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Development and Application of 100% Solar Powered Diffusion-Absorption Refrigeration as a Panacea for Nigeria Electricity Challenges

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ABSTRACT

The paper, discussed the development and application of 100% solar powered diffusion-absorption refrigeration as a panacea for Nigeria electricity challenges. Over the years, Nigeria as a developing country uses fossil fuels like coal, oil and natural gas as a source of energy to power various domestic and industrial refrigeration plants. In the past two decades, fossil fuel expenditure has increased dramatically. The consumption of these fuels contributes greatly to environmental degradation. Fossil fuels in general are subject to depletion, and at the same time building a society without considering alternative energy sources might endanger the future generation energy drive benefit, hence creating a threat of adverse effect to the sustainable development in the long run. Consumption of fossil fuels also explicitly gives rise to greenhouse gas (GHG) concentrations in the atmosphere. Among the greenhouse gases, carbon dioxide (CO2), sulfur dioxide (SO2) emission is thus considered an emerging problem of the world community for its ongoing effect on the environment and the ecosystem, and especially on the surrounding climate change. Consequently, adopting 100% solar powered diffusion-absorption refrigeration system becomes a thing of paramount to local communities, if electricity challenges in Nigeria must be overcome. In addition, the paper serves as a sign post for achieving the development and application of the suggested 100% solar powered diffusion-absorption refrigeration model.

Key words: Solar power, Diffusion-absorption, Refrigeration system, model, Alternative energy.

1.0 INTRODUCTION

Consequently, the cost of refrigerating food items, industrial raw materials as well as low temperature processes becomes very challenging to the engineers and organizations. As electricity production is dominated by indigenous natural gas, coal and hydro which are now under the state of depletion and unsustainable; there is cogent need to device a reliable, eco-friendly, sustainable and cost effective means of generating energy to power most of the important machines such as refrigeration systems. Tailoring to ways and means to reducing the cost of energy consumption in refrigerating plants brought about the model of diffusion absorption refrigeration system where the hermetic compressor is replaced with thermal generator and bubble pump that consume less energy and they are 100% solar powered which makes the whole system economical.

Achieving a steady electricity power supply through the construction of additional power plants stations proposed by Federal Ministry of Power have also increased the price of electricity among the citizens. This is because energy is the lifeblood of modern civilization and an indispensable asset for sustainable development. The continued increase in world population and rapid urbanization has resulted in a rapid increase in global energy demands. As well, due to the growing concern and awareness of environmental issues among the scientific community, power generation from renewable energy sources, particularly solar energy has become significantly important for the last few decades.

Obviously, wind and solar energy resources are known for zero environmental negative impact. But the sparely nature of wind in Nigeria has limited its reliability as a means of powering refrigerators across the geo-political zones of Nigeria. Solar energy, being abundant in nature, not sparely seen, has been trenched as a reliable means through which refrigerator systems can be powered and as well bring to innovation. The constraints opposing the harnessing of this solar energy in Nigeria has been attributed to availability solar radiation due to weather changes, balancing rate of production and demand with its high initial cost implications. However, the cleanliness, zero operating noise and low operating cost have exacerbated its adoption in powering both industrial and domestic refrigeration systems.

According Chauhan et al (2022) as cited by Bisulandu et al (2023) maintained that many countries' fossil fuel depletion and energy-saving policies have contributed to the development and innovation of solar powered absorption chillers and have been considered an alternative to compression refrigeration chillers. Diffusion absorption refrigeration system can be operated using renewable energy sources, such as geothermal energy, solar heat energy, and waste gas heat from industrial processes. It is also noted that absorption refrigeration machines has contributed to huge reserve of fossil fuel and non-renewable resources that increase purchase costs of conventional cooling systems. The results data from the International Institute of Refrigeration (IIR) show that 17% of the world's electricity production is channeled into heating and cooling of conventional air-conditioning and refrigeration systems to meet the edification and comfort of the humans as well as industrial process plants.

Asfand and Bourouis (2015) in their study of review of membrane contactors applied in absorption refrigeration system stated that the globe is challenged with energy shortage problem. They proposed that there would be increase in interest of industries and engineers in absorption refrigeration system; since it can be operated with renewable energy sources and also environmentally friendly refrigerants that have zero ozone depletion potentials. The spread of absorption refrigeration system across the globe is well appreciated or a welcome development. However, the area of system plant and equipment optimization to achieve best cooling performance level is really on a speed lane and powered by erudite researchers.

Adjibade et al (2017) highlighted the various constituent elements of the diffusion absorption refrigeration system as absorber, generator or boiler, energy source, condenser, evaporator, heat exchanger, pump. They further added that different technologies could be combined such as compression refrigeration and adsorption refrigeration systems with several or a single energy source.

Siddiqui and Said (2015) as cited by Bisulandu et al (2023) stated that the solar energy is a renewable and environmentally friendly source and presents a substantial potential source of reducing ozone layer depletion and also sustain energy reserve. It was also observed that the harnessed solar energy could be either used directly from dish or trough collector to generator or could be converted to electrical energy, then to heaters or heat exchangers. There is also evolution of hybrid solar that could produce both the needed thermal energy by generator and electric energy required to start the bubble pump drive motor. This is the model the paper aims to adopt. Research studies reviewed, showed that increasing the operational temperature of 100% solar powered absorption refrigeration system, increases both generator and evaporator performances. Siddiqui and Said (2015) stated that a solar heat energy source temperature of 92.7 °C, would give an evaporation temperature of 13 °C, with cooling capacity of 1.9 W and a COP of 1.156.

1.1 PROBLEM STATEMENT

Obviously, studies from literatures showed the importance of delving into other means of powering diffusion absorption refrigeration systems to save the world's energy reserve. According to results data from the International Institute of Refrigeration (IIR), 17% of the world's electricity production is channeled into heating and cooling of conventional air-conditioning and refrigeration systems to meet the edification and comfort of the humans as well as industrial process plants. The review of countries' fossil fuel depletion and energy-saving policies by Bisulandu et al (2023) revealed that many countries suggested the development and innovation of solar powered absorption chillers and have been considered an alternative to compression refrigeration chillers as a means of energy savings.

Developed countries use fossil fuels like coal, oil and natural gas as a source of energy to power various domestic and industrial refrigeration plants. In the past two decades, fossil fuel expenditure has increased dramatically. The consumption of these fuels contributes greatly to environmental degradation. Fossil fuels in general are subject to depletion, and at the same time building a society without considering alternative energy sources might endanger the future generation, hence creating a threat of adverse effect to the sustainable development in the long run. In addition, as electricity production is dominated by indigenous natural gas, coal and hydro which are now under the state of depletion. There is immediate need to foster a reliable, affordable and eco-friendly means of generating energy to power most of the important machines such as refrigeration systems.

Finally, among the alternative energy sources through which diffusion absorption refrigeration system can be powered, solar energy showed more flexibility and could be harnessed, used as hybrid solar that could produce both the needed thermal energy by generator and electric energy required to start the bubble pump drive motor, according to (Siddiqui and Said, 2015). It is on this note that the project aimed at studying hybrid 100% solar powered diffusion- absorption refrigeration system.

1.2 PROCESS DESCRIPTION

1.2.1 Principle of Operation of 100% Solar Powered Diffusion Absorption Refrigeration System

Solar photovoltaic (SPV) refrigeration system consists of two 80W SPV panels used to convert solar energy into electrical energy and are arranged in parallel. The purpose of this arrangement was to have sufficient potential difference across the properly charging 12V battery. The panels are kept on fixed masonry structure at 35° (tilt angle) from horizontal, facing south direction. A battery is used so that it could give high starting current required to start the motor of the bubble pump. It consisted of one 12 V – 150 Ah sealed lead batteries connected in parallel. Panels were connected to the battery via charge controller which prevents the battery from deep discharge. Battery supplied DC current to refrigerator as it operated on DC current. The incident radiation falling on the surfaces of panels produces thermal energy that can be transferred to cooling water running inside tube under neat the panels. The heated water inside the tube can be piped to the generator or heat exchanger as a heat source.

According to Lingeswaran and Hemalatha (2014), the main components of 100% solar powered diffusion absorption refrigeration system are given below.

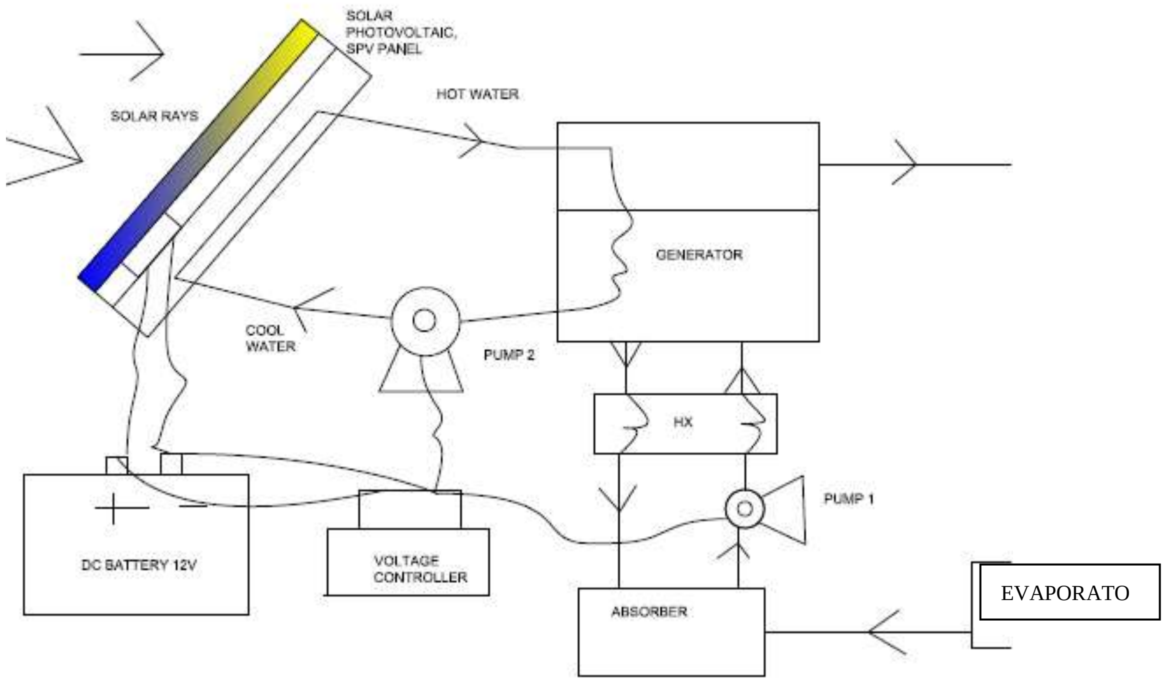

Fig 1.0: Adopted Model of 100% Solar Powered Diffusion Absorption Refrigeration System with

1.2.2 Solar Photovoltaic

The solar photovoltaic (SPV) refrigeration system generates both electrical and thermal energy from solar radiation. As a result, the energy and exergy analysis of the system is to be determined. The energy analysis is concerned only with the quantity of energy in use and the efficiency of energy processes. Exergy is the maximum work potential which can be obtained from energy. The Solar energy reaching the surface of the earth can be converted into both electric energy and thermal energy respectively, required to drive the motor pump and for heating the generator for low temperature heating.

1) **Evaporator-Gas Heat Exchanger**

The evaporator/gas heat exchanger is a shell and tube HX, to which the condensate refrigerant tube is attached in order to provide some sub-cooling of the liquid refrigerant before it gets in the evaporator.

2) **Absorber**

For the same reason, the absorber is also air-cooled. It is constituted of a folded tube (120 mm in length and 10 mm in diameter) which forms two planes with a variable angle between them. The absorber efficiency is a function of the residence times of the gas and the liquid which themselves depend on the opening between the planes.

3) Generator

It is a boiler and the covered with a reflecting layer. Which reflect bubble pump are not combined in one unit as in a solar rays on the face of a receiver placed classical DAR but separated in order to investigate each component independently from one another. Generator can be a single vertical tube (height: 800 mm, diameter: 8/10 is mm) to which the heat input is restricted to a small zone in the bottom or a vapor-liquid separator connected to the tube and a boiler.

4) **Condenser- Heat Exchanger**

The vapor is purified at the rectifier where it is a refrigerant, cooled down to 50C. The ammonia vapor is then liquefied equalizing inert gas in the air-cooled condenser. For normal operating conditions, the system pressure is approximately 8 bar. The liquid passes to the evaporator, which is divided into the two sections: a freezer and a food chiller.

Table 1.0: Shows the Effects of Solution and Heat Source on Performance of Diffusion Absorption Refrigeration

S/N	**Authors**	**Binary Solution**	**Source of Energy**	**Temperature of Heat Source (℃)**	**Temperature of Generator (℃)**	**Temperature of Evaporator (℃)**	**Cooling Capacity (Kw)**	**COP**
1	Nikbakti et al(2020)	LiBr-H_2O	Solar energy	60	-	-	13.7	0.4
2	Wang(2012)	$LiNO_3$-NH_3-He	Solar energy	92.7	87.0	-13.0	1.9	0.156
3	Ziapour et Tavakoli (2011)	NH_3- H_2O - He	Thermosiphon	90	90	5	7	0.20

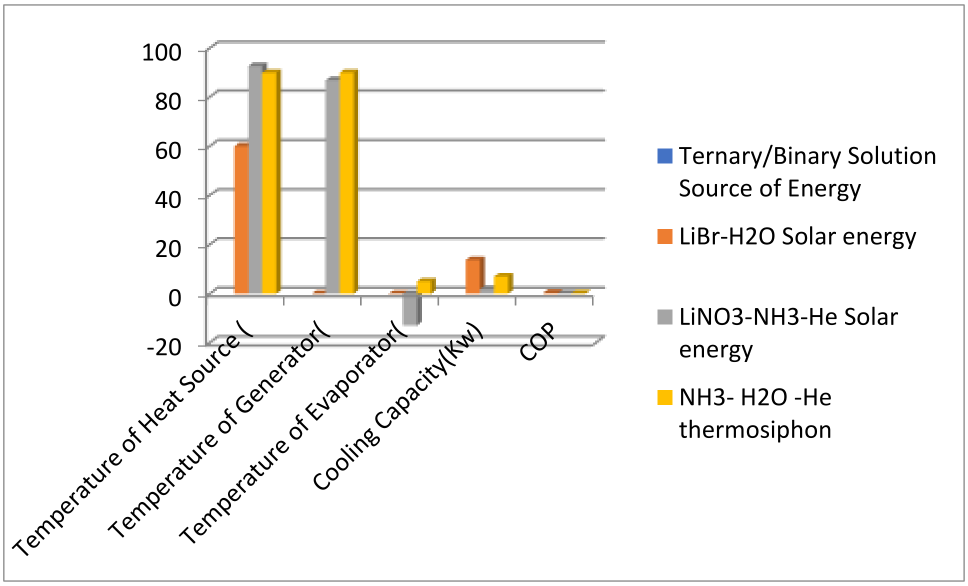

Fig 2.0: Bar Chart Shows the Effects of Solution and Heat Source on Performance of Diffusion Absorption Refrigeration

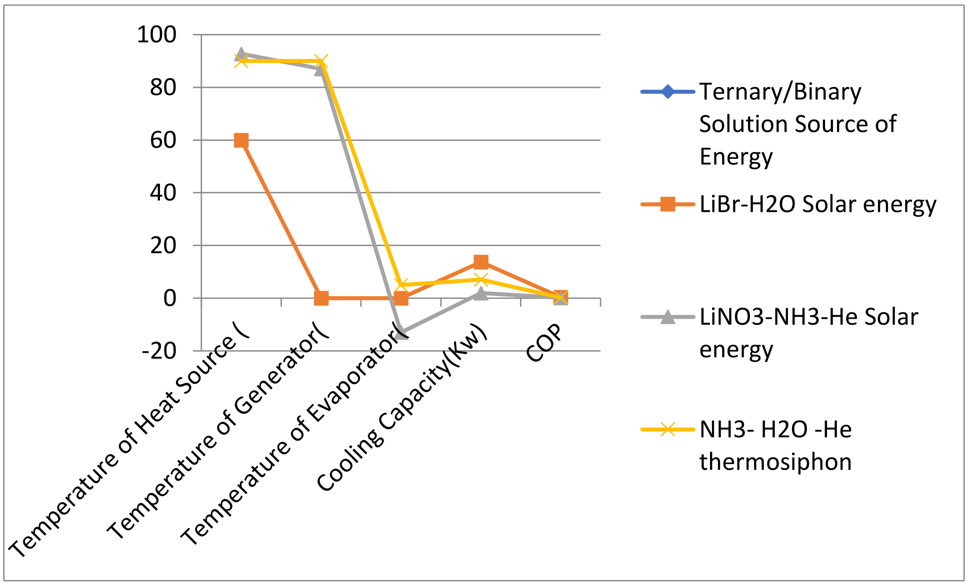

Fig 3.0: Line Graph Shows the Effects of Solution and Heat Source on Performance of Diffusion Absorption Refrigeration

From the table 1.0 and charts above, it is evident that the choice of binary solution influences the cooling capacity and coefficient of performance in solar powered absorption refrigeration system. In addition, the use of inert gas and equalization of temperature of heat source with that of generator increases both cooling capacity and COP of system. It can be observed from the table and charts that the increase in evaporator temperature increases the cooling capacity of system

Table 2.0: shows solar flux density received by panels with respect to time

S/N	**Solar Flux Density(W/m^2)**	**Time (hour)**
1	0	7
2	100	8
3	200	9
4	300	10
5	400	11
6	500	12
7	600	13
8	700	14
9	800	15

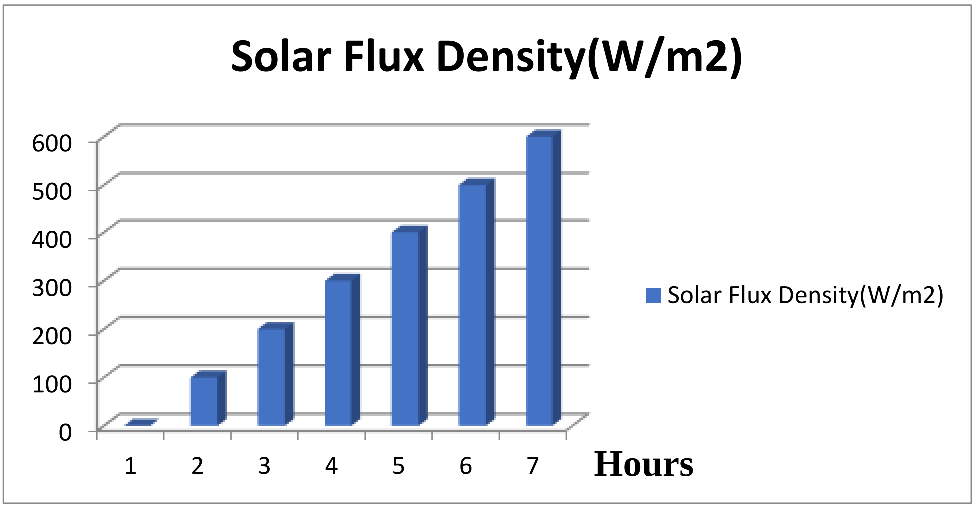

Fig 4.0: Bar Chart shows solar flux density received by panels with respect to time

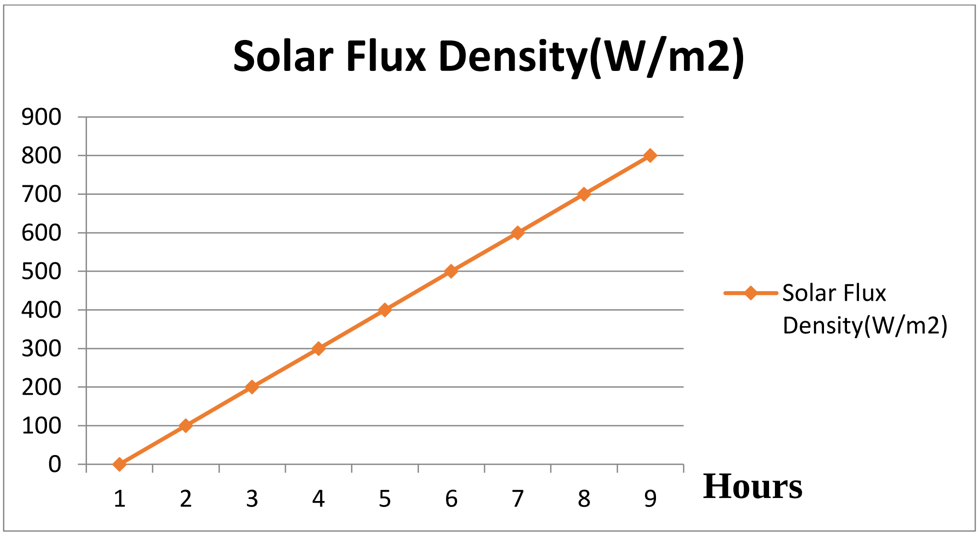

Fig 5.0: Line Graph shows solar flux density received by panels with respect to time

The table 2.0, fig 4.0 and fig 5.0 suggested that solar flux density received on the panels is a function of time and increases in magnitude with time increment. It can be seen also that for the first one hour of operation in a 100% solar powered diffusion absorption refrigeration, system response was poor or nearly to zero.

CURRENT STATUS, CHALLENGES, AND THE FUTURE DIRECTION OF TECHNOLOGY

The current techniques suggested by erudite researchers for improving 100% solar powered diffusion absorption refrigeration system include the addition of new heat exchangers and designing generators integrating both the boiler and the bubble pump.

The diffusion absorption refrigeration machine is used in many industrial and building sector applications. The management and storage of energy, and the intermittency of renewable resources (solar rays and panel effective surface area influence, for example) are real challenges facing diffusion absorption refrigeration machine. The issue of energy management and storage remains a significant issue that encompasses both the choice of energy sources and the availability of energy at all times. Other challenges faced by absorption machine generators are, among others, energy optimization, limitation of the temperature of the heat source used, and the control, the automatic and optimal control of the generator by taking into account all the operating parameters of the process.

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