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Enhancing of a DC Air-Conditioning System Based on Solar Power Generation

***Abstract**. Photovoltaics powered DC air conditioners have a lot of potential for energy-efficient cooling while also being very cost-effective. They have the potential to significantly cut energy consumption in the construction sector, which is critical in meeting the larger goal of lowering greenhouse gas emissions. In this paper, the performance of a split-unit DC air conditioner is evaluated. The DC air conditioner, which operates directly on 48 VDC and includes a variable-speed compressor, has lately become accessible on the international market. This study discusses a number of topics, including energy use, investigation of the coefficient of performance (COP) and power quality concerns. Solar power is the primary energy source, as it is a renewable resource that is both readily available and beneficial to future generations. The output of the DC air conditioner can be alternatively changed according to the size of the room by altering the speed of the Brushless DC motor in this work.*

Streszczenie**. Klimatyzatory DC zasilane fotowoltaiką mają duży potencjał w zakresie energooszczędnego chłodzenia, a jednocześnie są bardzo opłacalne. Mają potencjał, aby znacząco obniżyć zużycie energii w sektorze budowlanym, co ma kluczowe znaczenie dla osiągnięcia większego celu, jakim jest obniżenie emisji gazów cieplarnianych. W tym artykule oceniana jest wydajność klimatyzatora DC typu split. Klimatyzator DC, który działa bezpośrednio na 48 VDC i zawiera sprężarkę o zmiennej prędkości, stał się ostatnio dostępny na rynku międzynarodowym. W niniejszym opracowaniu omówiono szereg tematów, w tym zużycie energii, badanie współczynnika wydajności (COP) i problemy z jakością energii. Energia słoneczna jest podstawowym źródłem energii, ponieważ jest zasobem odnawialnym, który jest zarówno łatwo dostępny, jak i korzystny dla przyszłych pokoleń. Moc klimatyzatora DC można alternatywnie zmienić w zależności od wielkości pomieszczenia, zmieniając prędkość bezszczotkowego silnika prądu stałego w tej pracy.* (Wzmocnienie systemu klimatyzacji DC opartego na wykorzystaniu energii słonecznej***)
(

Keywords: DC Compressor, Performance, Solar Energy, COP, Solar air-conditioner,
Słowa kluczowe: kompresor DC, klimatyzacja, energia słoneczna

Introduction

The United Nations Framework Convention on Climate Change decided to keep global average temperature increases well below 2 degrees Celsius over pre-industrial levels in order to limit climate change risks and impacts. Aside from the need to reduce emissions, the growing number of HVAC systems leads to a rise in grid electricity costs due to high peak demands [1-5].

Direct current (DC) compressors have the potential to be used in energy-efficient refrigeration systems because these

compressors do not require additional components such as a power inverter that an alternative current compressor would require. By utilizing this compressor, any problem related to the interaction of the refrigerant cycle components and the rapidly-changing operating conditions of the air conditioners is solved [6-8].

Solar-powered air conditioning has made significant development in recent years, owing to the fact that air conditioning is nearly a requirement in every structure in Saudi Arabia if the summer temperature exceeds 45 degrees Celsius [9-11].

The building energy consumption accounts for about 75% of the total energy consumption, and air conditioning energy consumption accounts for more than half of the building energy consumption in KSA. So energy saving of the air conditioning system is necessary [12-14].

Air conditioners are important especially in countries like Kingdom of Saudi Arabia (KSA) which has a hot weather most of the year. Air conditioner consider as one of the devices which needs a lot of power to work properly and that may incur high cost so we want to use some technology to reduce this amount of power consumed. Photovoltaic solar energy is a suitable choice for usage in buildings because of its high reliability, availability, low maintenance requirements, and potential to reduce greenhouse gas emissions.

In fact, the number of solar cooling and heating systems on the market is steadily expanding, as are the technologies accessible [15-18].

DC grid has gained a special attention by many researchers, especially in the last decade. The two main factors that emphasize the DC grid area of study include the DC nature of the majority of distributed generation sources, as well as the emerging of new DC loads that need several power conversion stages when connected into the current AC network. Therefore, it is needed to study the possibility of converting, either partially or completely, the current AC network to a corresponding DC network [19-23].

Our paper which is enhancing technologies for solar powered DC air conditioners is aim to reduce the power consumed by the air conditioners by controlling the speed of the rotor of the brushless DC motor. In this paper we will going to explain this technology in details and try to understand all its advantages and disadvantages. Also, we will be going to explain the design of a solar-powered air conditioning system in depth in this paper, and its performance over the course of a cooling season will be explored using PV panels to generate the required electricity for a small-scale air conditioning system.

In comparison with other systems which also use renewable energy for air conditioning, this one presents significant advantages. It is comparatively simple, reliable, has low maintenance needs and its renewable energy production is entirely self-consumed.

Analysis of the DC Air Conditioner with Rotary Compressor

In order to calculate overall efficiency of air conditioner we must find electrical and thermal power and divide them to find ratio, but our focus here is only for efficiency. The next figure shows the refrigerant cycle inside air conditioner. In order to calculate thermal efficiency, we must measure temp before and after the desired component so in our case we need to do that for condenser, compressor, evaporator and expansion valve. so, we need to measure temperature on point 1,2,3 and 4 as shown in figure 1.

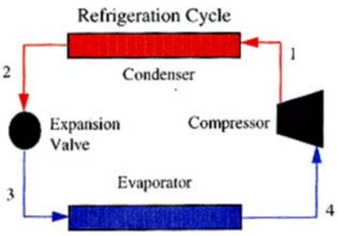

Fig.1: Regurgitant Cycle

Hence, we find efficiency of each part by doing rest of calculation and by the mean of using density and refrigerant flow rate.
For compressor: T4-T1;
For evaporator: T3-T4;
After measure temperature we can know calculate heat energy from this formula:

$$Q_{vaporator} = m_e C_p [T_3 - T_4]$$

Where:
Q: heat energy
me: mass flow rate
Cp: specific heat Air Flow Thermal Efficiency

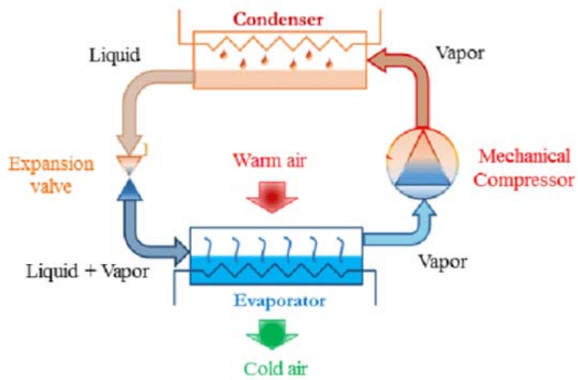

Fig. 2: cooling cycle

We can apply same concept but this time for air instead of refrigerant for evaporator we measure temperature of warm air before passing evaporator and then measure its temperature after passing it and same thing done for condenser. so, by calculating air efficiency and refrigerant efficiency we can now find the overall thermal efficiency.
Before calculating heat energy, we need first to find mass flow rate, which can be find by multiplying flow speed, cross sectional area and gas constant of air.

$$m_e = (\rho)(A)(V)$$

$$Q_{air} = m_e C_p [T_{warm} - T_{cold}]$$

Another way to express specific heat and temperature is Enthalpy, it can be expressed as:

$$\Delta h = C_p [T_{warm} - T_{cold}]$$

Hence

$$Q_{air} = m_e \Delta h$$

As we can see here there are four cases each case is set to percentage of compressor consumption so we can see the difference between measurement in each case. But we must mention that this case is in steady state which make calculation and measurement way easier.

where the room temperature is lower than reference value and hence compressor will not be working. The solution for this is to use heater in order to increase temperature in the room and hence compressor start working. In each case we must set different temperature.

After calculating output heat energy, we must compute input electric energy to compressor in order to find efficiency percentage. It can be expressed by the following formula:

$$\eta = W_{th}/W_{elc}$$

Ater find efficiency we can compare it to regular air conditioners to find if our project is sufficient to save energy or not.

Simulation of Air Conditioner

In this Part we are going to make simulation for two things: Refrigeration Cycle, Compressor and Refrigeration Cycle Simulation

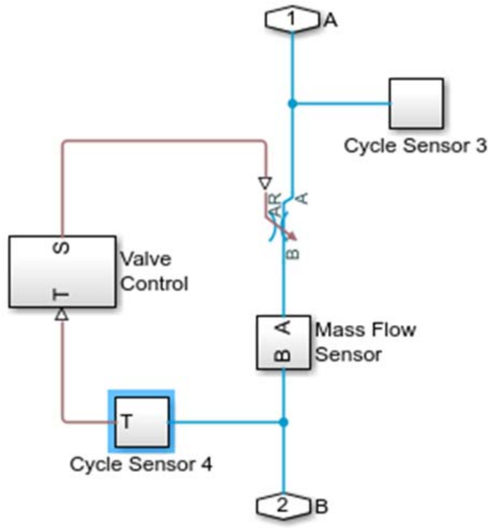

Fig.3: Expansion Valve

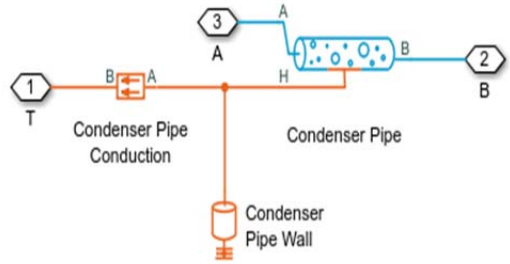

Fig. 4: Condenser

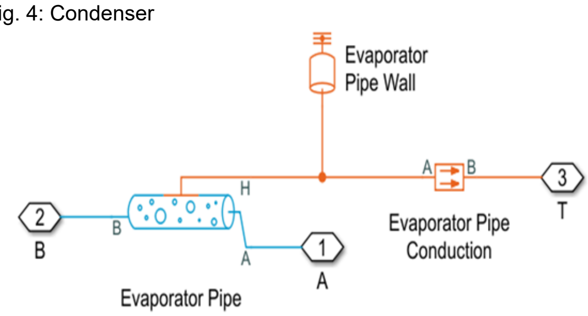

Fig. 5: Evaporator

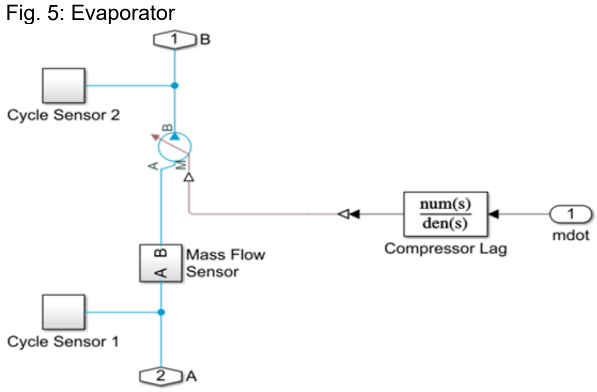

Fig.6: Compressor

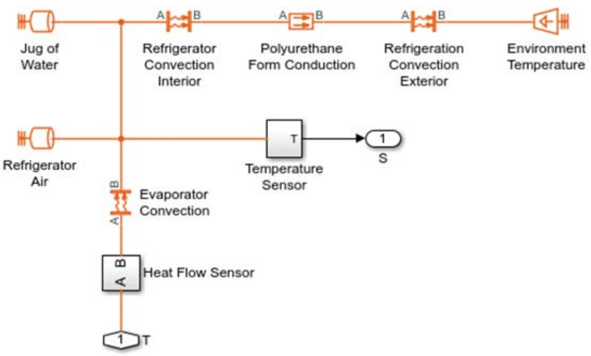

Fig.7: Refrigerator Compartment

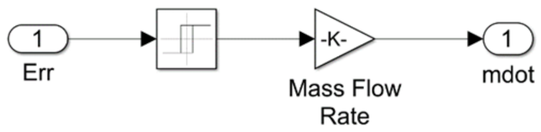

Fig. 8: Control of Refrigerator Cycle

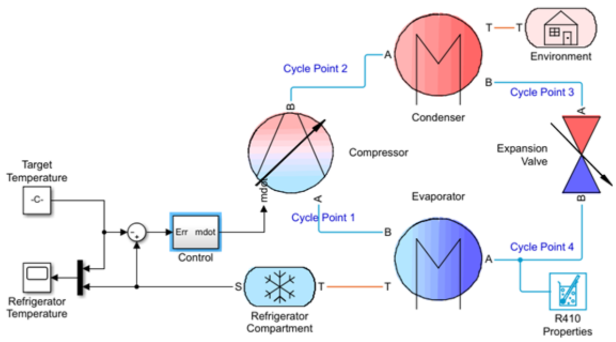

Fig.9: Refrigerator Cycle

And the results be as following:

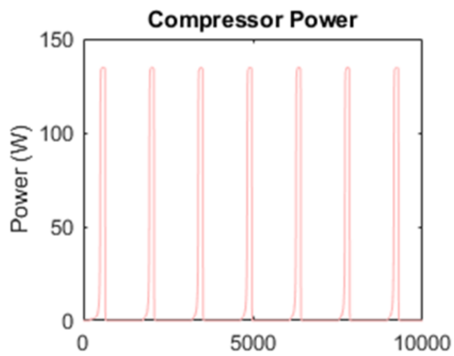

Fig. 10: Compressor Power

Inside compressor there is crankshaft that connected to piston that used to compress refrigerant, then we can imagine that compression curve is not continuous as rotation curve of the motor. Same thing that appears in figure 10.

The cooling capacity increased with decreasing the outdoor temperature and increasing the indoor temperature. Also, it increased with increasing the compressor operation ratio. The temperature of the condenser was more sensitive for the variation of the outdoor temperature and the temperature of the evaporator was more sensitive for the variation of the indoor temperature.

f the air conditioning system has reached steady state and normal operation, the temperature of air blowing out of the outside compressor/condenser unit will feel warmer than the ambient outdoor air temperature. Not too much to say here but as we can see compartment (room temperature) is almost constant and does not have sudden change as inlet temperature.

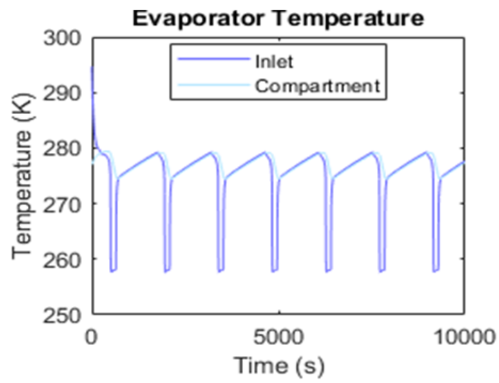

Fig. 11: Evaporator Temperature

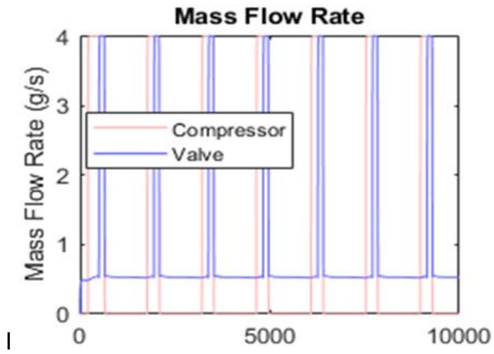

Fig. 12: Mass Flow Rate

Fig.12 shows mass flow of refrigerant inside cooling cycle. mass flow is arbitrary high now were piston pressures refrigerant. Again, shape must be as pulses.

As it absorbs as much heat as possible while it's a liquid the temperature Remains the same, roughly around 40 degrees but will vary according to conditions (room temperature, outside temperature, charge- over or undercharged) then it will begin to increase in temperature, what is called superheat (the temperature of a substance above its boiling point at a given pressure) superheat on most ac is 8–12 (so given that approximate 40 degrees it would be 48–52 degree) degrees depending on type of system and if it's operating properly.

Conclusion

The purpose of this research is to develop, simulate, and analyze the performance of a solar-powered air conditioning system that is also a photovoltaic (PV) system. Solar air conditioners can be a cost-effective alternative to traditional air conditioners. Electrical equivalent, characteristic curve, and factors affecting PV cell output are only a few of the parameters that must be considered whether on a PV system or an air conditioning system.

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