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A transient model for clean electricity generation using Solar energy and ocean thermal energy conversion (OTEC) - case study: Karkheh dam - southwest Iran

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ABSTRACT

Given the limitations of fossil fuels, humans must develop alternate energy sources. Solar energy and ocean thermal energy are known as a safe, secure, promising, and clean instrument for this purpose due to their enormous potential. A hybrid system of solar energy and ocean thermal energy with a thermoelectric generator is examined in this study to generate clean electricity and utilize the water temperature difference of the Karkheh dam. The system under consideration is made up of flat panel solar collector subsystems and a Rankin organic cycle. To model the analyzed system and acquire system analysis results, thermodynamic software of EES engineering equations solving was employed. The collector area, solar radiation intensity, ambient temperature, and input temperature to the turbine have all been studied as parameters affecting system outputs. The system's economic research revealed that the solar unit, evaporator, and ORC turbine have the highest cost rates among the system components. Furthermore, the system's exergy study revealed that the solar unit and evaporator suffered the highest exergy destruction. For one year, a case study was conducted on the water temperature difference at Karkheh Dam, and the findings of system performance were assessed. The results demonstrated that the best system performance is obtained under summer weather conditions in Andimeshk. The results showed that the proposed system's total output power in relation to the difference in water temperature of Karkheh Dam is 1,192,607/9 kW per year, and that this system can meet the energy needs of 111 households in Andimeshk throughout the year. According to the results, the system described in this study is suitable for the required applications.

1. Introduction

Today, energy is regarded as the driving force behind all productive, industrial, and basic human activity. Limitation of fossil fuels and anticipating price increases, environmental issues and air pollution, global warming, population expansion, and other subjects that have attracted planners' and policymakers' attentions to find appropriate solutions to the world's energy challenges, particularly environmental crises. Iran is one of the regions with a strong potential for using renewable resources, and with such abundant energy sources, it can easily generate a considerable amount of electricity. The presence of a hot and dry climate, particularly in the central regions of Iran, as well as a high amount of sunlight and wind in most areas, as well as high geothermal energy in the country and good access to Caspian Sea and Persian Gulf water, indicate that Iran has a high potential for solar energy, ocean thermal energy con, wind energy, and geothermal energy. Advances in science and technology, in addition to many achievements for human comfort and well-being, always bring new problems, such as environmental pollution caused by fossil fuels. In other words, the burning of fossil fuels releases toxic gasses into the air, making it difficult for humans to breathe and polluting the environment. There is a widespread climate on the planet called the greenhouse effect. If the temperature continues to rise according to the current trend, it will be almost impossible to return it to its previous state. The best solution most scientists have come up with is to stop the growth of these harmful gasses. Experts believe that using clean energy such as solar, ocean heat, wind and… instead of using energy from fossil fuels, can significantly prevent environmental pollution and its dangers [1]. Solar energy is one of the most important

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Nomenclature

A	Area, (m^2)
Gb	solar radiation intensity, (W/m^2)
$\dot{E}$	Exergy rate, (kW)
T_{sun}	The temperature of the sun, °) C)
U_l	overall collector loss coefficient, (-)
F_R	heat removal factor, (-)
F_1	collector efficiency factor, (-)
C_p	specific thermal capacity, (kj/kg.K)
$\dot{m}$	Mass flow rate, (kg/h)
h	Enthalpy, (kj/kg)
$\dot{W}$	Power, (kW)
n	life of the power plant, (-)
$\dot{Q}$	Heat transfer rate, (kW)
Q_L	collector heat losses, (kW)
$\dot{Q}_u$	collector heat gained, (kW)
t	Time, (h)
T	Temperature, (°C)
P	Pressure, (kPa)
$\dot{Z}$	Cost rate, ($/h)
Z	Investment cost of the component
ZT_m	Figure of merit

Abbreviation

ORC	organic Rankine cycle
TEG	Thermoelectric generator
CRF	Capital Recovery Factor
Evap	Evaporator
tur	Turbine
cv	Control volume
ex	exergy
e	out
i	in
EES	Engineering Equation Solver
0	Dead state
D	Destruction
Ph	Physical
Ch	Chemical

Greek symbols

$\tau\alpha$	effective product transmittanceeabsorptance
η	Efficiency (%)
φ	operation and maintenance factor
τ_l	Visual efficiency

sources of renewable energy that has attracted a lot of attention in recent years. Solar energy is very affordable compared to other renewable and even non-renewable energy sources. Solar energy is clean and does not emit greenhouse gasses and does not cause any pollution to nature. The conversion of solar energy into electrical energy is very useful in various fields. Sunlight has been used as a source of energy in ancient times and as its older applications to light fires or reflect sunlight by mirrors to set fire to enemy ships [1]. Using ocean thermal energy conversion technology, it is able to generate electricity by using the temperature difference between hot water on the ocean surface and cold water. Oceans are a vast source of energy that provide a viable alternative to depleting renewable resources. Among all the countries in the world, Iran is one of the countries that has a great potential for the use of solar energy and ocean thermal energy (OTEC) due to its geographical conditions and high solar radiation, but due to the abundant resources of oil and gas. Very little attention has been paid to its development in the country [2]. Among the ten challenges that the world will face in the next 50 years, energy shortages and how to supply them are among the most fundamental. Which has become very important in the future due to the finite nature of fossil energy sources [3]. Due to the energy crisis, all countries in the world are looking to reduce energy consumption and find new sources to meet their needs [4]. Therefore, moving to renewable energy sources as alternative sources that have high capacity, reliable, economically viable and permanent, is a necessity for the future [5, 6].

In this research, the use of ocean thermal energy and also the use of direct solar energy radiation on Karkheh Dam is one of the largest earth dams in the world and also the largest earth dam in Iran and the Middle East. This dam is built on Karkheh river in Andimeshk city. It has a crown with a length of 3030 m and a height of 127 m in terms of body volume. It is the largest dam in the history of Iran and with a reservoir volume of 7 billion and 300 million cubic meters, It has also become an artificial lake in Iran. Andimeshk city is a hot and dry city that has relatively warm weather and high solar radiation in different seasons of the year and during the day. Therefore, it can be said that the Karkheh dam area has a high potential of solar energy. For this reason, using both solar and ocean thermal renewable energy, a renewable hybrid system has been designed to meet the energy needs of this region. Chen et al. worked on optimizing and comparing solar power generation systems to suit the energy needs of complexes and public buildings in 2022. To get an appropriate energy supply system and construct an optimization approach for public health buildings, this study offered eight solar energy system ideas. Optimization models are developed to assess the cost of each solar energy system, and the system's equipment capacity is optimized and simulated. According to the findings, an integrated solar heat and hot water storage system has a 43% lower life cycle cost than an isolated solar hot air heating system and an independent photovoltaic system. The integrated system's yearly energy savings ratio was reported to be 85%, with a life cycle cost savings rate of around 50%. Furthermore, sensitivity analysis revealed that, when compared to interest rates and annual inflation, power costs are the most critical factor for life cycle cost. The cost of a solar collector and an air source heat pump has the biggest influence on the outcomes of a life cycle cost optimization of a photovoltaic-photothermal-thermal system and power storage [7]. Chen et al. developed a hydrogen generation system based on solar energy and ammonia-based chemical energy storage in 2021. In this work, a new technology for electrolysis of high temperature water and storage of chemical thermal energy based on ammonia was introduced for the first time. A new system, incorporating solar panel subsystems, ammonia-based energy storage, the Brighton cycle, and an electrolyzer, was studied in this study [8]. Asareh et al. worked on the evaluation of exergy and economics, as well as the optimization of a power production system combining solar, wind, and ocean energy to create electricity, as well as a case study for the city of Bandar Abbas, Iran, in 2021. Solar collector, Rankin organic cycle, and wind turbine subsystems comprised the system. The power generated by the Rankin organic cycle turbine is transformed into electrical energy and supplied to the global power distribution network in this system. At its best and most efficient, this system can generate 448 kW of power. Furthermore, the system's exergy efficiency is 13.88%. The results revealed that using thermoelectric in the Rankin organic cycle boosts system productivity [9]. Razmi et al. studied the thermodynamic evaluation of a compressed-air energy storage system (CAES) for two nearby wind farms with a combined nominal capacity of 162.5 MW at the Abhar and Kahak sites in Iran in 2021. The results showed that the wind speed in July is higher than in other months at both the Abhar and Kahak sites. Thus, during the 5 h of peak demand in July, August, and September, approximately 93, 74, and 60 MW of storage capacity in CAES facilities were added to the network, with return rates of 52, 47, and 43% [10].

Dezhdar and Asaareh, reviewed an Modeling, Optimization and exergoeconomic analysis a multiple energy production system based on solar Energy, Wind Energy and Ocean Thermal Energy Conversion (OTEC) in the onshore region 2020 [11]. Lopez et al. investigated and analyzed the utilization of two types of solar heat collectors to meet the electrical needs of a Colombian power station in 2021. The solar energy was used to preheat the boiler feed water, hence reducing fuel usage and the power plant's exergy deterioration. The performance of a parabolic solar collector and a linear collector was compared. Exergy studies for two types of solar collectors revealed that PTC performance is superior [12]. Kumargapta et al. presented an ORC with a triple pressure absorption system and a parabolic-linear solar collector system in 2020. This technology simultaneously generates electricity and refrigeration at two distinct temperatures. The data demonstrate that increasing the ambient temperature from 5 to 35 °Celsius reduces the quantity of electricity generation by 6.8 megawatts. Energy efficiency fell from 13.7% to 9.2%, and exergy efficiency fell from 54.9% to 36.7%, resulting in a cost rise [13]. Heidarnejad et al. published a comprehensive strategy for optimizing a geothermal power plant with biomass and freshwater production in 2020. In this system, municipal solid waste combustion was employed to improve system performance, and the exhaust gasses from the municipal solid waste combustion were used as the primary energy source for the multipurpose desalination subsystem. The results showed that the system's energy efficiency and exergy could reach 13.9% and 19.4%, respectively, with a total system cost of $ 285.3 per hour. Compared to the use of coal, using municipal solid waste saves 8092 tons of CO2 emissions and 36 tons of NOx emissions [14]. Parikhani et al. in 2020 investigated the thermodynamics and economics of a combined cycle for cooling, heating, and electricity generation. According to the findings, the condenser has the maximum share of the system exergy loss, accounting for approximately 32.03% of the entire system loss. Turbines have the greatest investment cost of any system component. Cooling efficiency, net power efficiency, and heating efficiency were reported to be $ 184, $ 300, and $ 116.4 per gigajoule, respectively. Net power generation, heating efficiency, and cooling efficiency were all 253 kW, 1972 kW, and 1610 kW, respectively [15]. Razmi et al. worked on the thermodynamic evaluation of a compressed air energy storage system (CAES) for two nearby wind farms with a combined nominal capacity of 162.5 MW at the Abhar and Kahak sites in Iran in 2021. The results showed that the wind speed in July is higher than in other months at both the Abhar and Kahak sites. Thus, during the 5 h of peak demand in July, August, and September, approximately 93, 74, and 60 MW of storage capacity in CAES facilities were added to the network, with return rates of 52, 47, and 43% [16]. Ishaq et al. developed a power generation system in 2021 that uses solar and wind energy to make hydrogen and absorb carbon dioxide. The system was designed to provide the energy needed for the proton exchange membrane electrolyzer to create hydrogen using a wind turbine, as well as to convert and store excess energy as ammonia. The solar panel's electricity was used to power the refrigerator air separation device. The results reveal that ammonia not only absorbs CO2 but also creates urea for the fertilizer sector in the proposed system. The system generates a total of 2.14 MW of electricity. The planned system generates 518.4 km of hydrogen and 86.4 km of urea every day [17]. Ishaq and Dincer collaborated in 2021 on dynamic modeling of the solar system to produce hydrogen, power, and ammonia. The system underwent dynamic analysis to evaluate its performance under various radiation intensities. A considerable portion of the electricity generated by the system must be directed to the PEM electrolyzer in order to produce hydrogen. Numerous parametric analyses were carried out in order to determine the effective parameters. The results showed that the maximum quantity of hydrogen and ammonia production in June at 17:00 is 5.85 mol/s and 1.38 mol/s, respectively, and that the system's maximum energy efficiency and exergy in November were 25.4% and 28.6%, respectively [18].

Asareh et al. worked on the thermodynamic evaluation of a cogeneration system to create electricity and hydrogen in conjunction with the CSP Driven-Brayton and Rankine cycles in 2022. This study's device employs solar energy to feed heat energy to a Brighton cycle. Using residual heat from a gas turbine, two Rankin cycles were employed to supply the energy requirements of PEM electrolysis. Six design variables were chosen and subsequently optimized for the proposed system using NSGA-II. According to the TOPSIS technique, the objective functions for exergy efficiency and capital cost rates were 22.2% and $ 272.6/h, respectively [19]. Asareh et al. worked on the thermodynamic-economic optimization of a hybrid energy system that generates power and fresh water using solar energy in 2022. A centralized solar power plant, steam Rankin cycle, Brighton cycle, Rankin organic cycle, reverse osmosis unit, and thermoelectric generator were all part of this system. The goal was to reduce annual costs while increasing exergy efficiency. This system is located in Isfahan (central Iran) and was designed to produce energy and fresh water. The number of heliostats, turbine efficiency and inlet temperature, compressor pressure ratio, and steam Rankin pump inlet temperature were the parameters that affected the performance of the standard direct irradiation system [20]. Ali Rahmi et al. worked on hydrogen and electricity generation in 2022 using a geothermal energy-based multiple generating system and the Rankin organic cycle. The system featured Rankin 1 and 2 organic cycle subsystems, a PEM electrolyzer, and a geothermal adsorption refrigeration cycle. Power is generated by Rankin cycle turbines in this system, and the power generated by the generator is converted into electrical energy. A portion of the electricity is then given to the electrolyzer to produce hydrogen, and the remainder is transferred to the global electricity distribution network. The results revealed that the input temperature of ORC turbines had the greatest influence on system performance. The results suggest that this system can generate 4696 MWh of electricity per year, which is enough to cover the energy needs of 160 homes. The findings of multi-objective optimization revealed that the optimal exergy efficiency was 37.85% and the system cost rate was 15.09 USD/h [21]. Saikia et al. worked on optimizing an integrated solar electrolyzer system for hydrogen production in 2021. The Taguchi technique was used in this study to optimize essential parameters of electrolyzer performance using a photovoltaic (PV) system for hydrogen production. In this study, ten operational parameters were chosen for optimization using an orthogonal array, and it was discovered that the highest hydrogen production is 319.35 Ncm3/hr. The Taguchi technique was then used to determine that the maximum hydrogen production is 645.89 Ncm3/hr, indicating an increase of 50.56% over the highest output obtained from the orthogonal array [22]. Jafari et al. studied the energy and exergy of two energy generation systems with different Rankin organic cycles in 2020. The studied system included the following subsystems: solar system, Rankin organic cycle, and absorption chiller. The difference between the two systems is related to the Rankin organic cycle unit, with one cycle coupled to an internal heat exchanger and the other equipped with mixed steam to reconstruct the Rankin organic cycle. Solar radiation and a parabolic collector are the primary drivers of both Rankin organic cycles. The influence of effective parameters such as turbine inlet pressure, condenser inlet pressure on heating and cooling system production, energy efficiency and net power generation was explored. The results showed that the internal heat exchanger enhanced the energy and efficiency of the Rankin organic cycle more than the modified Rankin organic cycle. The total efficiency of the system based on Rankin organic cycle with internal heat exchanger and the modified Rankin organic cycle system is 93.35% and 86.66%, respectively. According to the results, exergy efficiencies for the system based on Rankin organic cycle with internal heat exchanger and the modified Rankin organic cycle-based system, are 12.69% and 6.641%, respectively [23].

In 2021, Jafary et al. performed a complete energy and exergy analysis of a ternary solar power system with two new organic Rankine cycle (ORC) configurations. The results showed that the overall energy efficiency of the ORC-IHE-based system and the RORC-based systems are 93.35% and 86.66%, respectively. Accordingly, the overall exergy efficiency for the ORC-IHE-based system and the RORC-based system is 12.69% and 6.641%, respectively [24].

In 2021, Jalili et al. conducted an economic and environmental assessment using the emergence of geothermal power. The results of this study show that the economic emergence coefficient and the ecological emergence coefficient of the system are 34.1 and 4%, respectively.

Therefore, strategies should be adopted to reduce the emergency rate of destruction [25].

In 2022, Kefif et al. investigated the feasibility and optimal operation of the hybrid micro-energy system (water/wind) in the rural valley region. This system was proposed to reduce financial costs in addition to the possibility of supplying replaceable energy and operational reserves with a short start-up time [26].

In 2021, Cao et al. investigated the induction of swirling flow inside flat plate solar collector tubes using multiple nozzles to increase thermal performance. For this purpose, the effect of the number of peripheral nozzles and their tilt angles was considered [27].

In 2023, Assareh et al. addressed the techno-economic analysis of a combined cooling, heating and power (CCHP) system integrated with several renewable energy sources and energy storage units. This study investigates the optimal design of a multi-renewable energy cooling, heating and combined power (M-RCCHP) system integrated with energy storage units for an apartment community from techno-economic perspectives using response surface methodology (RSM) and dynamic evaluation [28].

In 2023, Assareh et al. investigated the integrated system for producing electricity and fresh water from a new gas power plant and a concentrated solar power plant and compared this system to climate changes in Australia, Spain, South Korea, and Iran. The exergy analysis of the system showed that the most exergy destruction is related to the combustion chamber, heliostat, solar receiver, multi-effect desalination, gas turbine 1 and thermoelectric, respectively. The total production power in this system is 190.7 MW and the exergy loss of the whole system is reported as 47.73 MWh [29].

Assareh et al. in 2022, analyzed the energy, exergy, exergoeconomic, exergoenvironmental and transient of a proposed system based on a gas power plant with a combined Rankine cycle and the use of a thermoelectric generator to produce power in weather conditions [30].

In 2022, Ranjbar Hasani et al. addressed the thermo-economic evaluation and operating fluid selection of geothermal-based ORC configurations integrated with PEM electrolysis. In this research, ORC systems with internal heat exchanger (IHE), open feed organic fluid heater (OFOH), closed feed organic fluid heater (CFOH), and a combination of IHE-CFOH was evaluated [31].

In 2022, Rejeb et al. investigated an innovative integrated multi-generation solar energy system for the production of hydrogen, oxygen, electricity and green heat. The innovative design included solar photovoltaic (PVT) thermal collectors with organic Rankine cycle (ORC), proton exchange membrane (PEM) electrolyzer and liquefied natural gas (LNG). Using the solution of engineering equations (EES), the thermodynamic (energy, exergy) and economic evaluation of the proposed power plant was carried out and system optimization was done with a Genetic algorithm [32].

In 2022, Assareh et al. addressed transient thermodynamic modeling and economic evaluation of cogeneration systems based on compressed air energy storage and multi-effect desalination. The proposed system consisted of the heliostat, gas turbine, multi-effect desalination and compressed air energy storage (CAES) subsystems. Engineering Equation Solver software was used for modeling and obtaining results through system analysis. Eight scenarios were investigated considering charging time, discharging time, number of sunny hours and different effects of desalinationc [33].

In 2022, Assari et al. integrated intelligent optimization algorithms with artificial neural networks to predict the performance of a counterflow wet cooling tower with rotary packing [34].

The thermodynamic evaluation and analysis of a power generation system based on a combination of solar energy and OTEC, as well as the use of thermoelectric to enhance the system's generation capacity in the Karkheh dam area to use the water temperature difference of the Karkheh dam, were carried out in this study. Flat panel solar collector subsystems, ocean thermal energy, and the Rankin organic cycle comprise the system. This system's major output is clean electricity. The major goal and innovation of this research is to generate clean power utilizing solar energy absorption and the water temperature difference behind the wall of Karkheh Dam to supply lighting to the dam's tunnels and restrooms. To model the system and acquire the results, the EES engineering equation solver is used. Given that solar energy-based renewable systems are not available all day and also on rainy days, it can be said that the solar system is an unstable system; therefore, the use of Ocean thermal energy as a secondary energy can contribute to the stability of this system and increase its reliability because when the stability of the system decreases at night or in rainy weather, the system uses energy resulting from the temperature difference of Karkheh dam water. These systems' advantages include high energy efficiency, reduced energy losses and exergy, high exergy efficiency, and reduced greenhouse effects. By producing energy with this renewable hybrid system, it is possible to help reduce drinking water and water required for agricultural purposes in this area, which is available in the reservoirs and artificial lake of this dam and is used to produce energy by Karkheh dam equipment. Because today the world is facing a shortage of drinking water and this danger.

According to the studies, many researches have been conducted in the field of using solar and ocean thermal energy for electricity generation, but the simultaneous use of these two energies to increase the reliability of the system and the stability of energy production has received less attention. Also, the use of temperature differences in dams and water storage tanks has not been noticed by researchers. There are many dams in the world that can be used to produce clean energy by using the difference in water temperature in the primary and secondary depths of these dams.

Ocean thermal energy conversion uses the ocean's thermal gradient between colder deep water and shallow or surface seawater to run a heat engine and generate useful work, usually in the form of electricity. Among the ocean energy sources, OTEC is one of the continuously available renewable energy sources that can help provide baseload energy. The resource potential for OTEC is considered much greater than for other forms of ocean energy. Systems may be closed cycle or open cycle. Closed cycle OTEC uses working fluids that are usually considered refrigerants. These fluids have a low boiling point and are therefore suitable for powering the system's generator to produce electricity. The most common thermal cycle used for OTEC to date is the Rankine cycle, which uses a low-pressure turbine. Open-cycle engines use sea water vapor as the working fluid. A thermal cycler is more efficient when it operates with a large temperature difference. OTEC plants can operate continuously and provide a base load source for a power generation system. OTEC is still considered an emerging technology.

Thermoelectric generators (TEG) are solid-state semiconductor devices that convert temperature difference and heat flow into a useful DC power source. Thermoelectric generator semiconductor devices use the Seebeck effect to generate voltage. This generated voltage drives the electric current and produces useful power. For the Sibak effect, the heat Q_h is transferred from the high-temperature heat source to the hot junction and the heat Q_L is transferred from the cold junction to the low-temperature heat source. The difference between these two amounts of heat is equal to the net electrical work produced. The thermoelectric power cycle can be considered similar to the cycle of a heat engine. Here, electrons play the role of working fluid. Therefore, the thermal efficiency of a thermoelectric generator that works between two temperatures Th and TL will be at most equal to the efficiency of the Carnoi cycle that works between these two temperatures, as a result, in the absence of all irreversibility factors, the efficiency of the thermoelectric generator with the cycle efficiency Carnot becomes equal.

2. System description

Fig. 1 depicts a schematic of the renewable system investigated in this study. The system uses solar energy and ocean thermal energy and is made up of flat panel solar collector subsystems, ocean thermal energy,

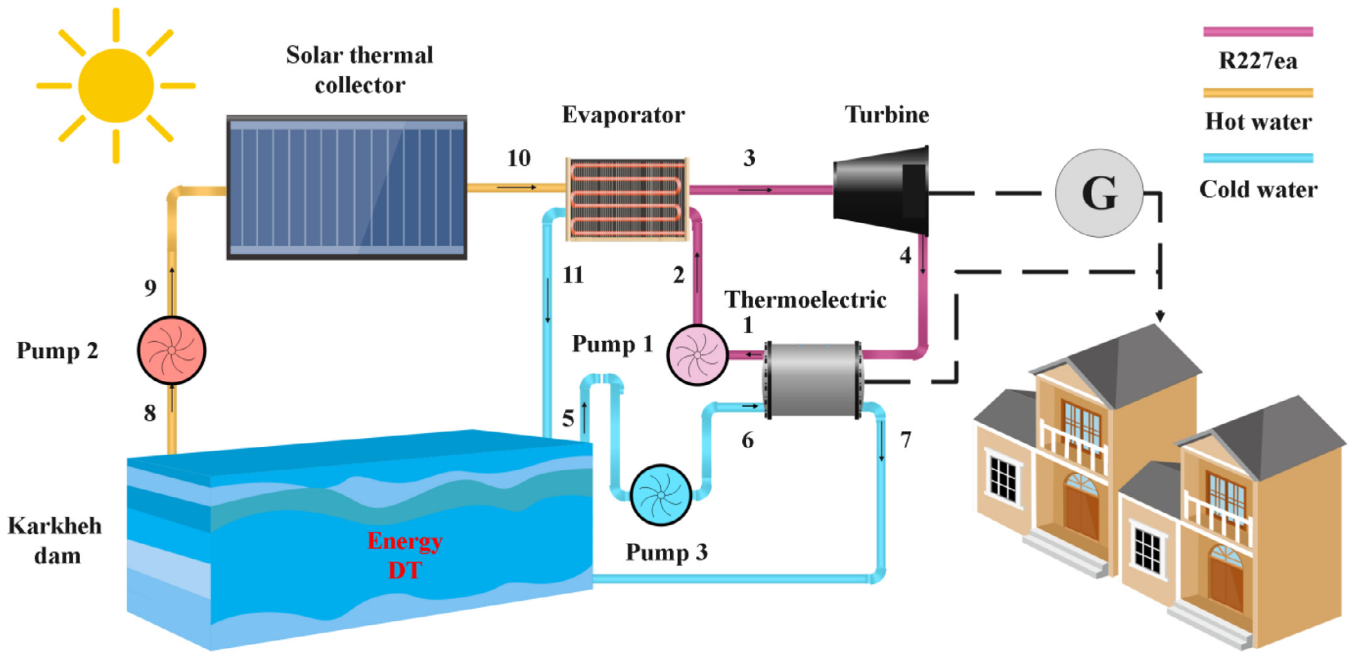

Fig. 1. Schematic of the proposed system.

and the Rankin organic cycle. This system's major output is clean electricity. The heat source in this system is two solar energies collected from solar irradiation and the ocean temperature difference derived from the artificial lake of Karkheh Dam, which is transferred to the solar collector, then to the evaporator, and lastly to the turbine and thermoelectric to generate power. In steps 1–2, the fluid is delivered from the thermoelectric to the pump as a saturated liquid. The fluid is then fed into the evaporator and evaporated to begin the cycle activity. The heat from the warm ocean water, which is heated by the solar collector, is utilized to evaporate the fluid, and electricity is generated as saturated vapor enters the electricity turbine. The steam from the turbine enters the thermoelectric and it is divided into two parts. The first half is provided to the pump, while the second part is converted to electricity after being cooled by thermoelectric and then used to improve the system's generation capacity. In these systems, R227ea refrigerant is employed as an organic fluid in the Rankin organic cycle, while water fluid is used in the Karkheh Dam's ocean heating system. The system's objective functions are exergy efficiency and cost rate. To solve the governing equations, model the system, and acquire the findings, thermodynamic software, EES engineering equation solver, is utilized.

3. Thermodynamic analysis

For thermodynamic analysis of the current work, energy and mass for each control volume are balanced. The following assumptions are considered to simplify the problem:

- Steady state condition
- The turbines and the pumps are isentrope.
- Pressure drop along the pipeline is negligible [35].
- Output of the condensor is saturated liquid and output of the evaporator is saturated vapor [35].
- Changes in potentil and kinetic energies is negligible [36].

Table 1 represents the input data for analysis of the solar-ocean thermal system.

Using the first law of thermodynamics for each control volume is given in Table 2.

$$\dot{Q} - \dot{W} + \sum_i \dot{m}_i\left(h_i + \frac{V_i^2}{2} + gZ_i\right) - \sum_e \dot{m}_e\left(h_e + \frac{V_e^2}{2} + gZ_e\right) = \frac{dE_{cv}}{dt} \quad (1)$$

Table 1
Main input parameters employed in the simulation of the proposed system.

No.	Data	Parameter	Value
1	T_0	*Ambient temperature*	*25 °C*
2	A_p	*Collector area*	$6000m^2$
3	T_8	*input temperature from the ocean*	*30 °C*
4	T_{10}	*Output temperature of the solar collector*	*95 °C*
5	P_0	*Ambient pressure*	*101.3kpa*
6	P_8	*Input pressure from the ocean*	*101.3kpa*
7	P_9	*Input pressure to the solar collector*	*150kpa*
8	$\dot{m}_9$	*Mass debi*	$10\ kg/s$
9	F_1	*Fixed collector efficiency*	*0.914%*
10	*Gb*	*Area's solar irradiation*	$800\ W/m^2$
11	T_{sun}	*Solar temperature*	*5770k*
12	τ_l	*Visual efficiency*	*3.82%*
13	T_3	*Output temperature of the evaporator*	*60 °C*
14	T_1	*Input temperature of pump 1*	*15 °C*
15	T_5	*Input temperature of pump 5*	*5 °C*
16	P_5	*Input pressure of pump 5*	*150kpa*
17	P_6	*Input pressure of thermoelectric*	*600kpa*

Table 2
Energy balance equations for the system components.

System component	Equation
Turbine	$\dot{W}_{Turbine} = \dot{m}_3 \times (h_4 - h_3)$
Pump 1	$\dot{W}_{pump2} = \dot{m}_1 \times (h_2 - h_1)$
Pump 2	$\dot{W}_{pump2} = \dot{m}_8 \times (h_9 - h_8)$
Pump 3	$\dot{W}_{pump3} = \dot{m}_5 \times (h_6 - h_5)$
Evaporator	$Q_{Evva} = \dot{m}_{10} \times (h_{10} - h_{11})$
Thermoelectric	$\dot{W}_{TEG} = \dot{m}_4 \times (h_4 - h_1)$
Total ORC Work	$\dot{W}_{ORC} = \dot{W}_{turbine} - \dot{W}_{pump1} - \dot{W}_{pump2} - \dot{W}_{pump3}$

Finally, it should be said that the net power of the whole system is obtained using Eq. (2):

$$\dot{W}_{net} = \dot{W}_{ORC} + \dot{W}_{TEG} \quad (2)$$

3.1. Solar unit analysis

One of the most well-known and commonly used types of solar systems for turning heat into electrical energy is flat panel solar collector. Solar power plant technology using parabolic concentrators is currently the most important thermal-electric approach for renewable energy generation. Direct normal irradiation (DNI) fluctuates throughout the day, peaking at noon. The area of the solar system is chosen based on the system's design conditions. Flat panel collectors are utilized as solar receivers because they are less expensive than other types of solar receivers. Eq (3) [20] is used to calculate the heat generated by the operating fluid.

$$\dot{Q}_u = \dot{m}C_p\left(T_{10} - T_9\right) \tag{3}$$

In this equation, T10 is the output water temperature t point 10, T9 is the input water temperature at point 9, C is the specific heat at constant pressure and m is the mass debi rate of the collector. In Eq. (4), FR is the heat rejection factor, UL is the total collector drop factor, Aap is the area of the collector, and S is the visual efficiency. Using Hottel-whillier equation, the thermal flow of the flat panel collector is calculated [36].

$$\dot{Q}_u = A_P F_R[\left(ta\right)G_b - Q_L\right) \tag{4}$$

In this equation:

$\tau\alpha$ is the optical efficiency, FR is the heat rejection factor:

$$F_R = \frac{\dot{m}C_p}{U_l A_P}\left[1 - e^{\{-\frac{F_1 U_l A_P}{\dot{m}C_p}\}}\right] \tag{5}$$

In this equation, F1 is the efficiency factor of the collector, which is almost 0.914 and U1 is the total drop factor of the collector that can be obtained using [36]. Finally, QL is obtained using Eq. (6):

$$Q_L = U_l\left(T_{in} - T^{\circ}\right) \tag{6}$$

3.2. Thermoelectric analysis

To analyze the thermoelectric output and the amount of electricity generated by the thermoelectric used in the system, the following equations are used [37, 38, 39]:

$$\dot{m}_6 \times h_6 + \dot{m}_9 \times h_9 = \dot{m}_7 \times h_7 + \dot{m}_{10} \times h_{10} + \dot{W}_{TEG} \tag{7}$$

$$h_{TEG} = h_{carnot} \times \left(\left(\sqrt{(1 + ZT_M)} - 1\right) / \left(\sqrt{(1 + ZT_M)} + (T_L/T_H)\right)\right) \tag{8}$$

ZT_M is the figure of merit and it is calculated as follows:

$$ZT_M = 0.8$$

Thermoelectric efficiency is obtained from Eq. (9):

$$h_{TEG} = \frac{\dot{W}_{TEG}}{Q_{Elegant}} \tag{9}$$

$$\eta_{carnot} = 1 - \left(\frac{T_L}{T_H}\right) \tag{10}$$

$$Q_{Elegant} = \dot{m}_6 \times (h_7 - h_6) \tag{11}$$

$$T_L = 0.5 \times (T_9 + T_{10}) \tag{12}$$

$$T_H = 0.5 \times (T_6 + T_7) \tag{13}$$

3.3. Exergy analysis

The following equations are used in this study for exergy analysis:

$$\dot{E}x_Q + \sum_{in} \dot{m}_{in} ex_{in} = \dot{E}x_W + \dot{E}x_D \sum_{out} \dot{m}_{out} ex_{out} \tag{14}$$

Here:

$$\dot{E}x_W = \dot{W} \tag{15}$$

$$\dot{E}x_Q = \dot{Q}_J \times \left(1 - \frac{T_0}{T_j}\right) \tag{16}$$

$$ex = ex_{ph} + ex_{ch} \tag{17}$$

The Exergy destruction equation of each element is given in Table 3.

Table 3

Exergy destruction rate balance equations for the system components.

component	Exergy destruction
Evaporator	$\dot{E}_{Eva} = \dot{E}x_2 + \dot{E}x_{10} - \dot{E}x_{11} - \dot{E}x_3$
Pump 1	$\dot{E}_{pump1} = \dot{E}x_1 + \dot{W}_{pump1} - \dot{E}x_2$
Pump 2	$\dot{E}_{pump2} = \dot{E}x_8 + \dot{W}_{pump2} - \dot{E}x_9$
Pump 3	$\dot{E}_{pump3} = \dot{E}x_5 + \dot{W}_{pump3} - \dot{E}x_6$
Turbine	$\dot{E}_{Turbine} = \dot{E}x_3 - \dot{E}x_4 - Ex_{Sun}$
Thermoelectric	$\dot{E}_{TEG} = \dot{E}x_4 + \dot{E}x_6 - \dot{E}x_7 - \dot{E}x_1 - \dot{W}_{TEG}$
Flat panel solar collector	$\dot{E}_{Collector} = Ex_{Sun} + \dot{E}x_9 - \dot{E}x_{10}$

3.4. Economic analysis

In order to achieve the cost of each part of the system and the total cost rate of the system, the cost function of each element is used. the cost rate is obtained using economic parameters like capital recovery factor, interest rate, as a result of which the system cost is evaluated better. The cost rate of each element is [40]:

$$\dot{Z}_k = \frac{Z_k \times CRF \times \varphi}{T} \tag{18}$$

In this equation, $\dot{Z}_k$ is the cost rate, φ is the repair and maintenance factor, which is 1.06. T is the operating hours of the system, which is 7446. The CRF is as follows [41]:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{19}$$

In this equation, i and n are the profit and operating cycle of the plant (year), which are 0.1 and 20, respectively. Table 4 demonstrates the cost of each element and the required auxiliary equations are also given:

The value of u_{Evap} is equal to [9]:

$$u_{Evap} = 4.39$$

And the amount $\Delta T_{lnEvap}$is obtained from the following relationship:

$$\Delta T_{lnEvap} = \frac{((T_{10} - T_3) - (T_{11} - T_2))}{\ln((T_{10} - T_3) - T_{11} - T_2))} \tag{20}$$

Finally, it should be said that the total cost is obtained by summing the cost of system elements as in Eq. (20):

$$Z_{total} = Z_{Solarcollector} + Z_{Turbine} + Z_{TEG} + Z_{Pump1} + Z_{Pump2} + Z_{Pump3} + Z_{Evap} \tag{21}$$

3.5. System efficiency

The exergy efficiency is defined as the key index for evaluating the system performance.

$$\eta = \frac{\dot{W}_{net} \times 100}{Ex_{Sun}} \tag{22}$$

Table 4

Capital cost functions for the components of the proposed system.

System component	Cost balance
Evaporator	$Z_{Evap} = 276 \times (A_{Evap}^{0.88})$
Evaporator area	$A_{Evap} = \frac{Q_{Evap}}{(u_{Evap}/\Delta T_{lnEvap})}$
Pump 1	$Z_{Pump1} = 3500 \times (\dot{W}_{Pump1}^{0.41})$
Pump 2	$Z_{Pump2} = 3500 \times (\dot{W}_{Pump2}^{0.41})$
Pump 3	$Z_{Pump3} = 3500 \times (\dot{W}_{Pump3}^{0.41})$
Turbine	$Z_{Turbine} = 4750 \times (\dot{W}_{turbine}^{0.75}) + 60 \times (\dot{W}_{turbine}^{0.95})$
Thermoelectric	$Z_{TEG} = 1500 \times \dot{W}_{TEG}$
Flat panel solar collector	$Z_{Solarcollector} = 235 \times A_p$

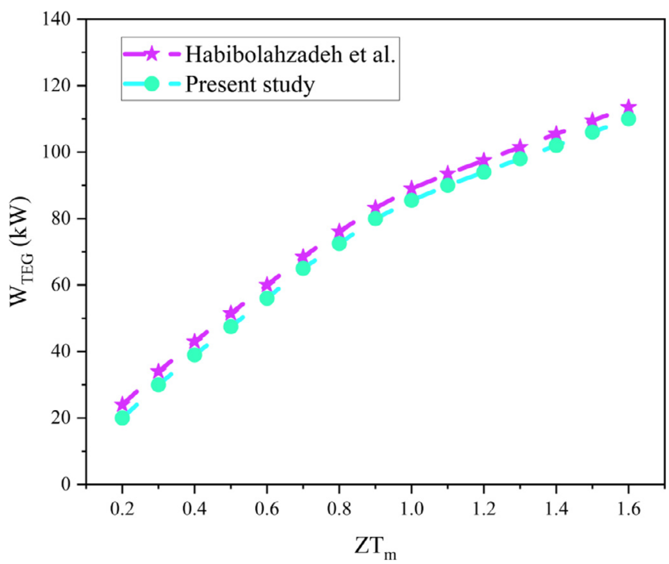

Fig. 2. Verification of the current study with the study of Mr. Habibollahzadeh et al. [42].

4. Results and discussion

4.1. Verification

To verify the outcomes, the current work's results are compared with the work of Mr. Habibollahzadeh et al. [41]. Because the introduced system is a new and newly built system, a thermoelectric subsystem was chosen for verification in this research. The work has a good reputation, as evidenced by the results. The verification findings of the current investigation are shown in Fig. 2. This study has a good reputation, as evidenced by the findings.

4.2. Results

The main challenge in analyzing power generation systems that are designed based on renewable energy is to find the most optimal and best answer for system efficiency, its costs and determine the parameters that affect the system. External costs are harmful results of economic activities and these costs appear as harmful effects on the environment. Energy generation from power plants and facilities incurs costs to the environment that are not included in the final price of the product. Failure to consider the environmental costs of power generation has a negative impact on natural resources in the country's energy complex, imposing external costs on the environment, causing air pollution, reducing fresh water resources, and so on. These expenditures can be reduced by substituting new and renewable energy sources.

4.2.1. Parametric study

The primary purpose of designing renewable energy power generation systems is to identify the most optimal and best response for system efficiency and costs, as well as to determine the kind and amount of various optimal parameters affecting the system. External costs are negative consequences of economic activity that manifest as negative environmental repercussions. Energy generation from power plants and facilities incurs environmental expenses that are not included in the end product pricing. Failure to consider the environmental costs of energy generation has a negative impact on natural resources. External expenses imposed on the environment in the country's energy complex create air and water pollution, loss of fresh water supplies, and so on. These expenditures can be reduced by substituting new and renewable energy sources.

The effect of design parameters on system outputs, including the output power of the ORC unit, thermoelectric power output, total output power of the system, exergy efficiency, and cost rate are evaluated to parametric study of the current system. Solar collectors are one of the most essential pieces of equipment for absorbing solar radiation energy, and they are one of the most important variables influencing the cost rate of solar systems, raising the cost of these systems and solar power plants. Fig. 3 depicts the influence of collector area ranging from 5000

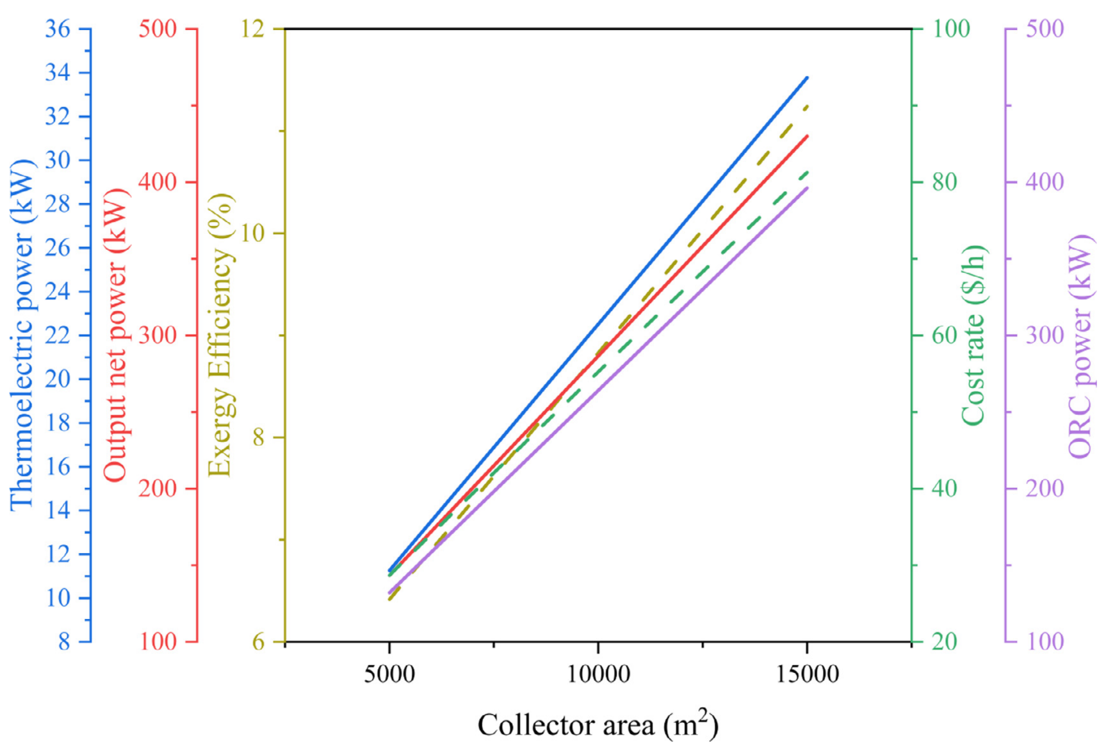

Fig. 3. The impact of collector area on the output parameters.

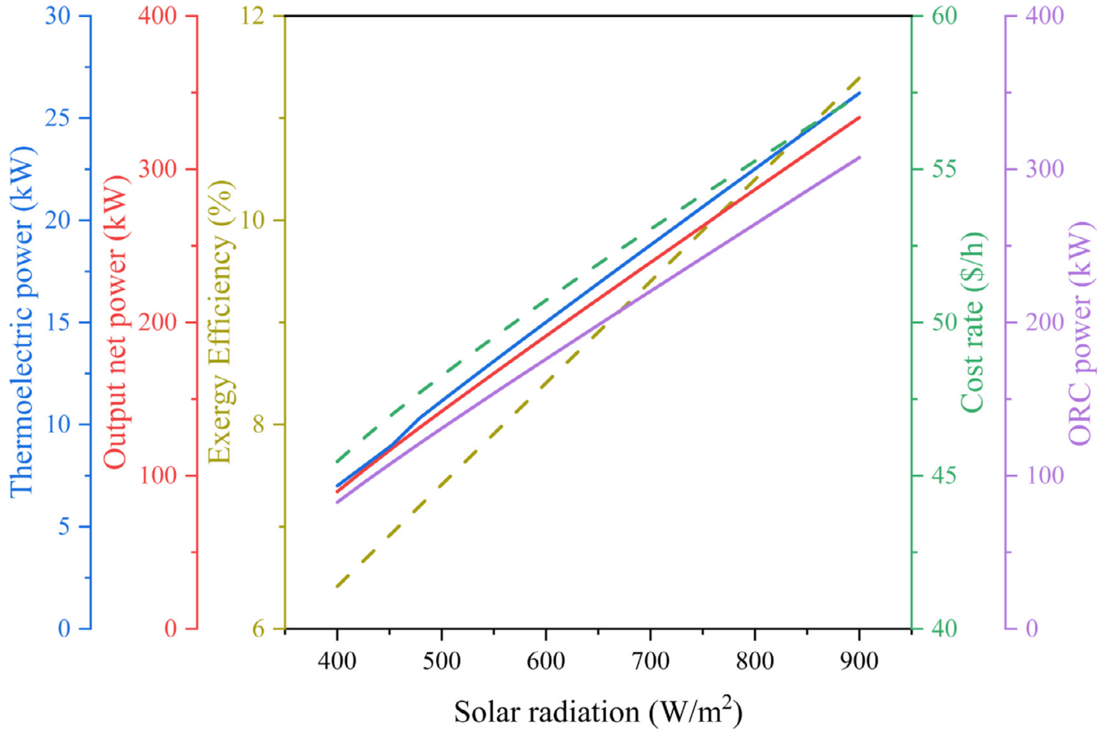

Fig. 4. The influence of solar irradiation on the output parameters.

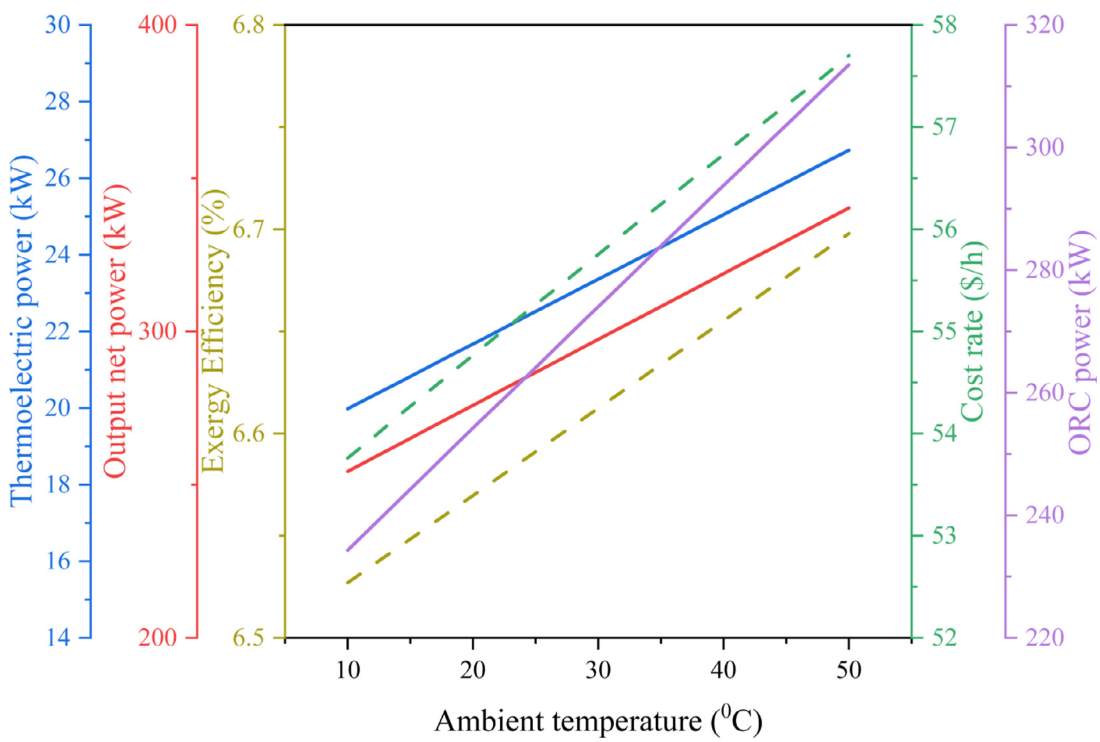

Fig. 5. The influence of Ambient temperature on the output parameters.

to 15,000 m^2s on system outputs. The collector area is one of the most important elements in this system. As shown in Fig. 3a, increasing the collector area enhanced both the thermoelectric generation capacity and the overall system generation capacity. Fig. 3b shows that increasing the collector area has boosted the ORC unit's generation capacity. Because exergy efficiency and generation power of the system are directly associated, increasing the power of the system likewise enhances its efficiency. As can be seen in Fig. 3, the exergy efficiency increases as the collector area increase. Also seen in Fig. 3c is a rise in the cost rate. Because, as the system's output capacity grows, the system requires more maintenance and repair, raising the cost of each device and, by extension, the cost of the entire system. By increasing the collector area, the energy

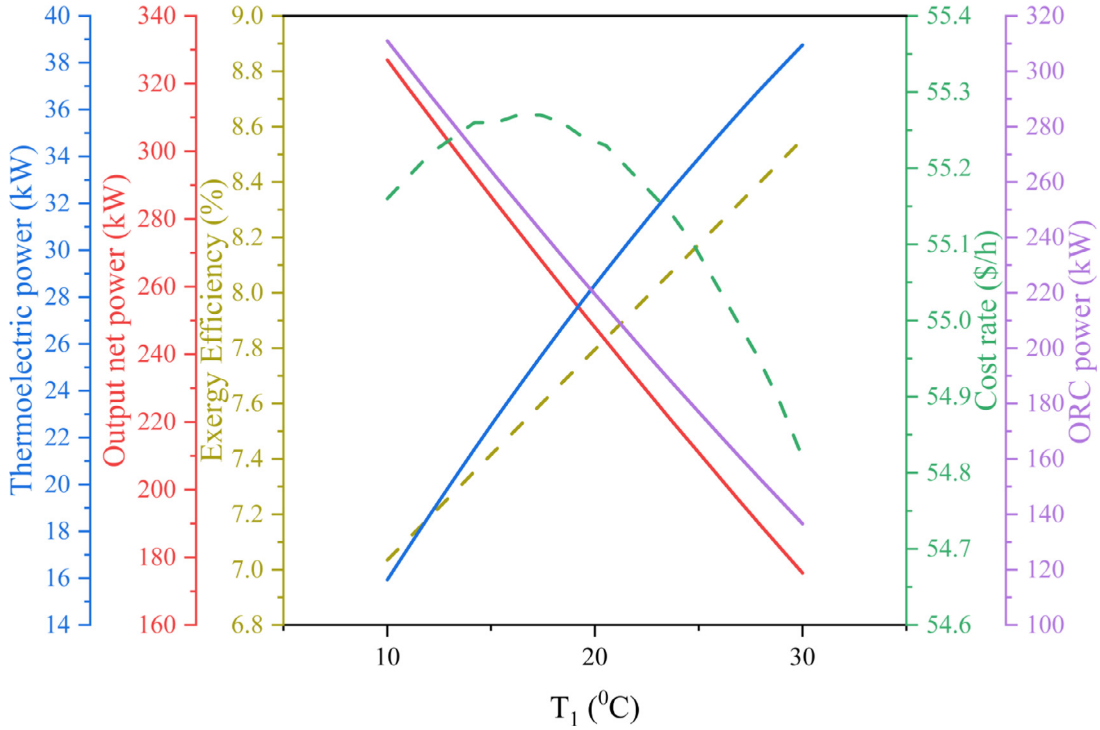

Fig. 6. The effect of the input temeprature of the ORC pump on the output parameters.

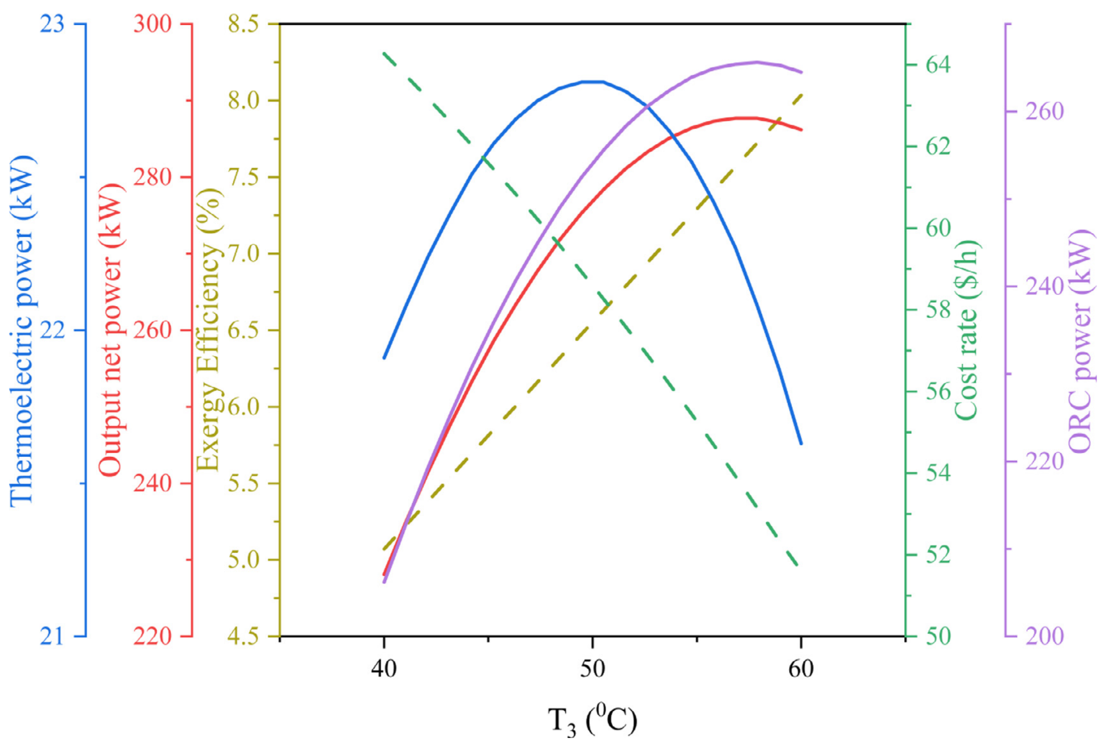

Fig. 7. The impact of input temperature on the output parameters.

absorbed from sun increases; thus, more thermal energy is delivered to the evaporator, which increases the power generation, exergy efficiency, and system cost rate.

There is a direct correlation between the efficiency of solar heat collectors and the amount of solar irradiation. Furthermore, as solar irradiation increases, flow rates of the fluid entering solar systems and wind turbines increase, resulting in an increase in subsystems' output work, which in turn increases the total output work and vice versa. For a 400–900 watt-per-square-meter solar irradiation intensity, the system outputs are shown in Fig. 4. The intensity of solar radiation is one of the most important factors in this system. For example, Fig. 4a shows that the thermoelectric power output and the total power generation have increased as solar radiation intensity has increased. Increasing the intensity of solar radiation has enhanced the ORC unit's output capac-

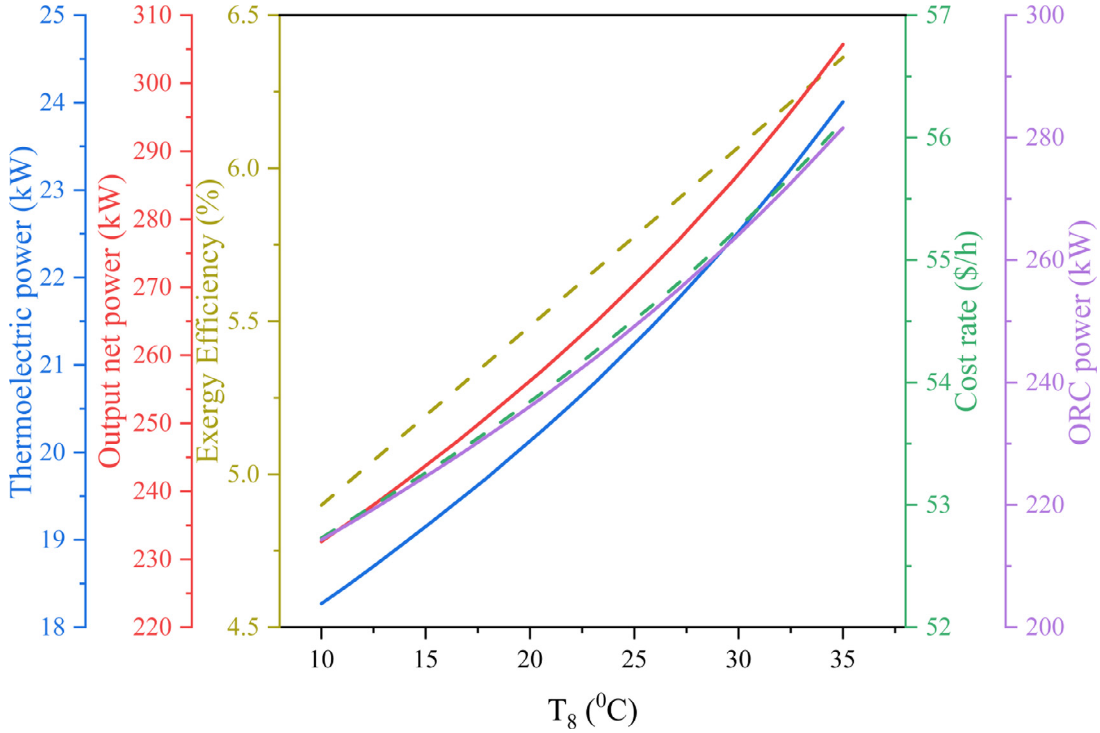

Fig. 8. The effect of input temperature of the solar collector on the output parameters.

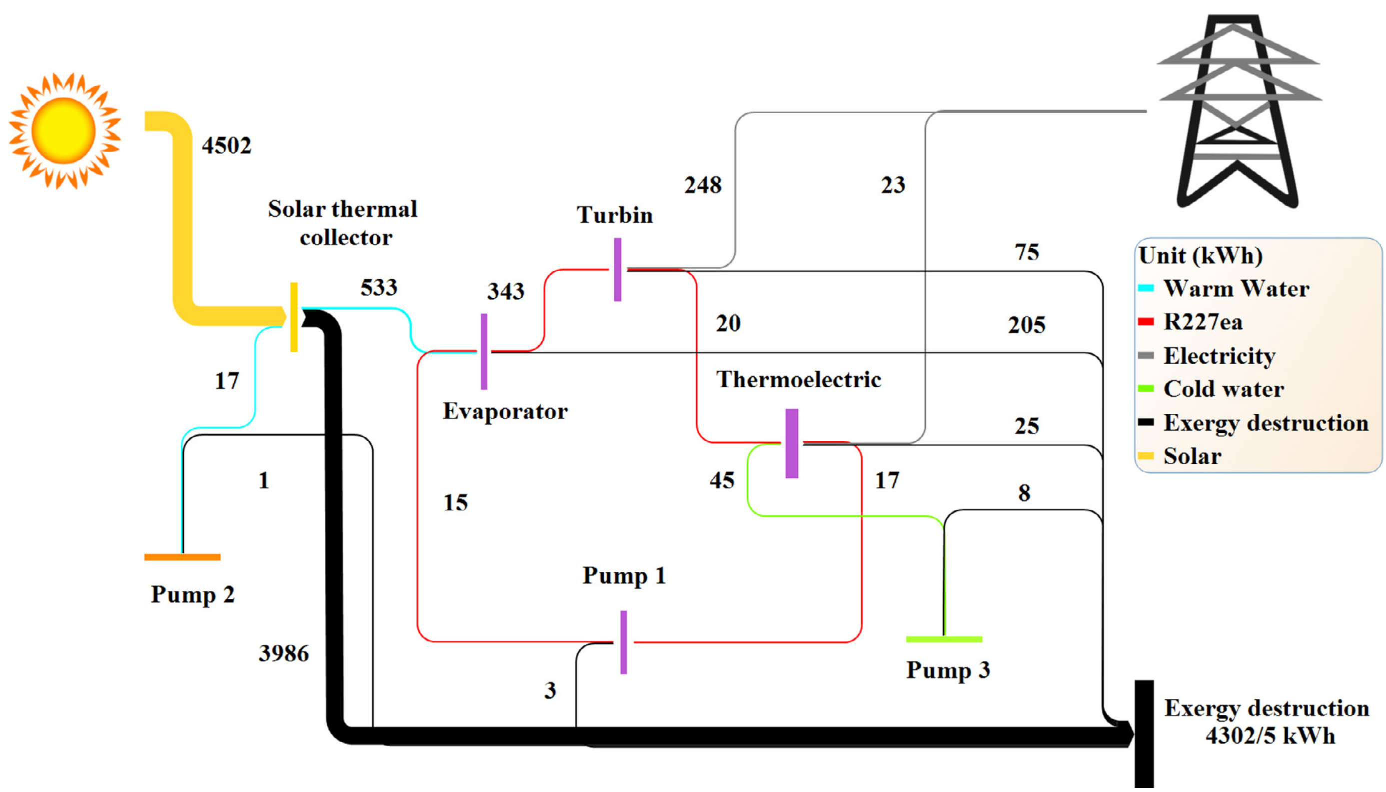

Fig. 9. The Grassmann diagram of the proposed system.

ity, as depicted in Fig. 4b. With increasing the system's output, exergy efficiency likewise rises. Fig. 4 illustrates that the exergy efficiency improves as the intensity of solar radiation increases. Fig. 4c shows a rise in the cost rate as well. Because as the power generation increases, more repair and maintenance is required, thus the cost rate of each individual device and of course the cost rate of the entire system increases.

Solar systems' output power and energy are affected by the ambient temperature. Intensity of the voltage and current rise with an increase in the ambient temperature. It is because the ambient temperature affects the amount of voltage and current the solar system produces. Temperatures between 10 and 50 °C have a significant impact on system outputs, as shown in Fig. 5. The ambient temperature is one of the most im-

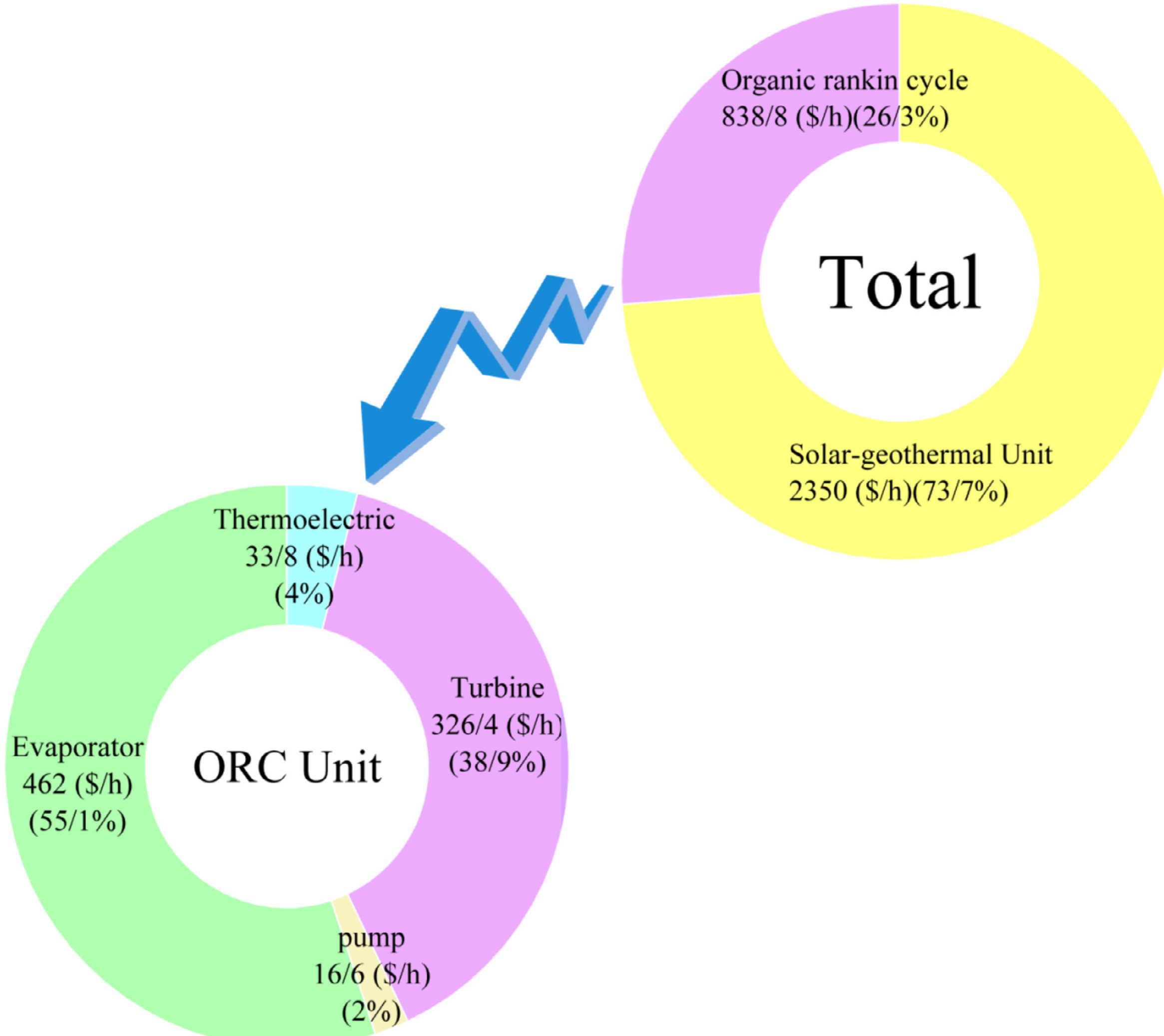

Fig. 10. Cost rate ($/h) distribution in different units and components of the proposed hybrid system.

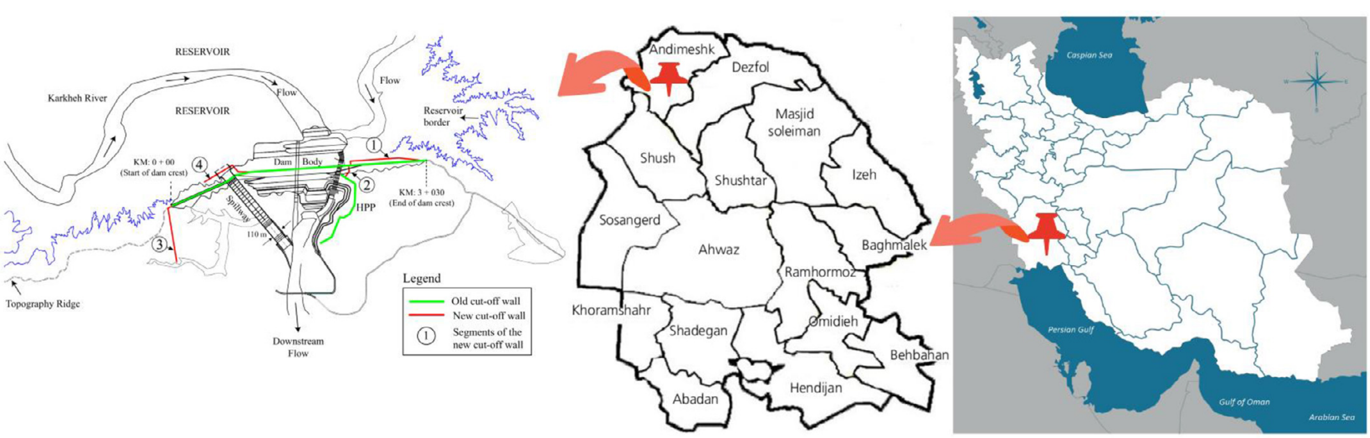

Fig. 11. Location of Karkheh Dam.

portant variables in this system. When the ambient temperature rises, the thermoelectric output power rises as well, as illustrated in Fig. 5a. Temperature rises have boosted the ORC unit's generation capacity, as seen in Fig. 5b. With increasing the system's output, exergy efficiency likewise rises. Fig. 5 shows that the exergy efficiency increases as the ambient temperature rises. Fig. 5c also shows a rise in the cost rate as well. Because as the power generation increases, more repair and maintenance is required, thus the cost rate of each individual device and of course the cost rate of the entire system increases. Equipment failure in solar systems can have considerable apparent and hidden costs. The apparent costs include maintenance and repair costs. The costs of personnel and repairs are also included. The hidden costs also affect the

Fig. 12. View of Karkheh Dam.

system's overall costs, including lost revenue from machine downtime, the purchase of low-quality replacement parts, and labor expenditures, resulting in failure over and over again.

The effect of n input temperature of 10 to 30 °C to the ORC pump on system outputs is shown in Fig. 6. Increasing the temperature of the Rankin organic cycle pump's input leads to an increase in thermoelectric power generation but a drop in overall system output, as illustrated in Fig. 6a. Increasing the input temperature of the Rankin organic cycle pump has a negative impact on the ORC unit's output capacity, as shown in Fig. 6b. Exergy efficiency and system output power are directly proportional, therefore as system power drops, so does exergy efficiency. It is seen in Fig. 6 that the exergy efficiency declines as the input temperature of the ORC pump increases. Furthermore, it can be observed from Fig. 6c that the cost rate initially rose, but then began to decline as the temperature rose to around 15. A drop in generation capacity means a decreased requirement for maintenance and repair, which in turn means a decreased cost rate for each individual device and the entire system.

An input temperature of 40 to 60 °C has a significant impact on system performance, as shown by in Fig. 7. As depicted in Fig. 6a, the thermoelectric power output initially increased as the temperature increases to 48 °C, but then decreased. However, the data reveal that by increasing the turbine's input temperature, the entire system's output capacity has increased. ORC unit output capacity has been enhanced by increasing the turbine's input temperature, as shown in Fig. 7b. Exergy efficiency and output power are directly proportional, which means that as system power rises, so does exergy efficiency. Fig. 7c shows a rise in the cost rate as well. Because as the power generation increases, more repair and maintenance is required, thus the cost rate of each individual device and of course the cost rate of the entire system increases.

Fig. 8 depicts the outputs of the system as a function of the solar collector's input temperature, ranging from 10 to 35 °C. Increasing the input temperature of the solar collector has enhanced the thermoelectric power generation and the whole system power output, as illustrated in Fig. 8a. It is seen in Fig. 8b that the output capacity of the ORC unit has been improved by increasing the input temperature of the collector. Exergy efficiency is directly proportional to the system's power generation, so as system power increases, so does exergy efficiency. Fig. 8c shows a rise in the cost rate as well. Because as the power generation increases, more repair and maintenance is required, thus the cost rate of each individual device and of course the cost rate of the entire system increases.

4.3. System performance under the Grassmann chart

In order to better understand and improve system performance, exergy analysis is a vital stage in the pORCess. Exergy analysis is made easier by using the Grossman diagram, which is depicted in Fig. 9. This diagram illustrates the exergy rate for each flow and the exergy destruction of all components. Due to the considerable temperature difference, the solar unit loses a significant amount of the overall exergy rate (3986 kW) during charging, and then 553 kWh is delivered the evaporator. The input energy of the evaporator is 343 kWh, and 205 kWh are lost. The turbine generates 248 kWh of electricity, which is delivered the electrical distribution network and 75 kWh is lost. In the rest of the cycle, 20 kWh is delivered to the thermoelectric that increases the output power of the thermoelectric to 23 kWh and 25 kWh is depleted. A total of 4302.5 kWh of exergy is degraded per year on average. Finally, 271 kWh of electricity is generated by the system.

4.4. Economic evulation of components

Fig. 10 depicts the current ocean solar-thermal system's total cost rate and the cost rates of the system's major components. The ORC unit is one of the primary components of the system. System costs per hour

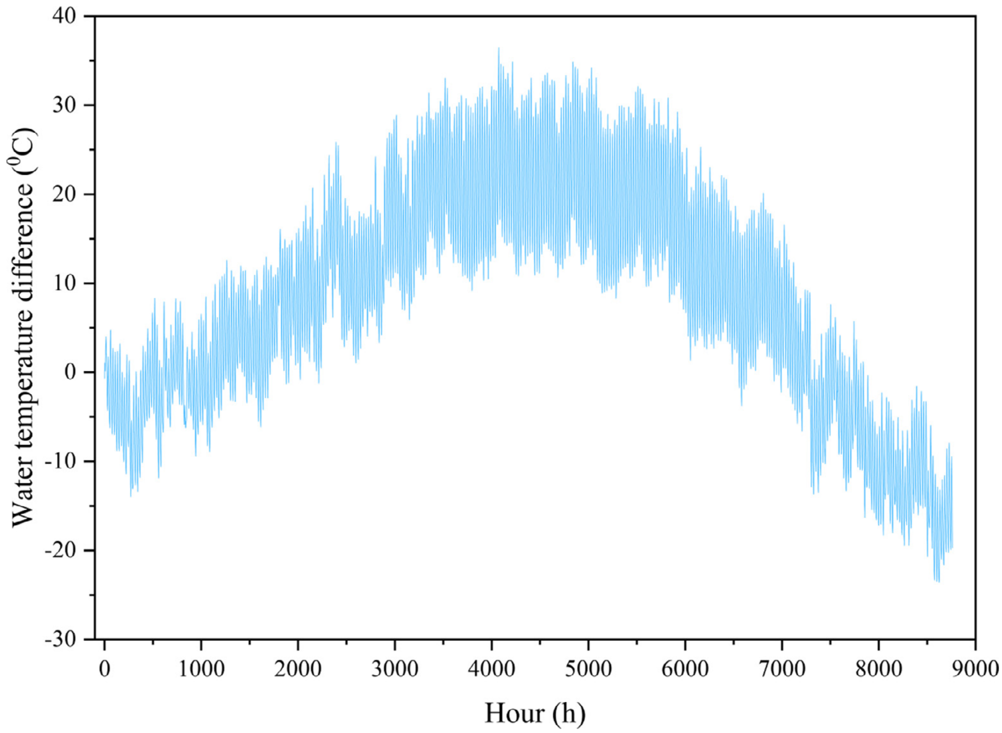

Fig. 13. The hourly variations of water temperature difference Karkheh dam.

are projected at $3188.8. maximum component cost belongs to the solar unit, which is $2350 per hour and the ORC unit is the next with $838.8. The evaporator's cost per hour is $462 and the turbine's cost is $326.4. The pump is the most affordable part of the system.

5. Case study

The Karkheh Dam is used to test the proposed system, and the findings are submitted for review and analysis. Karkheh Dam is located in Andimeshk. The Karkheh River in Andimeshk City in Khuzestan Province is home to the world's largest earthen dam, the Karkheh Dam, which was erected on the Karkheh River. With a total volume of 7 billion and 300 million cubic meters, Karkheh has produced the largest artificial lake in Iran's history, and it has a crown length of 3030 m and a height of 127 m. The Karkheh Dam may is shown in Fig. 11.

Fig 12 shows the view of Karkheh Dam, the largest earthen dam in the Middle East and the dam studied in this study.

Karkheh Dam is built on Karkheh River in Andimeshk city located in Khuzestan province of Iran. The dam has a large artificial lake that can be converted from the temperature difference received from it as ocean thermal energy as a clean and highly efficient renewable energy to produce energy in this area and even eliminate the need for lighting and energy in this area. Used the dam and helped reduce the environmental pollution caused by fossil fuels in this region and the world, and by producing energy through this system, reduced drinking water and water needed for agricultural use in this region, which in The dam reservoir is available and helped to generate energy by the Karkheh dam equipment. Because today the world is facing a shortage of drinking water and this danger.

In this study, the influence of the temperature difference between the artificial lake of Karkheh Dam and the solar-ocean thermal system of the present work was examined. The thermodynamic system was studied in order to determine the system's output power.

Changes of Karkheh dam water temperature difference througout a year is shown in Fig. 13. also Changes of ambient temperature througout a year City of Andimeshk is shown in Fig. 14.

Also Changes of solar radiation througout a year City of Andimeshk is shown in Fig. 15.

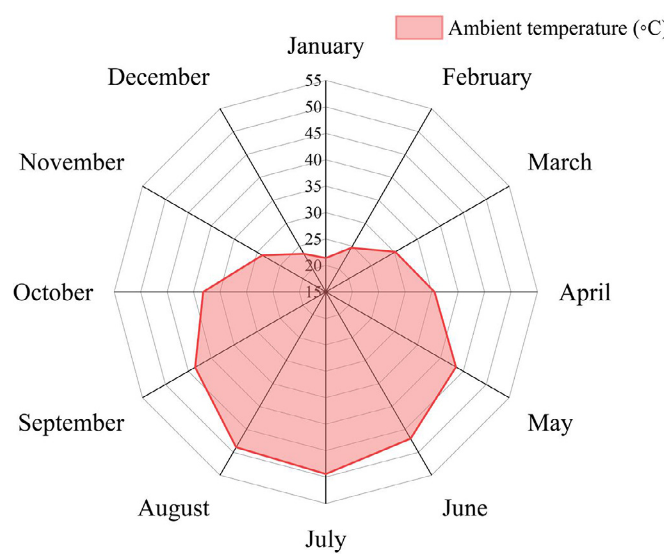

Fig. 14. The hourly variations of ambient temperature City of Andimeshk.

5.1. Case study analysis

The influence of changes in water temperature difference of Karkheh dam during the year on the performance of the present work's solar system was explored in this study. The purpose of this research is to compute the generation capacity of the Rankin organic cycle at all hours of the day, the thermoelectric generation capacity, and the overall system generation capacity throughout the year. The results of this study demonstrate that as the water temperature difference of the Karkheh dam increases, the system's generation capacity reaches its maximum in June and July, which is the summer, and as a result, the thermal energy of the system increases. In addition, when output power increases, system costs will rise due to the requirement for greater equipment and equipment maintenance.

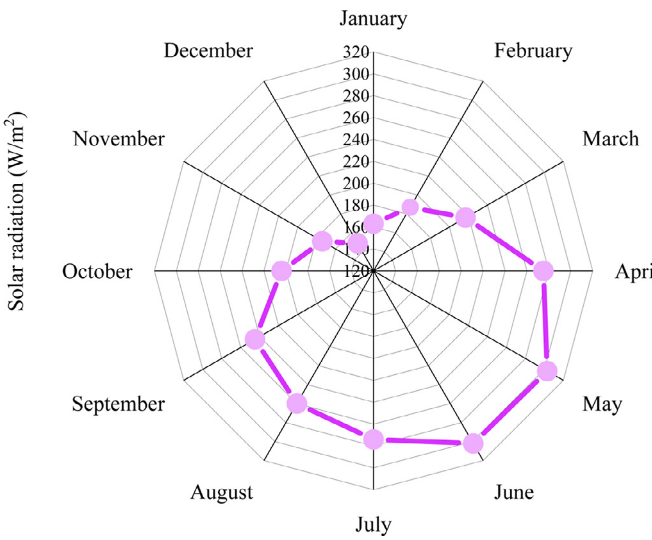

Fig. 15. The amount of Solar radiation City of Andimeshk.

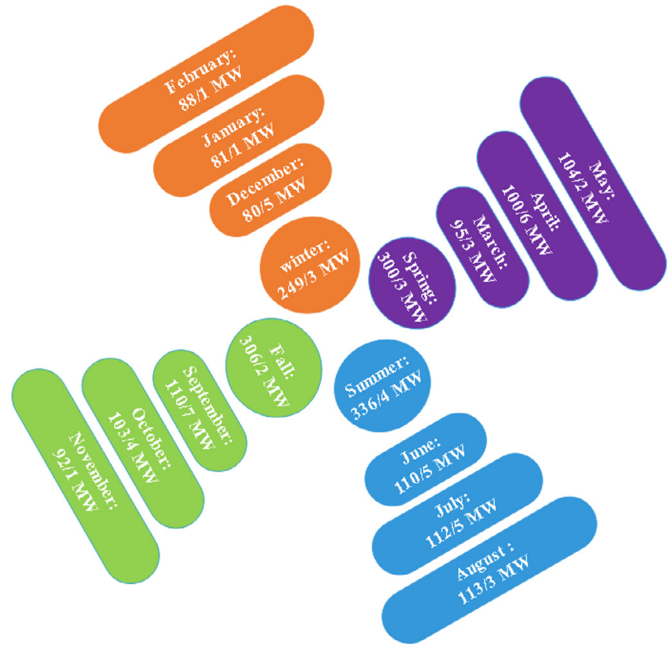

Fig. 17. Calculation results for monthly power generation.

Fig. 16 depicts the peak output capacity of the entire system in relation to the water temperature difference of Karkheh Dam in June and July. The system's lowest generation capacity is associated with winter, when the difference in water temperature of the Karkheh dam is at its lowest.

Fig. 17 shows the monthly electricity generation of the system designed in the present work in relation to the temperature difference between Karkheh Dam and the use of solar radiant energy in this area. These results show that the highest production capacity of the system is obtained in summer and its amount is equal to 336 MWh, and the months of July and August have the maximum power generation among all months. It also has the lowest generating capacity of the system in winter with 249.3 MWh and has the lowest electricity generation in December and January among all months. The proposed system is fully environmentally friendly and does not burn fossil fuels to generate electricity.

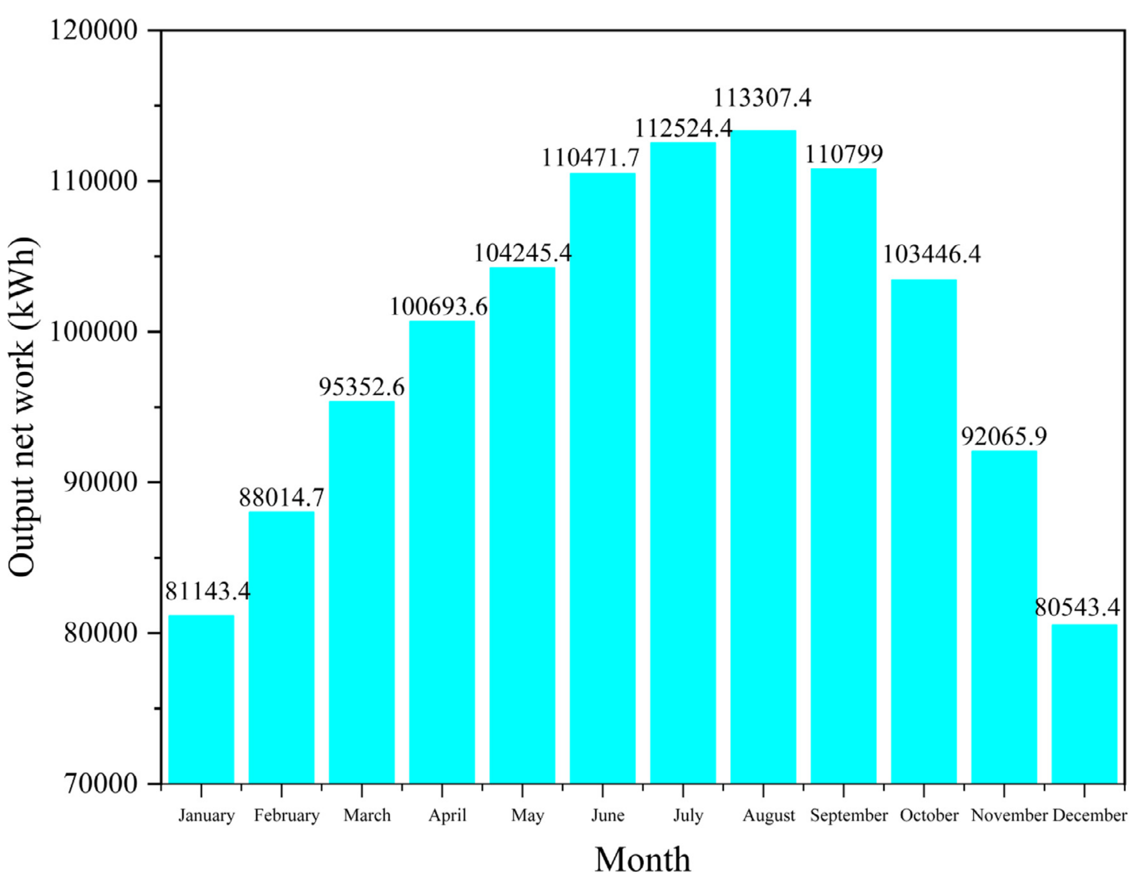

Fig. 16. Calculating the total system generation capacity.

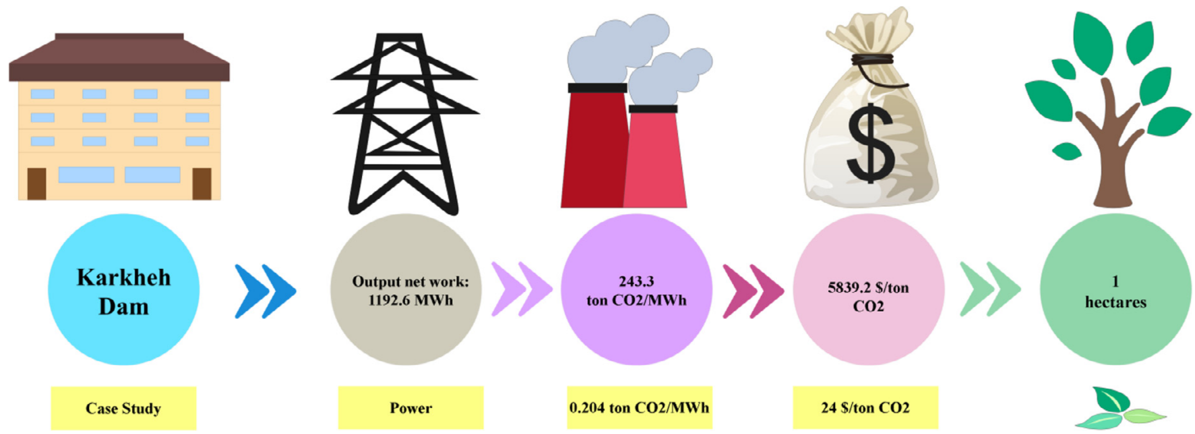

Fig. 18. Environmental advantages of the designed system in relation to temperature difference of the Karkheh Dam.

Table 5
The outputs of the system over a year in relation to the temperature difference of the Karkheh dam.

	ORC generation power	*Thermoelectric generation power*	*Total generation power*
Total	*1,127,117/3 kW*	*65,489/7 kW*	*1,192,607/9 kW*

Table 6
Calculation of the amount of electricity required by people.

City	electricity consumption for one person (kWh/per year)	power generation in peak time (kwh/peryear)	Electricity needed for the number of people (-)	source
Andimeshk	*3072*	*1,192,607/9*	*388*	*EIA (2019)*

Table 5 shows the total system generation capacity in one year, thermoelectric generation capacity in one year, and ORC generation capacity in one year in relation to the water temperature difference at Karkheh dam.

5.2. Average annual electricity consumption for case studies for one person

This section examines the output power generation of the multi-generation system during peak consumption. The hourly analysis has investigated the proposed system for providing the electrical energy needed by households in Iran. In Table 6, the results of the electrical energy production of the investigated power plant in the Karkheh Dam are calculated to supply the electrical energy required for each person. (EIA [42]). In Table 6, the calculation of the amount of electricity required by people is checked.

5.3. Environmental advantages of the system

Fig. 18 describes the environmental benefits of the designed system. A total of 0.204 tons of CO2 is released in conventional power plants to generate one megawatt hour of electricity [43]. Therefore, considering the total annual electricity generation of the current system, which was obtained 1192.6 MWh, 39.3 tons of CO2 emissions can be reduced using the proposed system in this study. As a result, the environment would pay out $24 for every ton of CO2 emission. As a result, if the proposed system is installed for $243/3 it will save the equivalent of 1 hectares of green space and plants every year. Additionally, an average price of $4940 per hectare for a non-sedimentary ecosystem was considered [44].

6. Conclusion

Renewable energy sources are becoming more popular due to the rising global demand for energy and the diminishing supply of fossil fuels (which pollute the environment and cause waste). Using ocean thermal energy can assist stabilize this unstable solar system and improve its reliability because solar energy isn't available 24 h a day or on cloudy days, so it's possible to say that the solar system is unstable. Ocean thermal energy is used when the system is unstable at night or during rainy weather. A combined system of solar energy and ocean thermal energy with a thermoelectric generator was examined in this study to generate clean electricity and utilize the water temperature difference of the Karkheh dam. The system under consideration is made up of flat panel solar collector subsystems and a Rankin organic cycle. To model the analyzed system and acquire system analysis results, EES thermodynamic software was employed. The collector area, solar radiation intensity, ambient temperature, and input temperature to the turbine have all been studied as parameters affecting system outputs. The system's economic research revealed that the solar unit, evaporator, and ORC turbine have the highest cost rates among the system components. Furthermore, the system's exergy study revealed that the solar unit and evaporator suffer the highest exergy destruction. For one year, a case study was conducted on the water temperature difference at Karkheh Dam, and the findings of system performance were assessed. The results demonstrated that the best system performance is obtained under summer weather conditions in Andimeshk. The results showed that the proposed system's total output power in relation to the change in water temperature of Karkheh Dam is 1,192,607.9 kW per year, and that this system can meet the energy needs of 111 households in Andimeshk throughout the year. According to the results, the system described in this study is suitable for the required applications. In this study, the use of ocean thermal energy and also the use of direct solar energy radiation on Karkheh Dam, which is one of the largest earth dams in the world and also the largest earth dam in Iran and the Middle East, was investigated. The results show that this dam with a reservoir volume of 7 billion and 300 million cubic meters and high depth, has a high potential for the use of ocean thermal energy because this dam has one of the largest artificial lakes in Iran. Andimeshk city is located in a hot and dry area that has high solar radiation intensity in different seasons and days of the year. Therefore, it was concluded that the Karkheh Dam area has a high potential for the use of two types of ocean thermal energy and solar energy, and also the use of a hybrid renewable system in this area is practical and cost-effective, which is recommended to meet the energy needs. Finally, the substitution of renewable energy with fossil fuels is now required for national industries, and more efficient energy systems and more efficient use of renewable resources are required for the long-term sustainability of energy systems.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgement

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