

# Solar Refrigeration – A Futuristic Idea for Cooling

Jijina K V, Fathima Shahna A S , Sneha D , Sneha V, Jayasree Joshi. T and Asha Ashok  
College of Dairy Science and Technology, Thiruvananthapuram, Kerala  
Kerala Veterinary and Animal Science University

**Abstract:-** The exigency for energy is increasing with developing technology and rapid rise in world population. The increasing energy rates and the urging need for environmentally friendly refrigerants has led scientists in the fields of refrigeration engineering to develop technologies for the utilization of conventional renewable energy resources. The deployment of insolation energy for refrigeration systems would help to unravel the existing energy crisis along with environmental protection. Hence an exertion has been made to understand the various approaches taken to make use of solar energy for refrigeration systems and its potential applications.

**Keywords:-** Solar Absorption Refrigeration System, Photovoltaic Refrigeration, Solar Mechanical Refrigeration.

## I. INTRODUCTION

The serious concerns of global warming and depleting resources have urged to develop eco-friendly refrigeration systems using renewable energy sources. Solar energy, if properly utilized can be an alternative solution for these problems. Solar energy finds its application in power generation, heating, cooking, drying and refrigeration (Hassan *et.al.*, 2012). This indigenous and inexhaustible energy resource can maintain sustainability in refrigeration industry by reducing pollution, global warming, energy crisis and ozone depletion caused by refrigerants like chlorofluorocarbons (CFCs), hydro chlorofluorocarbons (HCFCs) and hydro-fluorocarbons (HFCs). The paper

discusses the developments in domain of solar refrigeration system.

## II. SOLAR REFRIGERATION

Solar refrigeration system uses power obtained from sun for cooling function. Low temperature of the refrigerant is achieved mainly through solar photovoltaic cooling systems and solar thermal cooling systems. In solar photovoltaic cooling systems, photovoltaic cells converts solar energy into electrical energy and is used for refrigeration (Saidur *et.al.*, 2008) while in Solar thermal refrigeration system, solar collector raises the temperature of the refrigerant directly through collector tubes (Kalkan *et.al.*, 2012).

### A. Solar Photovoltaic Cooling System

Photovoltaic refrigeration system consist of a photo voltaic (PV) cell (capable of operating at wide range of conditions) which converts the insolation into direct current (DC). The electrical power (DC) generated by solar photovoltaic panels is used to operate a DC motor which is attached to the compressor of a vapor compression refrigeration (VCR) system. The DC thus produced can also be converted into alternating current (AC) using an inverter. The DC current produced can also be stored in batteries which can be used further when the solar radiation is unavailable. But the usage of batteries increases system's weight and decreases steady state efficiency.

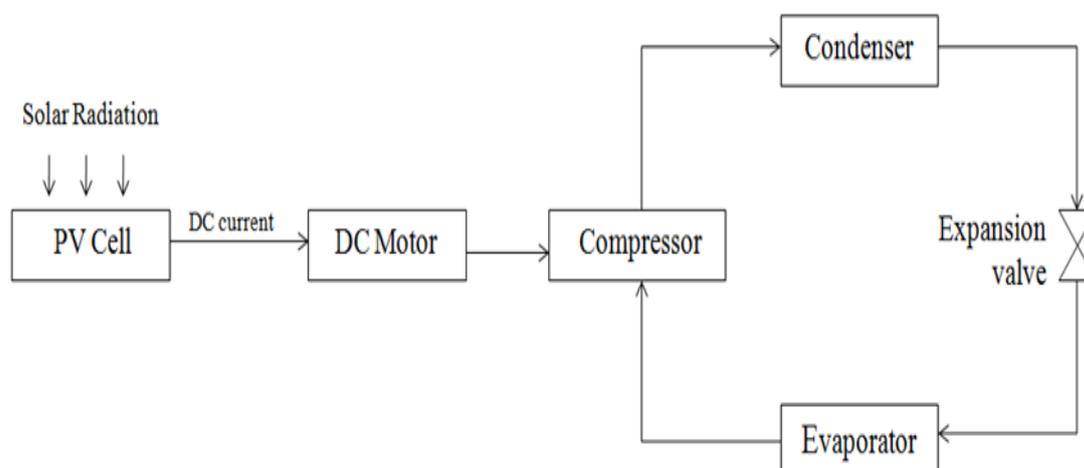


Fig. 1:- Schematic representation of solar photovoltaic refrigeration system

The schematic representation of solar photovoltaic refrigeration system is manifested in the Fig. 1. The system comprises a PV cell, DC Motor and the components of VCR system – i.e, compressor, condenser, expansion valve

and an evaporator. The requisite mechanical energy to run the compressor is provided by the DC motor. In the compressor, the working fluid (refrigerant) is compressed adiabatically to high pressure and high temperature vapor.

After which the refrigerant vapor is cooled and condensed in the condenser. The liquid refrigerant thus obtained is metered through an expansion valve which will reduce its pressure and temperature to suit the evaporator conditions. The evaporator takes up the heat from the surroundings and converts the refrigerant into vapor state and the cycle continues. The performance of this refrigeration system is expressed in terms of power-voltage and current voltage-characteristics and it depends on the module temperature and solar radiation. Solar Photovoltaic cooling system can be used in Refrigerators, ice makers, freezers, coolers, building air cooling system.

**B. Solar Absorption Refrigeration**

Solar absorption refrigeration is most frequently adopted and is highly energy conservative as it replaces energy-intensive compressor with a heat driven system for

compression process which require minimal mechanical power. Commonly used refrigerant-absorbent working pairs are water-lithium bromide (LiBr) pair, and ammonia-water pair. A schematic representation of solar driven ammonia absorption system is shown in Fig. 2. The system consists of solar collector, condenser, expansion valve, evaporator, generator, and absorber. The refrigerant vapors (ammonia) leaving the evaporator is absorbed by a liquid solution of water-ammonia (weak solution) in the absorber. The ammonia-rich liquid solution is then pumped at higher pressure to the generator. In the generator the solution is heated using the energy obtained from the solar collector. During the heating process the vapor refrigerant gets separated from the solution and passes into the condenser where it gets liquefied. The liquid refrigerant moves in to the evaporator and the cycle continues (Hassan and Mohamad, 2012).

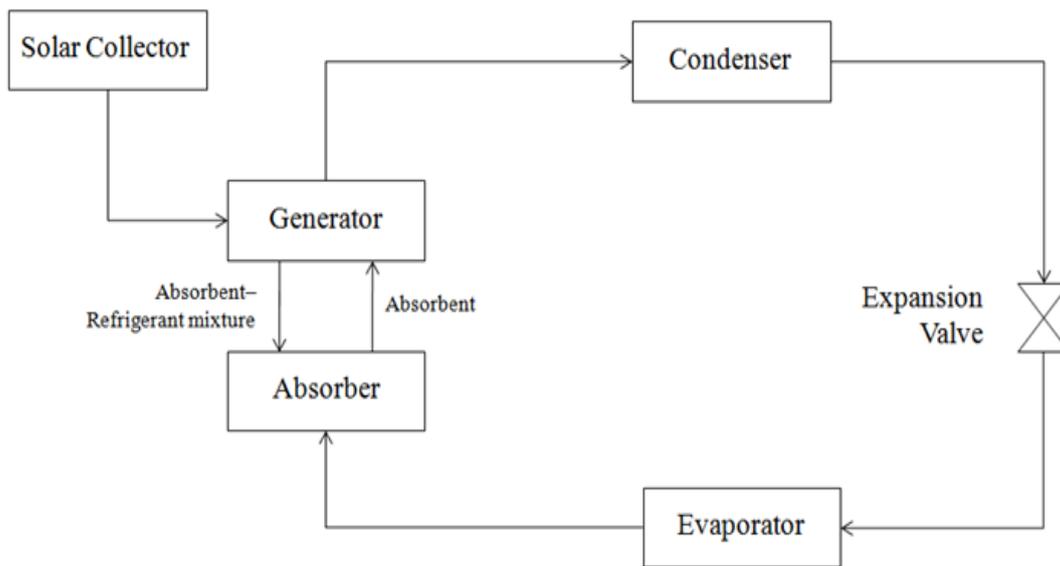


Fig. 2:- Schematic representation of solar absorption refrigeration system

Many researchers has developed new refrigerant absorbent pairs like ammonia-calcium chloride (Worsoe-Schmidt, 1979), ammonia- Lithium nitrate (River and Rivera, 2003), trifluoroethanol-tetraethyleneglycol dimethylether (Medrano *et. al.*, 2001 ), water-ethylene glycol (Abdelmessih *et. al.*, 2007), etc. Other than the above said single effect solar refrigeration systems, researchers has developed many other configurations also. Arivazhagan *et. al.*, (2006) has carried out an study to evaluate the performance of two-stage half effect vapor absorption cooling system using R134a as refrigerant and dimethylacetamide (DMAC) as absorbent. And he found that the system is competent enough to produce low evaporating temperature of  $-7^{\circ}\text{C}$  with generator temperatures in the range of  $55$  to  $75^{\circ}\text{C}$ . Rivera *et. al.*, (2011) developed a solar intermittent refrigeration system working with ammonia/lithium nitrate mixture for the production of ice.

**C. Solar Mechanical Refrigeration System**

Solar mechanical refrigeration system works on the ordinary vapor compression refrigeration cycle. The compressor is driven by the mechanical power obtained from a solar driven heat power cycle. The heat power cycle works on the principle of Rankine cycle. The schematic representation of solar mechanical refrigeration system is shown in Fig. .3. The working fluid absorbs the heat energy from the solar collector and gets evaporated. The vapor thus produced is used to heat the fluid in heat exchanger and it gets vaporized as shown in the Fig. 3. An expander converts the heat energy thus produced into mechanical power which is used to run the compressor of the vapor compression system. When the fluid exits the expander, it gets condensed and is pumped back into the heat exchanger.

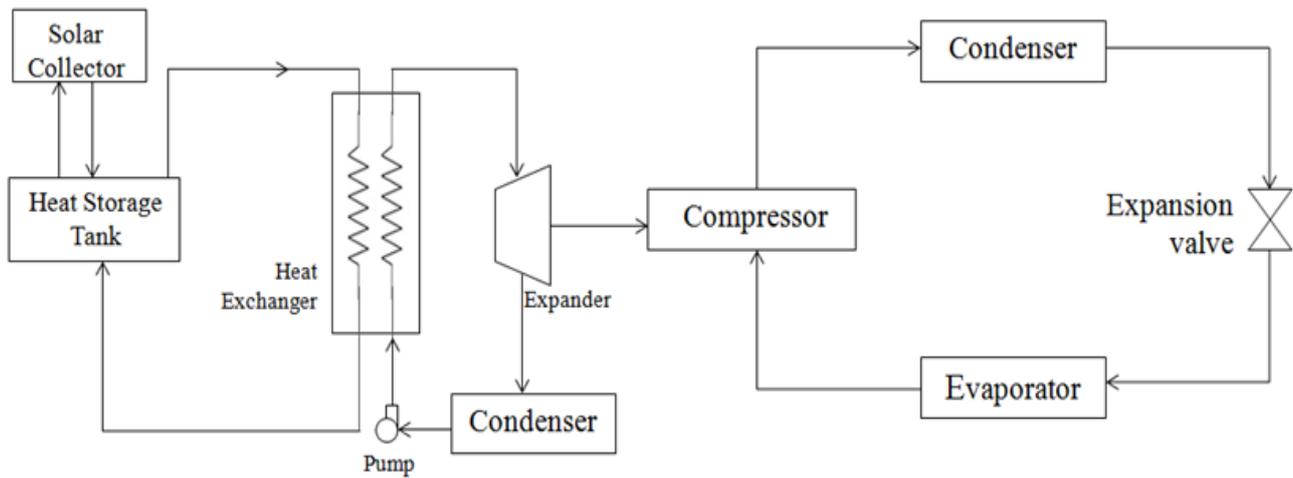


Fig. 3: Schematic representation of solar mechanical refrigeration system

Experiments on Solar mechanical refrigeration systems working on combined Rankine cycle and VCR cycle has been done by many researchers (Laidi and Hanini, 2013; Lu *et al.*, 2013). Jeong and Kang(2004) has developed a design with recuperator, reheater, and economizer and they found that the coefficient of performance (COP) depends mostly on the boiler pressure. Literatures are also available for the use of water (Delgado-Torres ,2009), ammonia, hydrocarbons (Kizilkan *et al.*, 2016), hydrofluorocarbons (Spayde *et al.*, 2015), siloxanes ( Desai *et al.*, 2016) etc. as working fluids in rankine cycle.

### III. COP OF SOLAR REFRIGERATION SYSTEM

The performance of solar refrigeration system is specified in terms of coefficient of performance (COP). It is the ratio between refrigeration capacity and input solar energy (Klein and Reindl, 2005). The COP of the system depends on various facets of the equipment, working fluid and temperature of generator, condenser and evaporator (Hatraf *et al.*, 2014). Otanicar *et al.*, (2012) studied the economical and environmental aspects of solar cooling and found that solar electric cooling will entail lowest capital investment by the year 2030 owing to the high COP and strong reduction in cost for PV technology.

### IV. ADVANTAGES AND DISADVANTAGES OF SOLAR REFRIGERATION SYSTEM.

The major advantage of solar refrigeration system is that we can save a noteworthy amount of electrical power and cause less pollution due to usage of conventional solar energy to produce power. Besides this solar energy is obtainable in every part of the world unlike fossil fuel and nuclear power and is a clean source of energy. Solar powered refrigerators can be effectively used to store perishable products such as meat and dairy products. It is a good option for refrigeration in the places where AC power is not available.

The system also has few disadvantages. Since the solar radiation is not obtainable throughout the day, power production is not consistent and also the amount of energy produced depends on the intensity of the radiation. To produce adequate energy, bigger solar collector is needed

which requires a bigger space. The initial investment is also large for the system.

### V. CONCLUSION

Solar refrigeration is a sound solution to reduce carbon dioxide emission and thereby global warming caused by the use synthetic refrigerants. The review discusses three major developments- solar photovoltaic cooling system, solar mechanical refrigeration system and solar absorption refrigeration system. More studies has to be made to exploit this environmentally friendly energy reserve for the efficient deployment in the domain of refrigeration and air conditioning.

### REFERENCES

- [1]. Abdelmessih AN, Abbas M, Al-Hashem A, Munson J. Ethylene glycol/water as working fluids for an experimental absorption cycle. *Journal of Thermal Energy Generation, Transport, Storage, and Conversion* (2007); 20 (2):87–102.
- [2]. Arivazhagan S, Saravanan R, Renganarayanan S. Experimental studies on HFC based two-stage half effect vapor absorption cooling system. *Applied Thermal Engineering* 2006 ; 26 (14–15) : 1455–1462.
- [3]. Delgado-Torres AM. Solar thermal heat engines for water pumping: an update. *Renew Sustain Energy Rev* 2009; 13:462–72.
- [4]. Desai NB and Bandyopadhyay S. Thermo-economic analysis and selection of working fluid for solar organic Rankine cycle. *Applied Thermal Engineering* 2016; 95:471–81.
- [5]. Hassan H, Mohamad A.A review on solar cold production through absorption technology. *Renewable and Sustainable Energy Reviews* 2012; 16:5331–48.
- [6]. Hassan H Z, Mohamad A A, Al-Ansary H A. Development of a continuously operating solar-driven absorption cooling system : thermodynamic analysis and parametric study. *Applied Thermal Engineering* (2012) ; 48:332–41.
- [7]. Hatraf. N, Abbas M and Merabti. L. The effect of external and operating conditions on a solar Lithium Bromide absorption chiller, *Revue des Energies Renouvelables*(2014). 17. 301-304.
- [8]. Jeong, Jinhee, and Yong Tae Kang. "Analysis of a refrigeration cycle driven by refrigerant steam turbine." *International journal of refrigeration* 27.1 (2004): 33-41.

- [9]. Kalkan N, Young E A, Celiktas A. Solar thermal air conditioning technology reducing the foot print of solar thermal air conditioning. *Renewable and Sustainable Energy Reviews* (2012); 16:6352–83.
- [10]. Kizilkan Ö, Nizetic S, Yildirim G. Solar assisted organic rankine cycle for power generation: a comparative analysis for natural working fluids. *Energy Transportation and Global Warming* (2016):175–92.
- [11]. Klein, S.A. and Reindl, Douglas. Solar refrigeration (2005). 47. S26-S30. [https://www.researchgate.net/publication/291059075\\_Solar\\_refrigeration](https://www.researchgate.net/publication/291059075_Solar_refrigeration).
- [12]. Laidi, Maamar, and Salah Hanini. "Optimal solar COP prediction of a solar-assisted adsorption refrigeration system working with activated carbon/methanol as working pairs using direct and inverse artificial neural network." *International Journal of Refrigeration* 36.1 (2013): 247-257.
- [13]. Lu, Z.S., Wang, R.Z., Xia, Z.Z., Lu, X.R., Yang, C.B., Ma, Y.C., Ma, G.B. Study of a novel solar adsorption cooling system and a solar absorption cooling system with new CPC collectors. *Renewable Energy* (2013) 50, 299–306.
- [14]. Medrano M, Bourouis M, Coronas A. Double-lift absorption refrigeration cycles driven by low-temperature heat sources using organic fluid mixtures as working pairs. *Applied Energy* (2001);68:173–85.
- [15]. Otanicar, T., Taylor, R. A., and Phelan, P. Prospects for solar cooling - An economic and environmental assessment. *Solar Energy*(2012). 86(5), 1287-1299.
- [16]. Rivera CO, Rivera W. Modeling of an intermittent solar absorption refrigeration system operating with ammonia/lithium nitrate mixture. *Solar Energy Materials and Solar Cells* (2003);76:417–27.
- [17]. Rivera W, Moreno-Quintanar G, Rivera CO, Best R, Martinez F. Evaluation of a solar intermittent refrigeration system for ice production operating with ammonia/lithium nitrate. *Solar Energy* (2011); 85(1):38–45.
- [18]. Saidur R, Masjuki H, Hasanuzzaman M, Mahlia T, Tan C, Ooi J.K and P.H. Yoon Performance investigation of a solar powered thermoelectric refrigerator. *International Journal of Mechanical and Materials Engineering* (2008); 3:7–16.
- [19]. Spayde E, Mago PJ, Pham D. Evaluation of a solar-powered organic Rankine cycle using dry organic working fluids. *Cogent Eng* (2015);2:1–22.
- [20]. Worsoe-Schmidt P. A solar-powered solid-absorption refrigeration system. *International Journal of Refrigeration* (1979);2:75–82.