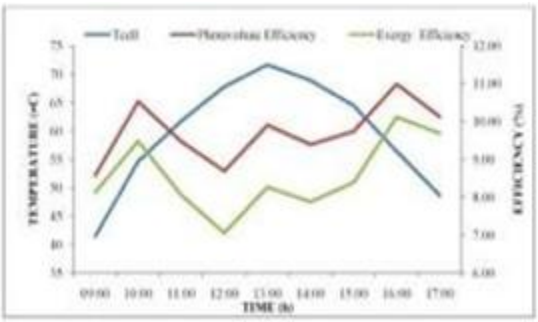

Figure 8: Energy & Exergy efficiency with time & cell temperature during full load condition

References

[1] Er. R.K. Rajput. "A textbook of Thermal engineering". Ninth edition. Laxmi publications (P) Ltd. , New Delhi.

[2] HP Garg, J Prakash. "A textbook of Solar energy (Fundamentals and Applications) ". First revised

edition. Tata Mc Graw Hill education Pvt. Ltd., New Delhi.

[3] Technical bulletin CSIR News on "Development of solar adsorption refrigeration system at CMERI, Durgapur, Vol. 61 No. 1 and 2011.

[4] Chetan Singh solanki. "Solar Photovoltaic, Fundamentals, Technology and Applications ". Second edition. PHI learning Pvt. Ltd., New Delhi.

[5] Khurmi, R.S and Gupta, J.K."A textbook of Refrigeration and Air conditioning ". Fifth edition 2011. Eurasiya Publication house (P) Ltd., New Delhi.

[6] Salah, M.M(2006). Solar refrigeration and Power generation – an overview. International conference on Energy and Environment.

[7] Rathor, N.S and Panwar, N.L(2010)." Performance Evaluation of solar photovoltaic refrigeration system ". IE(1) Journal- ID. Vol. 90. Page No. 15-16.

[8] Modi, A., Chaudhary, Vijay, B., and Mathur, A(2010). "Performance analysis of a solar photovoltaic operated domestic refrigerator". Applied Energy 86(2009),2583-2591.

[9] Ali Mansoori, G. And Vinod Patel, Basis for the choice of working fluids for solar absorption cooling system,Vol. 27 p.583,1981.

[10] Park I.S,2009, Robust numerical analysis based design of the thermal vapor compressor shape parameters for multi effect desalination plants, Desalination 242, 245-255.

[11] Kim. H D , Lee J. H , Setoguchi T , Matsuo.S,2006,Computational analysis of a variable ejector flow,J. Of Thermal science , Vol. 15 No. 2.

[12] Sun , DA-When ,1996, Variable geometory ejectors and there applications in ejector refrigeration system,Energy, 21 , 919-929.

[13] Chang Y.J. ,Chen Y.M 2000 , Enhancement of a stem jet refrigerator using a novle application of the nozel, Exp. Thermal fluid science , 22, 203-211.

[14] Meyer A.J , Harms T.M , Dobson R.T , 2009 , Stem jet ejector cooling powered by waste or solar heat , Renewable energy , 34 , 297-306.

[15] Khalil A , Fatouh . M , Elgendy . E , 2011 , Ejector design and theoretical study of R134a ejector refrigeration cycle , Int. J . Refrigeration , 34 , 1684-1698.