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ANALYSIS OF DISPLAY CABINET DESIGN WITH COMMISSIONING TEST FOR FRESH SEA FOOD

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Abstract. This research is a design of a display cabinet cooling system with integrated energy from PLN electricity and solar power. This equipment is used for displaying marine fish and other fresh sea food in restaurants or cafes in support of Balinese culinary specialties, namely grilled fish and seafood which are very well known and can be a very extraordinary carrying capacity for Bali tourism. This cooling system is designed to be able to maintain the temperature of the cooling room (cabin) up to -5 ^{o}C. This is in accordance with the standards for storing fresh sea fish and sea food in a temperature range of -2^{o}C to 2^{o}C, where fish and sea food are still in a very fresh condition for an average of 1 week. Other standards to maintain product freshness also require room humidity between RH 90% – RH 95%. Furthermore, data collection on system performance is carried out using the commissioning test method to determine the initial performance achievement of the tool so that its shortcomings can be evaluated which will be developed and corrected in further research. From the research, it is found that the temperature achievement is very good, the solar and PLN integration system with the Automatic Transfer Switch (ATS) control system has also worked well where the switch occurs when the battery charging condition is below 30% or below 10V. However, something that has not been achieved is the humidity in this system, the average relative humidity (RH) is 50% so that the final condition of the product becomes dry on the surface of the fish. This relatively low humidity is due to the fact that it still relies on the humidity increase system by opening the cooler cabin door. In the next development, the right humidifier system will be designed for this display cabinet system.

Keywords : Integrated energy, display cabinet, sea food, humidifier.

1. INTRODUCTION

At this time cooling in the display cabinet is done by adding ice to the meat or fish, when the ice starts to melt, the product will be submerged at a temperature of 0^{o}C or more. This condition is not suitable for the storage of meat and fish, so that there will be rapid spoilage of meat and fish which results in very low product quality and hygiene. On the other hand, the operation of the display cabinet still requires a lot of electrical energy so that the operational costs are relatively expensive. Because of the existing design, the display cabinet requires a relatively larger cooling load because of the high infiltration of the open display system. Another condition is that the electricity tariff (PLN) is quite expensive and in the future, it will be more expensive in line with the depleting supply of fossil energy. So, to maintain sustainability, as a tropical country, solar energy is a renewable energy for the future.

As a tropical country with abundant sunlight throughout the year with high intensity, solar power has the potential to be developed as one of the most effective renewable energies to be applied in various regions throughout Indonesia. On the other hand, electrical energy is getting more expensive than conventional generators from fossil energy. Meanwhile, the need for a cooling system for the storage of food ingredients, both fresh meat and fish, is urgent because of the abundant production. Thus, for the need for cooling engine propulsion, there has been much research on increasing the effectiveness and sustainability of solar power compared to conventional electrical energy. Santosa et.al [1] stated that Indonesia as a tropical country really needs a cold chain system for abundant horticultural and fishery products. Besides that, the cooling system (refrigeration) is very suitable for using solar energy as a very brilliant alternative energy. However, to maintain the quality of the stored product, it can remain fresh for a certain period, it is necessary to maintain a certain temperature and humidity with good refrigeration and humidifier technology. Chaomuang et al. [2] investigated the effects of operating conditions, including door opening frequency, ambient air temperature and product occupied volume, on the distribution of air and product temperatures in closed refrigerated display cabinets. Air infiltration due to door opening causes an increase in product temperature at the front and a decrease in temperature at the rear. At higher door opening frequencies (over 60 openings per hour per door), product temperature at the front center shelf level is most affected. The position of the product in the cabinet is a determining factor for its temperature: high temperatures are observed at the front, especially at the top of the cabinet, and low temperatures are observed at the rear. Both ambient temperature and filled volume also affect product temperature variations in closed display cabinets. Manson et al. [3] reviewed the modeling and optimization of supermarket refrigeration systems to food safety and customer modeling. It was found that the wastage of energy in the supermarket refrigeration system was caused by the frequency with which the display cabinet doors opened and other refrigerator systems. Li and Wang [4] stated that solar power is more appropriate to be developed for small capacity cooling systems that can be used as cold chains in remote areas. The system can be connected to the network or not depending on the condition of the existence of the network. At this time Photovoltaic (PV) has been applied to various cooling system capacities from a few kilowatts to several thousand kilowatts. As for the large capacity cooling system, it is better to use a power source from the state electricity network because the electricity output from photovoltaic fluctuates greatly. Gupta et al. [5] developed a stand-alone solar panel as an energy source for the refrigerator system and analyzed the appropriate solar panel design for a certain refrigerator capacity and found that solar power is very suitable for the refrigerator system. Bilgili [6], Modi et al. [7], Su et al [8] and Daffalah [9] state that a minimum initial subsidy of 15% is required to obtain a financial repayment period from the current system to the project's assumed life of 24 years and the system cannot survive economically without initial financial incentives or government subsidies, or a substantial reduction in the cost of more expensive components and a DC refrigeration system is more efficient than an AC system if it uses solar energy. Santosa et al [10] researched to improve the performance of the refrigerator system by improving the type of heat exchanger used and with better performance, the energy consumption of the ending system will also be lower.

To improve energy efficiency dan reduce energy losses especially as an effect infiltration and defrost, which freezing is the most damaging phenomenon to the efficiency. Frost accumulation blocks airflow, worsening cooling capacity and performance coefficient [11]. The thermal entrainment factor cannot be used randomly, although its use is suitable for designing better cabinets under the same climatic class conditions [12]. Installing doors on open-air refrigerated display cabinets is a simple and effective way to improve cabinet performance because it can reduce air entry warm and moist into the cupboard. Large unstable eddies develop in the mixing layer, thereby increasing the infiltration of larger external air. The model is then used to predict the effect of air infiltration through the door gap on the performance of closed display cabinets in both thermal and energy aspects. Applications in supermarkets were also observed that door opening is the main energy loss in display cabinets and in supermarkets a lot of waste is needed because many display cabinets are open [13,14,15]. In addition, Manson et al. [16] conducted an experimental study on the effects of operating conditions, including door opening frequency, ambient air temperature and product occupied volume, on the distribution of air and product temperatures in closed refrigerated display cabinets and obtained that this kind of operation cause significant energy loss.

From the above review, research on refrigeration systems with energy sources from solar energy is very important to conduct research in order to develop this system more efficient in future.

2. METHODS

This research is an experimental study on a prototype display cabinet system for storing fresh meat or fish with an integrated energy source from solar power. The design is based on the standard temperature for refrigerator storage (not frozen) to store fish and seafood at a temperature of -2.2 °C to 2.2 °C and a humidity of 90% -98% RH [17]. Thus the prototype is designed to be able to work up to -5 °C. The main components that are the focus of the design include:

1) Solar power system.
2) Solar and national *PLN* grid integration control system with automatic transfer switch method.
3) Display cabinet refrigeration system.

The calculation and analysis of system and component planning is assisted by on-line computer programs, namely: EES, Cool pack, PVSyst and Dancap. The commissioning test was carried out broadly, namely with the product load in the form of fresh fish which was stored for 6 days. In this commissioning test, the procedure consists of:

1) Test the characteristics of the temperature inside the cabin,
2) Temperature gain test and compressor on-off control
3) Achievement of air humidity (RH%).
4) Automatic transfer Switch (ATS) system performance and
5) Testing the characteristics of temperature and load quality of fresh fish products.

Measurements were made with a data logger system and temperature measurements with a precision of +-0.3 ºC, humidity measurements +-3% RH. while the performance data of each component of the support system is checked in a check list based on the design and planning that is planned for the operation of this system. The solar power system used is an integrated system with the national *PLN* grid. Product quality data was collected by measuring the temperature (T) and humidity (RH) of the cooling room. Overall analysis will be carried out to obtain system performance and product quality assisted by the @EES (Equation Engineering Solver) program, the @CoolPack program, and the spread sheet program. The results of the analysis will be shown with graphs and tables.

3. RESULTS AND DISCUSSION

Sea food storage needs for display cabinets on display for restaurants or cafes, especially for Balinese tourism supporters with the support of Balinese culinary specialties, spicy and fresh from quality seafood. Storage of fresh sea food ranges from -2.2 ºC to 2 ºC. From the results of the design, commissioning test and analysis analysis carried out, the following results were obtained.

3.1 Solar Power System (Photovoltaic) Design

Figure 1 shows a solar-photovoltaic power system consisting of a series and parallel photovoltaic circuit, Solar Charge Control (SCC), DC/AC Inverter and Batteries. In this system the output of solar energy is AC and DC current and can directly drive the display cabinet cooling system with AC current. The design of the solar power system begins with a simulation of the calculation of the capacity sizing of the components to be used, namely: solar panels (photovoltaic array), solar charge controller (SCC), batteries and DC/AC inverters. The balance of the capacity of each component is simulated with @spread sheet (excel) and the simulation is also assisted by the @PVSys software program. The simulation also considers the configuration of the solar panel arrangement, for example series, parallel or series-parallel combination and alternative battery voltage systems (e.g., 12V or 24V) to be implemented including the type and size of cable required.

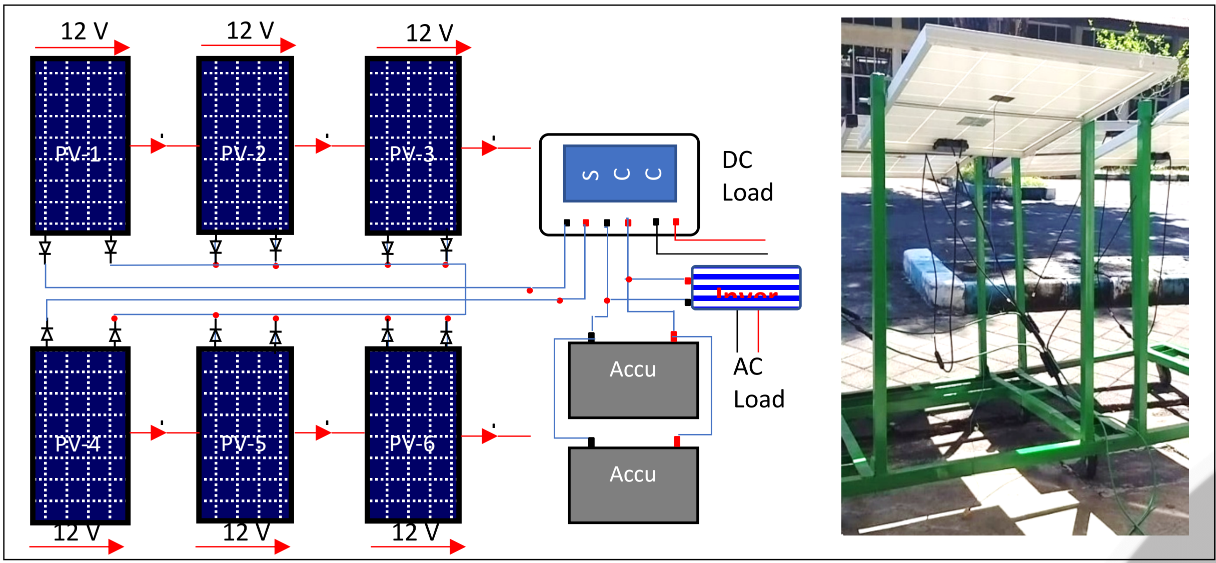

Figure 1. Photovoltaic array design

Photovoltaic arrays can be simulated according to the needs and the desired optimization. A combination of parallel, series, or parallel and series combinations of photovoltaic to obtain the desired current or voltage. Figure 1 also shows a photovoltaic designed to meet the electrical energy load of a prototype display cabinet. Meanwhile, the PVSyst software can be used to simulate off-grid PV mini-grid systems with a database of components such as solar panels, batteries, and SCC. The calculation results of component specifications are shown in Table 1 below.

Table 1. Summary of specification solar energy system

Components	Spesification	Amount	Capacity
Photovoltaic (PV)	- Rated Maximum Power(P_m) : 100W - Tolerance : +/-3% - Cell Efficiency : 16.93% - Voltage at Pmax (V_{mp}) : 17.8V - Current at Pmax (I_{mp}) : 5.62A - Open-Circuit Voltage (V_{oc}) : 21.8V - Short-Circuit Current (I_{sc}) : 6.05A - Series Fuse Rating(A) : 12 - Number of bypass diode : 2 - Dimension(mm) : 1000x670x30mm	6	600 WP
Solar Charge Control (SCC)	Minimum capacity 47,2 A	1	30 A
Inverter	Minimum capacity = 912,6 W	1	1000 W
Batterei	Minimum capacity 198 Ah	2 @100Ah	200Ah

The design of the photovoltaic system is designed to meet the experimental test results for the development of a display cabinet cooling system prototype. The photovoltaic design is an integrated system between the solar power system and the PLN electricity network with an Automatic Transfer Switch (ATS) mechanism that will switch automatically if the battery voltage in the solar power circuit drops to 10V or charging below 30%.

3.2 Display Cabinet Prototype Design

For the design of the display cabinet system, the main components have been designed which consist of determining compressor specifications, condenser capacity, evaporator capacity, capillary tube dimensions, cooling room volume which are designed to be tested continuously to get the best temperature and humidity conditions. Based on the specifications and capacity of the compressor, other major components are planned on the basis and assumptions as shown in Table 2 below.

Table 2. Data base of refrigeration design calculation

Database design	Base Value
Condesing temperature	45^{o}C
Evaporating temperature	-15^{o}C
Sub-cooled degree	2K
Super-heat degree	8K
Compressor	½ HP

By using the Engineering Equation Solver (EES), @Coolpack, and Dancap computer programs, the capacity of the main components is planned and adjusted to the capacity on the market, so that the specifications for the main components are obtained as shown in Table 3 as follows.

Table 3. Calculation result of refrigeration main component

Main Components	Capacity
Capacity of Condenser	144 W
Capacity of Evaporator	100 W
Capillary tube	Length: 1,85 m, diameter : 0,61 mm
Volume of Cabin	1,2 m x 0,40 m x 0,40 m
Compressor	½ HP

3.3 Prototype and Commissioning Test of Display Cabinet

The results of the prototype display cabinet design are shown in Figure 2. The body display cabinet is transparent and slightly open so that the products on display are very clearly visible. The main components of this prototype consist of a display cabinet cooling system and a control panel consisting of a solar panel control and control for ATS (automatic transfer switch) which is also equipped with instrumentation for measuring current, voltage and power.

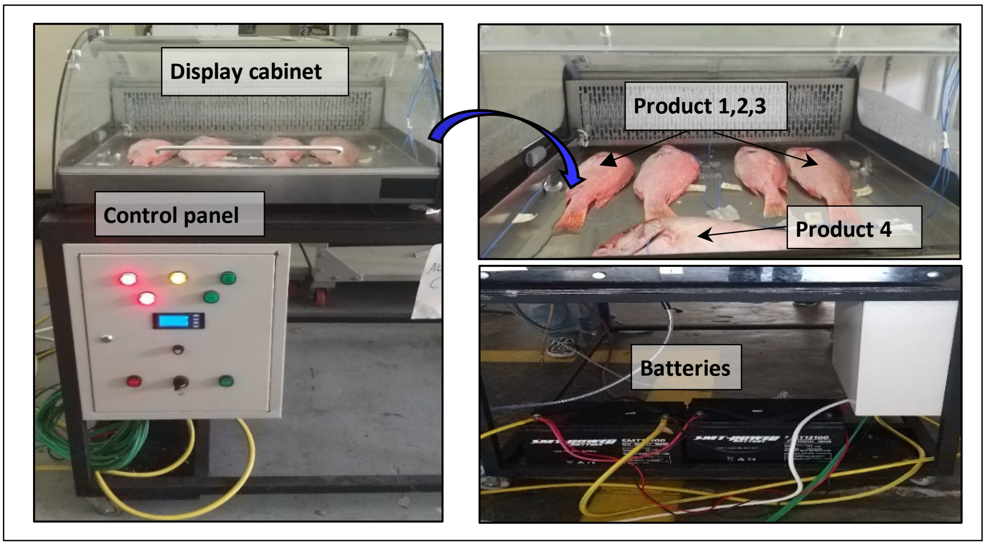

Figure 2. Prototype of display cabinet

The prototype was tested with high-pressure instruments such as a thermocouple with a precision of +-0.5K and a data logger that can retrieve data every 2 seconds. In the display cabinet cooling system, the temperature of each point in the system is measured, namely: point 1 at the compressor entry condition, point 2 to the compressor exit condition, point 3 to exit the condenser, point 4 to enter the capillary tube, point 5 to exit the capillary tube or enter the evaporator, and point 6 is evaporator exit condition. Where the temperature conditions of the commissioning test results are shown in Figure 3 below.

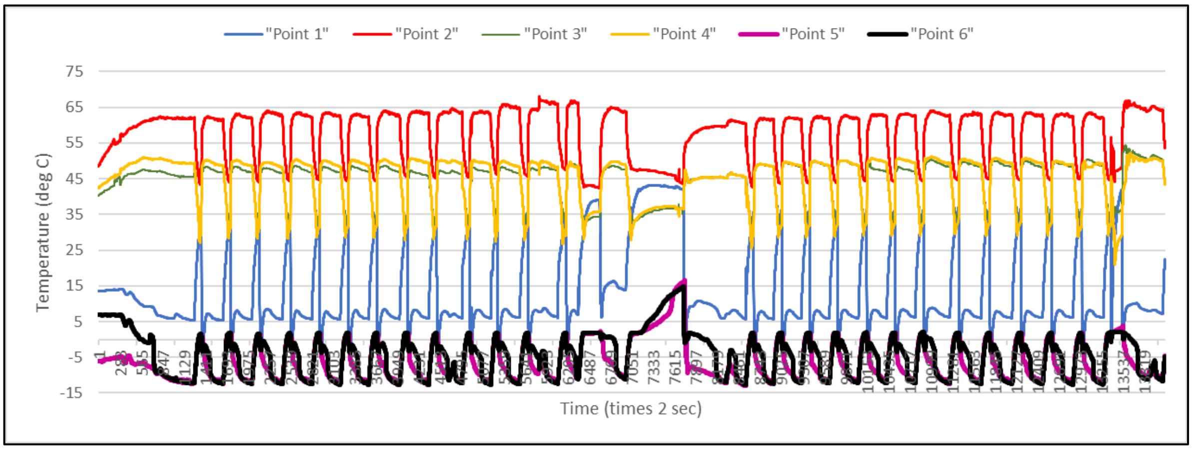

Figure 3. Temperature characteristics of refrigeration system

From the commissioning test results on the temperature of the display cabinet cooling system in Figure 3 above, it can be evaluated that the temperature has been achieved properly with continuous and stable compressor on and off conditions. Defrost occurs at the 4th hour operation (point 7333), during defrost it can be seen that there is an increase in temperature at point 5 and point 6 (temperature evaporator) up to 12^{o}C. While the temperature conditions in the condenser are still stable. It can be evaluated that the temperature gain performance of the display cabinet system is very good.

Testing the temperature of the product and the space stored in the form of fresh fish is shown in Figure 4. The commissioning temperature test data (T) of fish while it is stored in a display cabinet is placed in four positions, namely product 1, product 2 and product 3 in a lined position near the evaporator and product 4 in a position further ahead of the evaporator (see Figure 2). Product 1 to product 3 gets the same temperature while product 4 experiences a temperature of approximately 5^{o}C higher. While the display cabinet cooling room was measured in two positions, that is side 1 and side 2, where position 1 was closer to the evaporator and obtained a different temperature of approximately 3^{o}C. The relative humidity (RH) of the cooling room was measured separately with a special hygrometer and the average humidity in the cooling room was 50% even though the display cabinet door was opened periodically every 1 hour for 10 seconds. And from the evaluation with this method has not been able to get the desired humidity of at least 90%.

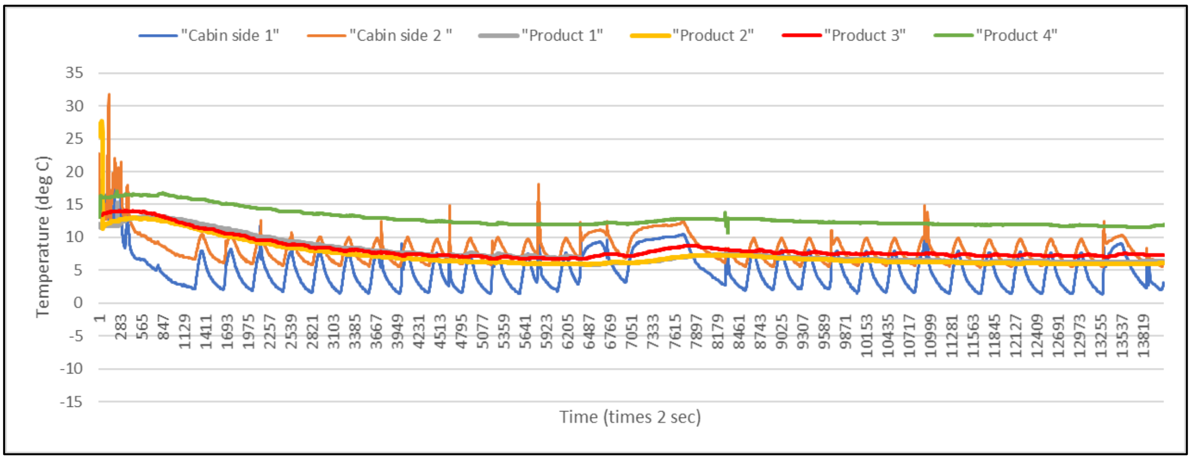

Figure 4. Temperature characteristic of cabin and products

From the analysis of fish products stored for 6 days in a display cabinet in general, it can be seen that the fish is still fresh with good quality (from the color of the gills, the smell and the suppleness of the meat). However, the upper fish skin is a little dry because of the lack of moisture in the display cabinet cooling chamber. This will be the focus of attention in further research, namely by developing a humidifier system that is suitable for display cabinets for storing fresh fish.

4. CONCLUSION

Based on the standard cold storage conditions in the display cabinet, it was stated that the conditions for displaying fresh fish were carried out at a temperature of -0.6 °C and 95% humidity to be stored for 1 week. From the results of this design, the temperature has been achieved very well but the optimal humidity has not been achieved, where the humidity achieved has only reached an average of 50%RH. From the results of the analysis found that the natural way alone has not been able to produce the desired moisture. From the results of the analysis of the product (fresh fish) stored in this prototype display cabinet, the conditions were hygienic and there was no spoilage during cold storage in the display cabinet. However, the product in dry conditions is less gentle on the upper skin surface. In future research, this weakness will be improved by adding a humidifier system. Meanwhile, the ATS system for the integration of solar and electricity from PLN has worked well and resulted in an excellent integration of energy sources to be developed in tropical countries, such as Indonesia.

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