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Hybrid Air Conditioning, Solar, HVAC, Energy Consumptions

Nader. A. Nader[1], Ibrahim M. Alghamdi[1], Rami S. Alsayed[2]

[1]*Mechanical Engineering Department, Prince Mohammad Bin Fahd University, Kingdom of Saudi Arabia*

[2]*Mechanical Project Engineer, East-West Pipeline Projects Department, Saudi Aramco, Kingdom of Saudi*

ABSTRACT: *The current electricity peak demand in the Kingdom of Saudi Arabia (KSA) is about 55 Gigawatt (GW). Of that, 72% is used for Heat Ventilation and Air conditioning system (HVAC). The peak demand is projected to reach 120 GW by the year 2032 and the Kingdom may face the risk to significantly reduce its petrol exports to meet local energy demands. Consequently, in 2007, the Saudi Government initiated a massive program to improve HVAC energy consumption efficiency. The program includes HVAC rating system, comprehensive implementation program for the new system, and public awareness campaigns. This study provides an overview on the current and future situation of solar cooling and power consumption in Saudi Arabia. Further, this study will describe a demonstration project of the use of solar energy to increase the efficiency of the split units and to decrease its energy consumption. The hybrid air conditioner consists of installing a solar panel between the compressor and the condenser. Comparing the EER and power for a fully system air conditioning system and the air conditioner equipped with the solar bypass improved the EER by 5.41% and the COP by 12.24 %. The consumption of power was reduced by 5.35%. The system can be optimized to reduce the energy consumption even further as will be discussed in this document.*

Index Terms: *Hybrid Air Conditioning, Solar air Conditioning, Solar HVAC.*

I. INTRODUCTION

One day, the traditional source of power such as fossil fuel will end; these days may be near or far away, most aspects of human being life depend on the products of this traditional source of power. So to be prepared for that day, everyone should search and contribute to find other sources of power to maintain the living way. In Saudi Arabia the main dependence is only on the oil to produce energy. There are many alternative energy sources such as solar, wind and water. Also, air and water pollution which is mainly caused from the use of traditional fuel will leads us to look for other sources of energy. Moreover, Saudi weather in summer required a massive power to run the air conditioning system. However, the air conditioning systems is consuming most of the powerthat is produced by oil. This study will focus on this issue how to reduce huge consumptions of power through utilizing the solar energy. Thus less usage of oil and an increase in the efficiency of the A/C units will be accomplished within the KSA.

Air condition plays a very high role for power consumption in Saudi Arabia. The increase in population, currently 20 million and expected to double in year 2030 [15], requires a massive power supply to run the air conditioning system. To reduce the power consumption by the A/C split unit, the solar energy gains from heat transmitted from the sun will be utilized. This study is aiming to solve the problem of power consumption and increasing the efficiency of the air conditioning split units

Energy consumption has been a serious problem facing Kingdom of Saudi Arabia. By statics the Kingdom is using 70% of its produced electricity in air- conditioning. Moreover, today the Kingdom is facing the risk of shutting down in exporting petrol due to the massive consumption of energy within 10 to 15 years. However, can we imagine the life without electricity? Can we visualize what will happen to the economy if exporting petrol is stopped? Have we considered the needs of energy for the next generations?

The kingdom energy, the main source of energy generation is the petrol where we are using more about 70 % of the amount of the produced oil for energy generation. The other part of the equation is the kingdom economy is totally depending on oil and gas, it is the main source for the kingdom wealth and economy strength, without it we will face a huge economic collapse which will lead to a big issue in the kingdom [1].The study is aiming to reduce the power consumption of air conditioning systems using solar thermal energy, since it is consider as an environment friendly source. Thermal solar energy can increase the COP of the air conditioning system . The power consumption of the system will be dropped as the efficiency of the system will be increased

[2]. This proposed thermodynamic system may save about 40-50% of total power consumption especially in hot and wet summer season. The heat energy required for regeneration of desiccant material can be achieved from the heat rejected from the condenser or solar air pre-heater [3]. Here complete thermodynamic analysis of the proposed system. The COP value for the refrigeration process is defined as the heat removal from the refrigerated space over network input.

$$COP = \frac{Qi}{Wnet \cdot i} = (ha - h5)/(h2 - h1) \quad \text{Eq. 1}$$

Increasing the coefficient of performance of a combined solar assisted Ejector Absorption Refrigeration system decreases the amount of consumed power [3]. The maximum increase in COP is about 50% higher than the basic cycle. In the experiment we found if we have higher cooling capacity in the same time we have lower evaporator temperature the result will be an increase in the generator temperature

The experimental procedure will determine the needed thermal energy using the solar energy. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat, which can be used in water heating systems. A commonly used solar collector is the flat-plate. A
lot of research has been conducted in order to analyze the flat-plate operation and improve its efficiency.

$$\frac{du}{dx} = \dot{Q}\,in - \dot{Q}out + \dot{Q}\,v \quad \text{Eq.2}$$

The study showed that a flat plate solar collector working temperature is 50-100 C while it is efficiency reaches 0.80 [5].Sayigh (1981) [6] performed that comparisons for a hot, arid climate like that of Riyadh, Saudi Arabia are made for four solar air conditioning systems. Mattarolo (1982) [7] conducted a general survey of solar-powered air conditioning systems, including descriptions of a continuous open cycle absorption cooler, and dehumidification-humidification systems. Solar-powered air conditioning system was designed, installed and operated in Singapore (Bong, 1987 [8]). Aly and Fathalah (1988) [9] presented a combined absorption-desiccant high performance air conditioning system suitable for hot humid areas. Feasibility of utilizing solar power for comfort cooling in Hong Kong has been studied; a solar-powered absorption air conditioning system was designed and successfully constructed on the campus of the University of Hong Kong (Yeung, 1992 [10]). Tsilingiris (1993) [11]

A solar hybrid desiccant air conditioning system has been configured, experimentally investigated and theoretically analyzed (Dong La et al., 2011 [12]). The potential applications and advantages of powering solar air-conditioning systems using concentrator augmented solar collector (Dan et al., 2012 [13]). Lavinia and Mario (2012) [14] investigated the solar heating and air-conditioning by GSHP coupled to PV system for a cost-effective high-energy performance building

II. PRELIMINARY DESIGN AND RESULTS

Our Solar air conditioning's design depends on three main parts; Solar collector, controlled valves and indoor/outdoor unit of the AC.

2.1 Solar Collector Design

In this study, a flat solar collector was designed. Flat SC is fit with Saudi Arabia environment, since the efficiency will be gained in the summer. It has the lower manufacturing price. The operational system will produce a high efficiency do to the summer season in the KSA. However, the main parts of the design are listed in the table below:

TABLE 2.1: SOLAR COLLECTOR MATERIALS

Part	Quantity	Thermal Conductivity
Wooded box (150 x 100 x25) cm	1	--
Copper tube (8 m) L, (3/8 in) D	1	380 W/mK
Tempered Glass (4 mm)	1	--
Gauge pressure (250/500 psi)	2	--
Thermal painting (	1	--

black)		
Insulations	2	--
Angle □45	-	--

According to table 2.1, designing the SC, we fixed the angle directed to the sun to 45˚to make sure; the sun radiation will be directed to the sun. In addition, we use tempered glass with 0.84 solar transmitting to ensure that with high temperature the glass will not brake. Also we use the gauge pressure to control the pressure and temperature inside the SC with a relief valve. Technically, we design the SC to fit with the refrigerant R 22.

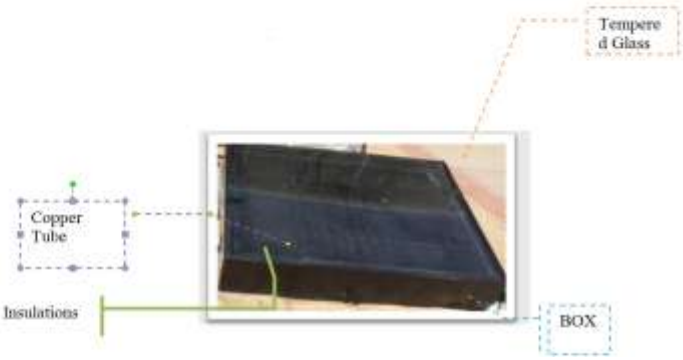

Fig. 2.1. The design of the solar collector.

2.2 Solar Collector Results

In this part, discussions will be about the efficiency, pressure drop, heat gained from the sun and the power output of the SC.

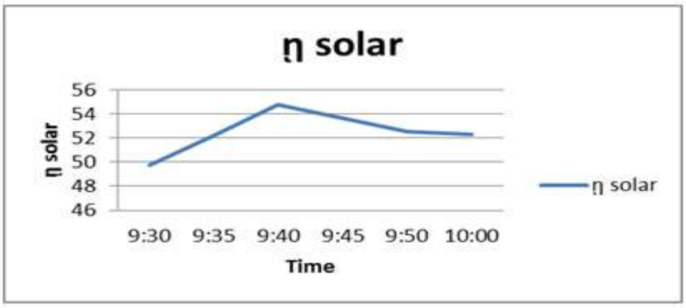

Fig. 2.2. SC efficiency %

Figure 2.2, the maximum efficiency gained on the SC is 54.7% at 9:40 am and the minimum efficiency gained by the SC is 49.7 % at 9:30 am. However, these results shows that the efficiency of the SC increasing with the sun radiation to the SC. Technically, the reason behinds getting lower efficiency is due to not including the absorber upper the copper tube to maintain the temperature at a high temperature. Another obstacle we faced during testing the efficiency of the SC is the weather.

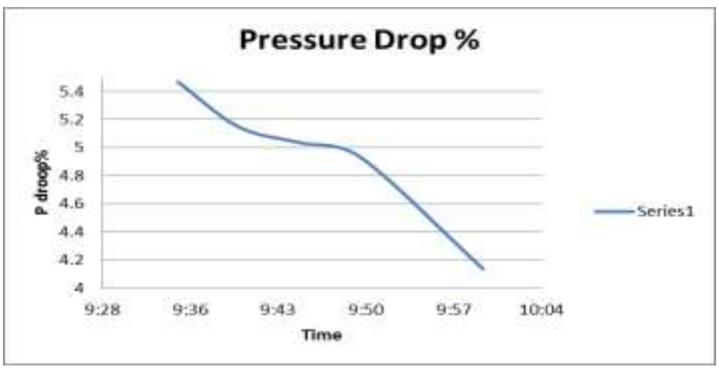

Fig. 2.3. Pressure drop %

Figure 2.3, the pressure drop at its maximum state at 9:35 am, and the pressure drop at its minimum state at 10:00 am. However, the refrigerant start entering the SC 9:35 am, so it takes 25 minutes to be at stable pressure with 139 psi and 4.13 % pressure drop.

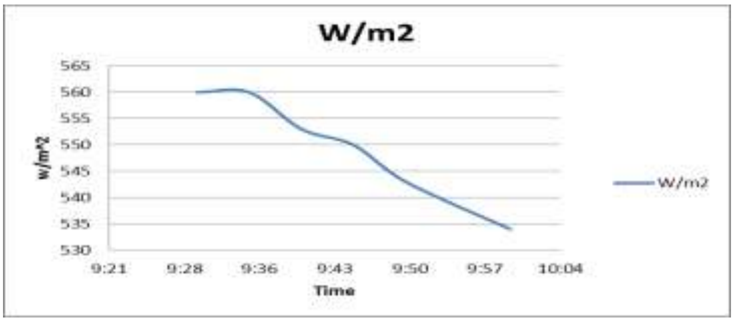

Figure 2.4. Heat gained from the sun due to time changing

The solar collector is directed to the sun in the east, so the radiation from the sun will be limited to 11:30 am. However, Figure 2.4 shows the heat gained from the sun. as showed in the figure above, the maximum heat gained is 560 $^{W}/_{m^2}$ at 9:35 am an the minimum heat gained is 534 $^{W}/_{m^2}$ at 10:00 am.

Figure 2.5. Daystar meter

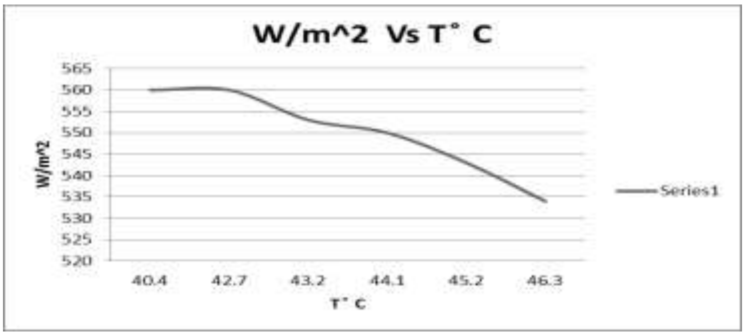

Figure 2.6. Heat gained due to time changing.

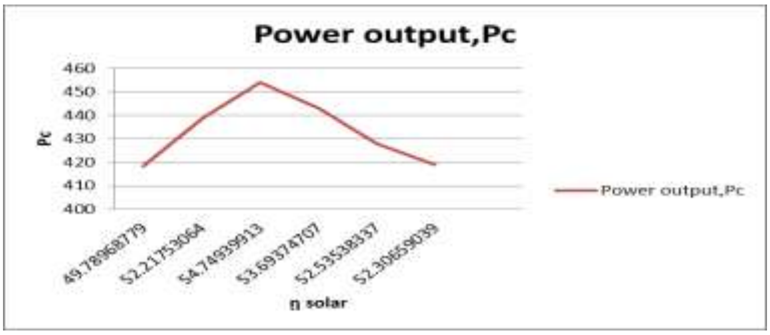

Figure 2.7. Power output due to efficiency of the SC

As shown in Figure 2.7, the maximum power out from the SC is 454.146 watt with an efficiency of 54.7%. While the minimum power output gained from the solar collector is 418.233 watt with an efficiency of 49.7%.

2.3 Solar Air Conditioning Design

In this part, discussion of design will focus on the systems we applied in our design. The systems application are: fully operation with the solar collector, by passes the solar collector system and, the mathematical modeling system.

2.4 Fully Operation system with the SC/ Bypass system

In this system, the refrigerant will enter the SC to increase the temperature (superheated) to increase the efficiency of the cycle. Moreover, in this design, system can be controlled via controlling valves as shown in figure 2.5. However, the SC will be connected between the compressor and condenser. To bypass the SC we have to close valve 1, 2 and 3.

Figure 2.8. Controlling valves system

Our design has indoor/outdoor unit and solar collector. However, table 2.2 shows the properties for the air conditioning system:

Cooling capacity (Btu/h)	12600
Current (A)	5.65
Input (watt)	1300
EER (Btu/h)/W	9.69
Refrigerant	R22/1050g
Power source	230V
Rated Current	10.0 A
Rated Input	1800 Watt

TABLE 3.2

Connection of the system is as below:

Figure 2.9. Solar Air Conditioning system.

TABLE 2.3

Solar Air Conditioning System Connection's Parts

Number	Name of connection
1	Solar Collector
2	Outdoor unit

3	Indoor unit
4	Controlling valves system
5	Refrigerant in to SC
6	Refrigerant out to condenser

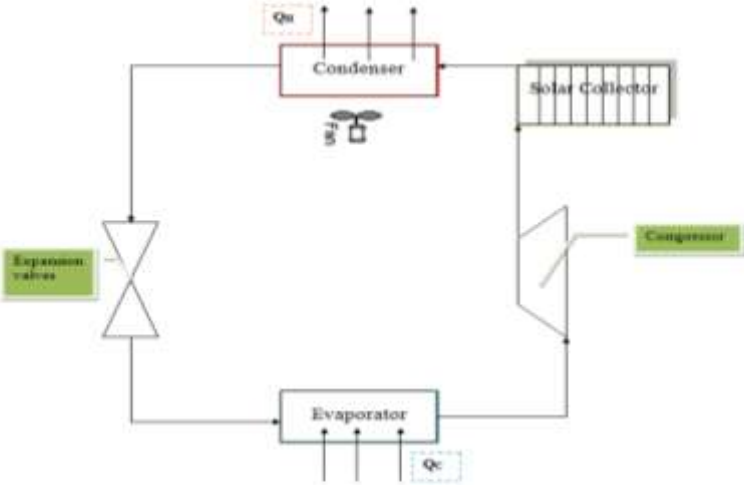

Figure 2.10. Solar Air Conditioning system cycle's diagram

According to figure 2.10, the diagram shows the sola air conditioning system. As shown in the figure, the SC connected between the compressor and the condenser.

2.5 Results for the Fully Operational System

After doing the experiment with sully operation system we found out the EER, Power and COP of the system. Moreover, in this experiment we used the laser sensor and the thermo couple to measure the temperature, but we found a huge difference between both devices. However, after making the mathematical modeling we found that the laser sensor is the corrected one, so we did our experiment based on the data provided by this device. However, table 2.4 shows the experimental maximum and minimum values based on maximum and minimum power:

TABLE 2.4

POWER, EER, COP AND PRESSURE DROP %

Time	Power	EER	COP	P drop %
10:45	974.68	12.92732	9.607616	6.081081
11:15	903.88	13.9399	8.328035	6.081081

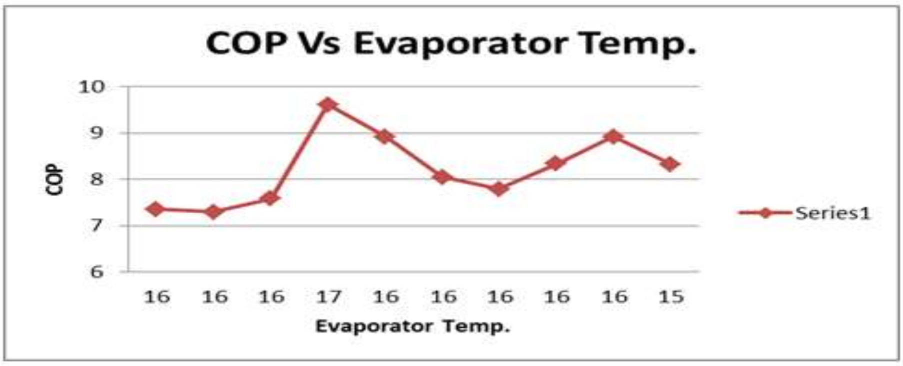

Figure 2.11. COP vs. evaporator temperature for the fully system.

2.6 Results for the Bypass SC System

Experimental result shows the result of the bypass system is different than the solar air conditioning system. However, table 2.5 shows the result of the experimental values with the laser sensor device:

Table 2.5

POWER, EER AND COP OF BYPASS SYSTEM

Time	Power	EER	COP
11:35	946.36	13.31417	10.86704
11:48	986.48	12.77269	9.150316

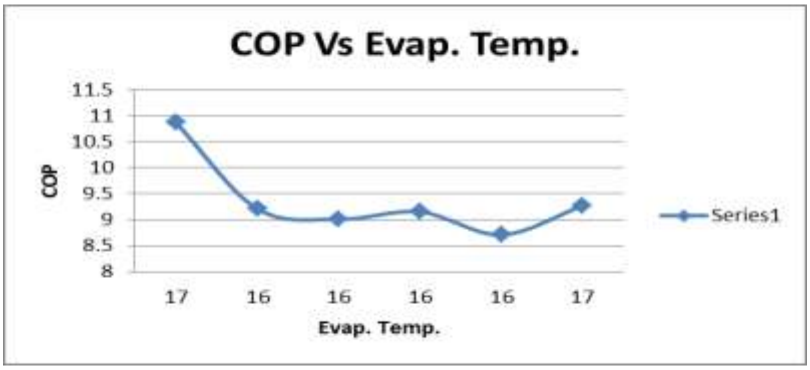

Figure 2.12. COP vs. evaporator temperature.

2.7 Mathematical Modeling

In the mathematical modeling we set the pressure at the readings from the gauges pressure, and then finding the other values of condenser temperature based on the R-22 thermodynamics Tables. However, Table 2.6 shows the result of calculating the COP for the mathematical modeling.

TABLE 2.6

COP, Mathematical modeling

p out, kpa	T cond	TH	Tindoor	COP
958.3712633	37.76313	310.9131	**16**	13.2862 3
937.6869914	36.96472	310.1147	16	13.7922 2
951.476506	37.49699	310.647	16	13.4507 2
958.3712633	37.76313	310.9131	17	13.9742 9
958.3712633	37.76313	310.9131	16	13.2862 3
937.6869914	36.96472	310.1147	16	13.7922 2
944.5817487	37.23086	310.3809	16	13.6193 3
958.3712633	37.76313	310.9131	16	13.2862 3
958.3712633	37.76313	310.9131	16	13.2862 3
958.3712633	37.76313	310.9131	15	12.6586 3

Table 2.6 shows the calculated temperature at the given pressure entering the condenser and the indoor unit (evaporator) temperature

2.8 Discussion of Results

By comparing the result for the fully system air conditioning and the Bypass system, we found that the EER is better in the SAC by 4.31%, COP 23.14 % in the minimum power required, while the maximum power required, EER is better in the SAC by 1.55%, COP 4.6 %. While, for the average data we found that SAC is better by EER 5.41% and 12.24 % COP. While the consumption of power reach to 5.35%. However, when we did our modeling for the COP we found that, there is a difference by 38.5% which is due to weather and calculation errors.

III. CONCLUSIONS

The project focused on the feasibility assessment of building a solar assets air conditioning system. In particular the project focused in the COP, EER and power consumption of the two systems; with SC and without SC. Finally, the project mentioned the expectation that it might happen by doing this project.The researchers found that, EER, COP and consumption of power is better in the solar Air conditioning system. However, the consumption of power reduced in the solar Air conditioning system. This research assumes that there is a large benefit of using solar Air conditioning system. The result came out from the COP and EER fits with our experimentation of the project. According to the analysis of data and discussion, solar Air conditioning system is the best way to increase the efficiency and reduce the consumption of power. By comparing the EER and power as stated in the table 3.9 and table 3.10, the outcome result to choose the solar air conditioning system as the best way to reduce the consumption of power and increase the efficiency of air conditioning system.By completing the discussion about the result of EER, COP and power consumption, the outcome result will be positive to improve the solar air conditioning system and establish it in the kingdom of Saudi Arabia.

IV. RECOMMENDATIONS

- Solar Collector: there are many types of solar collectors, flat plat solar collector, which has been used in the project. While the second one is the vacuum solar collector. In particular vacuum solar collector is better than flat plate solar collector. However, the weather in Saudi Arabia is almost sunny even in the winter. So flat plate is the best choice in Saudi Arabia but vacuum solar is the best in all seasons and everywhere.
- Photovoltaic: this system will reduce the consumption of power from 700 watt to 1400 watt. Addition of the two systems together, will minimize the requirementsfor electricity.
- Solar collector cleaning itself by itself: in our class of control system, our project was about this subject. This project helps to clean the glass plate of the solar to increase heat transmit ion from the sun to the solar collector or cells. However. This extra project will helps to let the system depends on the
- Solar tracker system: this system helps with the photovoltaic system to track the sun.

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