Performance evaluation of locally fabricated solar powered refrigerator

Environment, Ecology

ABSTRACT

Factors such as inconsistent power supply, coupled with the overdependence on fossil fuel resource and environmental factors such as global warming have had a diminishing effect on the application of refrigeration techniques. considering this factors, joint efforts have been made to evaluate the performance of a locally fabricated solar refrigeration system, a lot of work have been done by scientists and research centers on the subject of solar refrigerators, notably among them is work done by kim and Ferreira (2008) on overview of the state of the art of different solar refrigeration technologies including solar electric, thermo mechanical, and sorption technology.

A three (3) month comprehensive study of the Solar intensity was measured hourly and the open circuit voltage and short circuit current was measured during the off cycle of the refrigeration system. The average solar radiation at the location of study was 6. 5MJ/m2. The performance evaluation of the PV refrigeration system was done with“ PV syst” simulation software. The simulation process involves several dozens of variables, which are stored in monthly values in the results file, and presented with tables and graphs. The average photovoltaic efficiency and exergy efficiency was found near 8. 5% and 11% respectively. The efficiency was found less due to high module temperature hence exergy was destroyed highly in PV. The results reveals that, PV-refrigerator system can be reliably alternative to the conventional refrigerator in areas with fluctuating or no electricity with potentially low running costs.

INTRODUCTION

The awareness of global warming, high dependence on fossil fuel resource and the inconsistent state of power generation in underdeveloped countries, has intensified and reignited the search for energy sources that are cleaner and of renewable nature, Solar energy is a promising alternative to look into; it is produced by radiation released from the Sun caused by the thermonuclear reactions occurring inside its core. It has been calculated that the total solar radiation transmitted to the earth is approximately 1. 74×1017 W, whereas the overall energy consumption of the world is approximately 1. 84 ×1013 W (Solanki, 2013). From this data, there isn’t any doubt that there is bountiful supply of energy present in the sun and all we need is efficient devices to harness this energy. Solar energy can be harnessed basically in two ways viz. directly converting the solar radiation to the electricity for useful purposes by means of solar photovoltaic (SPV) modules or by heating the medium source for low temperature heating applications.

The aim of this study is to evaluate the performance of a locally fabricated solar powered refrigerator. The energy efficiency of a solar panel, the ratio of the power output to the energy originally delivered to the solar panel, conventionally is used to measure solar PV efficiency. The project is justified due to the coincidence of the high demand for refrigeration and the availabilityof abundant solar radiation at our disposal. Solar electrical and thermal powered refrigeration systems can be used to produce cooling.

There are a lot of solar refrigerator systems. (Kim and Feffeira, 2008; Papadapoulous et al., 2003; Ewert et al., 1998). As can be seen in the figure, a lot of technologies are available to deliversc refrigeration from solar energy. Scientists and research centers focusing on these technologies have made a lot of work on the subject. Kim and Ferreira (2008) presented an overview of the state of the art of the different solar refrigeration technologies including solar electric, thermo mechanical, and sorption and also some newly emerging technologies. Some researchers conducted experiments on theperformance analysis of photovoltaic driven vapor-compressor refrigeration system. Kattakayam et al. (1996)studied the electrical characteristics of a 100W AC operated domestic refrigerator using R-12 powered by a field of SPVpanels, a battery bank and an inverter.

A minimum currentregion was observed in the mains voltage range of 180–190V and at the inverter voltage range of 210–230V. Charters (2003) suggested its use in developing countries foressential purposes such as vaccine serum storage at medicalclinics in remote regions. Fatehmulla et al. (2011)designed and developed low power refrigeration systemusing PV modules, 2 modules each of 36 solar cells. Yilanciet al. (2011) studied the energy an analysis of a refrigerator, powered by a photovoltaic investigated to obtain efficientoperation conditions based on experimental data. Sobamowoet al. (2012) designed and developed photovoltaic-poweredDCvapour compression refrigeration system for developingcountries such as Nigeria and showed that its applicability todifferent climatic regions in Africa and could be used forperishable food storage, improvement in the

health servicesand living conditions in remote and rural areas which wereunable to access electricity from the grid.

RESEARCH METHODOLOGY

In this study, the comparative energetic and exergetic analysis of solar photovoltaic (SPV) modules has been carried for November, December and January month under different climatic condition.

TABLE I: SPECIFICATIONS OF THE EXPERIMENTAL SET-UP

S/N. Parameters Specification

1. Storage capacity 50 – 60 liters
2. Door Top opening
3. Type of refrigeration Vapor compression refrigeration system

   Compressor

4. Make Danfoss
5. Power consumption 90 W
6. Refrigerant R143a
7. Operating voltage 230V AC
8. Maximum and minimum internal temperature 0˚C to +8˚C
9. Insulation 100mm thick
10. Dimension 37 x 19 x 20cm
11. Weight 21. 2 kg

    Solar panel

12. Number of panels 1
13. Make REIL, Jaipur
14. Max. power output 110Wt
15. Size of the array (LxBxT) 1480mm x 540mm x 35mm
16. Orientation 35o from horizontal facing south

Inverter

17. Make Intelligent
18. Power output 1500WT

Thermal storage

19. Type Ice
20. Capacity 18litres

ENERGY EFFICIENCY OF THE SOLAR PANEL

Sarbu and Sebarchievici (2015) defined the efficiency of the solar panels as the ratio of the electrical power produced to the incident radiation and varies between 10 to 15% at maximum power conditions for the PV array. If the PV refrigeration system is to operate at high efficiency, it is essential that the voltage imposed on the PV array be close to the voltage that provides maximum power. The photovoltaic efficiency of solar panel was determined at no load and full load condition by using following formula.

. (Sudhakar and Srivastava 2013)

Where, ηpv= Efficiency of Photovoltaic system

Pmax= Maximum Power from photovoltaic system (W)

Apv = Area of the photovoltaic system (m2)

S = Solar irradiance (W/m2)

EXERGY ANALYSIS

Exergy analysis is used to find out the energy utilization efficiency of an energy conversion system. Exergy analysis yields useful results because it deals with irreversibility minimization or maximum exergy delivery. The exergy analysis has been increasing applied over the last several decades largely because of its advantages over energy analysis. To perform an exergy analysis of the solar PV, the quantities of input and output of energy and exergy must be evaluated.

PHOTOVOLTAIC EXERGY

The energy of a PV module depends on two major components; electrical and thermal. In SPV system electricity is generated by the PV effect, the PV cells are heated due to the thermal energy present in the solar radiation. The electricity (electrical energy), generated by a Photovoltaic system, is also termed as electrical exergy since 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 useful purpose it is considered to be heat loss to the ambient. Therefore, due to heat loss, it becomes exergy destruction. The energy output of the photovoltaic system can be calculated as: (Sudhakar and Srivastava 2013) . Sudhakar and Srivastava (2013) Where Vm, Im, hc, A, Tcelland Toare the maximum voltage

and current of the photovoltaic system, convective heat transfer coefficient from the photovoltaic cell to ambient, area of the photovoltaic surface, cell temperature and ambient temperature (dead state temperature), respectively.

The convective heat transfer coefficient from the photovoltaic cell to ambient can be calculated by using correlation.

hc = 5. 7 + 3. 8 × υ . Sudhakar and Srivastava (2013)

Where, v = Wind velocity (m)

The module or cell temperature is used to predict the energy production of the Photovoltaic module. Cell temperature (Tc) is a function of ambient temperature (Ta), wind speed and total irradiance. The cell temperature can be determined by the following relationship:

Tcell= 0. 943Ta + 0. 028 Irradiance – 1. 528Windspeed + 4. 3.(Sudhakar and Srivastava, 2013)

Exergy input of the photovoltaic system, which is the energy of solar energy, can be calculated approximately as below

Sudhakar and Srivastava (2013)

Where, T¬¬SUN = Temperature of the Sun taken as 5760˚ K

Energy efficiency of the photovoltaic system is defined as the ratio of the total output energy (recovered) to total output energy (supplied). It can be expressed as (Sudhakar and Srivastava, 2013)

EVALUATING THE PV SYSTEM PERFORMANCE

To carry out this task, we shall use powerful software for Photovoltaic systems called “ PV Syst.”. PV Syst is photovoltaic simulation software which is able to import meteor data from many different sources, as well as many personal data. PV Syst. presents results in the form of a full report, specific graphs and tables, and data can be exported for use in other software.

PV Syst, allows the user to input into the software the parameters of the PV array, parameters needed include Orientation of the PV array, user’s needs (in this domestic appliance), Sizing of the battery bank and PV array power, array configuration and control strategy and Detailed losses. Finally when all the parameters are accepted, the program gives access to the hourly simulation, the simulation dates are based on the Meteor file dates, and can be restricted to a limited period. The simulation process involves several dozens of variables, which are stored in monthly values in the results file, and will be available as monthly tables and graphs.

RESULT AND DISCUSSION

The performance of the photovoltaic system was evaluated in terms of photovoltaic energy and exergy efficiencies based on the information gotten from “ PV Syst.”. Solar intensity was measured hourly and the open circuit

voltage and short circuit current was measured during the off cycle of the refrigeration system. The simulation was carried out in Lagos Mushin local government area having an average solar insulation of 6. 5MJ/m2.