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Analysis Key Performance of Refrigerator Prototype With Photovoltaic

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***Abstract*—Indonesia as a tropical country is very suitable for the development of various alternative energies, especially solar power (photovoltaic). This development will be followed by the development of DC motor technology and batteries to replace equipment that uses AC electricity and conventional energy such as fossil energy. This study conducts an experimental research consisting of a refrigerator prototype and a photovoltaic array. Measurements and data acquisition were using data logger system. The refrigerator prototype measurements consist of temperature, pressure, power supply and mass flow rate. For solar power array system, measurement consist of current and voltage output. This study is a preliminary study with the focus on carried out on the calculation and analysis of coefficient of performance (COP) of the refrigerator. The results obtained are the photovoltaic arrays can provide energy continuously during high solar intensity (during the day). The performance of the refrigerator is quite good, with an average COP of 3.2. Furthermore, the future work will be done by further analysis of the solar energy supply. Followed by built a DC refrigerator to be able to compare in depth the performance of both refrigerators system. So that it can contribute to the development of the cooling system technology.**

Keywords—refrigerator, key performance, photovoltaic, solar power

I. INTRODUCTION

The feasibility of using solar power as an energy source in the refrigerator system has been studied in various countries that are similar to Indonesia's condition. Modi et al. [1] conducted a study on the use of solar power for conventional refrigerator systems. The system was re-designed with the addition of batteries, inverters and transformers with solar panel photovoltaic (SPV) energy sources. The results showed that the performance (COP) of the refrigerator decreased from morning to evening, with a maximum COP of 2.1 at 7 am and economically it still requires a rather high investment cost because the battery price is still relatively expensive. Bilgili [2] investigated by making a solar electric-vapor compression refrigeration (SEVCR) system, this system is very suitable for cooling during the day. Gupta et al. [3] conducted research with the development of stand-alone solar panels as an energy source for the refrigerator system, and analysed the suitable solar panel design for a certain refrigerator capacity and found that solar power was very suitable for the refrigerator system. Daffallah et al. [4] investigation an energy-efficient approach to providing cooling needs is one of the challenges facing most developing countries. This research was conducted to assess the performance of DC 12 V and 24 V photovoltaic refrigerators with / without loading which were operated at 25°C and 35°C. Experiments were carried out at different thermostat settings in the refrigerator. Daily compressor running time and refrigerator energy consumption are calculated under various operating conditions. Monthly and yearly refrigerator consumption is also carried out. Minimum and maximum increase in compressor running time per day for each degree increased (on average from 25 to 35°C) in ambient temperature.

The comparison of the operation of the DC 12 V refrigerator is much more efficient than the 24 V operation, especially at higher ambient temperatures with an average energy saving of 81.28 kWh / year. The performance of the refrigerator system compared to the solar powered system of conventional electric systems by adding batteries, inverters and transformers. The performance coefficient (COP) was observed to decrease with time from morning to evening and a maximum COP of 2,102 was observed at 7 am. As a refrigerator COP this is quite good. From an economic standpoint, it can only be economically viable by considering carbon trading options, and initial subsidies or reduced component costs - particularly photovoltaic panels and battery banks. The RET Screen simulation shows that the system cannot survive economically without initial financial incentives or Government subsidies, or a substantial reduction in the cost of the more expensive components. A minimum initial subsidy of 15% is required to bring the financial repayment period of the current system to an assumed project life of 24 years. Furthermore, to bring the repayment period back to an attractive figure, a minimum subsidy of 70% [5,6]. Temperature control in household refrigerators against environmental and economic plans is very important. Refrigerator energy consumption is greatly influenced by room temperature, door opening and thermostat setting. A household refrigerator powered by photovoltaic energy is tested in a laboratory to determine the effect of thermal regulation on energy consumption. Energy optimization reduces aggressive methods of electricity production. Energy efficiency and solar energy present important alternatives in the three fields of energy, economy and environment.

The reduction in energy consumption allows a reduction in the capacity of the PV generator and solar battery. This optimization reduces the cost of an autonomous PV installation and helps generalize renewable energy in the domestic refrigeration sector [7]. It has also been observed that AC refrigerators are associated with relatively high-power consumption and power spikes compared to DC refrigerators. The economic assessment carried out between an AC refrigerator (with inverter) and a developed DC refrigerator (without inverter) both powered by a solar / photovoltaic electric system indicates that a DC refrigerator has the potential to reduce the overall system installation cost by 18% as compared to an AC refrigerator. recommends that for stand-alone cooling using a solar PV system as an energy source, it is more economical to use a DC refrigerator than an AC refrigerator [8].

Simulation of a solar powered vapor compression refrigeration system with variable speed compressor in real weather conditions using data sheets (PV panel and compressor) available from the manufacturer. Compressor operating speed is determined to model the variation in the performance of the refrigeration system per hour. The analysis and simulation results show that the COP of the refrigeration cycle for the selected days is around 2.25 when the compressor is running at low speed, and the COP drops to the lowest value of 1.85 when the compressor operates at the highest speed. Furthermore, the simulation results show that an estimated radiation intensity of 315 W / m2 must be received at an inclined panel to run the compressor under consideration at a minimum rotating speed of 1800 rpm. To drive the compressor at its maximum rotating speed (4200 rpm), an estimated radiation intensity of 700 W / m2 is required to fall on the PV panel. Finally, the proposed method can be used to estimate the performance of a solar PV cooling system in direct combination with a variable speed compressor under certain weather condition [9]. The photovoltaic (DC) variable speed direct current cooling system of the photovoltaic (PV) cells is directly connected to the compressor without battery and inverter, and the speed of the DC compressor changes with the radiation intensity. Compared to the fixed speed mode, the cooling capacity of the variable speed mode increased by 32.76% and the average PV utilization efficiency increased by 45.69%. As ambient temperature increases, the average cooling capacity decreases significantly, but the increase in mean power consumption is not apparent, which suggests that the ambient temperature has a greater effect on cooling capacity and has less effect on power consumption. The radiation intensity has a significant effect on system performance. As the radiation intensity increases, the cooling capacity increases significantly [10].

Therefore, to improve refrigeration performance, several optimization strategies are recommended. From the review above, it was found that the DC refrigerator system which is directly supplied with energy from photovoltaics is more efficient and simpler than conventional systems and AC refrigerators with energy sourced from photovoltaics with an inverter. However, for the first step of this study is investigating the AC refrigerator with standalone photovoltaic as an energy resources, and for the future work will investigated DC refrigerator and then both systems will be deeply analysis for their efficiency when applicated in Indonesian Country.

II. METHODS

A. Experimental Set Up

In this study is the first stage of the experimental set up. There are two main experimental equipment in this research, the first is a prototype refrigerator using R600A refrigerant equipped with a humidifier system and the second is a solar power system consisting of photovoltaic, Solar Charge Control (SCC), inverter and batteries. In this system solar energy output are both AC and DC current and can directly drive the compressor. The refrigerator system is supported by a natural humidifier system. Other supporting system components such as fans and other electrical instrumentation components are all based on AC currents. Data loggers have been prepared for temperature, humidity and pressure. The refrigerator prototype was redesigned to meet the medium temperature conditions set at 0ºC, 5ºC and 8ºC storage temperatures, and the humidity controlled at 85%. The temperature measured uses a type K thermocouple, a pressure transducer with a voltage signal. Environmental conditions are measured using a special logger which includes air temperature, humidity and dew point. The thermocouple has an accuracy of +/- 0.5K, humidity +/- 0.5%, and a pressure (voltage output) of 0.08%. The experimental rig design and the solar control panel is shown in Figure 1 as follows.

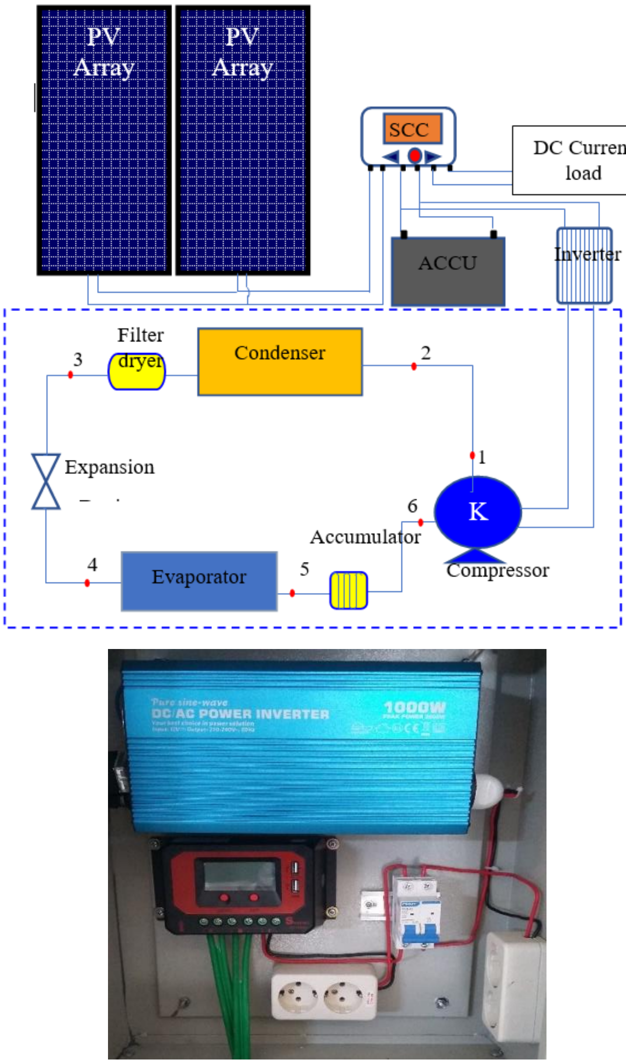

Fig. 1. Design of experimental rig and solar control panel.

The experimental set up of the photovoltaic array is shown in Figure 2(a). The photovoltaic panel covered three 150 Wp , 1000 W inverter and 200 Ah batteries, and a suitable SCC. On the other side, the apparatus of refrigerator prototype and position of temperature and pressure measurements is shown in Figure 2(b). The refrigerator cycle and the temperature data stage points refer to Figure 1. There are two extension coils, first in the super-heat area to ensure the refrigerant is in excellent superheated condition before enter the compressor. Second, after the compressor to lower the high pressure superheated temperature (internal cooling) to keep the process close to isentropic.

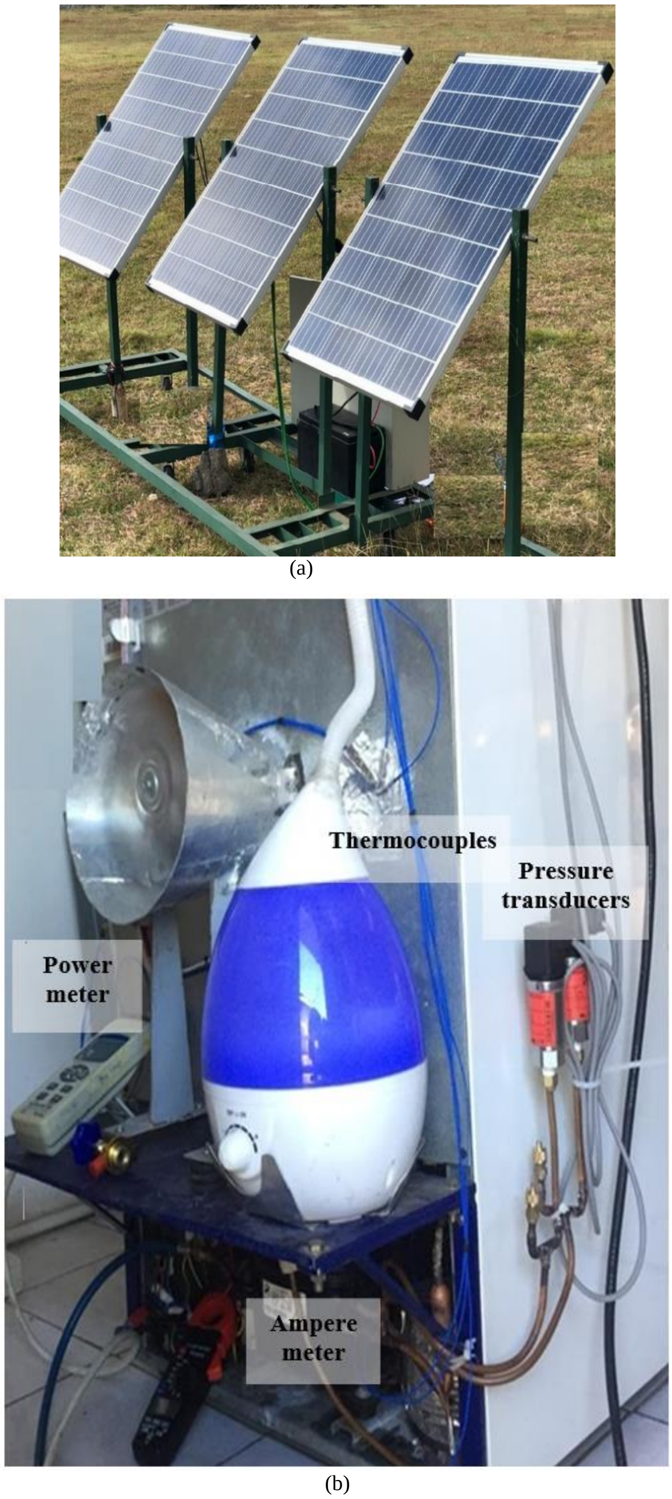

Fig. 2. Experimental set up: (a) photovoltaic array, (b) measurement position of the refrigerator prototype.

B. Procedures of Experiement

The solar panel is operated to produce an AC current input power. However the energy output from solar system is totally fluctuated, in this study the refrigerator investigated during the solar intensity is maximum, between 11.00 – 14.00 at local time.

The prototype refrigerator is designed for cooling fresh vegetables and fruit so that it can work in the medium temperature range, with the lowest temperature of 0ºC. The humidifier is designed using automatic control with the addition of a natural humidifier system. The high and low pressure lines are measured using pressure transduction connected to a data logger. Data has been logged in every 10 seconds.

In this preliminary study, the testing group was carried out under without and with a load. The cooling room temperature was set at 5ºC with humidity controlled at 85% RH. The second test is a load test that uses real vegetables to see the quality of the product after being stored in the refrigerator for a certain time.

C. Data Acquisition and Data Analysis

Login data every 10 seconds and save it on the laptop. All experimental data is imported into a spreadsheet for easier calculation and analysis using simple statistical methods. Data is tabulated in tables as well as in graphs. The calculation of the performance coefficient (COP) of the system uses a computer program @ Cool pack and is analysed under load and no load conditions.

III. Preliminary Results and Discussion

By using precise and detailed data retrieval, initial data has been obtained to measure the initial performance of the system. The data includes the temperature at each point or state which represents the vapor compression refrigeration cycle. Thus this data is sufficient to determine system performance such as superheated, sub cooled, isentropic efficiency and COP. Meanwhile, further optimization will be made and other test conditions will be developed. Temperature-based performance data, with test conditions with load and no load are shown in the following Figure 3 and Figure 4 as follows.

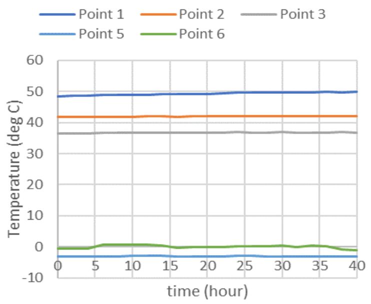

Fig. 3. Graph of performance data without load (room box temperature setting 5ºC).

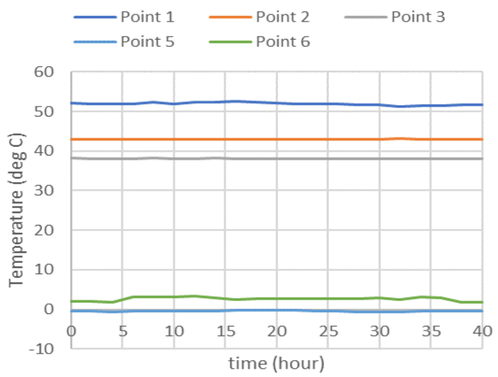

Fig. 4. Graph of performance data with load (room box temperature setting 5ºC).

From the data conditions, it can be seen that the compressor works very optimally so that data is taken while working only and the data is not shown as a whole (data on and off). Furthermore, the design of a better cooling room will be optimized, especially with higher insulation, so that the compressor load will be lighter to obtain more comprehensive data.

Performance data in the conditions mentioned above are obtained based on the calculation of the coefficient of performance (COP). From the results of calculations without load and using load, the theoretical COP and actual COP values are obtained:

Without load : theoretical COP 3.32, actual COP 3.29

With load : theoretical COP 3.26, actual COP 3.23

From the results of this COP, it can be seen that the system performance is quite good at 5ºC operating temperature conditions. And solar energy is fulfilled either directly or by means of batteries.

This experiment will be developed and continued by directly analysing the energy supply conditions of the solar power system. So that two systems will be analysed simultaneously in terms of energy supply and operating conditions of the refrigerator system. Furthermore, it will be able to compare the efficiency of the system with direct solar power and the refrigerator that uses solar power with an inverter and the refrigerator system is still an AC-based system.

IV. Conclusions

From the preliminary data obtained that the refrigerator prototype has worked well and the solar power supply can work continuously. The main indicator of performance, namely in terms of the actual COP obtained, which is an average of 3.2, it can be concluded that the refrigerator system already has a good COP. However, because these results were still preliminary results, the equipment will be developed with more comprehensive testing conditions, by expanding the operating temperature range, improving the control system with an analogue-digital system and developing system optimization to achieve a higher COP.

For further the future work will be continued with the solar panel data acquisition dan the will be built an DC refrigerator which can directly consumed the DC current from the solar panel without an inverter, and then will be analyzed in deep the comparison of efficiency between AC and DC refrigerator.

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