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Design of a Small Capacity Geothermal Power Plant for Cooling and Heating Systems of Health Resort in Jordan

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Authors' contributions

This work was carried out in collaboration among all authors. Author OOB designed the study, wrote the protocol and wrote the first draft of the manuscript. Author GSAI-M managed the literature searches and authors Al-F and IAA managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Jordan is a developing non-producing oil country; a major part of its needed energy is imported from the neighboring countries in the forms of oil and gas, the cost of this imported energy creates a heavy financial burden on the national economy which reflects on the development plans and the standard living of the people. Jordan has good potential of geothermal energy at different places. Therefore, several applications are suggested to be utilized in the agricultural and industrial fields. In this study the binary thermodynamic cycle is suggested to utilize the geothermal source into the form of power plant for generating electricity for heating and cooling system of a health resort in the nearby region of the geothermal field. Also in this study, the air- conditioning and heating loads for a health resort are calculated and the underground thermal power plant is designed to provide the suitable power supply to the health resort. It is concluded that the geothermal resources of energy is proved to be one of the good options of renewable energy sectors in Jordan. Therefore the geothermal power plant can be an option for electrical production of the Jordanian volcanic mountains resorts.

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Keywords: Geothermal; binary power plan; cooling and heating; Jordan; health resort.

1. INTRODUCTION

Two billion people - one in three of the world's population - lack access to modern energy services. Between 1990 and 2050, primary energy consumption is expected to increase by at least 50%, and by about 275% under the higher growth scenario [1,2]. Therefore, generating energy from naturally renewable sources such as wind, rain, sunlight, tides, waves, groundwater, and steam is set to become increasingly important. Access to affordable and clean energy is seen as a key to improving living standards of the world's poor people by 2100; renewable sources are expected to save 30-80 percent of total energy consumption [2].

Geothermal energy is one of the most important sources of energy for generating electricity and is also used directly in heating, food, agriculture, aquaculture, and some industrial processes [3]. It is stored as heat in magmas, or molten rocks, in the interior of the earth, where temperatures are extremely high, in hot water and rocks several kilometers below the surface of the earth and in some parts of the world - in shallow ground. The earliest reported use of geothermal energy dates to the pre-pottery period before 11000 BC, when people in Japan used hot springs for bathing and washing clothes [4]. One important fact is that the population of the planet is growing exponentially, between the years 1850 and 2006, the population increased from about 1.3 billion to about 6.5 billion, an increase of five times, current estimates indicate that between 2006 and 2050, the population will grow from about 6.1 billion, to about 8.9 billion, an increase of 32% in 44 years [5,6].

The International Geothermal Energy Association (IGEA) wrote in a recent press release on "The Renewable Energy Policy Network for the Twenty-first Century" that global production of renewable energies increased by 16% from 2007 to 2008 and totals 280 GigaWatts [7]. The growth in renewable energy consumption is greater than the increase in the consumption of fossil fuels in Europe and the United States, political and financial programs support the development and use of renewable energies in more than 60 countries, large hydroelectric systems had the largest share of electricity production from renewable energy sources in 2008 with 860 GigaWatts followed by wind power at 121 GW, small hydroelectric systems with 85 GW and biomass conversion with 52 GW of photovoltaic systems (13 GW) and geothermal systems (10 GW) follow with a large gap, biomass (250 GW) dominates thermal energy production from renewable sources, followed by solar thermal systems (145 GW) and geothermal energy systems (50 GW) [8]. Geothermal energy has the potential to become an important source of energy in the future because it is available everywhere and the withdrawals are constantly renewed from a human perspective, the resource is basically unlimited, heat and electricity can be produced continuously and thus it is a primary load source for use friendly to environmental installations with the earth's surface consumption is small. The coming years will show how optimistic forecasts and a positive perception of geothermal energy use will work in regions with geothermal resources with reduced enthalpy. Geothermal energy is a type of renewable energy that is generated inside the earth and can be used directly for heating or converted into electricity, and the advantage of geothermal energy over some other renewable energy sources is that it is available throughout the year (while solar and wind energy provide energy fluctuation and interruption higher and can be found all over the world, however, to generate electricity, medium to high temperature resources are needed, which are usually close to volcanically active areas. Geothermal energy has great potential for growth, and it is estimated that the amount of heat within 10,000 meters of the earth's surface contains 50,000 times more energy than all other energy resources such as petroleum around the world. The costs of generating electricity from geothermal technologies are becoming increasingly competitive and are expected to continue to decline through new technologies. Deploying geothermal energy has additional benefits, as it also contributes to reducing the impacts of global warming and public health risks from the use of traditional energy sources, moreover, the deployment of geothermal energy helps reduce the country's dependence on fossil fuels as a resource that is naturally replenished on a human timescale, and geothermal energy is not affected by the depletion of global resources or by rising fossil fuel prices, and thus, if the full potential of the resources can be realized. Geothermal energy, will lead to significant benefits both nationally and internationally, in addition to that, in comparison with fossil resources, the thermal energy is characterized by a number of benefits, including a lower rate of carbon dioxide emissions, thus reducing the rate of heat emissions and the ability to provide electricity to help the system and raise its ability to work.

2. GEOTHERMAL ENERGY: AN OVERVIEW

Geothermal energy is a clean, sustainable, and renewable resource that provides energy using heat derived from the earth, radioactive elements within the earth release heat at very high temperatures, which increase depending on the distance from the earth's surface. The temperature of the earth's core is estimated to be about 5000°C, and the outer core is about 4000°C – a similar temperature to that on the surface of the sun. The constant flow of heat energy from the earth's interior, equivalent to an estimated 42 million megawatts (MW) of power is expected to continue for billions of years [9].

2.1 Geothermal Energy in Jordan

Jordan is a developing country that is not an oil producer, the largest part of the energy it needs is imported from neighboring countries (such as Iraq, Saudi Arabia) in the form of oil and gas, for example in 2012 the demand for primary energy was about 8,438 million tons of oil equivalent, with a growth rate of 4%, or 1.6% more than the previous years and is expected to be much more in the future due to immigration from neighboring countries due to the war crisis in neighboring countries. The cost of this imported energy constitutes a heavy financial burden on the national economy, which is reflected in the development plans and the people's standard of living. Therefore, it is extremely necessary to find out other energy resources, after research and investigations conducted by the National Energy Center (NEC) and Natural Resources Authority (NRA); it was found that Jordan has sources of thermal energy that can be used to generate electricity. Geothermal energy was discovered in Jordan thirty years ago, were studies conducted by the authorities with the help of foreign companies, showing that Jordan has great potential for geothermal energy with low enthalpy and its spread in many thermal fields. A map of this geothermal gradient (Fig. 1) for Jordan shows two distinct regions at high temperatures, with temperatures reaching 80°C per km. The first zone is located to the east of the Dead Sea, where a number of springs that originate from the inferior Cretaceous and sandstones, the second is near the borders with Syria and Iraq. In this region, several thermal wells drain the upper Cretaceous limestone. The temperature of the thermal water for springs and wells ranges between 35 to 100 degrees Celsius, and springs and wells are currently used in health and recreational resorts, and it has also been used as irrigation water in many agricultural activities. These heat sources are planned to be used for greenhouse heating and fish farming. Geothermal energy sources in Jordan are considered one of the resources related to the deep circulation of meteor water along faults, and it can be divided into two types; the first is connected to natural springs, and the second in outcrops of sandstone, surface springs are the main source of thermal energy in Jordan, other aspects of geothermal energy, such as boiling and mud pools, have not been observed, therefore, there is no concrete evidence to suggest the presence of high temperatures at shallow depths. Another group of geothermal energy resource is those that were discovered during exploration. Oil is located within the deep layers of the Eastern Desert and along the rift edge of the Dead Sea, the main resources for this group are the Bir al-Shouneh and al-Makhiba fields, all thermal springs and hot wells are located near the Dead Sea Rift. These springs are distributed along the eastern escarpment of the Dead Sea for a distance of 200 km from the Al-Makhaiba field in the north to the Afra and Berbita thermal field in the south. The temperature is less than 45 degrees Celsius in most of the springs except for two regions where the temperature reaches 63 degrees Celsius in Moein, Zara and Zarqa springs. One of the uses of thermal springs in Jordan for bathing and irrigation, and many recreational and health resorts have been established in the locations of thermal springs, including a specific resort in Zarqa, and there are other uses planned to use geothermal water to raise fish to supply the local market with fresh fish and use it in agriculture for heating [10]. Among the above reasons it seems that the thermal water originates as the thermal water in the Paleozoic sandstone towards the east of the Dead Sea cliff. The heating of the water by deep circulation in a high temperature gradient that may be 50 degrees Celsius per km, which means that the deepest circulation is about 2 km, the water moves towards the fault and rises through the voids and fractures and is cooled by heat exchange with cold water [10,11,12]. The chemical type of mineralization in hot water refers to groundwater circulation in the Horn and Blue sandstones (Lower Cretaceous and Triassic) with the mixing of a limited amount of deep, confined aquifers [10,11,12,13,14,15, 16]. A map showing the hot water regions is shown in Fig. 1.

The dominant structural feature of Jordan is the north-south trending Dead Sea Rift; it is an active part of the African Syrian Rift (ASR), which extends for about 6000 km, from east Africans' through the Red Sea, Wadi Araba, Dead Sea, Jordan Valley to south Turkey. The ground waters aquifers of Jordan are divided into three main complexes: A deep sandstone aquifer complex, an Upper Cretaceous aquifer complex, and a shallow aquifer complex. The upper and lower aquifers are separated by impermeable marl and marly limestone of Upper Cretaceous age. Geothermal resources that were discovered during oil and groundwater exploration within the deep aquifers in the eastern deserts and along to the eastern margin of the Dead Sea Rift. The Zara – Zarqa Ma'in thermal springs are considered as the major geothermal manifestations in Jordan due to their high temperatures and flow rates. A detailed studies have been carried out for the three main deep wells in the Zara – Zarqa Ma'in areas in these studies a volumetric geothermal assessment has been done by using the Monte Carlo method, for the area which lies between the Zarqa Ma'in fault and the Dab 'a fault based on estimating the total heat stored in a volume of both rock matrix and water in the pores [12,13,14,15,16,17].

Thermal water in Jordan has been used in direct uses as curative water tourist industry. The therapeutic value of thermal waters in Jordan has been recognized since ancient times. Generally, thermal water has various properties and differs in its temperature and curative abilities. A study carried out by Salameh et al. [18,19] shows that the thermal water resources in Jordan are very useful in treating several diseases in various degrees of success, for example, thermal water of Zara and Zarqa Ma'in springs is quite useful in treating Osteo Arthritis, Degenerative Disc and Post Traumatic, and the thermal water of North Shouneh is good for cervical spondee losing, while the thermal water of Afra and Burletta is quite good in treating Degenerative Disc and Post Traumatic problems.

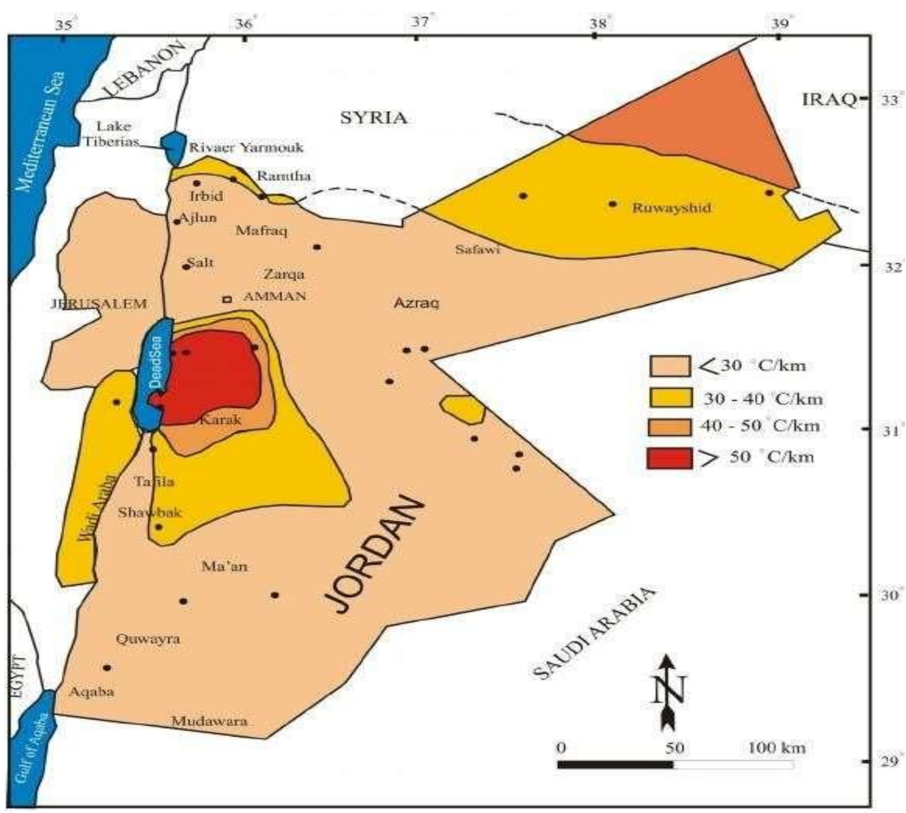


Fig. 1. A map showing the distribution of hot water regions in Jordan

3. DESIGN OF THE HEATING AND THE COOLING LOADS OF THE HEALTH RESORT

We have designed a health resorts that can accommodate more than 100 persons, as shown in Fig. 2. The heating and cooling loads were estimated using cooling and heating equations as following:

3.1 Sample Calculations for One Room

Table 1. Sample of the calculation for one room

Element	U (W/m^2.K)	To (C°)	Ti (C°)	ΔT	A(m^2)	Q(Watt)
window	5.066	35.2	22	13.2	4	267.485
door	3.1	35.2	22	13.2	4	163.68
roof	0.685	35.2	22	13.2	14.44	130.566
floor	0.496	35.2	22	13.2	14.44	94.5416
inside wall	2.62	26	22	6	20.8	326.976
outside wall	0.514	35.2	22	13.2	16.8	113.985
		Q walls		**1097.23**	**watt**	
		Q occ		**530**	**Watt**	
		Electrical equip.		**300**	**watt**	
		Total		**1927.23**	**watt**	

Health resort floor 1

Health resort floor 2

Fig. 2. Overall sketch of health resort

Q that gained from occupants is: Qocc = 2*265= 530 watt.

Q electrical equipment's = 300 Watt

The construction of an outside wall of the building is shown in Fig. 3. The wall constructed according to the Jordanian building codes.

Outside Wall Construction:

Table 2. Thermal Resistance for outside wall

Number	Material Type	Thickness (X) m	Thermal Conductivity (K) W/m.^{0}C	Thermal Resistances m^2. ^{0}C/W
1	Stone	0.05	1.7	0.029
2	Concrete	0.03	1.75	0.017
3	Polystyrene	0.03	0.04	0.75
4	Cement brick	0.1	0.105	0.952
5	Plaster	0.02	1.2	0.016

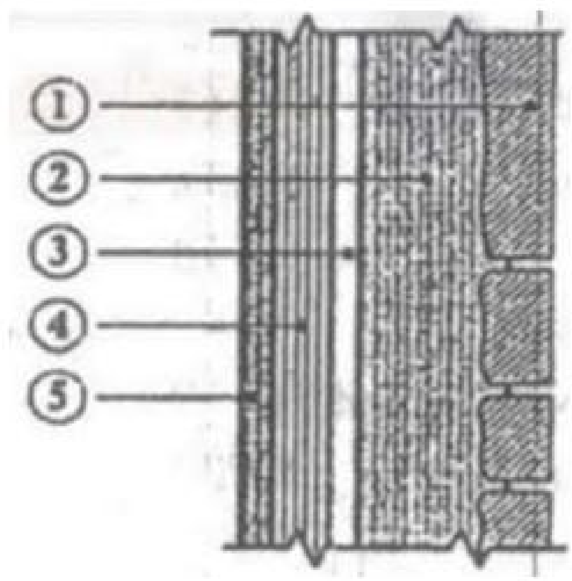


Fig. 3. Health resort wall components

$$R_{th} = R_{outside\ air} + R_{plaster} + R_{bricks} + R_{plaster} + R_{Hard\ stone} + R_{inside\ air}$$

$$R_{th} = R_{outside\ air} + R_{plaster} + R_{bricks} + R_{plaster} + R_{Hard\ stone} + R_{inside\ surface}$$

$$R_{th} = R_{outside\ air} + R_{plaster} + R_{bricks} + R_{plaster} + R_{Hard\ stone} + R_{inside\ surface}$$

$$R = \frac{X}{\kappa} \qquad U = \frac{1}{R}$$

$R1 = X1/K1 = 0.05/1.7 = 0.029$ (m^2.°C/W)

$R2 = X2/K2 = 0.03/1.75 = 0.017$ (m^2.°C/W)

$R3 = X3/K3 = 0.03/0.04 = 0.75$ (m^2.°C/W)

$R4 = X4/K4 = 0.10/0.105 = 0.952$ (m^2.°C/W)

$R5 = X5/K5 = 0.02/1.2= 0.016$ (m^2.°C/W)

$U_w = (Ri+R1+R2+R3+R4+R5+Ro)^{-1}$

$=(0.12+0.029+0.017+0.75+0.952+0.016+0.06)^{-1}$

Uw. out =0.514 (W/m2°C)

Where:

R: thermal Resistance, (m2.k/Wm**2**.k/W)   X: thickness of material.
k: thermal conductivity, (W/m. K). U: overall heat transfer coefficient, (W/$m^2.Km^2.K$).

Table 3. Thermal resistance for inside wall:

Number	Material Type	Thickness (X) m	Thermal Conductivity (K) W/m.^{0}C	Thermal Resistances m^2. ^{0}C/W
1	Plaster Cement	0.02	1.2	0.017
2	brick with air	0.1	0.9	0.111
3	Plaster	0.02	1.2	0.017

$R1 = X1/K1 = 0.02/1 = 0.017$ (m^2.°C/W)

$R2 = X2/K2 = 0.01/1 = 0.111$ (m2.°C/W) R3 =

$X3/K3 = 0.02/1 = 0.017$ (m2.°C/W)

Uw = (Ri+R1+R2+R3+Ri)-1

= (0.12+0.017+0.111+0.017+0.12)-1

Uw.in =2.6 (W/m2°C).

The inside wall has the same construction of outside wall but without hard stone layer.

Thermal resistance for ceiling:

-Note that all windows and doors are symmetric for the building.

$R1 = X1/K1= 0.03/1.4= 0.0214\ (m^2.°C/W)$

$R2 = X2/K2 = 0.07/1.75 = 0.04\ (m^2.°C/W)$

$R3 = X3/K3 = 0.05/0.03 = 1.66\ (m^2.°C/W)$

$R4 = X4/K4 = 0.26/1.75 = 0.034\ (m^2.°C/W)$

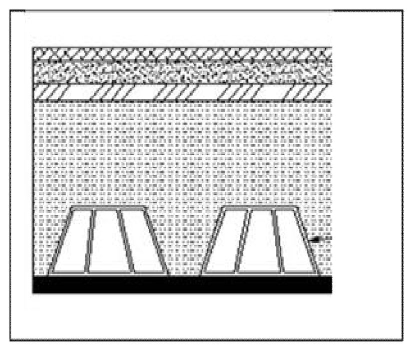
$R5 = X5/K5 = 0.\ 2/0.95= 0.21\ (m^2.°C/W)$

$R6 = X6/K6 = 0.02/1.2 = 0.017\ (m^2.°C/W)$

$U_{ceiling} = (Ri+R1+R2+R3+R4+ Ri)^{-1}$

U ceiling =0.458 (W/m2°C).

Number	Material Type	Thickness m	Thermal Conductivity W/m .°C	Thermal Resistances m^2.°C/W
1	Concrete titles	0.03	1.4	0.0214
2	Concrete	0.07	1.75	0.04
3	Polystyrene	0.05	0.03	1.66
4	Rain forced Concrete	0.06	1.75	0.034
5	Hollow brick	0.2	0.95	0.21
6	plaster	0.02	1.2	0.017



3.2 Design of Binary Power Plant

3.2.1 Basic binary geothermal power plant

Binary-cycle geothermal power generation plants essentially differ from dry steam and flash steam systems in that the water or steam from the geothermal reservoir never encounters the turbine/generator units, Low to moderately heated geothermal fluid (below 300°F) and a secondary (hence, "binary") fluid with a much lower boiling point than water passes through a heat exchanger, Heat from the geothermal fluid causes the secondary fluid to flash to vapor, which then drives the turbines and subsequently the generator. Binary-cycle power plants are closed-loop systems, and virtually nothing (except water vapor) is emitted to the atmosphere. Because resources below 300°F represent the most common geothermal resource, a significant proportion of geothermal electricity in the future could come from binary-cycle plants [20,21].

Organic Rankine Cycle (ORC) system for large-scale waste heat recovery (WHR) and low-temperature heat recovery is a promising technology with a vast potential market [20,21]. Although ORC systems have both cost and safety problems, they are proven to be suitable for medium/low-temperature heat sources, are reliable, an less complex than SRCs [20,21]. Applications of ORC for industrial waste heat, marine waste heat, waste heat from Distributed Energy Systems (DES) and recompression stations along pipelines is shown in Fig. 4.

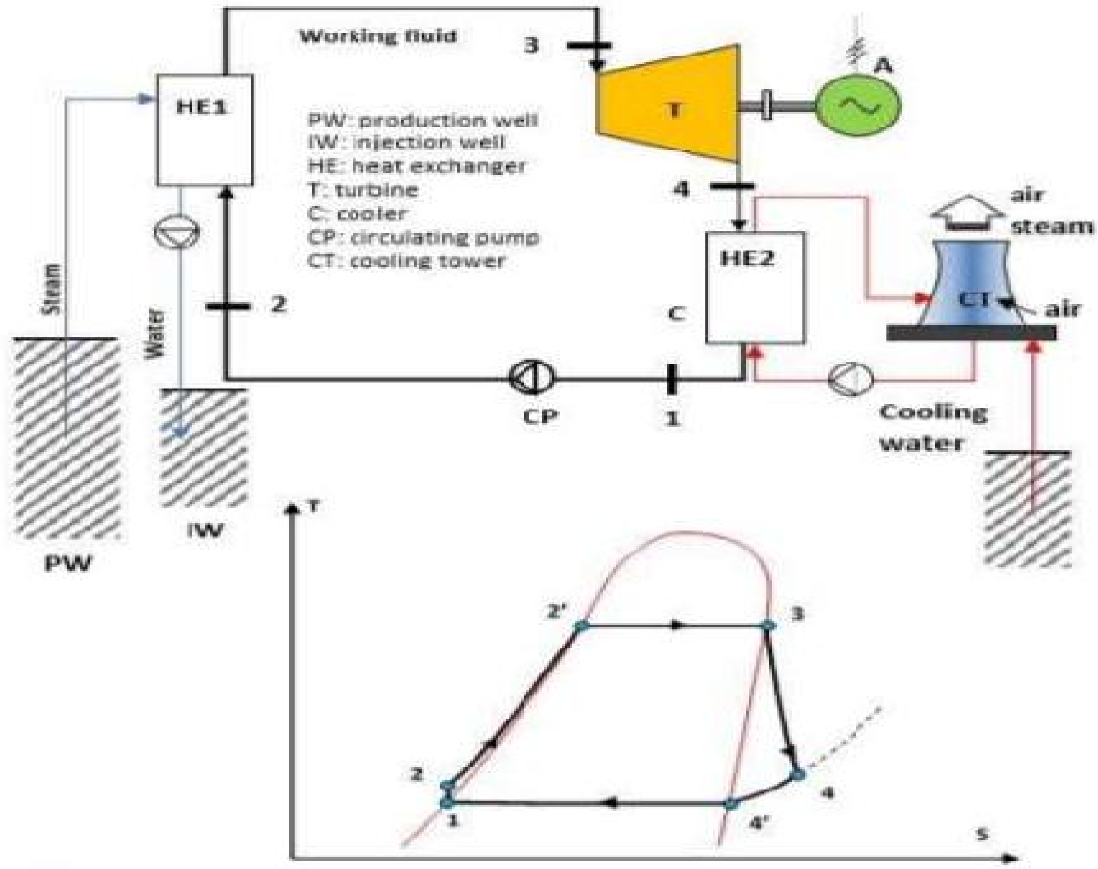


Fig. 4. Organic Rankine Cycle

A brief description of each state shown in Fig. 4 will be as following [22]:

State 1: In this state, the superheated Butane exists from the heat exchanger and enters the turbine.

State 2: The working fluid exits the turbine and enters the condenser; Butane is still in the superheated condition.

State 3: Butane is in the saturated vapor condition where it enters the cooling tower and starts to lose heat and transforms into a liquid state.

State 4: the working fluid is in the saturated liquid state and enters the pump to face an increase in the pressure.

State 5: Butane exits from the pump and enters heat exchanger where it receives heat from the geothermal source and temperature increases.

State 6: Butane exits heat exchanger at this point and goes into the evaporator where it faces with phase shift from saturated fluid to the superheated state [21].

3.2.2 Design procedure of a binary cycle

The design of the 97-kW dual cycle geothermal power plant is shown in Fig. 5. The heat exchangers in the 97-kW dual cycle station model include an evaporator, condenser, and cooling tower. The wet cooling tower for n- butane cooling is chosen as the condenser coolant, shell and tube selected evaporator and condenser, these types are preferred because they are simpler in design and ease of manufacture [20,21,22].

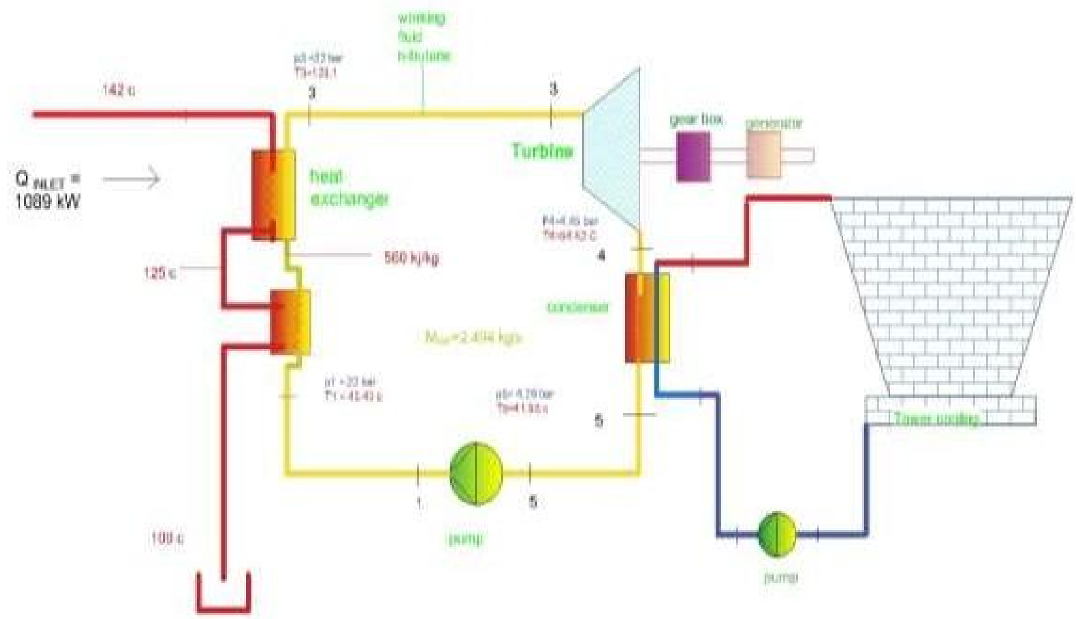


Fig. 5. Designed binary cycle power plant

3.2.2.1 Calculations procedure of the designed binary cycle will be as following [22];

1. **Turbine:**

$$W_t = m_{wf} \times [h_3 - h_4] = \eta_t [h_3 - h_4]$$

T_3=120.1°C T_4 =64.42°C
P_3= 21.8 bar
P_4 =4.54 bar h_3=743.015 kJ/kg h_4 = 686.72 kJ/kg m_{wf} =2.49 kg/s
Wt = 2.49 x (743.015 – 686.72) = 140.17 kW

2. **Condenser:**

$$Q_{con} = m_{wf} \times Cp_{wf} \times [T_4 - T_5] = m_w \times Cp_w \times [T_4 - T_5] \quad Q_{con} = m_{wf} \times [h_4 - h_5]$$
T_3=64.42°C T_4=41.93°C P_3=4.34 bar P_4=4.29 bar
h_3= 686.72 kJ/kg h_4=301.577 kJ/kg m_{wc}=20.85 m^3 /kg
Qcon=2.49 x [686.72- 301.577] = 960.54 kW

1. **Pump:**

$$Q_p = m_{wf} \times [h_5 - h_1]$$
T5=41.93°C **T1** =43.3°C **P5**= 4.29 bar **P1** =22.8 bar
h4=301.7 kJ/kg **h1** =306.577 kJ/kg

Qp=2.49 x [306.577- 301.7]=12.16 kW

2. **Heat exchanger :**

Preheater + evaporate

Mw Cpw [Ts2 – Ts3]= mwf x [h2 – h1]

$Q_{HE} = Q_i = m_{wf} \times [h_2 - h_1]$ [24]

QHE =2.494 x [743.015 – 306.577] = 1089 kW

<u>Heat added=1089 kW</u>

1. **Efficiency**

ηthcycle= [Wt/Qi] = [Qin – Qout] / Qin
$\eta_{thcycle}$ = [1089– 960] / [1089] = 0 .12
η_{cycle}=88%
η_T =0 .79
η_P= 0.65

Power output electric= $\eta_T \times \eta_m \times \eta_e \times P_i$

Cp = ηT x ηm x ηe = 0.69 Pe=140.71 x 0.69= 97 kW

4. RESULTS AND DISCUSSION

Tables 2 and 3 show the results of the calculations procedure of the whole power plant, to supply energy for cooling and heating systems of the suggested health resort.

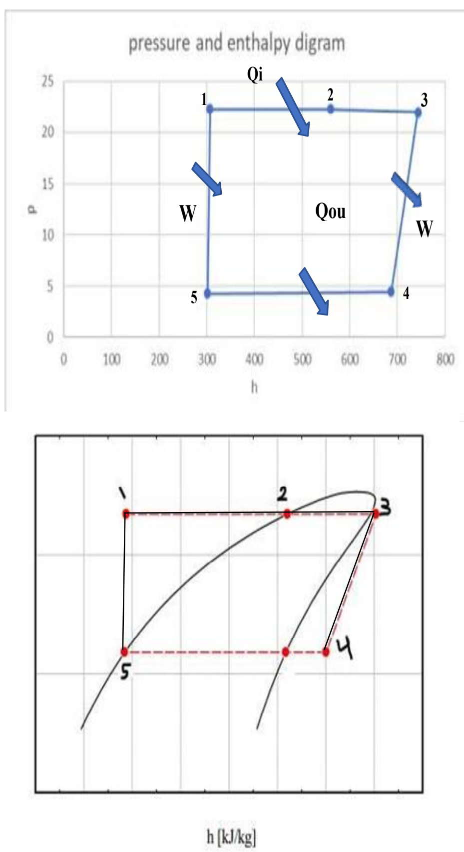


Fig. 6. Relationship between pressure and enthalpy

The concept of a binary cycle power plant, which it is known as an organic Rankine Cycle, is a modification of the Rankine cycle where the working fluid, instead of water, is an organic fluid having a lower boiling point and a higher vapor pressure than water.

The maintenance of binary cycle power plants is highly influenced by different factors such as: the nature of the geothermal fluid used in the primary loop, the nature of the working fluid, the technology and location of the plant, climate, and weather. Corrosion and scaling are the most common problems in binary power plants. To develop the maintenance activities, it is necessary to have a maintenance management program to help in coordination, control, planning, implementing, and monitoring the necessary activities required for each component of the binary plant [21,22].

4.1 Relationships between Pressure and Enthalpy, and Temperature and Entropy Diagrams

The results obtained from the simulation of the ORC binary plant using ANSYS software to find out the pressures and temperatures at different stages of the plant for thermodynamic analyses, are shown in Figs. 6 and 7. Then the pressures, temperatures, entropy and enthalpy are calculated from the thermodynamic equations fed to the simulation code to plot the main diagrams of the P-h and T-S (Figs. 6 and 7) of the power plant, to find out the trend of the results and also the overall behavior of the cycle and the net power output at different power processes. From the results shown in Figs. 6 and 7, it can be seen that the trend of the results are matching the ideal thermodynamics processes with an increase of the pressure at constant enthalpy in the heating process between the organic substance and the geothermal water (heat exchanger), and then pressure drop during the turbine stages till the turbine outlet where condensation occur, Fig. 6. The results showed the consistency of the pressure and temperature values at different stages of the simulation.

From Fig. 7, which represents the organic rankine cycle of the power plant, it can be seen that the temperatures increases in the heat exchanger with a dramatic increase of the entropy. Also the temperature drop noticed at all turbine stages in a good manner which matchs the ideal thermodynamics processes. These results proved that the simulation of the fluid flow through different stages of the binary cycle was similar to ideal thermodynamics processes, and the deviation of the error was less than 1%, according to the convergence which is around 3x10^-7.

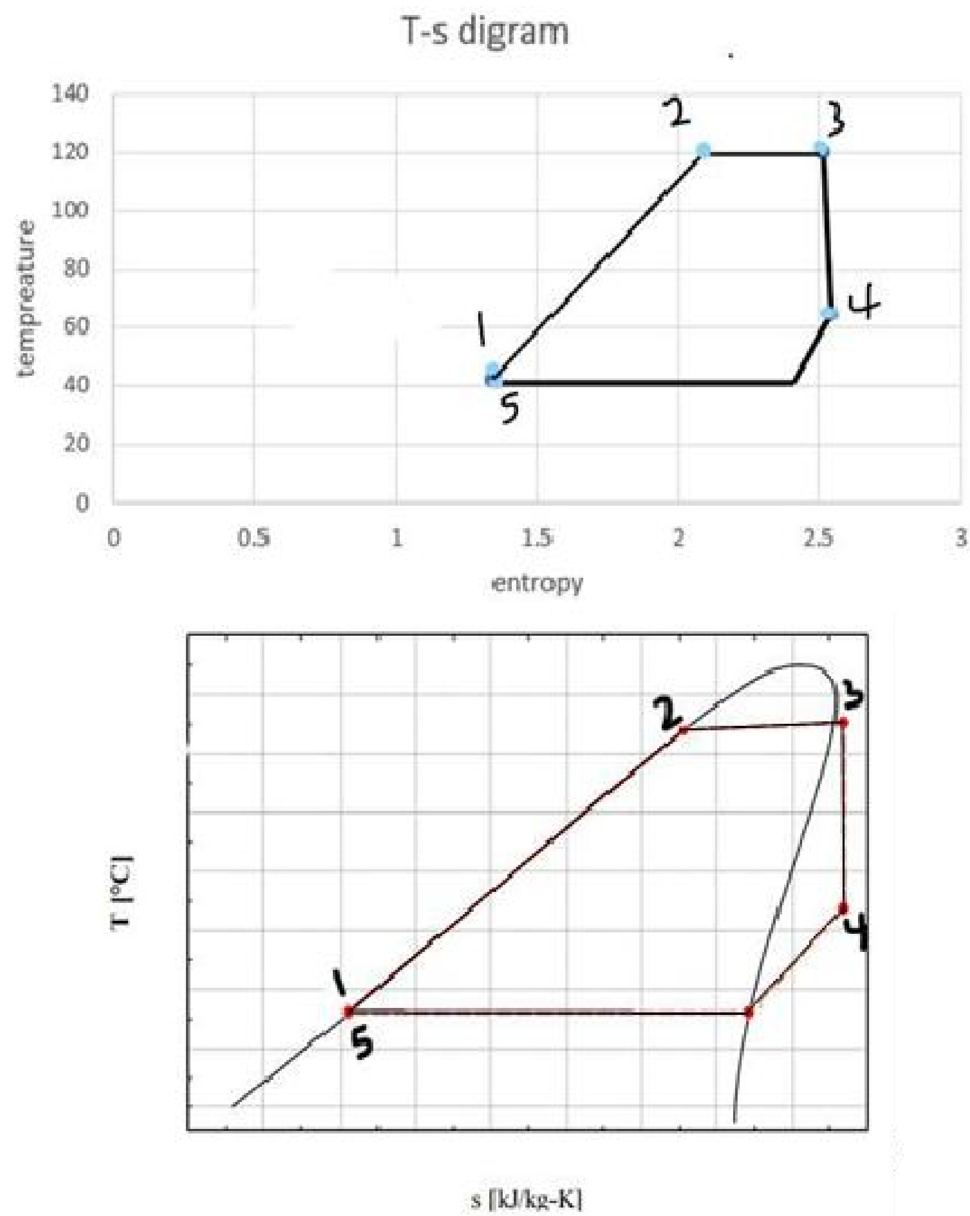


Fig. 7. Relationship between temperature and entropy

Table 2. The calculations procedure for health resort

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Aug 1700 C° C / 21.4° COOLING OA DB / WB 33.5			HEATING DATA AT DES HTG C° C / -2.5° HEATING OA DB / WB 0.7		
ZONE LOADS	**Details**	**Sensible (W)**	**Latent (W)**	**Details**	**Sensible (W)**	**Latent (W)**
Window & Skylight Solar Loads	m^2 76	8072	-	²m 76	-	-
Wall Transmission	m^2 421	8189	-	$m^2$421	19746	-
Roof Transmission	m^2 277	8225	-	$m^2$277	3872	-
Window Transmission	m^2 76	2838	-	$m^2$76	7859	-
Skylight Transmission	$m^2$0	0	-	$m^2$0	0	-
Door Loads	$m^2$16	366	-	$m^2$16	1012	-
Floor Transmission	$m^2$272	0	-	$m^2$272	0	-
Partitions	m^2 474	0	-	$m^2$474	0	-
Ceiling	m^2 60	0	-	$m^2$60	0	-
Overhead Lighting	W 7205	7204	-	0	0	-
Task Lighting	W 0	0	-	0	0	-
Electric Equipment	W 11800	11799	-	0	0	-
People	98	8477	13063	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	%0 / %0	0	0	%0	0	0
Total Zone Loads >>	**-**	**55170**	**13063**	**-**	**32489**	**0**
Zone Conditioning	-	52499	13063	-	31646	0
Plenum Wall Load	%0	0	-	0	0	-
Plenum Roof Load	%0	0	-	0	0	-
Plenum Lighting Load	%0	0	-	0	0	-
Return Fan Load	L/s 5227	0	-	L/s 4253	0	-
Ventilation Load	L/s 439	4281	1202	L/s 357	7741	0
Supply Fan Load	L/s 5227	0	-	L/s 4253	0	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	%0	0	-	%0	0	-
Total System Loads >>	**-**	**56780**	**14265**	**-**	**39387**	**0**
Central Cooling Coil	-	56777	14283	-	0	0
Central Heating Coil	-	0	-	-	39351	-
Total Conditioning >>	**-**	**56777**	**14283**	**-**	**39351**	**0**

Table 3. The results of the simulation of the designed binary power station

T [^{0}C]	P [bar]	H [kJ/kg]	S [kJ/kg.k]	V [m^3/kg]	Cp	state
120.1	22	743.082	2.5203	0.0167	3.1312	super-heated
64.42	4.4541	686.72	2.5451	0.0963	2.9	super-heated
41.93	4.29	301.74	1.3442	0.001809	2.5	sup cooled liquid
43.43	22.3	306.49	1.349	0.001816	2.53	sup cooled liquid

5. CONCLUSIONS

Geothermal energy is one of the alternative sources of energy which can be utilized for different purposes. Jordan is blessed with this energy source in several parts of the country. The production of electricity from binary cycle power plant is useful for harnessing low and medium temperature resources. The concept of a binary cycle power plant, which it is known as an organic Rankine Cycle, is a modification of the Rankine cycle where the working fluid, instead of water, is an organic fluid having a lower boiling point and a higher vapor pressure than water. The substance n_butane is used as a working fluid in the present power station, which has been proved by many studies and researches as an efficient and cheap option.

In this study the binary power plant station has been designed for supplying the arid health resort with electrical energy. From the results, we found that the power produced from the designed power plant is suitable to operate the health resort heating and cooling loads and other auxiliary equipments located in the site. The present results showed n_butane is the best option for geothermal power plants stations to produce the cheap electrical energy that can be used to supply arid regions having geothermal resources with low and medium temperatures such as Zara – Zarqa Ma'in regions, with sufficient electrical energy for different purposes (i.e. agriculture, recreation centers, and resorts). The present study encourages the government and private investors to consider the geothermal resources in Jordan as one of the best options for clean energy production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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