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Enhancement of Geothermal Energy in Rationalization of Electrical Power Consumption

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A B S T R A C T

Iraq is rich in renewable energy resources while suffering from a severe shortage of electrical power supplying hours, accordingly the current study aims at design a ground source heat pump system (two-ton compression air conditioning systems) utilizing from shallow subterranean energy in order to rationalization electricity consumption. The results refer to huge contribution of shallow geothermal energy source in rationalization in electric power consumption. The results show a doubling in coefficient of performance and reduction in active electric power to more than the half of its original value.

Keywords: Geothermal energy, open cycle ground source heat pump, traditional air-conditioning system.

1. Introduction

The important component of the universe is energy and it is represent a major form of existence. Nature produce energy which is called the renewable energy and non-nature energy is known as conventional (fossil fuel). In recent years, the world's countries have been moving towards investing renewable energy sources, particularly Solar energy to produce power for the benefit of its environmental friendly. Renewable inexhaustible and contribute effectively to reducing environmental pollution caused by conventional energy sources, which are characterized by high extraction costs, as well as being sources of depletion.

Geothermal energy, one of the most important renewable sources that are energized in the form of heat beneath the earth's surface, is an important means of delivering renewable thermal energy. The idea is based on the use of low enthalpy temperatures stored in the Earth's crust at shallow depths (less than 200m). Because the temperature in the earth at these depths is relatively constant throughout the year, even though temperatures close to (less than 15m) fluctuate seasonally due to solar radiation patterns in winter, the earth's temperature is higher than the air temperature, although it is lower in summer; the earth's temperature is

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higher than the air temperature. This means that in the winter, the land can be used as a source of heat and in the summer, it can be used as a heat sink. Shallow thermal energy is a renewable energy source that is good for the environment [1].

Geothermal energy were used for different applications. Abeer Ahmed in 2013 used geothermal potentials to minimize the energy consumption of both domestic hot water and HVAC systems in buildings in Amman, Jordan [2]. Shahari and Harbinarayana in 2015 investigated geothermal-based space conditioning using a heat exchanger in the summer and solar energy as the primary source of space heating in the winter [3]. In 2017 an experimental study was carried out on the development of a traditional 2tn air conditioner (24,000BTU/hr), a window type that is equivalent to an adaptive thermal power of 7kW and consumes an effective electrical power of 2.8kW in Iraqi weather conditions utilizing from shallow geothermal energy [4]. In 2019 shallow geothermal energy was used to cool of concentrated PV system to reduce the losses in output power due to rise in solar cell temperature [5].

In recent years, Iraq has suffered from a shortage of electricity. The air conditioning systems are one of the main consumptions of electricity, and represents, approximately, 70% of the total consumption of the residential sectors, government buildings and hospitals, so the current research aims at design a ground source heat pump system utilizing from shallow geothermal energy.

2. Case of study

In the present work a traditional 2-ton nets window-type air conditioner (24,000BTU/hr) is the case of the present work. Figure 1 shows the components of this type of device. The important parameters for assessing the performance efficiency of this traditional air conditioner are listed in table 1.

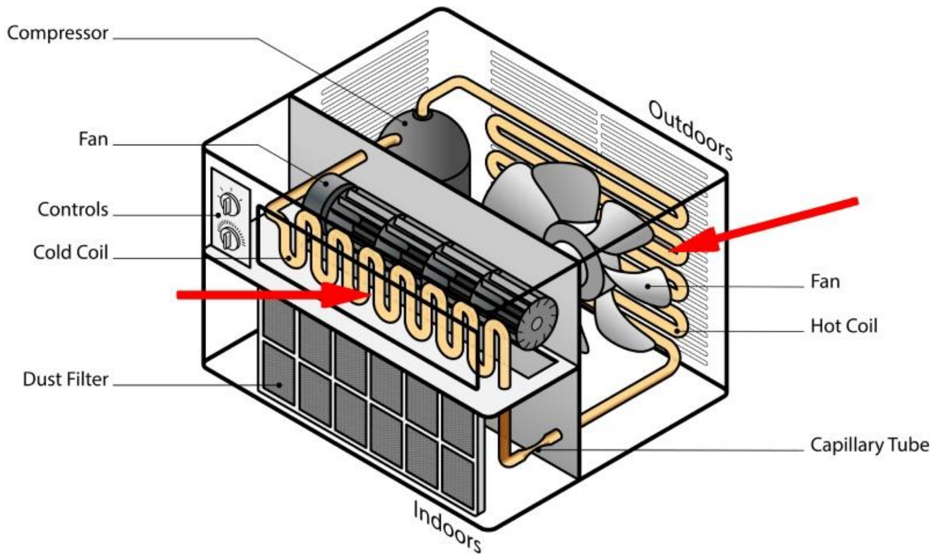

Figure 1. Components of traditional window-type air-conditioner.

Table 1. Basic parameters for assessing the performance efficiency of traditional air conditioner (220-240 volt ~ 50Hz)

Parameter	Value	Parameter	Value
Capacity in BTU/h	**24000**	Air-flow volume in m^3/h	**1200**
Applied Voltage in V	**230**	Wight in kg	**16.5**
Consumed Current in A	**14**	Maximum suction pressure in MPa	**1.2**
Active Power in kW	**2.9**	Maximum discharge pressure in MPa	**4.2**
Power Factor	**0.9**	Cooling capacity in kW	**7**
COP	**2.4**		

The ground can be used as a large thermal reservoir in summer cooling processes and as a major thermal source for winter heating operations and this source is promising in the field of energy efficiency of air conditioning systems, which spread widely in the European Union and Scandinavia as well as the United States of America, especially after 2000, which focused heavily on the subject of heating for their urgent and large need for it. While modest efforts are made to apply them in the Middle East and in Iraq’s neighboring countries in the field of cooling systems with difficult weather conditions prevailing from high temperatures in summer to very high values may reach in some areas up to 54 degrees Celsius such as Basra, Kuwait and Saudi Arabia in the shadow areas, and reach more than 65 degrees in these areas under direct exposure to sunlight and low in winter where it reaches less than 5°C on winter nights Long.

Applications for this type of energy depend on the temperature of the earth's interior, depending on the geographical location, geological nature and water content of the Earth, where its temperature is lower than that of the outer environment in summer and higher than in winter (Baghdad is 23°C).

The thermal pump generally adapts the air as it is used for cooling in summer and heating in winter, where the new heat pump consists of two main parts: the open-cycle geothermal exchanger which is achieved with a hole 12 meters deep as show in figure 2, and the thermal pump (see figure 3), which are designed according to the requirements of this demand, operating with four basic processes (evaporation, compression, condensation and expansion) which are similar in their work to the air conditioning cycle in traditional compression air conditioners. The design of the thermal pump that fits this application is the most important topic as it relates directly to the earth temperature, the required adaptive capacity, the efficiency of the geothermal exchanger, the efficiency of the new condenser, the efficiency of the thermal expansion valve, the rate of flow of the heat transfer fluid, the type and efficiency of the compressor used, and the type of cooling fluid, and in this request all these factors have been adapted to reach the desired goal.

Figure (2): The Source and drain holes.

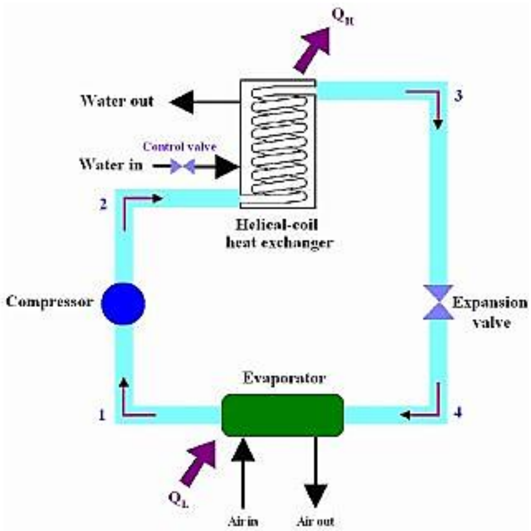

Figure (3): The schematic diagram of the air conditioning- heat pump unit.

3. Heat pump condenser design

For the purpose of condenser design cooled by heat conveyor fluid instead of the traditional air-cooled condenser the amount of heat inherent to condensation is calculated by the following equation [6]:

$$Q_{con.} = m_{ref.} * h_{con.} \quad (1)$$

Where $h_{con.}$ the latent heat of condensation is, $m_{ref.}$ is the flow rate of air conditioning fluids.

The cooling effect is given by the following equation [6]:

$$\varepsilon = Q_{con.}/C_{min}(T_{ref.in} - T_{con.in}) \quad (2)$$

$$C_{min} = C_{pref.} * m_{ref.} \tag{3}$$

Where ε is the cooling effect, $T_{con.in}$ is the temperature of the heat-transfer fluid and the inlet to the condenser, $T_{ref.in}$ is the fluid temperature of the inward air conditioning and inlet to the condenser, and $C_{pref.}$ is the qualitative thermal capacity of the air conditioning fluid.

The product of multiplying the total thermal transmission factor in the pipe area is given the following equation:

$$U_{\circ}A_{\circ} = C_{min.}\, lin(\frac{1}{1-\varepsilon}) \tag{4}$$

The length of the tube needed for the condenser can be calculated using the following equation [6]:

$$L_p = U_{\circ}A_{\circ}\left[\left(\frac{1}{\pi D_{\circ} h_{\circ f}}\right) + \left(\frac{lin\left(\frac{r_{\circ p}}{r_{ip}}\right)}{2\pi k_p}\right) + \left(\frac{1}{\pi D_i h_{i.ref}}\right)\right] \tag{5}$$

Where $D_{\circ}$ is the external diameter of the tube, D_i is the inner diameter of the tube, k_p is the thermal conduction coefficient, r_{op}, r_{ip} are the radius of outer tube and inner tube respectively, $h_{\circ f}$ is the heat transfer factors with load in terms of heat transfer liquid, and $h_{i.ref}$ is the heat transfer factors by load for air conditioning fluid.

The technical specifications of tube in tube heat exchanger in the developed air conditioner are listed in table 2.

Table 2. The technical specifications of tube in tube heat exchanger in the developed air conditioner

Parameter	**HEX**
Outer diameter of Refrigerant tube (m)	0.016
Inner diameter of Refrigerant tube (m)	0.014
Outer diameter of fluid tube (m)	0.04
Inner diameter of fluid tube (m)	0.036
Number of turns of HEX	8
Length of pipe (m)	5

In the first step of the practical and practical aspect, the performance of a traditional 2-ton nets air conditioner (24,000BTU/hr) was assessed. At the same time, the developed air conditioner under consideration, shown in its full outline, was assembled in Figure (4), and shipped with the required amount of R-134a gas (Table 3) to suit the pressures of the circuit with a set of controls that control the pressure and run of the heat transfer fluid and air conditioning fluid to obtain the highest performance efficiency and in accordance with Iraqi environment. After the operation of the developed air conditioner and all the required tests, the adaptive capacity of the traditional and developed air conditioners was calculated by measuring the air temperature entering and leaving the air conditioner and measuring the rate of air flow using the following equation [7]:

$$Q_{cooling} = m_{air} C_p (T_{air\ in} - T_{air\ out}) \quad (6)$$

Where $Q_{cooling}$ is the cooling capacity, m_{air} is the air flow rate, C_p is the air thermal capacity, $T_{air\ in}$ is the air temperature in-house to evaporator, and $T_{air\ out}$ is the air temperature coming out of evaporator.

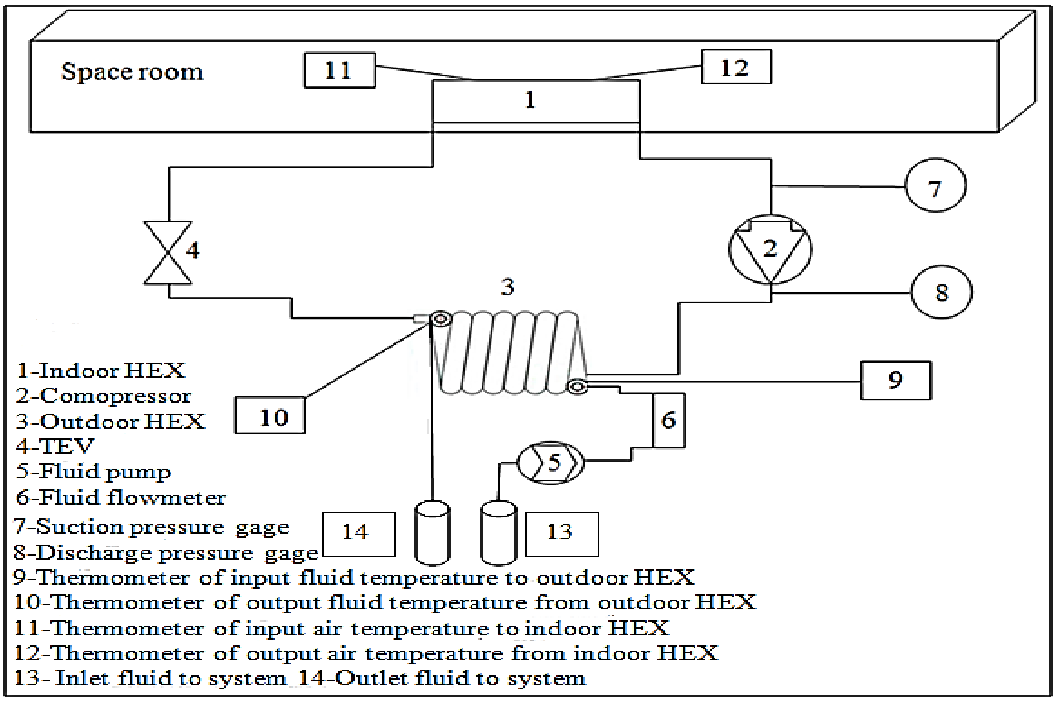

Figure 4. Full configuration for developed air conditioner[8].

Table 3. Technical specifications for the fluids of environmentally friendly R-134a air conditioning

	Properties	**R-134a**
1	Boiling Point	-26.1 ºC
2	Auto Ignition Temperature	770 ºC
3	Ozon Depletion Level	0.0
4	Solubility in Water	0.1% at 25 ºC
5	Critical Temperature	122ºC
6	Cylinder Color Code	Light Blue
7	Global Warming Potential (GWP)	1200

The capacity consumed by the compressor, fan and heat transfer fluid sucking pump was measured through the use of the Energy Analyzer, and performance efficiency was calculated by using the following equation [7]:

$$COP = \left(\frac{Q_{evap.air}}{\left(W_{comp.} + W_{fan} + W_{pump}\right)}\right) \quad (7)$$

Where $COP$the coefficient of performance, $\dot{Q}_{evap}$ is the cooling capacity of the system, and W_{total} is the power consumed by compressor + fan + sucking pump.

4. Results and discussion

The performance of traditional air-conditioner, whose characteristics was listed in table 1, was evaluated under Baghdad environment in twenty ninth of July at two O'clock PM. The environ temperature was 48^{o}C in shadow and the indoor temperature was 36^{o}C. The value of each of applied voltage, consumed current, input of air temperature to evaporator, output of air temperature from evaporator, and power factor were measured after ten minutes of operation. The value of consumed power and coefficient of performance were calculated as shown in table 4.

Table 4. The evaluation results of performance efficiency of traditional air-conditioner (220-240 volt ~ 50Hz)

Parameter	Value
Applied Voltage in V	228
Consumed Current in A	13.9
Active Power in kW	2.85
Power Factor	0.9
Input temperature to evaporator in ^{o}C	36
Output temperature from evaporator in ^{o}C	22
COP	2.45

The above experiment in was repeated for the developed air-conditioner at two O'clock PM in thirteenth of July. The environment temperature was 50^{o}C in shadow and the indoor temperature was 37^{o}C, and the water flow rate (W_{flow}) was 10L/min. After ten minutes of system operation the results of performance efficiency of the developed air-conditioner were recorded and listed in table 5.

Table 5. The evaluation results of performance efficiency of developed air-conditioner

(220-240 volt ~ 50Hz)

Parameter	Value
Applied Voltage in V	228
Consumed Current in A	6.8
Active Power in kW	1.4
Power Factor	0.9
Input temperature to evaporator in ^{o}C	37
Output temperature from evaporator in ^{o}C	23
COP	5

The results in table 5 refer to huge contribution of shallow geothermal energy source in power supplying for powering the cooling air-conditioning system. The results show a doubling in coefficient of performance and reduction in active electric power to more than the half of its original value.

The values of applied voltage, consumed current, input of air temperature to evaporator, output of air temperature from evaporator, and power factor were continued measured each fifteen minutes and the values of consumed power, coefficient of performance, cooling capacity, and rationalization energy percentage were recorded and listed in table 6. This table assures the stability of performance efficiency of the developed window-type air-conditioner device.

Table 6. The detailed evaluation results of performance efficiency of developed air-conditioner (220-240 volt ~ 50Hz), W_{flow}=10L/min, PF=0.9

Time	**I_T (A)**	**V (v)**	**P (kW)**	**$T_{in,ev}$ (^oC)**	**$T_{out,ev}$ (^oC)**	**$T_{in,ev}$-$T_{out,ev}$**	**Q_{cool} (kW)**	**COP**	**R.E %**
2:0	6.8	228	1.395	37	23	14	7	5	**51.9**
2:15	6.8	228	1.395	36	22	14	7	5	**51.9**
2:30	6.8	228	1.395	34.8	21	13.8	6.9	4.95	**51.9**
2:45	6.9	226	1.4	32.9	19	13.9	6.95	5	**51.7**
3:0	6.8	227	1.389	30.3	16.5	13.8	6.9	4.96	**52**
3:15	6.8	228	1.395	28	14	14	7	5	**51.9**
3:30	6.9	227	1.4	25.2	11.3	13.9	6.95	4.96	**52**
3:45	6.8	228	1.395	22.4	8.6	13.8	6.9	4.95	**51.9**
4:0	6.8	228	1.395	20.1	6.1	14	7	5	**43.33**

The current experiment was conducted along the lines of the patent for the invention carried out in the field of energy efficiency of compression air conditioning systems [9].

5. Conclusions

From the present results it can be concluded that the shallow geothermal energy contributes to reducing power usage by more than half. Iraq's abundance of renewable energy resources makes it an ideal location for investing in these resources to rationalization electricity consumption, which is urgently needed to keep up with population growth, technological advancement, and the expansion of services that require more energy, as well as environmental preservation.

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