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Design of Hybrid Solar Air Conditioning System Based On the Weather and Environmental Conditions of Nigeria.

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ABSTRACT: Producing air conditioning from solar energy technology has emerged as a feasible option that could meet the cooling load demand of buildings within few hours during maximum solar irradiation. This research presents the design of a hybrid solar air conditioning system; the system comprises of conventional direct expansion air conditioning system components combined with a solar collector (evacuated tube) as additional heat source, which is installed after the compressor to reduce the power consumption of the compressor. The objective of the research is to design the system with high COP/EER ie, with less energy consumption of the compressor due to the solar input in the system based on the weather and environmental conditions of Nigeria. The refrigeration capacity of the system is assumed as 20KW, a capacity enough to satisfy the requirements of a small building. Refrigerants R134a and R410a are used as refrigeration materials. The EER was found to be 4.11(13.85%) and 4.10(10.81%) for the refrigerant R134a and R410a, respectively, at sub cooled 12^{o}C and 10^{o}C compare with standard vapor compression refrigeration cycle without solar assistance. The yearly energy savings are, compared to a standard unit without solar assistance, 12.08% and 8.8% for the system with refrigerant R134a and R410a respectively. The reduced energy use resulted in reduced CO_2 emissions, calculated to be 481.2kg/yr and 317.4kg/yr for the refrigerant R134a and R410a respectively when compared with the Vapour compression refrigeration cycle system without solar assistance.

KEYWORDS: Solar energy, Hybrid Solar Air conditioning, Conventional Air conditioner, Refrigerant, Renewable energy.

I. INTRODUCTION

Nigeria is among the top leading countries in Africa with blessed with renewable energy resources in abundance, and has the ability to improve their own energy generation possibilities; which will contribute to the promotion of industrialization, socio-economic growth, create green jobs and reduce global warming (Ibrahim et al,. 2021). In spite of the renewable energy wealth in the country, they are yet harness to fully potentials, hence resulting in the deficiencies in supporting power generation in the country.

Heating, Ventilation and air conditioning systems (HVAC) are one of the major consumers of the overall energy in building sector, there consumption are above 50% of total energy in buildings (Al-Abidiet al., 2012). They also contribute in the production of greenhouse gases emission which causes ozone depletion and reduction of fossil fuel sources from natural reserves (Choudhuryet al., 2010). Moreover, fossil fuels that contribute about 80% of the global primary energy are seem to be inadequate to match with energy demands in the near feature of the world (Abbasogluet al. 2010). In the recent decades due to fast decay of fossil reserves, solar energy with the combination of many types of cooling technology are being explored. Therefore, solar energy technology is applied to an Air conditioning system (ACs) either by thermal driven or photovoltaic panels. Applying solar energy technology to HVAC systems has shown positive result in energy saving (Vakiloroyaet al. 2012).

The electricity peak demand during summer causes serious problems in most electric power generation and distribution sectors especially in countries with hot weather climate. Electric energy produces from fossil fuels also increases emission of CO_2 that lead to the global warming and environmental pollution. Likewise, conventional air conditioning systems has effective impact on global warming and ozone depletion based on the fluorinated gases (refrigerants) they use such as hydrochlofluorocarbon (HCFC) and hydrofluorocarbon (HFC) which are thousands times much greater than that produce by CO2 Zhao et al., (2015). Solar energy is among the best technologies that can drive cooling cycles because the higher cooling load demand in the summer can be achieved with the available high solar energy during the season especially in the hot and humid climatic areas. A space can be cooled with the combination of solar thermal system and conventional vapor compression cycle, VCC with the assistance of solar collector to reduce the power input of compressor and reach the effect of power saving Ha, and Vakiloroaye, (2012). In summer period the comfort cooling demands are at peak and so is the solar radiation which can produce required energy to drive the cooling system. Conventional electric compressors cannot provide the required cooling demand for hottest hours with acceptable energy efficiencies Shesho, (2014).

Solar energy technology has been used for cooling purposes either for comfort (Air conditioning) or for refrigeration (Refrigerator). Comfort cooling is essential in space conditioning of the environment in warm climate region. Cooling loads and solar radiation are going together because the time for high cooling demand is approximately matches with the high solar radiation season. Therefore, solar air condition technology can be applied or energy conservation and saving would be achieved through the following solar technologies: solar mechanical processes, desiccant cycle and sorption cycle technologies.

ACs is necessary in building especially in hot and humid climate countries like Nigeria. ACs in building sectors are installed to provide comfort to the occupants with healthy environment.

ACs are designed with the equipment and components arranged in order to provide cool or heat, purify and clean, humidify and dehumidify, transport the conditioned air to recirculate in indoor space (Saradaet al., 2015). An ACs is very vital for retaining thermal comport in an environment, especially in hot and humid countries. Nowadays, ACs that enables cooling and dehumidification became essential in residential, commercial and industrial processes. The demand for electricity during the summer is increasing because of the uses of appliances for comfort cooling or air conditioning. The electricity peak demand during summer causes serious problems in most electric power generation and distribution sectors especially in countries with hot weather climate. Electric energy produces from fossil fuels also increases emission of CO_2 that lead to the global warming and environmental pollution. Likewise, conventional air conditioning systems has effective impact on global warming and ozone depletion based on the Fluorinated gases (refrigerants) they use such as hydrochlofluorocarbon (HCFC) and hydrofluorocarbon (HFC) which are thousands times much greater than that produce by CO^2 (Zhao et al. 2015).

Studies show that the primary energy consumption by the building sector is about 40% while the emission of the green house to the world is about 33% (Ravi et al., 2015).

Demand of energy in terms cooling, heating, hot water, electricity and lighting are among the major challenges and concern issues in the world at this present time and in feature. Due to the growing energy demand, global warming and effect of climate changes, high oil prices and all environmental impacts makes numerous development and ongoing researches on renewable energy. Energy efficiency issues and renewable energy (RE) development and applications are currently at high priority.

Solar energy is among the best technologies that can drive cooling cycles because the higher cooling load demand in the summer can be achieved with the available high solar energy during the season especially in the hot and humid climatic areas. A space can be cooled with the combination of solar thermal system and conventional vapor compression cycle, VCC with the assistance of solar collector to reduce the power input of compressor and reach the effect of power saving (Ha, Q.P; and Vakiloroaye, V. 2012).

Solar energy (SE) is an abundant RE source, which is available to the human society and it is free but utilization is not. The SE has been used since human history. However, SE as one of the RE source is least in utilization (Ravi et al. 2015).

Renewable energy is the energy resources that comes naturally from the nature and replenished in a short time. It is environmentally friendly, includes: solar, wind, hydro and biomass. (Ellabbanet al.2014). RE resources are alternative energy source that are replacing the use of conventional fossil fuels resources in term of energy services in residential, commercial, automotive and industrial purposes. RE resources contributed about 19% of the world energy

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consumptions in 2012 and about 22% of the electricity generation in the 2013 REN21 (2014).

Renewable energy potential in Nigeria

Nigeria is a country sub-Sahara Africa (Lat. 4-14°N, Long. 2-15°E) with abundance of energy resources both conventional fossil fuels and renewable resources (solar, hydro, wind, biomass etc.). The RE resources in are available in all the seasons. About 80% of the people in the country depend on forest biomass, the other RE source which is under-tapped. Nigeria has huge RE potential, estimated to as 697.15 TJ from crop residue, 455.80 TJ from animal waste and 442 MW from solid waste in Lagos metropolis area (Mohammed et al. 2013).

Solar energy potential in Nigeria

Nigeria has vast solar energy potentials with area of land 923,768 km^2 and solar radiation of about 229.1667W/m^2 (Ibrahim et al.,2021) , it found to be within a high altitude of sunshine. Average solar radiation for the country is about 20MJm^{-2} day^{-1} and 6hrs sunshine hour average per day. If at least 1% of the land area of the country would be utilized and covered with solar collectors, it is possible for the country to generate solar electricity of about 1850 x 10^3 GWH per year which is 100 times more than the present electricity consumption in the country (Uzomaet al. 2010)

The average monthly solar radiation potential for the northern region ranges from 7.01 – 5.62 kWh/m^{2-}day and 5.43 – 3.54 kWh/m^{2-}day for southern region (Farade 2009). However, the whole country has adequate solar radiation that can sustain and provide the electricity demand for domestic energy demand, especially in areas with lower electrical load demand (Mohamed et al. 2013).

According to Ogunmodimu&Okoroigwe as summarized in (Ibrahim et al.,2021) suggested that the Concentrated solar power (CSP) Technology using Solar Thermal power plant is best alternative for commercial enterprises in Nigeria.

Solar Energy Technology

Solar energy technology (SET) can provide the energy demands for building sectors both residential and non-residential including HVAC, domestic hot water, electricity and lighting. SE does not emit greenhouse gases or CO_2 to the environment like conventional energy fossil fuels. SET can be applied in most places for all energy demand of buildings.

In summer period the comfort cooling demands are at peak and so is the solar radiation which can produce required energy to drive the cooling system. Conventional electric compressor cannot provide the required cooling demand for hottest hours with acceptable energy efficiencies (Shesho, I. 2014).

According to International Energy Agency outlook report (2012) building sector consume above 35% of the total final energy, and above 20% of the primary energy.

According to (Shesho, I. 2014) solar cooling systems can bring more economic advantage to the users. The investments are higher than conventional Vapor compression system of cooling. However, solar cooling system economic advantage can range from low operational cost of the system, low maintenance of the system and reduced electrical energy consumption.

SE can be utilized in different purposes, the solar cooling process can be done by converting the radiation of the solar to thermal energy by the use of solar thermal collectors to capture the heat and drive the cooling cycle system (absorption or adsorption cycle). SE can be also converted directly to electrical energy by the use of Photovoltaic (PV) panels to provide electrical power to drive VCC system (Al- Alili, A. 2012)

Solar cooling technology can be categorized into three main categories as summarized by (Al- Aliliet al. 2013): solar electric cooling technology, solar thermal cooling technology and solar combined power / cooling technology as shown in fig 2.5. The solar electric cooling technology is also sub divided into three sub processes as PV-pelties cooling system, PV-VCC system and thermoelectric system. The second category, solar thermal cooling, is also sub divided into some processes as open cycle, closed cycle and thermo mechanical system.

Hybrid Solar air conditioning system

Solar air conditioning system can be referred to as any use of SE to condition air and can be one of the processes; passive solar, solar thermal energy or Photovoltaic conversion system. The hybrid solar air AC for this study uses Vacuum tube solar collector which is highly efficient and is filled with an organic fluid product. The organic fluid inside the vacuum tube solar collector is heated to a very high temperature above 200°C using solar radiation and superheat the refrigerant material over the temperature that mechanical compressor can perform with electricity. The additional heat input by solar collector reduce the compressor work load and lead to the energy saving.

HSCA system was introduced to improve the efficiency and reduce reliance on conventional vapor compression system which consumes more energy and contribute in greenhouse gases emission. Thermal driving technology for air conditioning was introduced in the beginning of 20^{th} century. Smith (1940) introduced an apparatus and method for cooling in order to adjust the air moisture content by use of desiccant wheel in which operation was thermally driven. The efficiency of the smith system was improved compared to the previous technology because of the separation of cooling and dehumidification. The dependency upon electricity in the improved systems is also decreased. In subsequent years a gas engine was proposed by Maclaine-cross et al (1987), the VCC worked as the heat sink while gas engine served as the heat source for the system and the system was referred to as hybrid system.

Pennington (1951), was the first person who eliminated the need for a VCC and combine the desiccant assisted ACs with evaporative cooling. Lather Dunkle (1965) amended and modified the system to increase its efficiency, he used various heat exchangers and also solar thermal energy as source of heat.

According to the research by Daouet al (2006), Khalid, (2009) and Al-Alili et al(2012) open cycle desiccant Assisted Air conditioning could make reasonable reduction of primary energy consumption especially by using solar thermal energy to serve as heat source for to the system.

Solar hybrid AC system shows significant advantage due to the higher level temperature of the heat sink and the supply air for the pre – dehumidification (Burns and Mitchell, 1985; Fong et al., 2011; and Liang et al., 2011). According to Mertz (1992) and Niuet al., (2002) combination of radiant heat exchanger and open cycle AC system can reduced the primary energy consumption.

According to Wrobelet al. (2013), present pilot installation for AC systems operate with the assistances of solar thermal and geothermal energy in Germany. HVAC system can be highly efficient at different climate region worldwide with the combination of radiant heat exchanger and desiccant assisted AC system.

Ha, Q.P. and Vakiloroaye, V. (2012) present novel research on the performance enhancement on direct expansion AC with solar vacuum collector installed between the compressor and condenser, proportional control is also proposed on the research. From the design energy saved from compressor is 6.25% compare to conventional VCC and COP increased more than commonly used design by about 6.7%.

II. METHODOLOGY

Hybrid solar air conditioner (HSAC) has been used for long for comfort cooling with different technological approaches, and solar assistance is found to be a solution to energy peak load demand for air conditioning system during summer period. The HSAC system, during hot periods, can receive enough radiation from sun and deliver required cooling demand without any inconveniences because of the peak radiation it gets. Many approaches and technologies have been practiced for solar air conditioning system which includes solar mechanical processes, absorption cycles and desiccant cycles. Nigeria has enough solar potential to drive any solar system for air conditioning during summer seasons.

The objective of this research is to design the system with high COP/EER, reduce the electrical energy consumption of the compressor due to the vacuum solar collector combined with direct expansion air conditioner and to abate CO_2 emission. According to Shesho, (2014) solar cooling systems can bring more economic advantage to the users. The initial investments are higher than conventional Vapor compression system of cooling. However, the economic advantages of solar cooling system can range from low operational cost of the system, low maintenance of the system and reduced electrical energy consumption. SE can be utilized in different purposes, the solar cooling process can be done by converting the radiation of the solar to thermal energy by the use of solar thermal collectors to capture the heat and drive the cooling cycle system (absorption or adsorption cycle). SE can be also converted directly to electrical energy by the use of Photovoltaic (PV) panels to provide electrical power to drive VCC system Al- Alili, (2012). According to the research by Daouet al., (2006), Khalid, (2009) and Al-Alili et al., (2012) open cycle desiccant Assisted Air conditioning could make reasonable reduction of primary energy consumption especially by using solar thermal energy to serve as heat source for to the system. According to Wrobelet al., (2013), present pilot installation for AC systems operate with the assistances of solar thermal and geothermal energy in Germany and it shows reasonable result. Ha and Vakiloroaye, (2012) presented a novel research on the performance enhancement on direct expansion AC with solar vacuum collector installed between the compressor and condenser, proportional control is also proposed on the research. From the design

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energy saved from compressor is 6.25% compare to conventional VCC and COP increased more than commonly used design by about 6.7%.

Design approach

In order to come up with this design of hybrid solar air conditioning (HSAC) system, there are four major aspects that have been considered. These include the space to be conditioned, the meteorological data of the location, type of air conditioning and the suitable solar collector. The HSAC is designed to produce 20kW (68,240 Btu/hr) cooling capacity for small and medium house. Two different refrigerants R410a and R134a will be used to see which one can give better efficiency (COP, EER). The design will include three different sub cool temperatures for the condenser. Considering the environmental conditions of Nigeria, the operating parameters of the refrigeration system is set as given in table 1 below. The refrigeration capacity of the system is assumed as 20 kW, a capacity to satisfy the requirements of a small to medium building. Refrigerant charts and also a commercial refrigeration computer program was used to calculate the heat rejection, heat absorption and compressor power requirements of the designed refrigeration cycle. In all tests, for both refrigerants, the condensing temperature is set at 50°C and evaporation temperature was set at 5°C. A 5°C superheat (state 2, exit from the evaporator) was assumed for all cases. The sub-cooling temperature (state 6, exit from the condenser) however was varied between 4.6°C and 12°C.

Refrigerant charts and also the commercial program was used to test the cycle with and without solar assistance. Solar heat addition is aimed at reducing the compressor power requirement. For this purpose, the compressor outlet (state 3) is adjusted to be at a lower pressure (corresponding to a lower condensing temperature), and solar heat is then supplied at constant volume (states 3-4) to increase the pressure to the designed condensing (corresponding to 50°C) pressure of the system. In all cases, the solar heating portion of the cycle is limited to 100°C.

Refrigerants	R134a	R410a
Cooling capacity	20kW	20kW
Condensing temperature	50°C	50°C
Evaporating temperature	5°C	5°C
Sub cool temperature	7°C, 10 °C and 12 °C	4.6°C, 7.8 °C and 10 °C
Super heat temperature	5°C	5°C
Flow rate	483 kg/h	673kg/h

Table 1. Design operating parameters

System configuration and description

The Hybrid solar air conditioning (HSAC) system is a combination of single-stage vapor compression cycle with solar collector as additional heat input to the system with six major components: a solar vacuum collector, a solar storage tank, a compressor, an evaporator, an expansion valve, and a condenser. Figure (3.5.1) shows the schematic diagram of (HSAC) the system cycle stars with the combination of liquid and vapor at the evaporator inlet and at the exit it become gas and superheated due to the heat absorbed from the conditioning space. At the inlet of the compressor the refrigerant is superheated, after it enters the compressor, isentropic compression take place where both the temperature and pressure increased. A heat source solar vacuum collector is installed after a compressor uses solar energy to heat up water inside highly insulated water tank and the storage tank is connected together with solar vacuum collector to retain the temperature of the water, solar collector heats up the refrigerant at constant volume to 100°C above the capacity of the compressor can be able to perform with electricity in order to reach the required refrigerant condensing temperature and reduces the power consumption by the compressor. The superheated refrigerant at high-pressure travels from the solar collector to the condenser where the heat is rejected to the ambient air, at the inlet of the

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condenser the refrigerant is 100% gas and at the exit of the condenser the refrigerant become saturated liquid (constant pressure heat rejection), refrigerant is then condensing at the selected condensing temperature of 50°C. Then it is throttled at the expansion valve to causes the sudden drop of temperature to the evaporator pressure (throttling) because of it is adiabatic process and vaporizes as it enters the evaporator and absorbed heat (constant pressure heat addition) from the refrigerated space the cycle is complete.

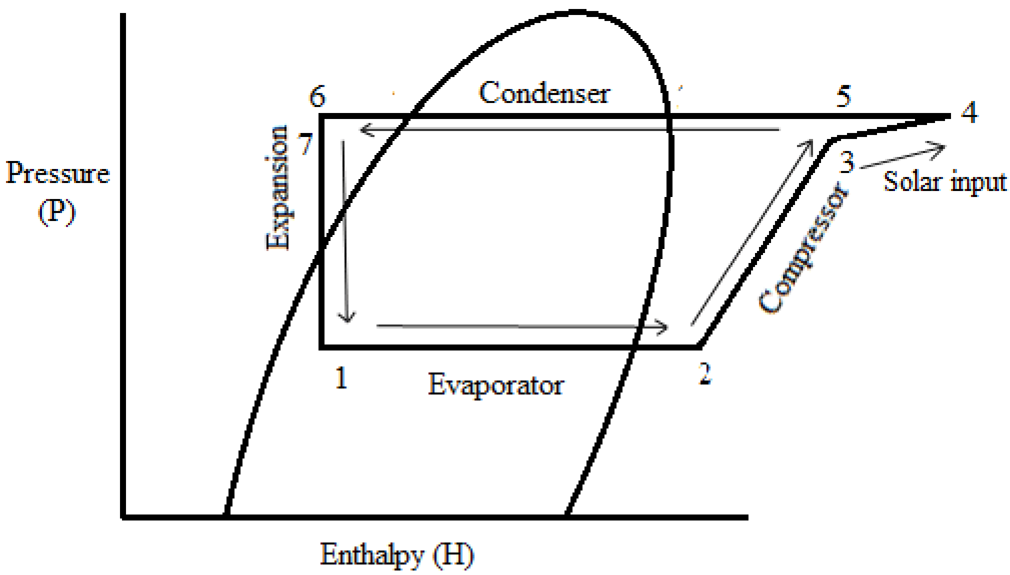

Fig. 1 Pressure enthalpy chart of HSAC

To evaluate the effect of solar assistance, energy saving per year and CO_2 reduction and compared with the standard method, the following tests were carried out using a refrigeration chart, commercial refrigeration program and cooling degree day for Abuja Nigeria: the standard refrigeration cycle 2-5: compressing, 5-6: condensing, 6-1: expansion, 1-2: evaporation. The solar assisted refrigeration cycle 2-3: compressing, 3-4: solar heating (constant volume), 4-6: condensing, 6-1: expansion and 1-2: evaporation. State 3 and state 5 correspond to compressor outlet condition with and without solar assistance respectively and with equal isentropic efficiencies.

Description:	Celsius-based cooling degree days for a base temperature of 25.0C	
Source:	www.degreedays.net (using temperature data from www.wunderground.com)	
Accuracy:	Estimates were made to account for missing data: the "% Estimated" column shows how much each figure was affected (0% is best, 100% is worst)	
Station:	Abuja, NG (7.26E,9.01N)	
Station ID:	DNAA	
Month starting	CDD	% Estimated
01-04-15	122	30
01-05-15	102	25
01-06-15	39	10
01-07-15	48	33
01-08-15	19	18
01-09-15	32	59
01-10-15	47	48
01-11-15	92	43
TOTAL	501	

Table 2 Cooling degree days for Abuja

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Energy saved per year

The cooling capacity required during peak hot season for this design is 20kW

The cooling degree days from table 2 is 501 degree days

The outside design temperature T_o=40^{O}C

The indoor design temperature T_i=25^{O}C

The effective, full capacity operation time (H_f) of the air conditioning unit is estimated as follows:

$$H_f = CDD * 24 / (T_o - T_i)$$
$$H_f = 501 * 24/(40 - 15) = 801.6 \text{ hrs}$$

For the refrigerant R134a

Electrical energy used, E_e for the cooling purpose is thus calculated as:

$$E_e = H_f * (\text{Compressor input})$$

a) Without solar assistance, with 12°C subcooling

$$E_e = 801.6 * 11.67 = 9354.67 \text{ kWh}_e$$

b) With solar assistance with 12°C subcooling

$$E_e = 801.6 * 10.264.96 = 8224.4\text{kWh}_e$$

Electrical energy saved

$E_s = 9354.67 - 8224.4$

E_s= 1130.27kwh$_e$ per year (12.08%)

For the refrigerant R410a

Electrical energy used, E_e for the cooling purpose is thus calculated as:

$$E_e = H_f * (\text{Compressor input})$$

a) Without solar assistance, with 10°C subcooling

$$E_e = 801.6 * 12.16 = 9747.5\text{kWh}_e$$

b) With solar assistance with 10°C subcooling

$$E_e = 801.6 * 11.09 = 8889.74 \text{ kWh}_e$$

Electrical energy saved

$E_s = 9747.5 - 8889.74$

E_s= 857.76kwh$_e$ per year (8.8%)

CO_2 abate

Under normal and standard conditions, natural gas may be combusted in a thermal power station for the production of electricity. Using chemical analysis and assuming a conversion efficiency of 50%, it may be calculated to show that, for every kWh$_e$produced, 0.37 kg of $CO_2$is emitted into the atmosphere.

Total CO_2 emission avoided by this process is

$$CO_{2,s} = \text{Electrical energy saved} * 0.37 \text{ kg/yr}$$

For the case of R134a

$$CO_{2,s} = 1130.27 * 0.37 = 481.2 \text{ kg/yr}$$

For the case of R410a

$$CO_{2,s} = 857.76 * 0.37 = 317.4 \text{ kg/yr}$$

III RESULTS AND DISCUSSION

Table 3 compares compressor input and COP/EER of HSAC with conventional VCC, both of them at same parameters. From the findings it can be seen that there are considerable difference between the compressor input with and without solar input in the system, the difference in terms of percentage decreased are 12.08% and 8.97% for the refrigerant R134a and R410a respectively. For the COP/EER it is cleanly seen form the chart that at 12^o sub cooled there is increase of 13.85% for the refrigerant R134a and 10.81% increase for the refrigerant R410a. The annual electrical energy saved per year using this design are also considerable which result as E_s= 1130.27 kwh$_e$ per year (12.08%) for R134a and E_s= 857.76 kwh$_e$ per year (8.8%) for R410a. Similarly for the CO_2 emission avoided by this process is per year per kilogram are CO2,s 481.2 kg/yr and 317.4 kg/yr for R134a and R410a respectively. It is also shown that higher sub cooled temperature give better result, this corresponds with the research on Hybrid AC compared with standalone VCC carried out by Ge et al. (2008), similarly sub cooled 12^{o}C and 10^{o}C, and gives has higher COP/EER. It is suggested that when designing HSAC using R134a or R410a as working fluid, higher sub cooled temperature should be used, this correspond with the research of Ha, and Vakiloroaya, (2012) on energy enhancement solar air condition, which shows that after heat rejection to the ambient by condenser, higher sub cool temperature significantly increases the overall system COP.

The percentage decrease of the compressor input of the HSAC compared to the conventional VCC at sub cooled 12 is:

$$\Delta(W) = (11.67 - 10.26) * 100\% = 1.41$$
$$= 12.08\%$$

The percentage increase in EER by the solar input of the HSAC compared to the conventional VCC at sub cooled 12 is:

$$\Delta(EER) = (3.61 - 4.11) * 100\% = -0.5$$
$$= 13.85\%$$

The percentage decrease of the compressor input of the HSAC compared to the conventional VCC at sub cooled 10^{o}C is:

$$\Delta(W) = (12.16 - 11.09) * 100\% = 1.07$$
$$= 8.79\%$$

The percentage increase in EER of the HSAC compared to the conventional VCC at sub cooled 10^{o}C is:

$$\Delta(EER) = (3.70 - 4.10) * 100\% = -0.40$$
$$= 10.81\%$$

	R134a			R410a		
Sub cooled	7	10	12	4.6	7.8	10
Condensing (Heat removal Q_{4-6}) wh/kg	63.14	64.6	65.40	60.97	62.50	63.61
Condensing (wh/kg) Q_{5-6} without solar input	51.75	53.00	53.83	54.38	56.16	57.20
Evaporating (cooling effect Q_{2-1})wh/kg	39.96	41.40	41.88	42.9	44.44	45.54
Cooling effect Q_{2-1} (wh/kg) without solar input	40.12	41.38	42.23	42.20	43.98	45.02
Compressor input (Q_{3-2}) wh/kg	10.26	10.26	10.26	11.09	11.09	11.09
Power input Q_{5-2} (wh/kg) without solar input	11.67	11.67	11.67	12.16	12.16	12.16
Solar input (Q_{4-3}) wh/kg	12.90	12.90	12.90	6.93	6.93	6.93
EER	3.89	4.03	4.11	3.86	4.01	4.10
COP/EER without solar input	3.43	3.54	3.61	3.47	3.61	3.70
Mass flow kg/h	1	1	1	1	1	1

Table 3. Summary of Refrigerant R134a at sub cooled 7, 10, 12, R410a at sub cooled 4.6, 7.8 and 10 (per unit refrigerant flow rate)

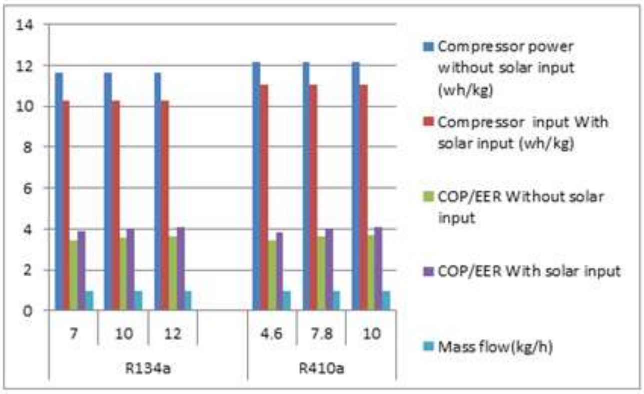

Figure 2 shows graphical representation of table 3

CONCLUSION

From the review of literature, it is found that energy is one of the basic necessities for development of any country. Solar energy technology is promising, reliable and efficient. From the result of the research, for both of the refrigerants used the COP/EER of the HSAC is higher than that of the conventional VCC with considerable differences, the electrical energy saved per year are also considerable and the CO2 emission reduction also is considerable. The energy savings and, CO_2 reduction using HSAC system is considerable and has potential for much higher values.

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