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Development Of Hybrid Air Conditioning As An Air Cooler And Clothes Dryer Using Solar Power

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Abstract:

The human need for clean and dry clothes cannot be separated from the washing and drying process. Drying clothes with sunlight has limitations because it depends on the weather. This study aims to design a clothes dryer that utilizes waste heat from AC (Air Conditioner) condensers in homes and buildings.. Currently, solar powered air conditioning machines have experienced increasing progress because air conditioning systems are almost a must in every building in Indonesia. Indonesia is a tropical area that can receive sunshine all year round. This study examines the design and performance of a solar powered air conditioning system integrated with a photovoltaic (PV) system consisting of PV panels, solar chargers, DC power controller/inverters and batteries. This air conditioning system can be used in areas without electricity. The first step in this study is the calculation of the cooling load for the space to be conditioned and it is obtained about 1 ton of refrigeration (3.52 kW). Based on this cooling load, a photovoltaic (PV) system has been estimated and built with the necessary connections. A data logging system has been used to measure the temperature at the main components in the cycle such as the inlet and outlet of the compressor as well as the evaporator and condenser. The input power for the system and the coefficient of performance (COP) for the system under Indonesian climate conditions are measured throughout the day. The coefficient of performance varies from 2.9 to 8.5 for the system and these results are compared with the performance of a conventional system.

Keywords : Solar Energy, Solar Panels, Air Conditioning Machines, Clean Energy

I. INTRODUCTION

Washing is an essential need for everyone, as is drying. In the modern era, single-tub washing machines have been equipped with a dryer feature that can immediately dry clothes after washing. However, for washing machines without this feature, the drying process takes longer, especially when using solar energy as a heat source. The main disadvantage of this method is the unpredictable weather factor, especially during the rainy season. Drying clothes in direct sunlight also has several disadvantages, including dependence on the weather, the risk of fading clothes colors, and time constraints. [1] In the past, sunlight was the only way to dry clothes. Now, with advances in technology, dryers that produce heat have become the main choice. This has encouraged the creation of various types of increasingly sophisticated clothes dryers. [2]

Drying can be defined as the process of separating water from a material using heat energy. This process involves the simultaneous transfer of heat and water vapor. Heat energy is used to convert water in the material into water vapor, which is then removed from the surface of the material. The medium used for this process is generally heat. Drying is done to remove some or all of the water contained in the material. Evaporation is the core of the drying process, where water in the material is evaporated by providing heat.[3]

Drying is basically the process of moving a liquid from a solid object. The most common liquid transferred is water. Solid objects that are dried can vary, such as wet clothes after washing. In this example, the fabric acts as a solid and the water contained in it acts as a liquid. Water content is an important measurement in materials, indicating how much water is contained in them. Usually expressed as a weight percentage of water to wet material (wet basis water content) or grams of water per 100 grams of material. Dry or solid weight is calculated after heating the material until its weight no longer changes, it is the same as before washing or wetting it with water.[4]

Temperature	Maximum Temperature	Types of Clothing
Low	131°F (55°C)	Wool, Nylon and Fine
Currently	150°F (65°C)	Tops, T-shirts, Jerseys and Shirts
Tall	167°F (75°C)	Jeans, Towels

Each type of clothing has a different heat resistance. Most clothes dryers reach temperatures of 100°C. Cotton and synthetic clothes can be heated up to 120°C, but it is not recommended to exceed this temperature because of the risk of burning. To avoid damage such as fading or stiffening, choose a dryer temperature that is appropriate for the type of fabric.[5]

References for dryer temperatures based on fabric types can be seen in Table 1. Refrigeration is a process of absorbing heat from a substance or product so that its temperature is below the ambient temperature. A refrigeration machine or also called a cooling machine is a machine that can cause the refrigeration effect, while a refrigerant is a substance used as a working fluid in the heat absorption process [6]. Various efforts have been made to develop a system that uses the principles of refrigeration and heat pumps in one machine. In this integrated machine, the cooling effect and heating effect can be produced and utilized simultaneously, so that the machine's efficiency becomes higher. This integrated machine with dual functions is known as a hybrid air conditioning machine, because most air conditioning machines operate with a vapor compression cycle, so this machine is called a hybrid vapor compression cycle air conditioning machine [7].

The clothes dryer machine uses a ½ PK Air Conditioner. This air conditioner has two important functions, namely as a cooler and heater, where the heat generated by the condenser is used as a heat source for drying clothes. The condenser operates at higher pressure and temperature, the heat transfer process that occurs in the condenser is in principle the same as the evaporator. Both involve changes in the refrigerant phase. The design of the condenser is influenced by the specific gravity of the refrigerant, the type of refrigerant used in this study, namely R-22, temperature and the density of air entering the condenser. In this design, the condenser temperature is 45˚C with a condenser load of 2.3404 kJ / s. The material used in the condenser design is a copper pipe with a total length of 20 m and 30 passes. So the length of the condenser in this design is 0.66 m with a heat transfer area of 0.14 m² [8].

Testing of clothes dryer machine engineering by utilizing AC condenser waste heat to dry clothes. The study was conducted within 30 minutes of drying time. The clothing material used in the study was 100% Cotton + 100% polyester with a wet mass of 0.440 kg and a dry mass of 0.330 kg. The results obtained from this study obtained the mass of dry clothes in the 13th minute with a drying rate of 0.0085 kg / s. The conclusion obtained that the use of condenser output for drying clothes is very beneficial for the utilization of wasted condenser heat [9].

Hybrid air conditioning machines have the advantage of increasing the efficiency of energy use, but because both sides are utilized, changes on one side are expected not to disrupt the process on the other side, so they are generally equipped with additional components in the form of a dummy condenser as a water heater [10].

By utilizing both sides, hybrid air conditioning machines can make efficient use of electrical energy and can reduce the impact of global warming from the use of waste heat as a clothes dryer.

II. METHOD

2.1. Experimental Equipment To conduct this experiment, a drying cabinet with a volume of 1.5 m3 is required to be designed and made. The drying process utilizes waste heat from the condenser of a split-type cooling machine. The cooling machine used in this study is the size of a household AC with a capacity of 6000 BTU which is commonly used for rooms measuring 4 m-5 m-3 m in Indonesia. The conditioned room is a laboratory room with dimensions of 4 m-5 m-3 m. The adjacent rooms on the south, west, and north walls of the room are not air-conditioned. The east wall is open to solar radiation. The cooling load in the room comes from two 100 W fluorescent lamps, one computer, and 5 laboratory assistants. The heat from the condenser of the cooling machine is channeled into the drying cabinet. The dimensions of the drying cabinet are 875 mm-850 mm-1600 mm. Made of aluminum plate. To reduce heat loss from the drying cabinet, the walls are insulated using 20 mm thick glass wool. Glass wool is placed between the inner and outer aluminum plates.

For electrical energy in this study using solar energy by using 3 units of solar panels with a capacity of 240 Watts each. The battery used has a capacity of 200 mah. The Solar Charging Controller used is 60 A. As well as a 2500 watt inverter.

An analysis was conducted to calculate the total thermal resistance of the drying cabinet, which was 0.746 W/m K. The schematic diagram of the drying cabinet and the outdoor unit of the refrigeration machine is shown in Fig. 1. The drying cabinet was located in a non-air-conditioned room. The maximum and minimum average dry air temperatures at the experimental site were 45.9°C and 19.9°C, respectively. The test was conducted using cotton clothes of size L and M with two variations of the number of clothes: 10 clothes and 20 clothes. The test was conducted at a room temperature set at 22°C, a common room temperature with a refrigerated machine for cities in Indonesia. Each experiment began at 08.00 am. Initially, the refrigeration machine was operated with an empty drying room for 30 minutes, which is called the dwell time. After the dwell time, the wet clothes were placed by hanging them in the drying room. The experiment began and all temperatures, weights, electric currents, and electric voltages and hot air speeds were measured and recorded using a data acquisition unit.

2.2. Design and Sizing of the Air Conditioning System

The air conditioning unit has been selected with the following specification: unit capacity 5000 BTU/h 0.390 kW split unit, 220 V, input power 0.950 - 1.250 kW to provide the suitable COP

2.4. PV System Sizing and Material Selection

Based on air conditioning unit capacity that has been selected under West Sumatra Indonesia climatic conditions and the data collected, where the intensity of solar radiation about 1.9 – 6.5 kWh/m, the PV solar-powered system specifications can be selected and designed.

Nowadays, solar-powered air conditioning has witnessed an increased progress because air conditioning system is almost a must in every building in Saudi Arabia where the outside temperature in summer is higher than 42˚C. Al Madinah Al Munawwarah is one of the important holy places in the world, and therefore, this paper investigates the design and performance of solar-powered air conditioning system integrated with photovoltaic (PV) system which consists of PV panels, solar charger, inverter and batteries. This air conditioning system can be used in non-electrified areas near AlMadinah where the cost of electricity for this area is very high. The first step in this project is the cooling load calculations for the selected space that will be cooled and it was found about 1 ton of refrigeration (3.52 kW). Based on this cooling load, the photovoltaic (PV) system has been estimated and built with the necessary connections. The data logging system has been used to measure the temperatures at the main components in the cycle such as compressor inlet and outlet as well as evaporator and condenser. The input powers for the system as well as the coefficient of performance (COP) for the system under AlMadinah climatic conditions were measured along the day. The coefficient of performance varies from 2.16 to 4.22 for the system and these results compared with the conventional system performance with a good agreement.[26].

2.5. PV System Installation and Connections

After the material selection for PV panels, batteries, charge controller and inverter then using suitable basement, cabinets to protect the system, the frame for the panels designed at an optimum tilt angle, the system is installed with the help of technical asshown in Fig 1 whichexplain the actual final cycle that includes the air conditioning unit and power supply system that can be used at any time; the system has been tested for 8 hours per day with a full capacity.

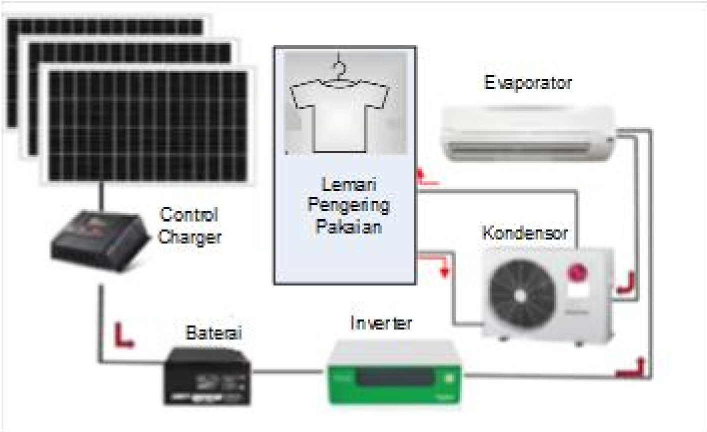
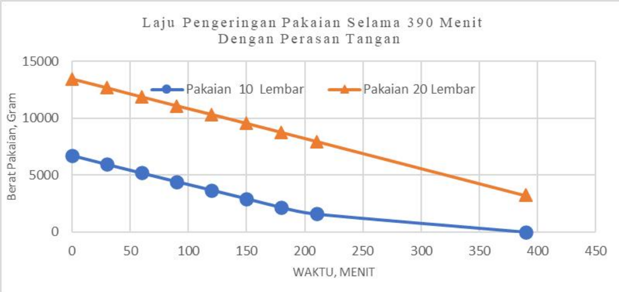


Fig 1. Installation of Hybrid Refrigeration Machine Testing Equipment for Clothes Dryer

3. Results and Discussion

The most common type of air conditioning is technically referred to the vapor-compression refrigeration system. The operation of the air conditioning system starts when the refrigerant flows across the evaporator inside the space to absorb heat. The refrigerant that went into the evaporator leaves as vapor. Then, the low pressure and cool vapor is taken outside and compressed by the compressor to become a hot, high pressure gas. The compressor is electrically operated and can be described as the heart of the air conditioning system as it pumps refrigerant throughout the system. The main function of a compressor is to compress refrigerant vapor to a high pressure, making it hot for the circulation process. Next, the hot vapor passes through the condenser and gives off some of its heat as out-door air is blown across the condenser coil. The warm liquid is carried back to the evaporator to repeat the cycle again.

Based on research, the drying machine has been proven to be able to work optimally.



Figu 2. Drying rate of clothes for 390 minutes manually wrung out by hand

Fig 2. Shows a graph of the clothes drying process for 390 minutes. This graph illustrates the relationship between the mass of wet clothes and the drying time for the hand wringing and washing machine wringing methods. At the beginning of drying, the drying rate is fast. Over time, the drying rate gradually slows down until it reaches the initial dry weight of the clothes. The results show that the washing machine wringing method takes 90 minutes to dry clothes, while the hand wringing method takes 210 minutes.

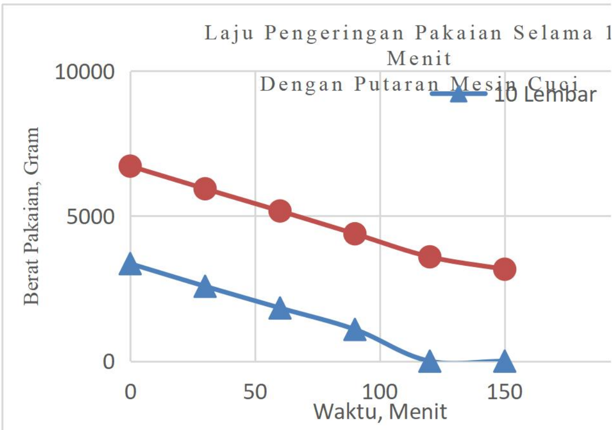


Fig 3. Drying rate of clothes for 150 minutes dried by washing machine.

Fig 3. Shows the time required to dry clothes in 150 minutes. The drying time is influenced by the initial condition of the clothes before entering the drying room. The less water left on the clothes, the faster the time required to dry them. The spinning method of the washing machine produces clothes with a lighter initial weight, so the drying time is shorter.

In this study using solar panels or Photovoltaics. The value of solar intensity depends on weather conditions at the research location.The solar intensity value obtained is highly dependent on weather conditions at the time of testing. The rise and fall of the solar intensity value is influenced by weather conditions and the thickness of the clouds that block the sun as shown in Fig 4.

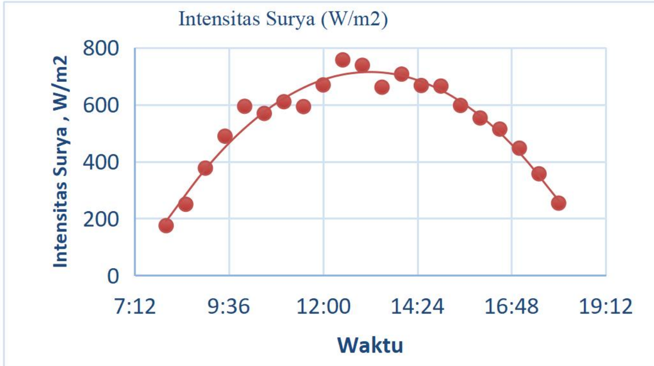


Fig 4. Solar intensity value against time

The voltage and current values produced by solar panels are directly proportional, where if there is a decrease in voltage, the current produced will also decrease in value. This is influenced by the value of the sun's intensity captured by the solar panel, which can be seen in Fig 5.

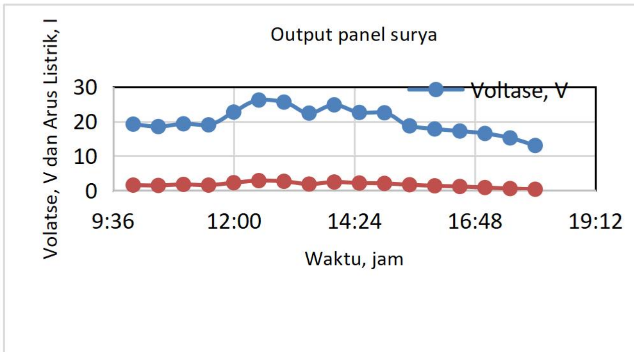


Fig 5. Solar Panel Voltage Value Against Time

The value of the electric voltage that comes out of the solar panel charger control remains at 13 Volts in a straight line, while the electric current produced varies slightly. This is influenced by the value of the sun's intensity captured by the solar panel, which can be seen in Fig 5.

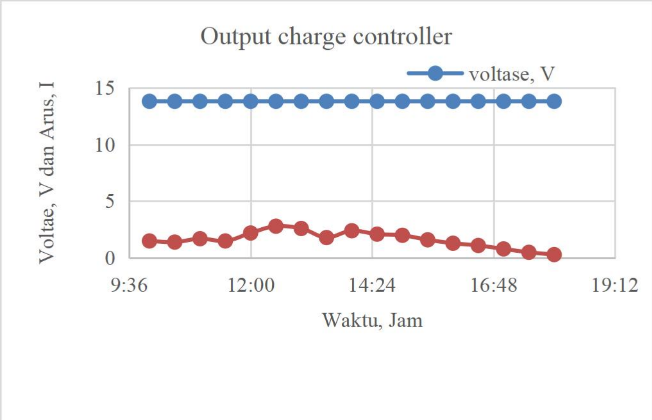


Fig 6. Voltage and Output Current Values of Control Charger Against Time

In Fig 6.it can be concluded that the decrease in COP and EER values against the test time is caused by a decrease in the calorific value absorbed by the evaporator. The decrease in value makes the temperature of the test room low. Where at the beginning of the test the COP value was 8.5, the EER value was 28.7, the test room temperature was 28°C while at the end of the test the COP value was 2.9 and the EER was 9.7 at a room temperature of 22°C for 7 hours.

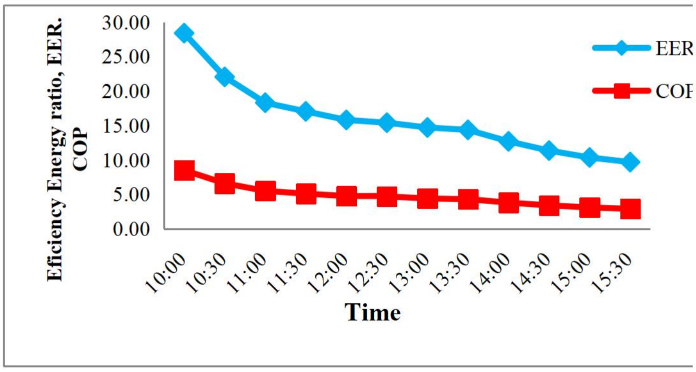


Fig 7. Efficiency Energy ratio, EER and COP

In Fig 8. there is a decrease in the COP value against the test time caused by a decrease in the calorific value absorbed by the evaporator. The decrease in value makes the room temperature low. Where at the beginning of the test the COP value was 8.5 at a cooled room temperature of 28 OC while at the end of the test the COP value was 2.9 at a room temperature conditioned at 22 OC.

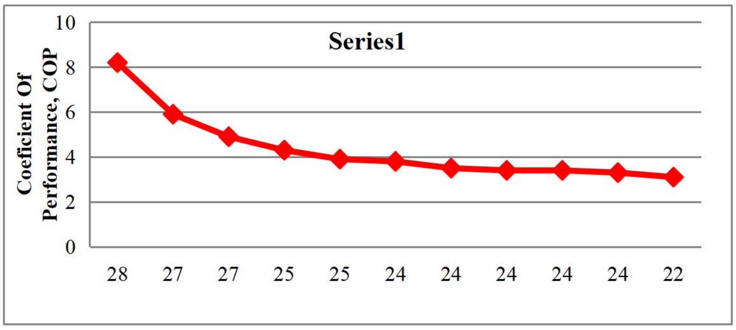


Fig 8. Coefficient of Performance, COP with Room Temperature

Research on a hybrid air conditioning machine with a capacity of 1 hp as a room air conditioner and can also produce hot water with a maximum hot water temperature of 88.5 OC in 6 hours, with a water volume of 100 liters.

Fig 9 shows the coefficient of performance (COP), hybrid air conditioning machine. In this Fig can be seen the actual coefficient of performance (COP) performance (COP) C and Rankine (COP) R. With increasing temperature (TCO-TEV), the value of the three COP parameters decreases. The value of the actual coefficient of performance (COP) A is in the range of 2.99 to 4.21, the value of the Rankine coefficient of performance (COP) R with a range of 7.29 to 9.96, and the value of the Carnot coefficient of performance (COP) C with a range of 8.87 to 11.35.

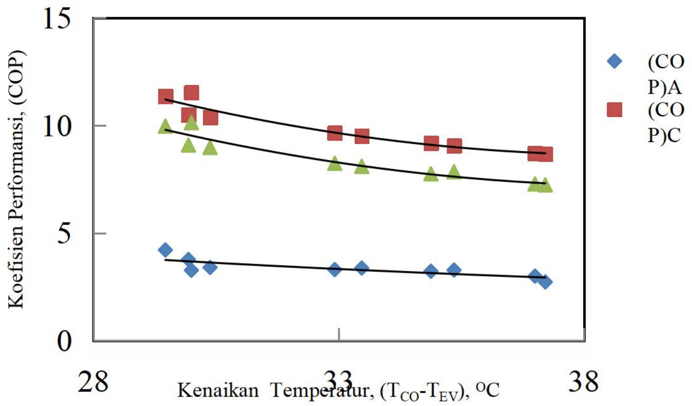


Fig 9. Coefficient of performance (COP) with temperature rise, (TCO-TEV).

The heat released by the condenser Qkon, the heat absorbed by the evaporator QEvap and the work or power of the compressor WKomp of the hybrid refrigeration machine studied are as shown in Fig 10. The compressor power increases slightly with the increase in temperature in the range of 1.12 to 1.27 kW. The heat absorbed by the evaporator is relatively stable at an average of 1.721 kW. While the heat released by the condenser decreases with the increase in temperature of the hybrid refrigeration machine in the range of 4.39 kW at a temperature increase of 30 OC and 3.45 kW at a temperature increase of 37.4 OC.

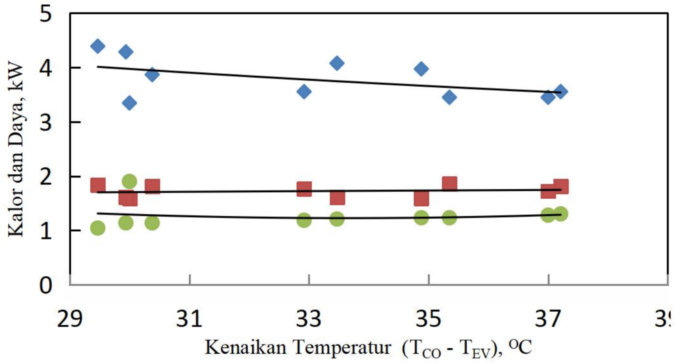
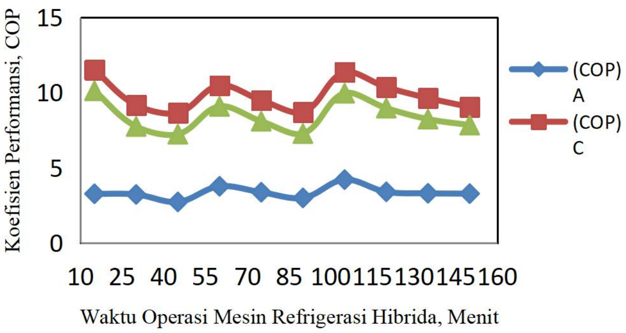


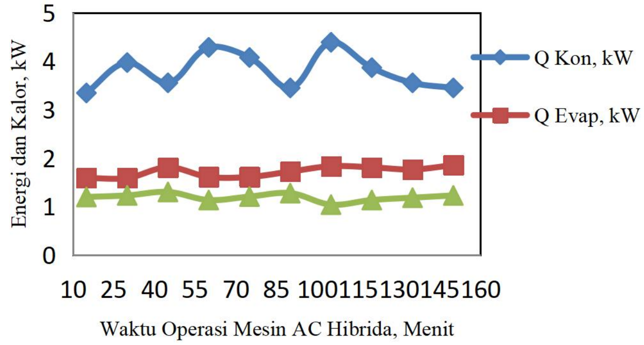
Fig 10. Heat and power, kW of a hybrid refrigeration machine with increasing temperature, (TCO - TEV), OC.

Coefficient of Performance, COP of hybrid air conditioning machine, air cooler and clothes dryer with time variation can be seen in Fig 11. The actual coefficient of performance of hybrid air refrigeration machine, (COP) A average of 3.35. The coefficient of performance of hybrid air refrigeration machine Rankine, (COP) R average of 8.46. And the coefficient of performance of hybrid air refrigeration machine Carnot, (COP) C average of 9.85.

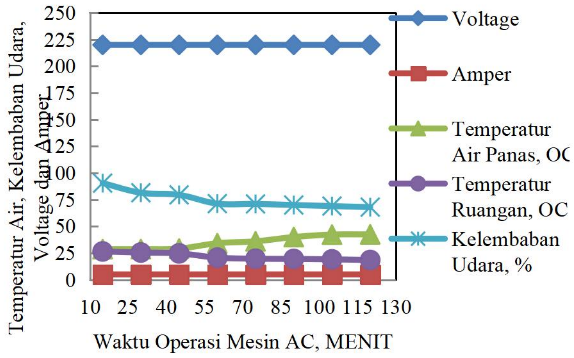


Gambar 11. Koefisien Performansi, COP Dengan Waktu Operasi Mesin Refrigerasi Udara Hibrida

During the operating time of the hybrid air refrigeration machine for 150 minutes, the average compressor power value is 1.195 kW, the amount of refrigeration effect or heat absorbed by the evaporator is an average of 1.72 kW and the heat released by the condenser is an average of 3.79 kW as can be seen in Fig 12.

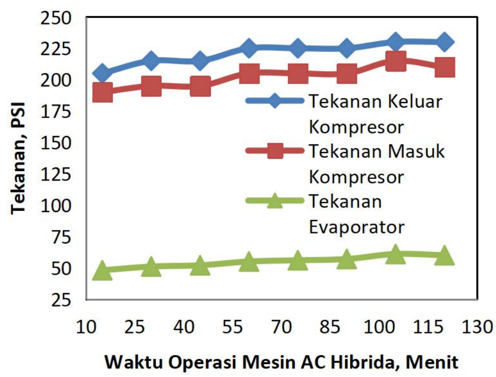


Gambar 12. Daya dan Kalor vs Waktu Operasi Mesin AC Hibrida



Gambar 13. Temperatur, Voltage, Amper vs Waktu Operasi

The working pressure of the compressor and the condenser pressure and the pressure in the evaporator can be seen in Fig 14. below. The working pressure of the hybrid air conditioning machine studied is 40 psi to 60 psi, the initial pressure of the working fluid entering the compressor is 190 psi to a maximum pressure of 210 psi, and the initial pressure of the R-22 refrigerant exiting the compressor is 205 and the final pressure of this working fluid is 230 psi.



Gambar 14. Tekanan dengan Waktu Operasi Mesin pengkondisian udara Hibrida

In Graph 14. Comparison of time to water temperature with water volumes of 10, 20, and 30 liters of water in the heating tank is shown in Fig 14. Of the three water volumes, when compared to the test time at a volume of 10 liters, the high water temperature is 66.6 at 120 minutes of testing. And℃at a volume of 20 liters the water temperature for 120 minutes reached 52.6℃.

6. CONCLUSION AND SUGGESTIONS

6.1 Conclusion

This research focuses on the design, construction, and performance testing of a solar-powered air conditioning system integrated with a photovoltaic (PV) system and applying it to Indonesian climate conditions.This research is a solution to reduce electricity needs throughout the year and can be used efficiently in remote areas where electricity is not available.

In the research that has been done, the intensity of the sun has an effect on the use of solar panels as an energy source to drive the cooling machine. The amount of current and voltage entering the battery depends on the intensity of the sun received by the solar panel.The intensity of the sun depends on the time and the sunny weather during the day. There are several characteristics that must be considered to be known both in the solar panel system and in the air conditioning system such as electrical equivalent, characteristic curves, and factors that affect the output of solar panel cells.

In terms of the efficiency ratio value between solar panels and electricity from PLN, it is stated that the EER value from PLN electricity is higher, which indicates that the performance of the cooling machine is more optimal.

The maximum solar intensity was obtained at 757 watts at 12.45 WIB, decreasing towards the afternoon to a minimum of 254 watts at 17.45 WIB. The average electric current was obtained at 4.825 Amps and the average electric voltage was 224.125 Volts.

Energy Efficiency Rating, maximum EER was obtained at 10.00 WIB of 28 and the performance coefficient value, COP was obtained at 8.5 at 10.00 WIB and decreased to 3.5 at 15.30 WIB in the afternoon.

The results of the research on clothes wrung out manually by hand, the drying rate of 10 sheets of clothes with an initial weight of 3360 grams, after drying for 210 minutes, the weight of the clothes was the same as the initial weight of 1588 grams. For drying 20 sheets of clothes, the drying rate starts from the initial weight of 1588 grams.13440 grams and final weight 3183 grams with a time of 390 minutes.

For clothes dried by spinning the washing machine for 20 pieces of clothing, the initial weight is 6720 grams, the final weight is 3166 grams in 150 minutes. While for 10 pieces of clothing, the initial weight is 3360 grams, over time the drying weight of the clothes decreases, finally in 90 minutes 1092 grams.

The results of the research that has been done obtained the Performance coefficient of the hybrid air conditioning machine, as follows, the average value of the actual hybrid air refrigeration machine performance coefficient, (COP) A = 3.35. The average value of the Rankine hybrid air refrigeration machine performance coefficient, (COP) R = 8.46. And the average value of the Carnot hybrid air refrigeration machine performance coefficient, (COP) C = 9.85.

Suggestion

In this research, the electrical energy generated from solar panels cannot be directly used to drive the compressor of the air conditioning machine, AC. It must be stored in a battery used as much as 1 battery unit with a capacity of 200 mAh. The solar panel units used are 3 units with a capacity of 200 WP each. For further research, it is recommended that the AC machine can be driven directly with solar power must increase the use of solar panels to 8 units each with a capacity of 200 WP.

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