Journal of Modern Computing and Engineering Research
JMCER
Volume 2022, p. 38-48
https://jmcer.org

Investigation the Solar Powered Hybrid Air Conditioning System with Different Approaches: A Review

Mukhtar Noori Saddam [1] , Mushtaq Ismael Hasan [2]
[1,2] *Mech. Eng. Dept. College of Engineering, University of Thi-Qar, AL-Nasiriyah, IRAQ*

[1]mukhtarnoori@utq.edu.iq., [2]mushtaq76h@gmail.com

Received: April 22, 2022 *Revised: June 27, 2022* *Accepted: August 3, 2022*

Abstract: *This paper presents the recent studies on hybrid air conditioning systems. Additionally, the fundamental vapour compression system and components involved within the solar air conditioning system are discussed. The introduction of low-temperature storage is an interactive solution and improve economically which portrays different modes of operating strategies. Yet, only a few studies have examined on the optimal operating strategy of the hybrid system. Finally, the findings of this review will help suggest optimization of solar absorption and vapour compression-based hybrid air-con systems for* future work while considering both economic and environmental factors. *A comprehensive review has been conducted on the previous research's that were published, which includes studies, specifications, and experimentally measured values of air conditioning systems in various tropical or subtropical climates in all countries of the world. The air conditioning regulators were divided into two main parts, the traditional cycle and the hybrid cycle, and a study of the working mechanism of each of the two systems, with illustrations for each cycle. A brief overview of solar collectors with different specifications and values, available spaces, and amounts of energy produced from emitted solar radiation was also discussed. Solar energy is also categorized into two main categories: solar thermal collectors, solar photovoltaic panels. The focus of the research has been on the past ten years. Different results were obtained in terms of economic and energy savings, with an average of 25% to 60% of the total energy consumed in the refrigeration cycle annually. Improvement in COP (Coefficient of Performance) is also observed at rates ranging from 10% to 20% at peak temperatures during the summer. Researchers recommended the use of vacuum tube types of solar collectors because they are more efficient, effective, and serviceable in volatile conditions, as well as occupying less space than other types of solar collectors. In terms of performance, the COP was recorded at a rate of 5.6 to 4.6, while the COP for the absorbance system was very low, with a rate of 1.2 to 2.*

Keywords: *Keywords: Hybrid air conditioning system solar powered AC, solar assisted AC, hybrid air conditioners.*

1. Introduction

Conventional air conditioners or vapor compression systems are primary contributors to energy consumption in modern buildings. Common environmental issues emanating from vapor compression systems include greenhouse emission and warmth waste. These problems are often reduced by the adaptation of alternative energy components to vapor compression systems. However, intermittence input of daily solar radiation was the central issue of the solar power system Due to the remarkable population increase in the world during recent years, the increase in demand for electric power, and the depletion of fossil fuels in the world have been enrolled, leading to an increase in environmental pollution. The increase in pollution leads to an increase in global warming, which in turn negatively affects the climate significantly as a result of carbon emissions resulting from the combustion of fossil fuels, and global warming that affects the ozone layer (Cabeza & Serrano, 2015 and Kabeel, 2017) causing negative changes in the climatic atmosphere leading to negative changes in temperature and humidity, (Sevinç & Güngör, 2012) increasing average temperatures and weather fluctuations during the seasons of the year, especially during the summer. Higher temperatures during the summer lead to an increase in the demand for air conditioning.

Air conditioners excessively consume electrical energy, exacerbating the increase in energy and fossil fuel consumption, which is the main cause of climate and environmental pollution from carbon emissions (El-Sayed et al., 2018) with the study and investigations taking place all over the world, the air

JMCER

conditioners are the most resident and communicant appliances, which consume electrical energy by (Pinto et al., 2019).

Scientists and researchers around the world have come up with economic solutions and found strategic systems that reduce fossil fuel consumption by switching to a sustainable and environmentally friendly renewable energy sector with zero carbon emissions (Mohanraj et al., 2018). Solar energy is renewable and sustainable energy.

Solar energy is more feasible and effective than other energies because it is more, more available than other renewable energies, and less expensive to reach the earth, the amount of solar energy day-by-day solar dose of 108 kW-hr, which is identical to 500,000 billion oil (Fong et al., 2018). The emitted solar radiation is exploited by converting solar radiation into thermal energy or electrical energy through solar thermal collectors or photovoltaic solar panels (Brahmankar & Bhushan, 2018). Researchers used solar energy by connecting solar collectors to air conditioners to reduce compressor power consumption (Jani et al., 2016). The solar compressor is responsible for increasing the pressure of the refrigerant to reduce the consumed energy to get the required amount of work. The compressor consumes the bulk of the energy in the air conditioning cycle (Wang et al., 2014).

2. The refrigeration cycles

2.1 The conventional

A conventional air conditioning system consists of the following main parts: an evaporator, compressor, condenser, expansion valve, and refrigerant, with appropriate physical properties. The conventional refrigeration cycle system consists of the following main parts as shown in Figure 1:

- Evaporator
- Compressor
- Condenser
- Valve expansion control

The cycle starts from 2 as shown in Figure 1. Where the refrigerant absorbs temperatures from inside the room through the evaporator that contains the liquid refrigerant at a low temperature and low pressure. After obtaining room temperature, the refrigerant reaches the saturation temperature for evaporation, after which it begins to evaporate, and after gaining heat, the vapor moves to compressor 3. The compressor increases the pressure of the gas and pushes it from the compressor to condenser 4.

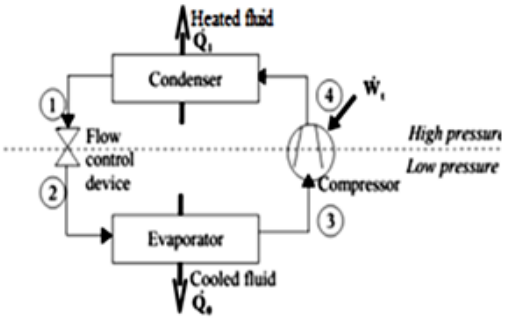


Figure 1: Conventional air conditioning system.

The compressor acts as a pump in the cycle increases vapor flow rate and pressure amount. The vapor goes to condenser 4 in the cycle. The fan works by forced convection method to remove the heat generated and transfer it from the refrigerant from the indoor environment represented in the room to the outdoor environment by placing air on the fins of the condenser. Then the gas goes to expansion valve 1 as shown in the Figure 1. The valve serves to convert the cooled gas into a cooled liquid with a lower pressure, the lower the pressure, the lower and the saturation temperature for evaporation. Then the refrigerant fluid returns to the evaporator, at low pressure and temperature, to the compressor...etc. The cycle continues until the cooling load required to provide adequate comfort conditions for an individual is reached (Al-Alili & Reinhard, 2012).

2.2 Hybrid air conditioning cycle

The cycle of hybrid air conditioners is quite similar to that of a conventional air conditioning system that relies on the electrical grid as the power source. The two cycles, hybrid and conventional, consume the most energy in the compressor. The energy source in a conventional air conditioning system depends entirely on the electric power from the electric power grid.

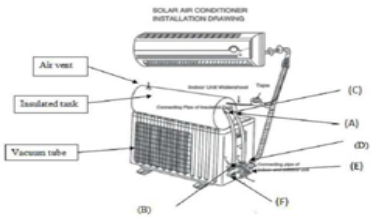


Figure 2: Hybrid air conditioning system with solar.

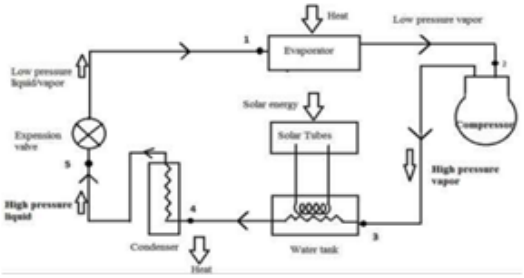


Figure 3: Cycle of Hybrid air conditioning system with heating.

The hybrid air conditioning system derives part or all of the energy required to accomplish the cooling process from sustainable solar energy sources (Fatouh et al., 2017). The compressor draws energy from the solar inverter directly as photovoltaic energy or through solar panels or batteries charged by solar panels and a solar inverter that converts solar PV energy into electrical energy (Al-Alili & Reinhard, 2012).

Another method reduces the workload imposed on the compressor by solar thermal collectors and its service function, increasing the temperature and pressure of the refrigerant, which leads to a reduction in energy expenditure on the compressor (Al-Alili & Reinhard, 2012). As shown in Figures 2 and 3 (Vakiloroaya et al., 2013).

The last method is absorption it is a cycle that operates within the refrigeration cycle that compensates for the work of the compressor and depends on the heat provided by the solar thermal collectors. Dependent on the heat supplied from the solar collector (Bellos & Tzivanidis, 2017). The hybrid cooling system consists of the following main parts, as shown in Figure 2:

- Evaporator
- Compressor
- Condenser
- Expansion Valve control
- Solar collector

The system performance was studied in previous researches through the process of connecting a solar thermal collector with a commercial air conditioning system as shown in Figure 3.

Air conditioning is carried out through the process of transferring the refrigerant from the expansion valve to evaporator (1). Figure 4 at low pressure and low temperature, the evaporator works as a heat exchanger between the internal environment and the refrigerant liquid in the evaporator. Because of the temperature difference, heat is transferred from the point with high temperature to the point with low temperature, and thus the temperature of the refrigerant increases. Gradually the refrigerant begins to shift from the liquid phase to the gas phase and then moves to the compressor (2) as shown in Figure (3). The amount of energy entering the compressor is controlled to reduce the operation of the compressor and thus reduce the energy consumed through the power regulator works to reduce compressor action. The solar thermal collector compensates the lack of pressure required for the refrigerant in the cycle. The refrigerant goes to the heat exchanger (3) as shown in Figure 3, connected to the solar thermal collector. The cooled vapor is heated to a high temperature; the pressure rises because of the high temperature of the refrigerant acquired from the solar thermal collector, which derives its energy from the solar radiation available on the surface of the complex Figure 6. The refrigerant exits from the solar collector to the condenser (4) as shown in Figure 3. The condenser expels heat to the external environment by applying forced air to the fins of the condenser. The role of the condenser is a heat exchanger with the external environment.

The refrigerant temperature drops and then moves to the expansion valve (5) in Figure 3 the valve reduces the pressure and temperature of the refrigerant, so the refrigerant returns from the gas phase to the liquid phase at a lower temperature and pressure. The refrigerant at a temperature of between (0-10°C) arrives at the evaporator and the refrigerant is heated up to be transferred to the compressor. Then on to the solar collector etc. The justification process continues to reach the desired temperature for the individual's comfort or the appropriate conditions for human comfort.

Figure 4: Evaporator.

JMCER

Figure 5: Compressor.

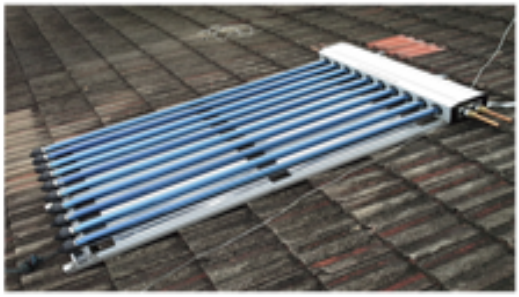


Figure 6: Solar Collector.

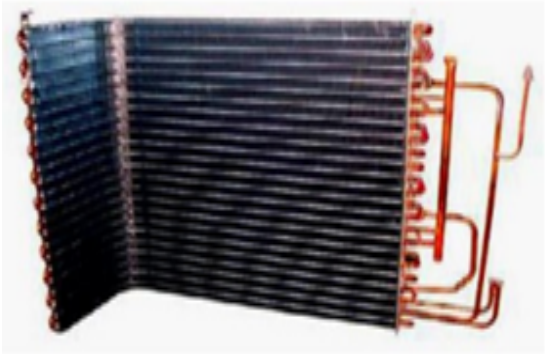


Figure 7: Condenser.

Figure 8: Expansion valve.

3. Solar system combined with air condition

The solar collector is a system that works on the energy of the solar radiation emitted to the surface of the earth. The solar collector works on absorbing the available solar radiation to heat the liquid inside the thermal conductors that absorb solar heat, from the available solar radiation, the water or liquid is heated, which is responsible for transferring the heat energy resulting from the fall of solar radiation on the solar collector (Goswami, 2015). Many carrier Medias are selected according to the thermal conductivity and the thermal conductivity coefficient of the material as shown in Table 1.

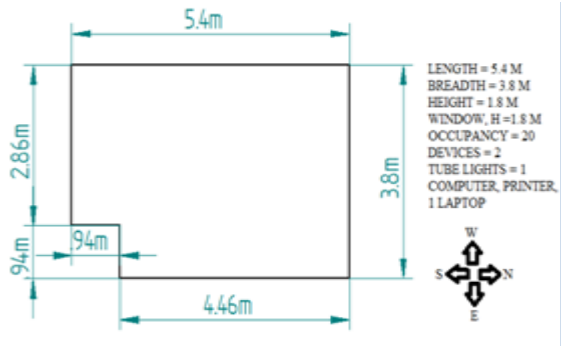
The best and most widely used solar collectors are flat-panel thermal solar collectors. The average efficiency of a flat-panel solar collector is (45% to 65%) of the total solar energy flowing onto the surface of the solar collector.

Table 1: Thermal conductivity coefficient of some material.

No.	Materials	Density	Heat Capacity	The Resulting	ΔT (℃)
1	Water	1.00	4.19	4.19	0-100
2	Ethanol	0.78	2.46	1.92	-117-79
3	Glycerin	1.26	2.42	3.05	17-290
4	Canola oil	0.91	1.80	1.64	-10-204
5	Synthetic oil	0.91	1.80	1.64	-10-400

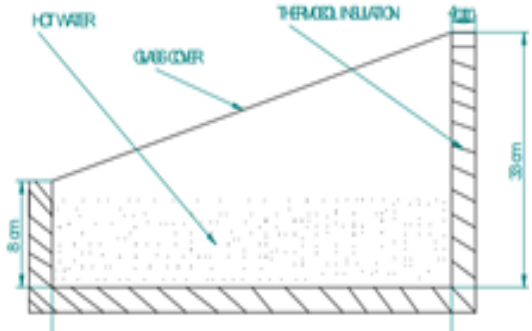
Flat-panel solar collectors are considered the least expensive and most abundant, the other type of solar collectors Thermal evacuated tube solar collectors are the best types of current solar energy solar collectors because their design allows for preference in their use (Nagaraj et al., 2020. It consists of glass evacuated tubes of air containing a heat transfer medium inside the inner tube that transfers the absorbed heat. The vacuum tube acts as an insulating medium that increases the efficiency of the solar collector. The average efficiency of the evacuated tube solar collector is 95% of the total solar energy absorbed by the evacuated tubes of the collector Solar (Chen, 2011). In addition to the presence of another type of

multi-use, there is another type of solar thermal collector, a solar heater placed on the surface of the basin at a certain angle of 18 ºC shown in the figure (9) that works to introduce the incoming solar radiation. In addition, the bathtub is painted from the inside in black or good dark colors that absorb solar radiation, Average temperatures from 45 ºC to 65 ºC (Nagaraj et al., 2020). The solar heater consists of a well-insulated basin that contains internal tubes and a glass plate.



(a)

(b)



(c)

Figure 9 (a, b, and c): Experimental setup of a solar water heater tank with the detailed dimensions of the solar tank for the researcher (Nagaraj et al., 2020).

3.1 Solar PV panel hybrid air conditioning

Photovoltaic solar collectors are a type of solar energy collector that is based on renewable energy. These collectors convert light energy from the sun into electrical energy that is used to power air conditioning systems (Jie et al., 2008).

The solar panel system consists of a photovoltaic solar panel made of chemically treated silicon with gaps to increase cooling and increase the performance of the solar panels. For solar modules, several methods have been proposed to cool the solar panels to increase production efficiency and prevent damage caused by damage to treated silicon modules manufactured for photovoltaic cells. Solar PV Hybrid HVAC System consists of (Air conditioning system with suitable cooling load, PV solar panels (modules), inverter, batteries, power charger, charge controller, meter...etc.) (Al Qdah, 2015). The proposed system works by linking the hybrid air-conditioning system with the photovoltaic units, the inverter, the batteries, and the battery charger as shown in the following Figure 10 and 11.

To compensate for the lack of energy supplied to the compressor during operation due to increased heat load, climatic changes, cloudy clouds that need sunlight, Low level of solar radiation, reduced sunrise hours, and the fact that photovoltaic panels act as a mechanism. To produce energy from the available solar radiation to generate more energy. The energy-consuming refrigeration cycle that circulates the refrigerant and compresses the vapor to the required pressure is the refrigeration cycle that circulates the refrigerant and compresses the vapor to the required pressure. This is done by studying the connection of solar panels directly to the air conditioning system.

Figure 10: PV panels.

JMCER

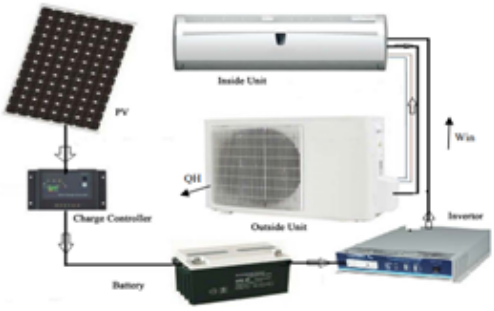


Figure 11: Cycle hybrid air conditioning system with PV panels solar.

Among the most important papers presented. (Al Qdah, 2015) presented a study on solar panels in the atmosphere of Medina in the Kingdom of Saudi Arabia, with six panels, two batteries for 8 hours, and 12 batteries for two days, with a cooling capacity of 3.5 kilowatts in areas not connected to the electrical network in the mountainous areas surrounding the Haram al-Sharif in August and January.

Mohankumar et al, (2017) used photovoltaic collectors to produce electrical energy 4 panels of 250 watts and 48 volts batteries were used. 220-watt inverter and 12-volt battery to feed the 3.5 kW cooling load. Hashim A. H. et al, (2020) also presented a detailed study of the mechanism of solar panels in the atmosphere of the State of Iraq in the city of Baghdad in the Tajik region. Where the researcher used 8 solar panels and batteries with a capacity of 75 AH 3.5 KW cooling load the experiment was conducted from 11:00 to 17:00.

Li et al, (2020) took advantage of photovoltaic collectors to provide electrical energy to withstand the required cooling in the volatile atmosphere of the city of Shanghai and a rate of 37.17% was obtained, while in the atmosphere of Shenyang the average energy saving rate was 26.40%.

Abdoulha et al, (2021) where the researchers conducted a study on the required cooling load on the SHIATS campus by relying on photovoltaic panels to provide electrical energy. The data were studied each month separately, in July; 2,942.8 watts were obtained from solar PV panels. The energy that the solar photovoltaic panels can provide is used to run the required cooling load and also transfer the excess energy via the charger to the batteries during the afternoon from 1:30 to 4:00 pm, when solar radiation and solar modules are at their peak during some time In the afternoon and afternoon, recover the energy stored in the batteries charged by the inverter to compensate for the reduced amount of energy supplied to the compressor during periods when solar PV output is low and during the night due to lack of solar radiation which is the main generator of energy production.

The amount of energy was taken into account. The equipment required and the amount of cooling load required for a room, office, or space intended to provide it with individual thermal comfort conditions in a well-thought-out, accurate, and recorded form of data and tabular calculations to reduce consumption is to exhaust the available energy and reduce the economic costs of building a photovoltaic system on the individual consumer.

3.2 Flat plate solar collector hybrid air conditioning

As for the hybrid air-conditioning system connected to a flat-type solar collector, it was used to reduce energy consumption in the compressor. Al-Nayer et al, (2015) presented an empirical study on the work of the flat solar collector and the efficiency of water heating in the atmosphere of the city of Sudan during winter periods in addition to heating and daily used. Other studies also presented descriptions on the work of solar panels connected to a cooling load of 3.5 kilowatts in four different climatic regions in the State of Egypt and the results were 66.02% in Alexandria, 60.10% in Cairo, and 50.39% in Al-Fardqa, while in Aswan it amounted to 41.16% while consuming more from the traditional previous regime in Aswan.

Jingkang et al, (2020) presented a detailed study on the mechanism for developing the efficiency of the level solar collector to bring the thermal productivity to an average of 100 Up to 120 ° C under the effects of ambient air without optical focus, where the rate of improvement in the efficiency of solar radiation reached 13%.

Nagaraj et al, (2020) took advantage of the simplified solar collector that was connected to a conventional cooling system with a capacity of 3.5 kilowatts. The experiment was conducted at times between 1:30 in the afternoon and 4:00 in the afternoon, the highest rates were recorded during time between 3:00 and 3:30 in the afternoon In April and May, 32% of the total energy consumed in the compressor was saved, but in the height of the summer it was saved by 45%, and it also improved the performance coefficient of the system from 2.25 to 4.04.

3.3 Evacuated tube solar collector hybrid air conditioning

Increasing the temperature and efficiency of the solar heating collector increases the amount of energy saved, and according to the available studies it was found that the efficiency of the solar collector is directly proportional to the area exposed to solar radiation, that is, the larger the area of the solar collector. Collector, ACR (Air Conditioning & Refrigeration) increases the amount of water heating and reduces the required period. The researchers urge the use of vacuum tube solar collectors consisting of double glass tubes. Among the most important research presented in the hybrid air conditioning cycle in recent years has been the proposal to reduce the amounts of energy expended in the air conditioning cycle is Fong et al, (2010) where researchers studied the performance of a hybrid system that derives thermal energy from solar radiation emitted on a pressurized vacuum tube, which is one of the proposed types of solar thermal collectors, and compared it with the conventional system. One-year air conditioning regimen in the climatic atmosphere of Hong Kong with a subtropical climate. Researchers have 6 alternatives, including 3 alternatives to an air distribution system and a completely fresh air split, and 3 to return air to the building. Through this process, an amount of energy was saved with 35.2% of the energy consumption.

Vakiloroaya et al, (2013) exploited the mechanism of working on a hybrid air conditioning system connected to a vacuum solar collector, where the researcher worked to increase the gas pressure through the process of adding a solenoid valve installed after the compressor and regulating the compressor rate. Compressor block. The passage of gas vapor through the hot water tank when testing the system results in reduced energy consumption between 25 and 45% of the total energy per month, with a cooling capacity of 6 Assadi et al, (2016) studied the hybrid air conditioning system with a cooling rate of 3.5 kW on five different models of the evacuated solar tube collector by equipping an evacuated tube between 10, 12, 14, 16, and 22) and in five different regions where 45% of The total energy consumed in the compressor during the day and 25% during the night period. 3.5 KW cooling capacity.

Kaidir et al, (2017) worked on a compressor with a cooling capacity of 3.51 kW. The study and work were carried out in the atmosphere of the city of Indonesia; temperatures from 50 to 65 ° C were recorded in 105 to 290 minutes, with a storage capacity of 22.5 to 120 liters for a hot water tank. Thermal temperature recorded the highest temperature of 88.5 ºC as the recorded starting temperature was raised to 27 ºC and the results of the performance coefficient for a period between 3.35 to 8.86 ºC during an average of 6 hours a day. Chetan et al, (2018) presented the results of energy saving of 29% of the total electrical energy when using a vacuum-type solar collector and the comparison was made between the conventional system and the hybrid solar system.

Rahman et al, (2019) worked on adding 5% of the volume of secondary single-walled pipes from the total area of the cooler and the temperatures were from (283 to 308 K) in addition to reducing the required cooling load. Through the process of shadowing the buildings with trees and using double-glazed thermal insulators for the walls and ceiling of the cold room, a 31.5% reduction in the amount of refrigerant required was achieved, the researchers obtained a 17.02% improvement in COP performance and 10.06 at a given heat for the dual system operation, as a result of reducing compressor load With 34% of the total energy and an increase in COP of 4, 39% compared to the. Per day by noting the change in the conventional system.

Patel et al., (2020) presented a detailed study on the performance of the hybrid air conditioning system and its comparison with the traditional system. Where the results were presented to save an amount of energy ranging from 25% to 40% of the total energy and saved energy by 30% of the total energy per month, Rankine cycle shown in Figure 12.

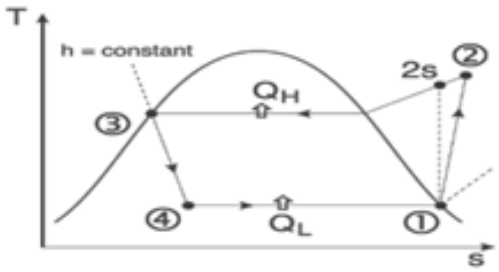


Figure 12: T-s diagram of vapor compression refrigeration cycle.

After adding the solar discharge tube and improving the obtained through the process of developing the refrigeration cycle and improving its performance. Consisting of double glass tubes and an outer tube that allows the entry of solar radiation, and the inner tube is coated with a dark substance.

JMCER

The inner tube is made of copper or aluminum, being conductive materials and possessing a high thermal quality that absorbs solar radiation and reduces light reflection Incoming radiation there is a space gap between the two tubes to increase thermal insulation and reduce heat loss from incoming radiation. On the evacuated solar tube. Vacuum tubes vary in size.

Tube diameter 65mm, length from 850mm to 1080mm, the distance between tubes 20mm to provide optimum heat transfer and heat exchange between surroundings and tubes, and has an engineering design that allows working in fluctuating climatic conditions with high-performance efficiency and less exploited surface area. Several flat pools, in which the overall temperature increase above the ambient temperature is estimated to be 95 °C (Figure 6, 13, and 14 (A partial section of the evacuated tube assembly detailing the assembly and operation of the solar collector.

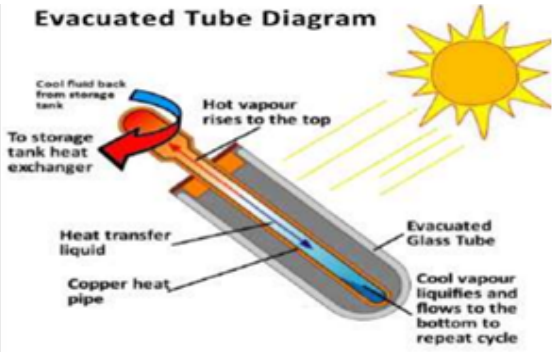


Figure 13: Vertical cross-section of the evacuated tube (Kumar et al., 2016).

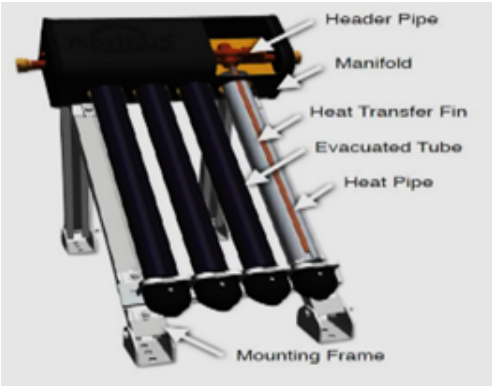


Figure 14: Critical component of the evacuated tube.

4. Absorption refrigeration cycle with solar energy

One of the most important modern methods that have spread over the past two decades is the sorption air conditioning system. The researchers resorted to such methods to reduce the excessive consumption of electric energy and fossil fuels, and the resulting carbon emissions, which negatively affect the Where the environmental rates. The mechanism of action in the absorption system depends in particular on the physical properties of materials, crystals of salt, ammonia, and water, chemical reactions, and changes of their phases in the substance, since a change in temperature and pressure periodically occurs through an organized system. In addition, a sequential, periodically stable process, as shown in Figure 15-a and 15-b. System works on absorption or a small absorption cycle. The compressor works in the refrigeration cycle system, and the absorption depends entirely on the temperatures gained from the solar collectors that receive it. The heat from solar radiation or through conventional heaters or electric heaters, in the absence of sufficient temperatures from solar energy sources.

Jasim et al, (2008) the researchers added different types of liquids, depended on the basics of the material and a detailed study of the energy balance, and based on the thermal properties of ammonia and water where ammonia and lithium nitrate were added. Ammonia and sodium thiocyanate were added and it was found that the ammonium nitrate, lithium, ammonia, and sodium thiocyanate cycles are much better than the ammonia and water cycles.

Farhan et al, (2013) used solid particles as an auxiliary medium in increasing the absorption of solar energy, as the metals silver, copper, iron, secondary materials carbon oxide, and ammonia have high thermal conductivity, and AGO was added with weights 1.0, 0.2 and 0.4% and compared them among themselves where it was found The best weight used is 0.1% and the results are an increase in the heat transfer rate of the solar collector and a decrease in the fluid quantity required for cooling, the system In addition to increasing the heat capacity of the system.

El-Shaarawi & Al-Ugla, (2017) studied the performance of the absorption device in the atmosphere of the city of Dhahran, Kingdom of Saudi Arabia. The researcher used a flat-type solar collector to provide the necessary heat, the system provided a cooling amount of 5 kilowatts for 24 hours throughout the year, and the researchers observed a

decrease in the level of COP during the winter due to the decrease. At the level of the solar heat source.

Solanoe-Olivares et al, (2019) presented a study on the performance of the absorptive air conditioning system in the weather conditions of the city of Mexico, and the results were saving nearly 80%. Reducing carbon emissions causing greenhouse gas emissions, and saving between 20% and 80% of conventional energy annually, in addition to an environmental study on the negative effects of the system and its operational life, where the operational life reaches 25 years.

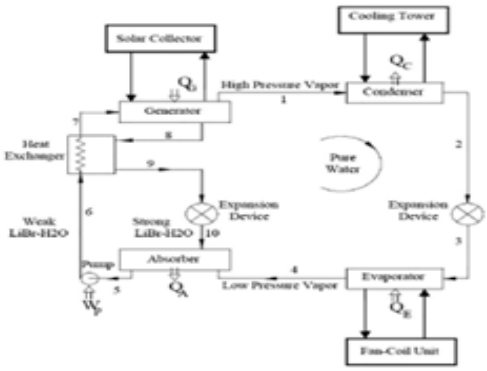
Bouhal et al, (2020) used vacuum tube-type solar collectors in the atmosphere of the city of Morocco. The study was conducted in the residential, office, and corporate buildings in three different climate zones: Fez, Marrakesh, and Zagora, with the researchers concluding that it is possible to save between 40% and 70% of energy annually.

Dardouch et al, (2020) benefited from the pressurized cooling technology, which relies on solar energy as a source of energy, as it was developed from the system through the use of a distillation column, which facilitates the process of ammonia distillation. Steam instead of a boiler, which has a negative role in system performance, and the results have been an increase in scientific performance, system cooling efficiency and longer service life. The distillation column also provides 30% less space than the total area of a conventional system.

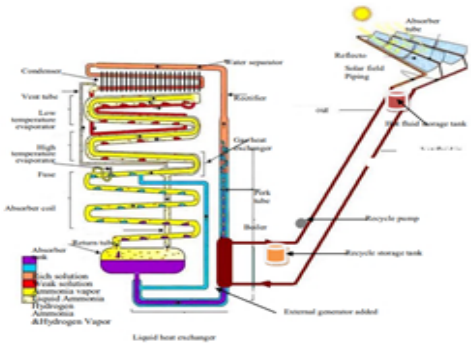
Areeba et al, (2021) the R410A refrigerant was used in the climatic atmospheres of the city of Pakistan, where the solar collector saved about 71% of the required energy used program simulation software TRNSYS ® to finished the word. In addition, the tank temperature was up to 92 ° C, which was studied on three different rooms and the cooling results obtained from during the process. Average temperatures ranged between 30 and 19 °C in thermal conditions recorded at 78 °C, over one week.

5. Conclusions

Practical and theoretical studies by previous researchers explained a number of important results and hypotheses in the mechanism of work and development of hybrid and conventional systems, and a comparison between hybrid air conditioning systems (integrated with photovoltaic panels - integrated with solar thermal collector with compressor unit). The results reached in the following points clarified the following:



(a)



(b)

Figure 15: **(a)** Solar generation system with collector. **(b)** Modified solar-driven platen-munter diffusion absorption refrigerator.

1. a) One of the advantages of the hybrid cooling system by solar panels is that it works with high efficiency and a good performance factor of 4 to 5 COP= and an energy-saving rate ranging from 30% to 80%.

b) From an economic point of view, this type of system is very expensive. Moreover, needs a large space for providing a small amount of cooling load and it needs periodic and continuous maintenance to avoid damage to solar cells and batteries, and this is one of the common defects in it.

2. a) While the absorption cooling system is characterized by high-energy savings, as it directly depends on solar thermal energy.

b) However, it has a low-performance factor that does not exceed 1.2 to 2, and the cooling rate is directly proportional to the low rate of heat available, in addition to the large area and complex

JMCER

composition of the embedded parts, as well as the chemicals used in the absorption process.

3. a) While the hybrid cooling system has proven to be efficient in both practical and service terms, it has saved an average of 25% to 60% of total energy annually, in addition to being easy to install and low economical cost.

b) You need small spaces to operate a system to provide cooling with a variable load, but it is limited to working in terms of climatic conditions in addition to the high and good performance coefficient.

REFERENCES

A. Kumar, A. Raj, S. Kumar, J.P. Kesar" Development of solar powered air conditioner using flat plate collector", Materials Today,(2021), https://doi.org/10.1016/j.matpr.2021.04.058 .

AE Kabeel, "Performance improvement of a hybrid AC system using the indirect evaporative cooler with internal baffle as a pre-cooling unit", Alexandriya Engineering Journal, (2017), dx.doi.org/10.1016/j.aej.2017. 04.005.

Ali Al-Alili, Reinhard R., 2012, A HYBRID AIR CONDITIONER DRIVEN BY A HYBRID SOLAR COLLECTOR. Pp.18-23

Ali Al-Alili, Reinhard R., 2012, A HYBRID AIR CONDITIONER DRIVEN BY A HYBRID SOLAR COLLECTOR. Pp.8-16

Ali M. Abdoulha M. , Mohamed M. M. Abdul Galil, Mohammad T.," Solar power air conditioning system for SHIATS University campus," Materials Today, 2214-7853, 2021, https://doi.org/10.1016/j.matpr.2021.01.250 .

Areeba R., Naeem A., Saad D., Muhammad S. S.," A case study of thermal analysis of a solar assisted absorption air-conditioning system using R-410A for domestic applications" Case Studies in Thermal Engineering ,26, (2021) , https://doi.org/10.1016/j.csite.2021.101008 .

Bellos E, Tzivanidis C, Performance analysis and optimization of an absorption chiller driven by nanofluid based solar flat plate collector, Journal of Cleaner Production (2017), doi: 10.1016/j.jclepro.2017.10.313.

Brian H., Marc F., Frank F., Elieser T.," Solar PV Powered Air Conditioner Analysis for an Office/Classroom in a Tropical Climate" European Solar Engineering School , 3031, No.195, (2015).

Chetan B., Hrishikesh B., Akshay G., Himanshu Ranjan," Study of solar-thermal collector assisted hybrid split air conditioner" International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 04 (2018), www.irjet.net .

Chetan Brahmankar, Hrishikesh Bhushan. Study of solar-thermal collector assisted hybrid split air conditioner', International Research Journal of Engineering and Technology. 2018; 5(4):pp. 2921–2925.

D. Patel" Performance assessment and thermodynamic analysis of a hybrid solar air conditioning system" Materials Today (2020), doi: https://doi.org/10.1016/j.matpr.2020.09.521 .

D. Urge-Vorsatz, L. F. Cabeza, S. Serrano, C. Barreneche, and K. ¨ Petrichenko, "Heating and cooling energy trends and drivers in buildings," Renewable and Sustainable Energy Reviews, vol. 41, pp. 85–98, 2015.

El-Sayed, A.R., El Morsi, M., Mahmoud, N.A., A review of the potential replacements of HCFC/HFCs using environment-friendly refrigerants. Int. J. Air Cond. Refrig. 26(03), 1830002 (2018)

Farhan L. R., Muhammad A. E., Hisham A. H." Design Study of Nanofluid Solar Absorption Refrigeration system" International Journal of Innovative Research in Engineering & Science ISSN 2319-5665, volume 6, issue 2 ,(2013).

Francisco J. Aguilar, Pedro V. Quiles , Simón A.," Operation and energy efficiency of a hybrid air conditioner simultaneously connected to the grid and to photovoltaic panel," Energy Procedia, 48, (2014),pp. 768 – 777

Hashim A. H., Ali H. N., Krar M. K., "Solar Photovoltaic Direct-Driven Air Conditioning System Performance in Iraq," Engineering and Technology Journal, Vol. 38, Part A , No. 07, pp.984-991, 2020. DOI: https://doi.org/10.30684/etj.v38i7A.477 .

IEA, 2014. "Emissions Reduction through Upgrade of Coalfired Power Plants", International Energy Agency, https://www.iea.or.

J. Dardouch, M. Charia, A. Bernatchou," Modeling and simulation of absorption solar air conditioning in Morocco weather conditions" Materials Today: Proceedings 27 (2020) 3217–3223.

J. Jie, L. Keliang, C. Tin-tai, et al. 2008,"Performance analysis of a photovoltaic heat pumps," Applied Energy,

Jani, D.B., Mishra, M. Sahoo, P.K., Experimental investigation on solid desiccant—vapor compression hybrid air-conditioning system in hot and humid weather. Appl. Therm. Eng. 104, 556–564 (2016)

JASIM M. A., KAMARUZZAMAN S., M. A. ALGHOUL, MOHD Y. S., AZAMI Z., IBRAHIM A." Solar Absorption Refrigeration System using New Working Fluid Pairs" SOLAR ENERGY RESEARCH INSTITUTE.=, , University of Cambridge, UK, February 23-25,(2008).

Jingkang Liang, Xu Ji, Jingyang Han, Yunfeng Wang," Modeling and experimental investigation on a direct steam generation solar collector with flat plate thermal concentration", Energy Exploration & Exploitation, pp.1-14, 2020, DOI: 10.1177/0144598720922681 journals.sagepub.com/home/eea.

Juwari P. S., Serlya A., Novita S., Renanto H.," Utilization of Solar Energy for Air Conditioning System", MATEC Web of Conferences ,156, 03040 ,2018,https://doi.org/10.1051/matecconf/201815603040 .

K. Solanoe-Olivares , R.J. Romero , E. Santoyo, I. Herrera , Y.R. Galindo-eLuna, A. Rodrígueze-Martínez , E. Santoyo-Castelazo , J. Cerezo" Life cycle assessment of a solar absorption air-conditioning system" ournal of Cleaner Production 240 (2019) 118206.

K.F. Fong, T.T. Chow, C.K. Lee, Z. Lin, L.S. Chan "Advancement of solar desiccant cooling system for building use in subtropical Hong Kong" Energy and Buildings 42 (2010) 2386–2399, www.elsevier.com/locate/enbuild .

Kaidir, Mulyanef, Burmawi" PERFORMANCE STUDY ON A SOLAR HYBRID AIR-CONDITIONING SYSTEM FOR RESIDENTIAL WATER HEATING" International Journal of Civil Engineering and Technology (IJCIET), Volume 8, Issue 10, (2017), pp. 706–714, http://iaeme.com/Home/issue/IJCIET .

KF Fong, CK Lee, Z Li," Investigation on effect of indoor air distribution strategy on solar air-conditioning systems", Renewable Energy, 2018, doi.org/10.1016/j.renene.201 8.07.065

Khaled S. Al Qdah ," Performance of Solar-Powered Air Conditioning System under AlMadinah AlMunawwarah

Climatic Conditions," Research Publishing, 6, pp. 209-219, 2015. . http://www.scirp.org/journal/sgre .

Low Exergy Systems for High-Performance Buildings and Communities, http://www.annex49.info/background.html.

M Fatouh, H Abou-Ziyan, O Mahmoud, D Abd El-Raheim, experimental analysis of hybrid and conventional air conditioning system working in hot-humid climate", Applied Thermal Engineering, 2017. dx.doi.org/10.1016/j.applthermaleng.2017.03.019.

M. ElHelw, A. A. ElHefni" Novel thermoelectric cell-enthalpy wheel air conditioning system integrated with solar panels" solar Energy ,176 ,(2018),pp. 526–534, www.elsevier.com/locate/solener .

M. Khalaji Assadi, S. I. Gilani, T. C. Jun Yen," DESIGN a solar hybrid air conditioning compressor system," MATEC Web of Conferences, 38, 020021,2016,https://www.researchgate.net/publication/290219635 .

M.A.I. El-Shaarawi , A.A. Al-Ugla" Unsteady analysis for solar-powered hybrid storage LiBr-water absorption air-conditioning" Solar Energy 144 ,(2017) 556–568.

Mohankumar.G, Vijay.A, Sasikumar R, Kanagaraj.M ," FABRICATION OF SOLAR ENERGY FOR AIR CONDITIONING SYSTEM" IJARIIE-ISSN (O)-2395-4396, Vol-3 Issue-3 (2017).

Mohanraj, M., Belyayev, Y., Jayaraj, S., Kaltayev, A., Research and developments on solar assisted compression heat pump systems–a comprehensive review (part A: modeling and modifications). Renew. Sustain. Energy Rev. 83, 90–123 (2018)

Muzaffar M. M. N. al-Nayer, Musab Abd al-Moneim, Muhammad I. al-Din," designing a solar collector for water heating", Sudan University of Science and Technology, 2015

Nagaraj K., Ashok K., J. Muthukumaran, Santhosh D. N., Shivaprakash K. S., Hybrid Air-Conditioning System Using Solar Heater. Thermal Energy Systems, Volume-5, Issue-3, ISSN: 2582-5747, pp. 8-13, 2020, https://doi.org/10.46610/JoTES.2020.v05i03.002 .

Nagaraj K., Ashok K., J. Muthukumaran, Santhosh D. N., Shivaprakash K. S., Hybrid Air-Conditioning System Using Solar Heater. Thermal Energy Systems, Volume-5, Issue-3, ISSN: 2582-5747, pp. 8-13, 2020, https://doi.org/10.46610/JoTES.2020.v05i03.002 .

Physics of solar energy, C. Julian Chen, 2011, ch11, pp.348-385

Physics of solar energy, C. Julian Chen, 2011, ch12, pp.388-390

Pinto, S.P., Karanam, P., Raghavendra, B.G., Boopathi, V., Mathad, P., Behera, U., Kasthurirengan, S., Development and studies of low capacity adsorption refrigeration systems based on silica gel-water and activated carbon-R134a pairs. Int. J. Heat Mass Transf. 55(2), 513–531 (2019)

PRINGCIPLES OF SOLAR ENGINEERING Third Edition, D. Yogi Goswami, 2015, ch.3, pp.199-150, Standard Book Number-13: 978-1-4665-6379-7 (eBook - PDF)

Q.P. Ha, V. Vakiloroaya," A novel solar-assisted air-conditioner system for energy savings with performance enhancement, Procedia Engineering, 49, (2012), pp. 116 – 123.

S. Rahman, S. Issa, Z. Said, M. El Haj Assad, R. Zadeh, Y. Barani, Performance enhancement of a solar powered air conditioning system using passive techniques and SWCNT /R-407c Nano refrigerant, Case Studies in Thermal Engineering (2019), doi: https://doi.org/10.1016/j.csite.2019.100565 .

Sandeep K., D .Buddhi, Mr.Hari K. S., (2016) Performance Analysis of Solar Hybrid Air-Conditioning System with Different Operating Conditions. Imperial Journal of Interdisciplinary Research (IJIR) Vol-2, Issue-10, ISSN: 2454-1362, http://www.onlinejournal.in .

Sevinç, K., Güngör, A." Güneş Enerjisi Kaynaklı Soğutma Sistemleri ve Bu Alandaki Yeni Uygulamalar, Mühendis ve Makina", pp. 53- 635, 59-70, 2012.

Sihui L., Jinqing P., Yutong T., Tao M., Xiwang L., Bin H.," Study of the application potential of photovoltaic direct-driven air conditioners in different climate zones" Energy & Buildings 226 (2020) 110387.

T. Bouhal, Z. Aqachmar, T. Kousksou, T. El Rhafiki, A. Jamil, Y. Zeraouli" Energy and economic assessment of a solar air-conditioning process for thermal comfort requirements" Solar Energy 208 ,(2020) 101–114.

V. Vakiloroaya, R. Ismail, Q.P. Ha" DEVELOPMENT OF A NEW ENERGY-EFFICIENT HYBRID SOLAR-ASSISTED AIR CONDITIONING SYSTEM" School of Electrical, Mechanical and Mechatronic Systems, University of Technology, Sydney, Australia,(2013) Corresponding author:vahid.vakiloroaya@engineer.com .

Wang, Q., Ren, B., Zeng, Z.Y., He, W., Liu, W, Xiangguo, Y.Q., Chen, G.M., Development of a novel indirect-expansion solarassisted multifunctional heat pump with four heat exchangers. Build. Serv. Eng. Res. Technol. 2, 1–13 (2014)

Y. V. Vankov, A. K. Al–Okbi1, M. H. Hasanen," Solar hybrid air conditioning system to use in Iraq to save energy". E3S Web of Conferences, 124, 01024, (2019), https://doi.org/10.1051/e3sconf/201912401024 .

Mukhtar Noori Saddam a lecturer at College of Engineering, University of Thi-Qar, IRAQ. His research interests are Fabricating and testing of the ground coupled air conditioner for residential applications.

Mushtaq Ismael Hasan a Lecturer at College of Engineering, University of Thi- Qar, IRAQ. his research of interest is: Fabricating and testing of the ground coupled air conditioner for residential applications in Iraqi weather).