Comparative Analysis of Using Inverters in Solar Power System Display Cabinets

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Abstract. The use of solar power for cooling systems continues to be developed to obtain efficiency and cheap operations for food storage. In recent times or conventionally to keep fresh meat or fish in display cabinets usually use ice cubes. This condition causes a temperature more than 0˚C which can cause the product to submerge in cool water. Fresh fish and meat are not suitable for storage in this condition, so spoilage can occur and reduce the quality and hygiene quickly. This research is focused on a comparative analysis between refrigeration systems directly from solar power without an inverter (using a DC motor) and systems from solar power with an inverter (using an AC motor). The temperature range set is 0˚C to -5˚C with a precise control system. The comparative result is using AC compressor has a better Coefficient of Performance with 3.7 comparing 3.1 for AC compressor and DC compressor respectively, however, for the AC compressor using an inverter for the energy solar supply that causes lower electricity power efficiency.

Keywords: Comparative Analysis, Display Cabinet, Solar Power

1 Introduction

Cooling in the display cabinets compartment conventionally use ice cubes and water in order to keep the meat or fish still fresh. This way is not good for meat and fish storing characteristics, it can cause the meat and fish to quickly reduce quality and less hygiene, because of the average temperature up to 0˚ Celcius.

Li & Wang, (2016) summarize their study that, for the cold chain needs of the distribution of fresh fish and ivory as an energy source, it is still better to use conventional electricity for cooling with a large capacity. Meanwhile, solar power is very good for small capacities because the output power from solar or photovoltaic power fluctuates according to the conditions of sunlight. Gupta et al., (2014) and Biswas, (2023) developed stand-alone solar panels as an energy source for refrigerator systems, analyzed solar panel designs suitable for certain refrigerator capacities, and found that solar power was very suitable for refrigerator systems.

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From an economic aspect, the benefits of this system can be considered indirect benefits from the reduction of carbon dioxide emissions. So the initial subsidy program or reduction in component costs is very good for developing installations or using photovoltaics and batteries. Meanwhile, the coefficient of performance (COP) was found to decrease from morning to evening, where the maximum COP was found to be 2.1, however, this condition was still considered quite good.

Saha & Azad, (2024); Ouali et al., (2017) suggested that the government should provide incentives for the installation of renewable energy to support its development. In general, projects for 24 years economically must be given an incentive fee of 15% of the total investment. The investment is expensive because currently, the price of batteries is still expensive with a relatively short service life.

Daffallah et al., (2017); Daffallah, (2018) found that operating a 12 V DC refrigerator is greatly further efficient than operating 24 V with regular energy savings of 81.28 kWh/year. They investigated the performance of 12 V and 24 V DC photovoltaic refrigerators with and without loading at higher ambient temperatures. Opoku et al., (2016) obtained interesting results with a good and energy-saving method in terms of techno-economic comparative calculation of direct current (DC) refrigerators and alternating current (AC) refrigerators, both powered by photovoltaic (PV) systems. The results obtained were that both refrigerators maintained almost the same cabinet and evaporator temperatures, around 2 ºC and -10 ºC respectively.

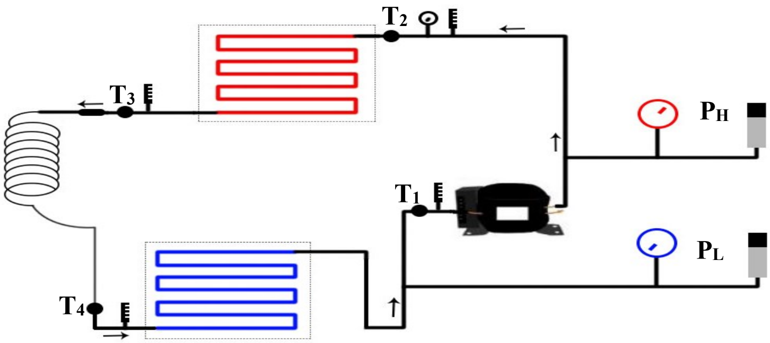
However, refrigerators with AC motor system need relatively high power and power surges compared to DC refrigerators. Meanwhile, The economic calculation found that DC refrigerators (without inverter) compared to AC refrigerators (with inverter), can reduce general system prices by 18%. In the DC refrigerator system with the variable speed method associated with the fixed speed mode, the cooling capacity of the variable speed mode improved by 32.76%, and the average PV utilization augmented by 45.69% (Su et al., 2020; Torres-Toledo et al., 2016). Furthermore, Salilih & Birhane, (2019) recommends that for stand-alone cooling using a solar PV system as an energy basis, it is more economical to use a DC refrigerator than an AC refrigerator (Uddin et al., 2021).

Wirajati & Santosa, (2024); and Santosa et al., (2024) developed an alternative cooling system to save energy where research has been carried out using solar power as an energy producer and as a heat producer to generate an alternative cooling system other than a cooling system using the vapor compression method, although this system still produces a low COP but has become one of the alternative solutions for the development of energy-efficient cooling systems.

From the explanation above, studies for developing cooling systems that use energy sources from solar power have not been studied in detail, so this research is very useful for producing energy-saving methods and clean energy for display cabinet cooling systems.

2 Methodology

The research design was carried out by making a prototype consisting of a solar power system, display cabinet system, and instrumentation and measurement system as shown in Figure 1. Data acquisition to determine system performance was carried out by measuring temperature (T) and pressure (P) in each condition. (state) refrigerator display cabinet cycle and refrigerant mass flow rate. For additional data as a whole system of solar energy sources and components, the electrical power, current and input voltage are also measured carefully. Product quality data is collected by measuring the temperature (T) of the compartment/cooling room.



Legend:

1.T_1 = Temperature at compressor inlet
2.T_2 = Temperature at compressor outlet
3.T_3 = Temperature at at condenser outlet
4.T_4 = Temperature at evaporator inlet
5.P_H = High pressure
6.P_L = Low pressure

Figure 1. Schematic diagram of measuring point on display cabinet

Data collection is carried out using standard refrigeration system testing procedures which are based on the thermal system performance of alternating current (AC) motors and direct current (DC) motors. In general, before starting to record data, first make sure that the machine's operating conditions are running normally. The measuring instrument has been validated and calibrated to obtain standard measurement results. Data collection is carried out by following the following testing procedures:

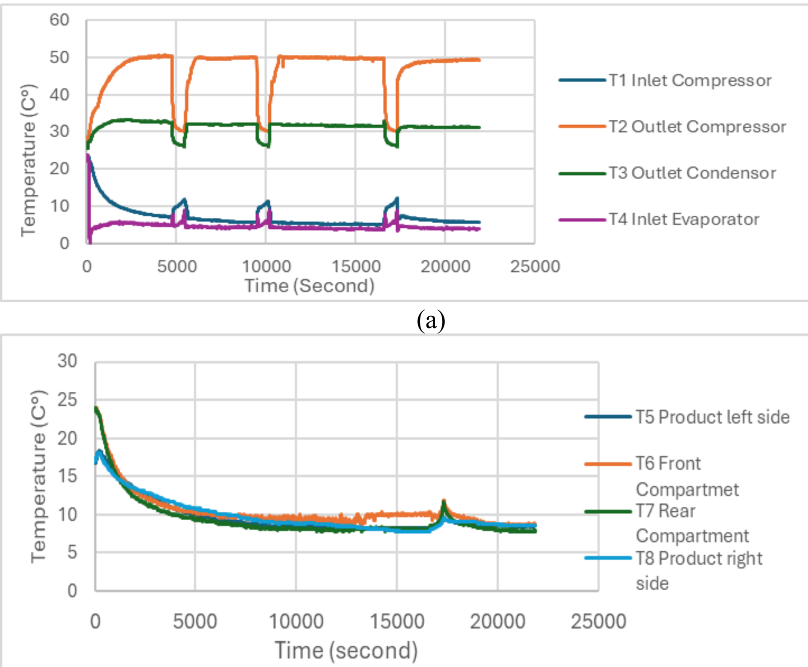
1. Prepare all instruments and other devices that are used for data collection.
2. Ensure that all equipment is working correctly
3. Connection of thermocouple properly, and also multichannel thermometer displays with data loggers.
4. Ensuring that all measuring tools are correctly connected at fixed points to get accurate results.
5. High and low-pressure measurements depend on position before and after the compressor line

Further analysis, to facilitate system performance calculations and component analysis as well as product quality, several computer programs are used, such as the Computation Fluid Dynamic (CFD) program, EES (Equation Engineering Solver), @CoolPack program, and Excel or spreadsheet programs. And comparative analysis is carried out by comparing data from AC refrigeration systems and DC refrigeration systems. The comparative analysis in this research is only limited to comparing the thermal performance of refrigeration systems and is shown with pictures and graphs. while solar power efficiency analysis will be carried out in future research.

3 Result and Discussion

3.1 Data Acquisition of The Study

The data from this research consists of two groups of data, namely data related to display cabinet systems with AC motors and DC motors with energy sources from photovoltaics. Further comparisons were made in terms of the coefficient of performance (COP) as well as analysis of additional factors related to energy sources from the sun. Test result data is shown in the following graphs.



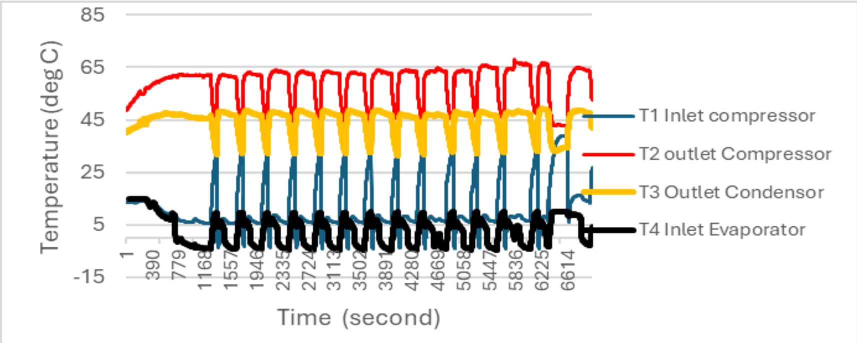
(b)

Figure 2. Temperatures state system Direct Current (DC) without inverter (a) temperatures at display cabinet state and (b) temperature at compartment/cabin and product

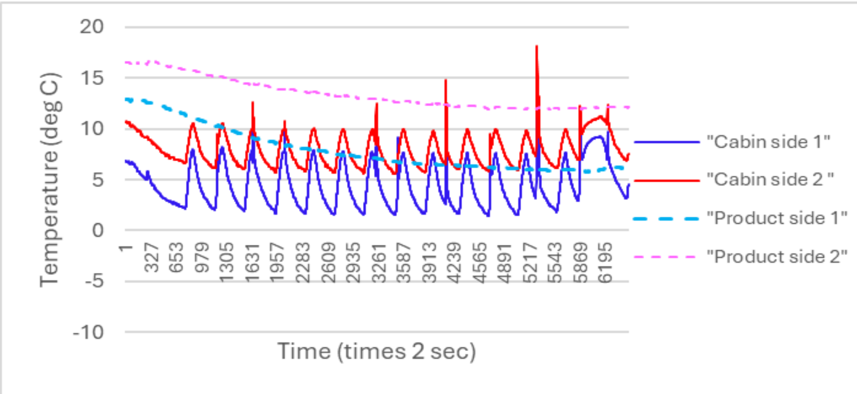
This test was carried out using the no-load method and using a chicken meat product load with a compartment temperature set at 5°C. The temperature data observed were the temperatures of the refrigeration system components and the temperature in the cooling room or compartment.

Figures 2 (a) and (b) above show the operating temperature of the display cabin system which is set at 5ºC and shows that the temperature in the display has reached 8ºC and there is a slightly higher temperature, especially at the front (farthest from the evaporite), this is normal. occurs in display cabinets that use transparent doors so that they have low isolation from environmental temperature. With these conditions, it is optimal to achieve low energy operations and temperature control can operate well.

Figures 3 (a) and (b) are tests carried out on the AC compressor system using a comparable method to obtain operational performance data in terms of performance temperatures in the refrigeration system and temperatures in compartments and products as in the following graph.



(a)



(b)

Figure 3. Temperatures state system alternating current (AC) using inverter (a) temperatures at display cabinet state and (b) temperature at compartment/ cabin and product

3.2 Performance Analysis

The performance analysis in this study is based on a comparison of the Coefficient of Performance (COP). Based on the data values obtained from the test results that have been carried out, the data can be plotted in a P-h Diagram with the help of the Coolpack application and validated manually to obtain other data, so we can find the COP value for each test data for both compressors. After the data is entered, namely pressure, temperature T1, T2, and T3, T4 the COP is obtained as follows (see Figure 4).

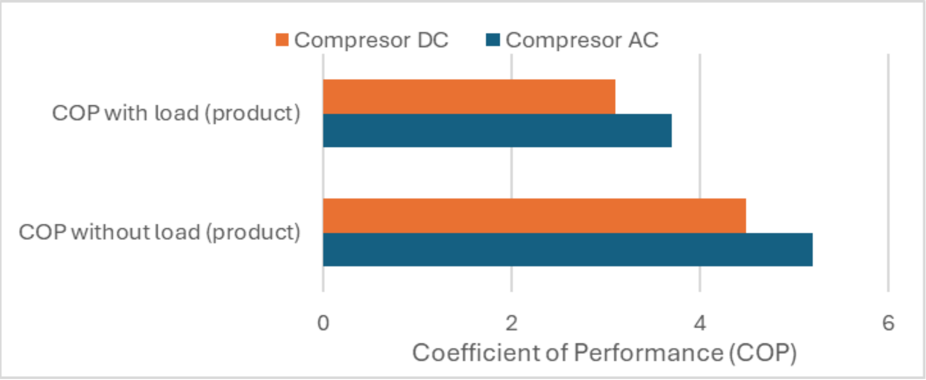


Figure 4. COP comparative between compressor DC and AC for display cabinet

Based on the graph above, it is explained that the COP that has better or higher efficiency is owned by display cabinet machines that use AC compressors, which have a COP of 5.5 with no-load testing and 3.7 with load testing, but display cabinet machines use DC compressors. has a COP of 4.5 from testing without load and 3.1 from testing with load. However, it does not require an inverter in the operational system, so it is more efficient in terms of solar energy supply.

4 Conclusion

In testing the display cabinet with both compressors, both using a load and without using a load, it can be said that both have good efficiency in terms of the COP obtained because the cooling in the cabin/compartment and the product is even. From the results of the analysis carried out, the theoretical COP results were obtained for the display cabinet machine using an AC compressor, with a theoretical COP load of 5.5 and without a theoretical COP load of 3.7. Meanwhile, the COP results of the display cabinet machine using a DC compressor with a theoretical COP load of 4.5 and without a theoretical COP load of 3.1. Display cabinet machines that use DC compressors experience a slight decrease in efficiency in terms of COP compared to display cabinet machines that use AC compressors. However, economically a display cabinet machine with a DC compressor can be said to be more efficient because it uses direct current (DC). After all, direct current directly supplies the display cabinet without using an inverter.

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