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Performance Study of Air Conditioning System Using Solar Power Photovoltaic as Environmentally Friendly Alternatives

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Abstract:

Nowadays, solar powered air conditioning machines have made increasing progress as air conditioning systems are almost a must in every building in Indonesia. Indonesia is a tropical area that can receive sunlight all year round. This study examines the design and performance of a solar-powered air conditioning system that is integrated with a photovoltaic (PV) system consisting of PV panels, solar chargers, DC power controllers/inverters and batteries. This air conditioning system can be used in non-electrical areas. The first step in this research is the calculation of the cooling load for the space to be conditioned and obtained about 1 ton of refrigeration (3.52 kW). Based on this cooling load, a photovoltaic (PV) system has been estimated and constructed with the necessary connections. Data logging systems have been used to measure the temperature of the main components in the cycle such as the compressor inlet and outlet as well as the evaporator and condenser. The input power for the system as well as the coefficient of performance (COP) for the system under Indonesian climatic conditions are measured throughout the day. The coefficient of performance varies from 2.9 to 8.5 for the system and this result is compared with the performance of the conventional system.

Keywords — Solar Energy, Photovoltaic, Air Conditioning, Environmentally Friendly.

I. INTRODUCTION

Air conditioning (AC) is an air conditioning device that is used to create a comfortable room, air conditioner (AC) is used to provide cool and comfortable air in a conditioned room. increasing electrical energy. In office buildings, mosques, hotels, supermarkets, and even people's homes. The air conditioning machine (AC) uses an electric motor which consumes a large amount of electrical energy because it can be used for up to 24 hours. Saving energy by using alternative energy is one of the steps to reduce the negative impacts of the environment. To expand the use of alternative energy, it is necessary to introduce it in household life, so that the role of reducing environmental impacts is more realized. Renewable energy generators whose availability is not constant such as solar power, wind power, micro hydro, ocean waves, and tides are still underutilized AD Peanus et al [1]. Research on air conditioning systems that are energy efficient and environmentally friendly, because they use solar energy as a source of thermal energy and do not use refrigerant as the working fluid. This system is designed to meet the needs of the cooling space in the building, where this system results in energy savings of up to 80% compared to compressed gas air conditioning systems [2]. Nowadays, solar powered air conditioners have made increasing progress as air

conditioning are almost a must in every building in Saudi Arabia where the outside temperature in summer is higher than 42˚C. AlMadinah AlMunawwarah is one of the most important holy places in the world, therefore, this paper examines the design and performance of a solar-powered air conditioning system that is integrated with a photovoltaic (PV) system consisting of PV panels, solar chargers, inverters and batteries. This air conditioning system can be used in non-electrical areas near Al-Madinah where electricity costs for this area are very high [3]. The research focuses on the design and construction of an integrated direct current (DC) air conditioning system with a photovoltaic (PV) system consisting of PV panels, solar chargers, inverters and batteries. The air conditioning system can be operated by solar power and can be used in non-electrical areas. As we know, solar energy is cost-effective, renewable, and environmentally friendly [4]. Simulation research of air conditioning system using solar energy with single effect absorption refrigeration method, analysis of performance coefficient (COP) for each refrigerant absorber variable and comparing the effectiveness of each absorbent-refrigerant variable used. From the simulation results, it can be concluded that solar air conditioning can achieve 98.85% energy savings compared to commercial air conditioning. Furthermore, from the COP calculation, the highest COP value was achieved by a solar conditioning system with LiNO3-NH3 as the working fluid where 55% of the composition was refrigerant and 45% absorbent [5].

Solar PV Panel

The use of solar PV panels as electricity generators has become very popular in recent years. Solar potential is widespread in various regions in Indonesia so that the Indonesian government has launched a power plant in 2050. dominated by PLT Solar, PLT Biomass, and PLT Water. The development of PLTS cannot be separated from the components of solar panels. The problem with solar panels that often arises is that when the temperature of the panels increases, the efficiency of the solar panels decreases, so a cooling medium is needed. In this study, experiments on the effect of air conditioning on the surface temperature of the panel by utilizing a cooling box and a series of solar panels combined with a 12 V LED light load. The experimental results show that air cooling at a speed of 5 m/s can reduce the panel temperature by 21%, increase the output power and electrical efficiency by 7-10% and 0.3%, respectively. The higher the cooling air speed panel, then the surface temperature of the panel decreases. The higher the surface temperature of the panel, the lower the output power and electrical efficiency of the solar panel [6].

Experimental investigation to increase the output power of solar cells using cooling and reflection of light from mirrors. The results showed that by adding a mirror, the solar cell output current and power increased but the open circuit voltage and maximum power voltage decreased due to heat. By adding cooling, the open circuit voltage and maximum power voltage are increased, so that the output power also increases [7].

This research aims to provide a clear picture of the efficiency of using solar panels as an alternative energy source when compared to the use of generators as an energy source for electrical equipment. In this study, a solar panel with a capacity of 100 WP is used, in which the energy produced by the solar panel is then stored in a battery with a capacity of 12 volts 70 Ah. The electrical energy produced by the Solar Panel is still in the form of electrical energy with direct voltage. Because most existing electrical equipment uses alternating voltage, an inverter is needed to convert the direct voltage generated by the Solar Panel into an alternating voltage. which will then be used as a source of electrical energy for electrical equipment in the form of blenders and electric lights [8].

A popular solar technology is the integration of solar thermal and photovoltaic (PV) technology, which is called thermal photovoltaic (PVT) technology. This technology converts solar energy into electrical energy and heat. The efficiency of solar energy conversion through PVP is higher than that of photovoltaic and solar systems. The efficiency of a PV cell decreases as the operating temperature of the system is higher. Therefore, the solar system attached to the PV cells acts to cool the PV cells and increase the overall efficiency of the PVP system.

The space-saving construction of PVP, suitable for domestic consumption, and long-term cost savings make PVP currently being researched by the latest energy technology researchers. This review presents a description of and previous work done on the performance analysis of PVP water collectors. PVP water collector performance results are summarized. The energy and exergy efficiency of PVP water collectors ranged from 28.5% to 85% and 6.8% to 14%, respectively [9].

Solar Charge Controller

Solar Charge Controller is one of the components in the solar power generation system, functions as a regulator of electric current both for incoming current from the Solar Panel and outgoing load current/used. With the increasing demand for power and energy, energy conservation and the use of renewable resources have become an important requirement. Solar energy will become the main and main source of energy in the near future. Therefore, highly efficient and low energy consuming solar powered equipment and applications will soon become a major requirement. In this paper, a solar charge controller using Maximum Power Point Tracking (MPPT) and Pulse Width Modulation (PWM) has been analyzed and compared, which is required in all solar power systems that use batteries. Its role is to regulate the power flowing from the solar panels to the battery. Most modern load controllers include PWM and MPPT. This charge controller is designed in such a way that the solar battery can be recharged quickly and does not run out, [10].

The results obtained in the field of analysis and development of controllers for charging solar power plants are presented. A description of the solar panel charge controller (SP) is given and a solar installation scheme with its use is proposed. The maximum power point (MPP) of the polycrystalline silicon (SB) solar battery is calculated. Pascal software for load control research and analysis, which can be used for various types of SP, including perovskite panels, is proposed. It is seen that the type of controller that tracks MPP has better characteristics because it provides a higher payload [11].

Research presents a new technology-based solar PV charge controller containing a series charge controller, a shunt. Lead acid battery is chosen for series charge and discharge, shunt charge controller because of its features. I use MOSFET for switching purpose and it will reduce switching loss. The proposed charge controller has been developed using MATLAB and the charge and discharge processes of the developed charge controller have been verified. Furthermore, the developed charge controller has been maintained within the SOC limits taking into account the battery efficiency is well maintained, so that the battery life can be increased to a greater extent. In addition, an analysis of various load controllers has been discussed and on the basis of this it can be proved that; the performance of the proposed load controller is improved and requires fewer switches so that the system cost is also reduced. It is suitable for optimizing the energy crisis in rural areas to an affordable level [12].

DC Power Control

DC power control is a circuit that converts DC voltage to AC. Or rather the inverter transfers the voltage from a DC source to an AC load. The inverter voltage source can be a battery, solar panels or other DC voltage sources. Improving the quality of electrical power Uninterruptible Power Supply (UPS) is an important part in ensuring the reliability of the power system. To optimize the output of the UPS voltage waveform, a filter branch can be added to the existing UPS inverter circuit. This paper studies the circuit control problem after adding RLC filter branch in UPS inverter circuit. Through the inverter circuit analysis directly consider the addition of the filtering branch, the function state of the built circuit system. The double closed loop PI control strategy is designed to control the inverter circuit, and the effectiveness of this method is verified by simulation. Using the method in this paper, the output of the inverter circuit with the added filter branch can reach stable state quickly. The research conclusion of this paper is to help to improve the quality of UPS output power. [13].

Research on the use of inverters in grid-connected solar photovoltaic (PV) systems to control grid-connected three-phase inverters to meet the requirements of controlling zero-reactive power at distribution network nodes while maximizing the active power transmitted to the grid. The control circuit was synthesized on the dq coordinate system and verified on the simulation model by Matlab/Simulink. Simulation and experimental prototypes of a 5 kW inverter, connected to a low voltage grid, have been built to show good results and practical readiness for implementation [14].

Most countries in the world are at a critical point regarding the use of unconventional energy to meet the growing energy needs. In India; clean, unlimited, free solar energy has proven its utility and potential in the energy sector. This article highlights a simple, clean and inexpensive design for building a voltage driven but powerful inverter circuit using a power MOSFET as a switching device that converts a 12V DC signal to a single phase 220V AC; filled with solar energy. The advent of monocrystalline solar panels, the most efficient solar panels to date has ushered in a revolution in the concept of solar farming in India. This design can be powered by solar energy and contribute significantly to the reduction of carbon emissions.[15].

ENERGY CONSIDERATION

In order to study the Solar Power Photovoltaic As Energy Source the important parameters can be calculated from following equation.

Cooling capacity at evaporator (Q_{Evap})

$$Q_{Evap} = m.(h_1 - h_4) \quad (1)$$

Compressor work (W_{Comp})

$$W_{Comp} = m.(h_2 - h_1) \quad (2)$$

Heating Capacity at Condensor, (Q_{Cond})

$$Q_{Cond} = m.(h_2 - h_3) \quad (3)$$

Coefficient of performance (COP)

$$COP = \frac{Q_{Evap}}{W_{Comp}} \quad (4)$$

where h_1 and h_2 are the enthalpy at inlet and exit of compressor, respectively. h_3 is the enthalpy at exit condensor and h_4 is the enthalpy at inlet of evaporator.

For a given flow and ambient conditions, Equations (1) to (4) form a closed set of equations and together with the relevant refrigerant property routine, a numerical scheme can be established. The relevant properties, such as the storage liquid temperature, can be solved as functions of time.

METHODS AND MATERIALS

Meteorological Data Collection Required Such as design temperature, humidity, daily solar radiation values for the location and number of hours worked. The space chosen to be cooled in this work is an office space measuring 3×3×3 m used by Mechanical Engineering Department lecturers.

Design and Sizing of the Air Conditioning System

Design and Sizing of the Air Conditioning System Based on cooling load calculations, the air conditioning unit has been selected with the following specification: unit capacity 2,5 kW or 9000 BTU 0,7 ton refrigeration (0,7 TR) split unit, 220 V, input power 0.750 - 1.250 kW to provide the suitable COP.

PV System Sizing and Material Selection

Based on air conditioning unit capacity that has been selected under Indonesia climatic conditions and the data collected, where the intensity of solar radiation about 3.6 – 6 kWh/m2, the PV solar-powered system specifications can be selected and design. We used photovoltaic solar system with capacity 250 Watt 4 panels, and 2 battery 12 Volt 120 A.h. The inverter specification are: DC input 48 V, AC output 220 - 240 V, output power 2.5 kW and the charge controller 12 Volts each and charge rating 24 Ampers with over load and short circuit protection.

PV 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 installed with the help of technical

as shown in Figure 1 which explain the actual final cycle that includes the air condi- tioning 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 Air Conditioning Test Scheme Using Solar Energy

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. Compressor is electrically operated can be described as the heart of air conditioning system as it pump 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 pass through the condenser and gives off some of its heat as outdoor air is blown across the condenser coil. The warm liquid is carried back to the evaporator to repeat the cycle again. The system performance measured by measuring the temperature at each previous component in the cycle by using data logging system connected with thermocouples, these data transfer through the USB to the computer for analysis where a lot of readings carried out through a specific time. The system worked between 10 am to 18 pm usually for 8 hours a day, Extensive measurement were taken through the two months. Figure 2. Schematic for the Solar Energy Cooling Engine.

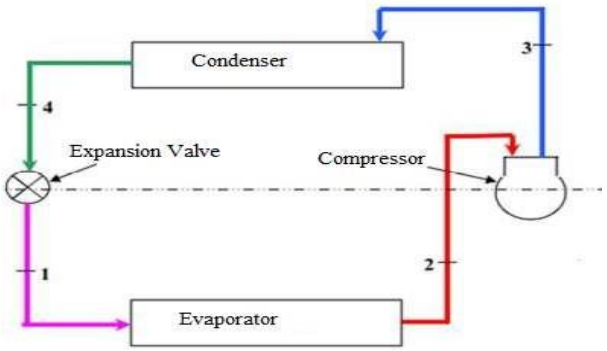

Fig. 2 Schematic for the Solar Air Conditioning System

The solar intensity value obtained is highly dependent on the weather conditions at the time of the test. The rise and fall of the solar intensity value is influenced by the thickness of the clouds that block the sun as shown in Figure 3.

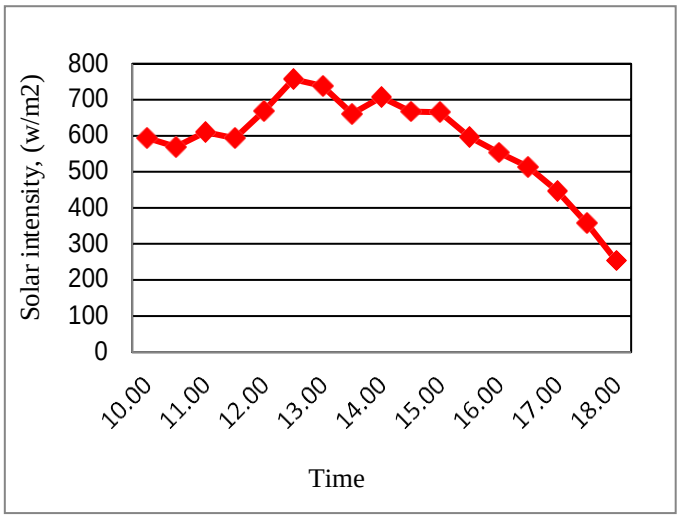

Fig. 3 Solar intensity from 10.00 am to 18.00 PM

The value of the voltage and electric current produced by the solar panel is directly proportional, where if there is a decrease in the voltage, the current generated will also decrease in value. This is influenced by the value of the intensity of the sun

captured by the solar panels can be seen in Figure 4.

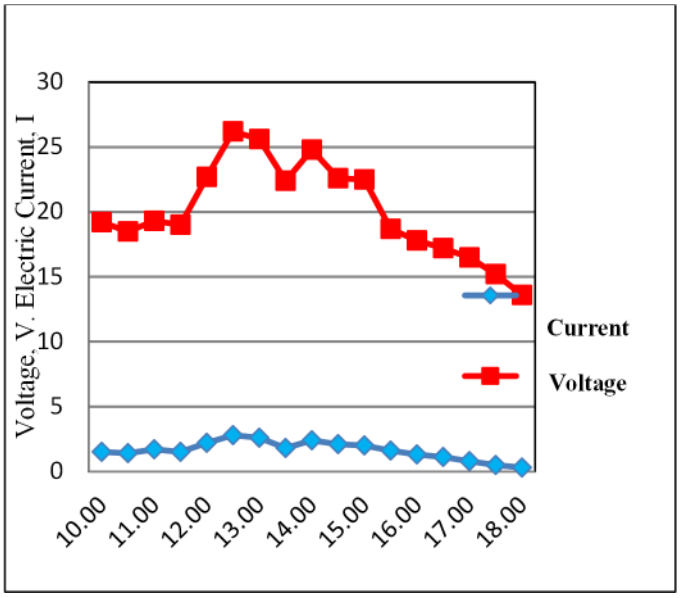

Fig. 4 Electrical Voltage solar PV panels from 10.00 am to 18.00 PM

In Figure 5. it can be concluded that the decrease in COP and EER values with time
test caused by a decrease in the calorific value absorbed by the evaporator. This decrease in value makes the temperature of the test room lower. Where at the beginning of the test the COP value is 8.5, the EER value is 28.7, the temperature of the test room is 28°C while at the end of the test the COP value is 2.9 and the EER is 9.7 at the end of the test room temperature 22°C for 5.5 hours.

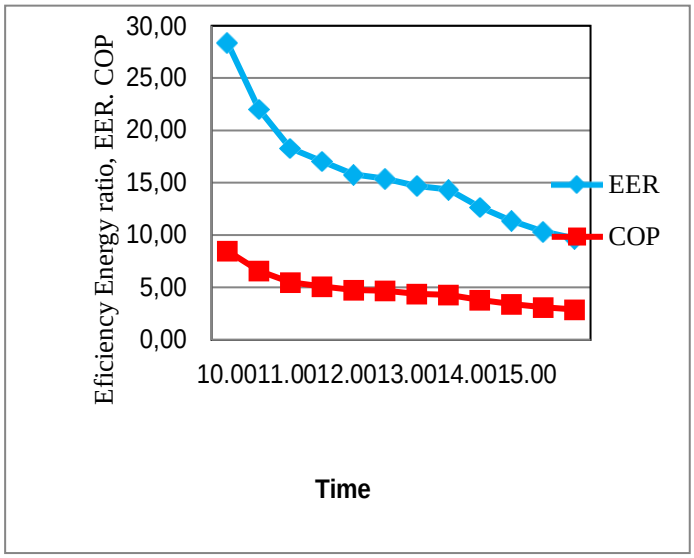

Fig. 5 Efficiency Energy ratio, EER and COP from 10.00 am to 15.30 PM

In Figure 6. the occurrence of a decrease in the value of COP with respect to the time of testing due to a decrease on the calorific value absorbed by the evaporator. This decrease in value makes the room temperature lower. Where at the beginning of the test the COP value was 8.5 at a cooled room temperature of 28^{O}C while at the end of the test the COP value is 2.9 at room temperature conditioned at 22 ^{O}C.

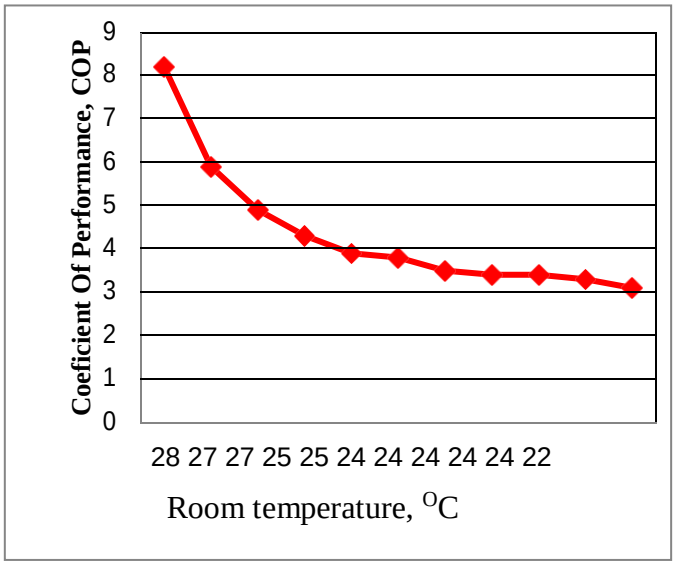

Fig.6 Coeficient Of Performance, COP with Room Temperature

CONCLUSION

This research focuses on the design, construction, and performance testing of solar-powered air conditioning systems integrated with photovoltaic (PV) systems and applying them to Indonesia's climatic conditions. This project is present as a solution to reduce electricity demand throughout the year and can be used efficiently in remote areas where electricity is not available. It is designed by two different methods: one of them is

preferred over the other because of the acceptable voltage range and easy connection. The COP for the system was found to match the conventional system as well, it was very difficult to keep the overall performance of the system components constant in the trial period because the sunlight was time dependent and the weather was sunny during the day.

As the level of demand for air conditioning is expected to grow, the exploitation of solar energy, especially in urban areas, seems to be a valuable option for reducing conventional fuel consumption due to the use of engine cooling. Solar air conditioning systems can be a reasonable alternative to conventional air conditioning systems. There are several characteristics that must be considered to be known both in PV systems and in air conditioning systems such as electrical equivalents, characteristic curves, and factors that affect the output of PV cells. Solar energy as a power source can reduce peak energy demand and increase the use of renewable energy, while providing energy savings to end users.

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