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Solar Powered Air Conditioning System

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Abstract

The development of renewable energy is on the rise worldwide because of the growing demand on energy, high oil prices, and concerns of environmental impacts. In recent years, progress on solar-powered air conditioning has increased as nowadays, air conditioning system is almost a must in every building if we want to have a good indoor comfort inside the building. Therefore, this paper focuses in the design and construction of a direct current (DC) air conditioning system integrated with photovoltaic (PV) system which consists of PV panels, solar charger, inverter and batteries. The air conditioning system can be operated on solar and can be used in non-electrified areas. As we all known, solar energy is cost effective, renewable and environmentally friendly.

Keywords: Solar; Direct current, Air conditioning system

1. Introduction

The demand of air conditioning is increasing due to the effect of climate change and global warming. If we still rely on the conventional electric air conditioning but electricity is generated form fossil fuels, the greenhouse gas emission would continuously worsen global warming, in turn the demand of air conditioning would be further increasing. In subtropical cities, air conditioning is a standard provision for buildings. However, air conditioning would commonly take up half of building electricity consumption [1].

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Air conditioning is defined as the simultaneous processing of temperature, humidity, purification and distribution of air current in compliance with the requirement of space needing air conditioning [2]. In general, air conditioning which also can be known as refrigeration is defined as any process of heat removal. To produce the process, it requires energy where the sources are commonly gas and electricity. With increasing gas and electricity tariffs, solar energy becomes attractive once the system has been installed [3]. As one of the sources of renewable energy, solar energy is likely the most suitable system for installation in sub-tropical countries.

The most common globally, preferred type of thermally driven technology is absorption cooling. The system, which has simpler capacity control, mechanism, easier implementation, high reliability, silent operation, long life and low maintenance cost was a genuine candidate for efficient and economic use of solar energy for cooling applications [3]. But in this project concentrates on development and improvement of a normal air conditioner unit in order to operate using electricity generated from the PV system.

Utilizing solar energy to run the air conditioning system is a practical technique to replace conventional electricity. In order to obtain a feasibility of the air conditioning system using solar, a lot research and testing have been initiated to learn and discover the design and operation of the air conditioning and solar system which is consist of PV system.

The purpose of this paper is to design and construct a direct current air conditioning system besides describe the component and characteristics of the system including its advantages and limitations. The actual performance of the system will be studied based on operational view and commercial applications.

2. Methodology

The approaches used in this project are based on suggestion by Tsoutsos et al [4], and are as follows:

a) Collection of the required meteorological data: meteorological data for Perlis was used. A typical meteorological year (TMY) was created and the hourly, monthly and annual values of solar radiation processed.
b) Cooling load calculation: Determine what kind of cooling and how much of cooling needed.
c) Design and sizing of the air conditioning system: Using the weather data, and the selected design conditions, the components of the system could be sized.
d) Optimisation of the system: The aim was to use least cost energy so the designed system was optimised with that in mind.
e) Material procurement and construction of the experimental system: Once the system had been optimised, the components were procured and the system was constructed and tested.
f) Performance evaluation and economic analysis: The energetic and economical effectiveness of the system was evaluated. The life cycle costs for solar cooling system were calculated and competitiveness with regards to price and thermal efficiency for domestic applications determined.
g) Analysis of results and making of recommendations: The results were analysed and necessary improvements recommended. Options for improving technical effectiveness and economic competitiveness were suggested. Ways of improving research and development efforts in this field were also investigated.

3. System Description

The proposed concept of the system consists of air conditioner and PV system is indicated in block diagram shown in Figure 1. In order to determine the characteristics and properties of all the components used, each component must be taken as a single unit.

The complete system must be able to operate in stable condition, and if possible achieving the efficiency as conventional air conditioning system. For example, as for the cooling purpose, performance of the DC air conditioning should be the same as normal AC air conditioner.

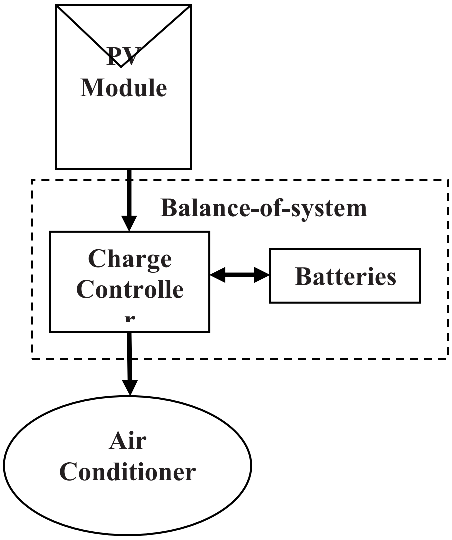

Fig. 1. Block diagram of PV system and air conditioning system

3.1 Refrigeration Load

Heat naturally flows from warmer places to cooler places. In other words, the heat is called as refrigeration load. Refrigeration equipment such as air conditioner is used to transfer heat from a cooler place to a warmer place. For example, the heat inside a house is absorbed and been transferred to the outside [4].

The refrigeration load is the rate at which heat must be removed from the refrigerated space in order to produce and maintain the desired temperature conditions. The total cooling load on the refrigerating equipment is the sum of heat-gain from several different sources which include the heat gained from walls, windows and doors [5].

There are several factors need to be considered in determining the cooling load [4]. The factors are for instance:

- Site – size and construction of the cooling area
- Human presence – human body continuously produces heat through a process called as metabolism.
- Activity level – sleeping and dancing inside of an area will give a different rate of heat.
- Equipment – printers, computers, etc contribute the heat

3.2 Air Conditioning System

Either for a building or a vehicle, the air conditioner mainly consists of five key components which are compressor, refrigerant, expansion device, evaporator and condenser [4].

As shown in Figure 2, 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 vapour to a high pressure, making it hot for the circulation process of the refrigerant.

Fig. 2. Air conditioner compressor

Refrigerant is a material that performs as cooling agent by absorbing heat into the system and will circulating inside the circuit of the air conditioning system.

Located in between of the condenser and evaporator, the expansion device allows a controlled amount of the liquid refrigerant to flow through into the low-pressure section of the process. Figure 3 illustrates the expansion device used in air conditioning system in vehicle.

Fig. 3. Expansion device for air conditioning system in vehicle

For the circulation process of the refrigerant, evaporator use the liquid state refrigerant to absorbs the heat from the cooling space into the system. As shown in Figure 4, the evaporator is located inside the indoor unit installed in the cooling area.

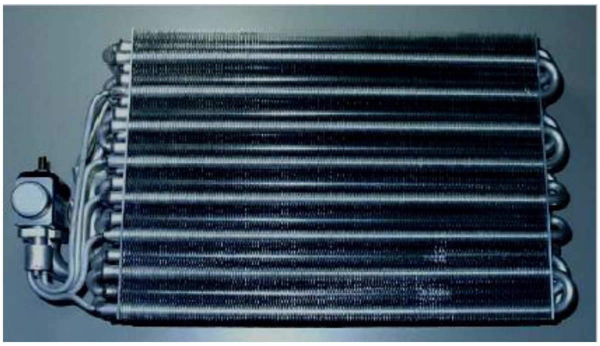

Fig. 4. Evaporator coil

At condenser, as the temperature of the refrigerant is low, the heat from the system that the evaporator absorbs is being removed. Presented in Figure 5, the condenser is situated inside outdoor unit with the compressor.

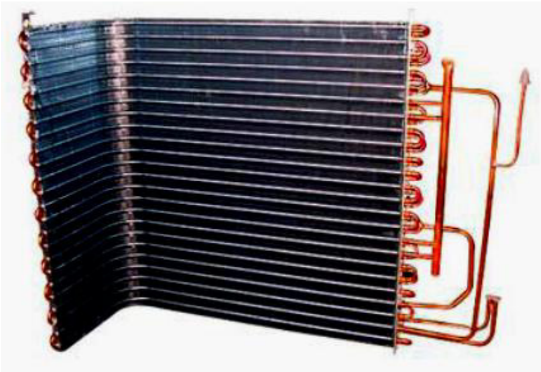

Fig. 5. Condenser coil

3.3 PV System

Even though there is many differences of the PV processes now either in research of commercial areas, the basic principle is simple. Photovoltaic which is combination of two words; photo for light and voltaic for electricity, converts the energy of sunlight directly into electricity. The conversion from the sunlight into electricity is occurred because of the PV effect. The term "solar cell" is reserved for devices intended specifically to capture energy from sunlight while the term "photovoltaic cell" is used when the light source is unspecified [7].

A complete PV system comprises two subsystems. First subsystem is the PV modules that convert sunlight into electricity. In between the first subsystem and air conditioner, there will be second subsystem which is a set of devices and structures that enables the PV electricity to be properly applied to the load. This third subsystem is known as "balance of system" or the BOS [8].

PV module is categorized according to their rated power output in Watts. This rating is the amount of power the solar panel would be expected to produce in 1 peak sun hour (PSHs). Different geographical locations receive different quantities of average peak sun hours per day [7].

The peak sun hour is essential in order to know the number of PV modules to be installed. Before doing so, the power that can be assumed generated by the PV modules must be determined based on solar irradiance of the location.

Fig 6. PV module

The BOS in this system consists of inverter, charge controller and battery. The function of charger is to regulate the voltage and current coming from the solar panel going to the battery. The battery is the key components in PV-SA systems as it act as energy back-up for the renewable energy systems. It also functions as storage devices for storing PV generated electricity during cloudy days and at night. In order to apply this system in AC load, the inverter is needed to convert the DC electricity generated by the PV panel into AC. The AC load is a common type of load and easily available with cheaper in price.

It is important when it comes to getting the right batteries and maintaining them. Economical and maintenance factors are the common issue to select suitable battery. The battery storage must have enough capacity to handle the energy demands by the system especially during periods of very low solar radiation. Rainy day, cloudy weather and at night are examples for the period of low solar radiation. Usually, for PV system, a deep cycle battery is usually used because it is specifically designed to be discharged over a long period of and recharged hundreds or thousands of times.

Fig 7. Deep cycle battery

The purpose of charge controller is to regulate the current from the PV module to prevent the batteries from overcharging. A charge controller is used to sense when the batteries are fully charged and to stop, or decrease, the amount of current flowing to the battery. Charge controller as in Figure 5 is rated by the amount of current they can receive from the solar panels [7].

Fig 8. Charge controller

3.4 System Operation

The solar energy is received by the PV module and transform into electrical energy. The electrical energy is then being regulated by charge controller either by supplies it directly into the load or charges the batteries. As the electrical energy coming from the PV module is in DC, inverter will convert it into AC as the compressor needs AC to operate.

The most common type of air conditioning is technically referred to as direct expansion, mechanical, vapour-compression refrigeration system. The goal with air conditioning is to capture heat in the cooling space and throw it outside [6]. The operation of the system starts when the cold, low pressure liquid (refrigerant) flows across the evaporator coil inside the cooling space to absorb heat. The cold liquid that went into the evaporator coil comes out as a low pressure gas. Then, the cool, low pressure gas is taken outside and compressed by the compressor to become a hot, high pressure gas. Next, the hot gas is passed through the condenser coil and gives off some of its heat as outdoor air is blown across the coil. This cause the hot gas to condense back to into a warm liquid. The warm liquid is carried back to the evaporator by passing through the expansion device which decreases the temperature and pressure of the liquid. Figure 4 shows the basic air conditioning operation.

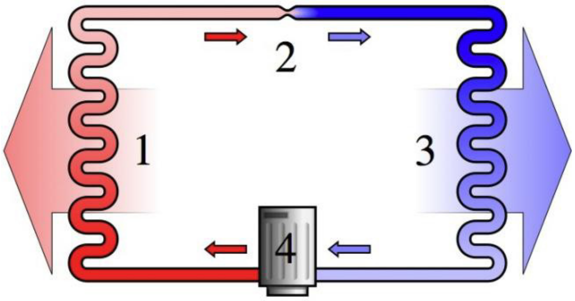

Fig 9. Air conditioning system [1. Condenser; 2. Expansion device; 3. Evaporator; 4. Compressor]

4. Conclusion

This paper concludes that the system design needs to consider both air conditioner and PV system in order to achieve the space cooling. There are several characteristics that are needed to know either on the PV system or air conditioning system. Electrical equivalent, IV characteristic curve and factors affect the output of PV cell is an important characteristic in photovoltaic. As for the air conditioning, cooling capacity must be determined first as it will give a rough idea on how to design and construct the system with enough electrical energy supplied to it. With considering of these several factors, it will help to improve the stability and efficiency of the system for greener solutions to the world’s energy needs.

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