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Abstract : The ocean thermal energy is abundant and is ready for clean energy output. Firstly, the global total is about 40 billion kW. The ocean thermal energy conversion (OTEC) is clean and renewable, the power generation is stable, and the energy stored capacity is high. Active exploitation of ocean thermal energy resources is of great significance to realize the strategy of maritime power. Next, in view of the efficiency limit of a traditional OTEC, authors propose an approach of multi-energy complementary system to improve the system efficiency based on OTEC. This approach integrates solar energy, wind energy and energy storage into a complementary OTEC system; this complementary system sets parameters at the system level. For example, a 1MW integrated power generation system is designed. Moreover, by calculating a theoretical model, researchers investigate the system with computer aided design and simulation. The efficiency of the complementary OTEC system with solar heating can reach 12.8% and the comprehensive efficiency can reach 18.6 %. Furthermore, there are many favorable by-products of OTEC that are considered beneficial for the eco-system. Finally, in this paper, the basic principle and working process of the approach are analyzed, and the system efficiency is calculated. The results show that in comparison to the traditional OTEC, the complementary system can improve the ratio of power generation output efficiency, stability and ocean energy utilization.

Key words: ocean thermal energy conversion, multiple energy complementarity, solar complementary heat, open-cycle OTEC

1. Introduction
In the modern times, the world's energy consumption is rapidly increasing, fossil energy is decreasing, environmental pollution and greenhouse effect are becoming more and more serious to affect our daily lives. Therefore, the renewable energy has played an important role to change the energy infrastructure and maintain the long-term development of human energy utilization. According to the statistics, the temperature of the water 1000m below 24° latitude from the equator is about 4 °C, and the temperature of the sea surface water is about 30°C. The potential energy from the temperature difference between the deep-sea and sea surface waters is about $10^{13}$W(Song,2019); the annual generating potential of ocean thermal energy is about therefore 87600TWh. In comparison, the global annual electricity demand is about 16000TWh(Khan et al,2017). Moreover, it is renewable, stable, clean and pollution-free, and has high development and utilization value.

The vast ocean power is a huge resource to tap into for the world. The ocean thermal energy conversion (OTEC) system generates electricity by driving a thermodynamics Carnot heat engine between warm seawater and cold deep seawater. The concept of OTEC system has rendered an advanced green energy technology with a century-old of history. It has been well known historically that the oceanic resources are of immense economic value (Torgeir 2019; Cheng 2019). The atmospheric deposition in some case carries critical nutrients, e.g., that dust carries iron, phosphorous, nitrogen that are critical to the ocean eco-system.

The OTEC technology was initially proposed in 1881 by a French physicist Jacques Arsene1; at a later time, Dr. Georges Claude demonstrated the OTEC in 1924(Georges 1931; Karottki 2015). Claude implemented an OTEC system in an industry scale in Matanzas Bay, Cuba. Going after the initial success, many development projects were accomplished between 1950 and 1960 by several research organizations. In 1964, American scientist J. H. Anderson et al. designed a new type of the closed-cycle "ocean thermal energy conversion" (OTEC) power station. Moreover, a new era of OTEC was propelled due to the needs for energy on the backdrop of the oil crisis in 1970s. The US Department of Energy has funded an OTEC program since 1970s, and later a wind program extending that one from the late 1970s to the present. Finally, the open cycle (Luis, 1992) has been reportedly successful with a net power production of 103KW. The OTEC is one of the significant energy resources that can play a prominent role in the future. There are significant milestones demarcated by previously successful engineering and demonstration projects (Robert, 1979; Saris, 1989).

The recent developments of the OTEC projects have proposed significant upgrade to deliver many mega-watts in power.
output (David, 2013; Setiawan, 2017) that has attracted extensive international collaborative efforts among which there are lots of the public and private partnership (Martin, 2010; Ivan, 2018; OTEC, 2017). The open-cycle OTEC has attracted exciting research by scientists around the world that can improve the its efficiency to 5% and above. Furthermore, in addition to the near shore projects (Makai, 2013; Comfort, 2011); there are off-shore OTEC project and big island project in development. Moreover, researchers generally consider richly available by-products that is favorable for OTEC applications. Nevertheless, interesting works (Karottki et al, 2015; Cochrane et al 2017) are reported to predict health effect of aerosol, particularly related to the seaborne issues and risks associated due to oceanic bound aerosol. Studies of the marine environment, environmental and air protection control is in progress so as to learn about the impacts on the terrestrial and marine eco-system. Authors will keep detailed studies on the ocean eco-system in the future. Finally, various aspects including potential environmental factors (Karottki et al, 2015; Cochrane et al 2017; Cunningham et al 2010; Lisa, 2014), costs and economics are studied in various model (Callaghan, 2006; Takahashi, 1991).

Since 2008, significant progress has been made in the research of some key technologies and small-scale demonstration of thermoelectric generators has come a long way. In terms of ocean thermal energy simulation and experimental research, many exciting researches are very active (Kim et al, 2009; Wang et al, 2010; Yamada et al, 2008; Yilmaz, 2019). The current research on the optimization design of ocean thermal energy system has attracted extensive attention and collaboration among scientists worldwide. In order to improve the efficiency of ocean thermal energy generation system, Hakan Aydin et al (Aydin et al, 2014) introduced solar complementary heat, significantly increased the gas temperature at turbine inlet, and increased the energy output by 20%~22%. Setiawan et al (Setiawan et al, 2017) studied the effect of heating warm seawater with plate solar energy in a 33MW OTEC system by combining solar energy with OTEC, and the results showed that the introduction of solar energy could improve the thermal efficiency of the system, but at the same time brought about a series of system matching problems.

The research on ocean thermal energy conversion system has made great progress, but it has not yet been in the mainstream for the energy generation. The main reasons are as follows: 1) The efficiency of traditional single ocean thermal energy conversion system is low, which is generally 1%; 2) It is difficult and expensive to extract cold seawater from the 800m~1000m deep sea (Fuller, 1978); 3) At the same time that deep ocean water is released into the surface ocean, microbes from the bottom are released into the ocean surface, and may trigger changes in the ecosystem. In order to fully address the above problems, this paper studies the integration of clean, efficient and pollution-free solar energy, wind energy and energy storage system into the ocean thermal energy conversion system, so as to form an efficient, stable, clean and pollution-free integrated power generation system.

2. Designs and Models

2.1 The overall design and principle of system

As shown in figure 1, the overall design is mainly composed of four parts, including solar power generation system, wind power generation system, ocean thermal energy conversion system and energy storage system. Under sunny or windy conditions, the photovoltaic cell or universal wind generator generates electricity. Part of it supplies the initial power of the ocean thermal energy conversion system to ensure the normal operation of the warm water pump, the cold water pump and the working medium pump (Ford, 1983). The other part is stored in the energy storage battery. The warm water pump works to extract seawater at 30°C on the ocean surface (set in the South China Sea in this paper) into the evaporator, which is used to preheat the flowing working medium and discharge it back to the ocean. The working medium at low boiling point heats up and begins to boil after preheating. The boiling gas is re-heated through the trough solar concentrator and heated to 70°C and become high temperature and high pressure gas. The high temperature and high pressure gas enters the turbine to promote its work and drive the turbine generator to generate electricity. After the high-temperature and high-pressure gas is cooled and depressurized, it will be condensed into liquid through the cold seawater condensation system into the working medium storage tank, and then pumped into the evaporator under pressure by the working medium pump to form a circulation system. In the cold seawater condensation system, the cold seawater (in this paper, the cold seawater is set at 5°C and 800m deep) is pumped from the cold water pipe to the condenser in the power generation system. After the work is done, the
working medium enters the condenser and is cooled by cold seawater. The step-down steam in the condenser is processed into liquid water after condensing into liquid water, which is directly passed through the fresh water pipe into the fresh water storage tank for other use. The remaining cold seawater can be discharged directly to the corresponding temperature layer.

Figure 1. Structure diagram of multi-energy integrated power generation system based on OTEC.

2.2 Design of photovoltaic power generation system

Photovoltaic power generation system refers to a power generation system that directly converts light into electricity, aka, the solar photovoltaic effect (PV). As shown in figure 2, its main components are solar PV cells, batteries, controllers and inverters. The solar PV cell is the core part of the whole power generation system. Perovskite solar cells (PSC) are favored because of its wide and adjustable bandgap and solution handling capacity [Jin,2020]. Its applications can significantly improve the stability and reduce the manufacturing cost of solar cells, so as to meet the expectation of universal utilization of solar energy(Correa et al.,2017).

Figure 2. Structure diagram of photovoltaic power generation system

Perovskite solar cells have the advantage of wide band gap adjustment by changing the concentration of dopant. The unjunction efficiency of these perovskite solar cells is comparable to that of poly silicon, cadmium telluride, and copper indium-gallium-selenium cells(Jeon,2014).Based on previous studies on perovskite solar cells, the optical and electrical properties (band gap, absorption constant, carrier, etc.) of perovskite materials depend on the crystal structure. Any lattice distortion caused by phase transition will have adverse effects on their optical and electrical properties and stability. Under the continuous exploration of relevant scholars, we can know that environmental conditions (temperature and humidity) have an important impact on perovskite. Under suitable conditions, we can improve the efficiency of perovskite batteries, develop a large area of perovskite batteries, and enhance the battery stability and series perovskite batteries to achieve the best results. The optimized perovskite battery is conducive to the development of efficient PSC series structure and interface engineering technology, as well as the realization of large-scale commercial application of perovskite solar cells. At the same time, through the case study of solar energy technology, there will be great development and important breakthroughs in perovskite solar cells.

In these cases, the associated new technologies have potentially superior properties, promising new materials, new processing methods and superior architectures. In the end, perovskite solar cells' efficiency is close to or above 30%(Chris,2018; Steve Hanley,2019). PSC's service life has been extended by about one year, and scientists' cooperative exploration of the perovskite solar cell(Christians,2017; Zhang,2017) has enabled it to exceed its service life of one year in just a few years. Perovskite is clearly the fastest growing solar technology to date. As the technology matures in the near future, it may soon be ready for large-scale commercialization and accommodate the rapid growth of China's photovoltaic industry and market.

2.3 Design of wind power generation system

Wind power generation system is an energy conversion system that converts mechanical energy into electrical energy. The wind turns the blades, which in turn push the generator's rotor, which in turn turns out alternating current. Wind power generation has the characteristics of renewable, short construction cycle, flexible installation scale, high reliability, simple operation and maintenance, and low cost(Li,2020).
As shown in figure 3, universal wind blade is the first choice in the wind power generation system as the generation blade, which is a generation mode involving energy conservation and emission reduction. Now, wind turbines are mainly designed and developed for the sites with large and stable perennial wind speed. The starting wind speed and working wind speed required by wind turbines are both relatively high, so the application area will be limited and wind energy with low speed cannot be fully utilized (Burton, 2001). For the universal wind driven motor, its wind power can work normally at level 3 or so. This expands the area where wind power can be generated, and also the scope of its use. If this kind of power generation system can be popularized, the cost of power generation can be greatly reduced, which is also of great value to the development of China's Marine industry.

2.4 The design of OTEC with solar heater

According to the basic principle of ocean thermal energy conversion (OTEC), this design divides OTEC into warm seawater heating circulation system (Jing et al., 2010), concentrator heating system, thermal transmission device, cold seawater condensation circulation system and energy storage device. The warm seawater heating circulation system can be used to replace the preheater to realize the function of preheating. The heat exchange between the surface warm seawater and the condensing medium makes the medium to absorb the heat energy stored in the warm seawater. After preheating, the next link - condenser heating starts. By directly utilizing the photo-thermal effect of solar energy, the concentrating heating system collects the light to a specific area for concentrated heat release. The heat generated by the concentrator can heat the medium and make the medium become a high-temperature gas state. The advantage of using concentrators for heating is that the renewable energy - solar energy can be directly used to generate heat to heat the medium without additional energy consumption in the system. The expansion of the high-temperature gas produced in the closed container pushes the turbine to carry out mechanical rotation, and the generator further converts the mechanical energy into electricity. The high-temperature gas becomes exhausted steam energy, which passes through the circulation system of cold seawater, and then the cold seawater and vapor exchange heat energy, and then condense into liquid medium. The liquid medium entering the warm seawater heating circulation system prepares for the next cycle. During the heat exchange between the cold seawater and exhausted steam energy, fresh water can be obtained by evaporation and condensation of the heated seawater by providing a vacuum environment. The energy consumption equipment in the whole system includes warm seawater pump, cold sea water pump, medium pump and vacuum pump. The energy consumption can be provided by the system's own generator and energy storage device. Its overall structure is shown in figure 4:

2.5 Design of energy storage system

The renewable distributed generation system is vulnerable to environment and generate electricity unsteadily, which hinders its further development. The application and development of energy storage technology will solve the problems of access and consumption of distributed generation sets. Energy storage device is equipped in the distributed generation system, which can enable actions to cut-peak and to fill valley of electric usage, energy scheduling and smoothing fluctuations (Yang et al., 2010). The existing energy storage methods are mainly through pumping water, phase transformation, compressed air, battery capacitor and flywheel. By comparing the characteristics of various energy storage methods, it can be concluded that, compared with mechanical storage and phase change storage and other energy storage technologies, battery capacitor energy storage has the advantages of loose site selection conditions and convenient distribution
on the power distribution side. A large number of batteries are arranged on the side of the distribution network, which can reduce the load peak-valley difference and improve the load characteristics.

By comparing different battery performance parameters, the distributed power generation and energy storage devices with high cost performance, stability and energy matching were selected as references. The performance of each battery is shown in table 1:

| Battery Type         | Lead Battery | Li-ion Battery | VRB | Supercapacitor |
|----------------------|--------------|----------------|-----|----------------|
| Operating voltage (V)| 2            | 3.6            | 1.4 | 1.4            |
| Operating T-range (°C)| -5~40       | -30~60         | 0~45| 40~70          |
| Power density (W/kg)| 75~300       | 150~315        | 120~150| 5000~10000   |
| Power density (Wh/kg)| 30~50       | 75~200         | 10~30| 2~5           |
| Cycle life (time)   | 500~1000     | <3000          | <10000<500000 |
| Charge time         | min.~hours   | min.~hrs       | min.~hrs| seconds     |
| Safety              | medium safe  | explosive      | medium safe| Safe       |
| Green standards     | toxic        | nontoxic       | Toxic | Nontoxic     |

After comparing the performance of each battery, lithium ion battery and super capacitor are more in line with the energy storage design requirements. However, the density of super-capacitors is too small, which makes the capacity and volume difficult to meet the actual demand. Therefore, lithium ion battery is selected as the energy storage battery. It has the advantages of high energy density, high power density, long cycle life and environmental protection.

The internal structure of lithium battery energy storage system is shown in figure 5. The MWh level energy storage can be realized by means of series and parallel batteries. To meet the operational safety requirements, it is equipped with smoke fire sensor, video monitoring system, fire protection system and air conditioning system. The air conditioning system can keep the energy storage system working at the optimum temperature. Energy management system (EMS) is an important part of energy storage system, which can optimize the control of the system and make the system work in a safe, efficient and healthy state. The integration of power generation and transmission system can be monitored, controlled and optimized with computer aided tools(Jiang et al,2013).

**3 Results and discussion**

This paper refers to the relevant information of OTEC system, photovoltaic power generation system and wind power generation system and make the hypothesis according to the actual conditions and parameters. The efficiency of ocean temperature difference energy generation system, integrated power generation efficiency and system power output are analyzed and calculated.

### 3.1 System operating condition selection

First of all, the South China Sea where the average light intensity was 692.5w /m²(Khan et al,2016), the average wind speed was up to level 5, and the average wind power density was between (146.721~ 695.312) W/m² was selected as the project research site. Ammonia is selected as the working medium for OTEC system(Yoon et al,2014). Ammonia has good thermal performance and low price. According to the actual situation of the South China Sea and the working evaporation and condensation temperatures of the system, the temperature of seawater in each link of the system is assumed. As shown in table 2 at below.

| Technical parameters | Temperature T/°C |
|----------------------|------------------|
| Cold sea temperature | 5                |
| Warm sea temperature | 30               |
| Cold seawater rise in temperature | 4          |
| The hot sea drops in temperature | 4        |
| Evaporator inlet temperature | 30       |
| Evaporator outlet temperature | 26        |
| Condenser inlet temperature | 5         |
| Condenser outlet temperature | 9         |

The power generation system is the core of the OTEC integrated power generation system. Both the warm water supply system and the cold water supply system are determined by the generation capacity. Therefore, the energy supply and consumption of the whole ocean
energy integrated power generation system are determined based on the power generation system.

3.2 Power systems computation

The system is designed as a megawatt power generation system, in which the ocean temperature difference energy generation 1MW, photovoltaic power generation 600kW, wind power generation 400kW.

3.2.1 Photovoltaic power generation systems required area computation

According to the calculation formula of conversion efficiency of solar cells(Vos,1976):

$$\eta = \frac{P \times \alpha}{L \times \sigma} \times 100\%$$  \hspace{1cm} (1)

P is the solar power generation power, α is the filling factor, L is the illumination intensity, and σ is the illumination area of photovoltaic panels. The calculated result is S=2540m²

3.2.2 Wind turbines for the quantity calculation

The wind power in South China Sea can reach level 5 or above all the year round. Therefore, according to the equipment of 20kW Universal wind turbines sold on the market, its diameter is 8.6m and the length is 12.8m, and a total of 20 Universal wind turbines are needed.

3.2.3 Calculation of OTEC system

The OTEC system is generated by Rankine cycle. Figure 6 is the T-S diagram of the system cycle.

<Figure 6 ammonia refrigerating cycle system T-S diagram>

Temperature, pressure, enthalpy and entropy at 1, 5 and 3 points can be obtained from the physical properties of ammonia. 2 and 4 point parameters can be obtained from the thermodynamic formula. The data is shown in table 3 below:

| Serial number | Temperature T/℃ | Pressure P/kPa | Enthalpy h/kJ/kg | Entropy s/KJ/(kg.K) |
|---------------|------------------|----------------|------------------|--------------------|
| 1             | 70               | 3312           | 1464.4           | 4.553              |
| 2             | 28               | 1100.7         | 332.1            | 1.456              |
| 3             | 7                | 555            | 232.5            | 1.116              |
| 4             | 7.05             | -              | 232.704          | 1.116              |

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| 4             | 7.05             | -              | 232.704          | 1.116              |

Table 3 main parameters of ammonia working medium cycle

Thermodynamic analysis of the circulation system was carried out according to the data in figure 6 and table 3: the output power of the generator was set at 1MW.

Work process of turbine:

$$W = M_i \times (H_1 - H_2) \eta_f \times \eta_t$$  \hspace{1cm} (2a)

$$M_i = 5.19kg/s$$  \hspace{1cm} (2b)

Turbine workmanship:

$$W_t = M_i (H_1 - H_3) = 1388.89kw$$  \hspace{1cm} (3)

W is the output work of the generator. M_i is the flow rate of working medium. H_1 is the specific enthalpy of working medium at turbine inlet. H_2 is the specific enthalpy of working medium at the outlet of turbine. The η_f is the generator efficiency and value of 0.9. The η_t is turbine efficiency and value of 0.8. W_t is the output work of turbine.

Heat released by working medium:

$$Q_c = M_i (H_3 - H_4) = 5004.71kw$$  \hspace{1cm} (4)

Q_c is the heat released by working medium, H_3 is the specific enthalpy of the condenser outlet working medium.

Working medium pump pressure:

$$W_g = M_i (H_4 - H_5) = 1.06kw$$  \hspace{1cm} (5)

W_g is the actual work consumed by the pump. H_4 is the enthalpy of working medium at the outlet of working medium pump.

Constant pressure heat absorption:

$$Q_e = M_i (H_5 - H_6) = 6392.50kw$$  \hspace{1cm} (6)

Q_e is the heat absorbed by the working medium.

Heat absorbed by working medium from warm seawater:

$$Q_{we} = M_i (H_6 - H_4) = 512.80kw$$  \hspace{1cm} (7)

Q_{we} is the heat of absorbing warm sea water for the working medium.

Solar energy absorbed by working medium:

$$Q_{re} = M_i (H_1 - H_6) = 5842.668kw$$  \hspace{1cm} (8)

Q_{re} is the heat of absorbing solar energy for the working medium.

The warm flow calculation:

$$M_{hs} = \frac{Q_{we}}{c_w \eta_{hr} (T_{wr} - T_{wc})} = 51.25kg/s$$  \hspace{1cm} (9)

M_{hs} is the flow of warm seawater. c_w is the heat capacity of warm seawater, with a value of 4.17kJ/(kg·℃). η_{hr} is the hr preheater in thermal efficiency. T_{wr} is the inlet temperature of warm seawater. T_{wc} is the outlet temperature of warm seawater.
Cold water flow calculation:

\[ M_{hc} = \frac{q_c}{c_n(T_{cr} - T_{cc})} = 495.67 \text{kg/s} \quad (10) \]

\( M_{hc} \) is the flow of cold seawater. \( C \) is the heat content of condensate, with a value of 4.207 kJ/(kg·℃). \( \eta_l \) is the heat exchange efficiency of the condenser. \( T_{cr} \) is the outlet temperature of cold seawater. \( T_{cc} \) is the outlet temperature of cold seawater.

Pump power:

\[ P = \frac{Vgh}{3600\eta} \quad (11) \]

\( V \) is the sea water flow, \( h \) is the pump head, \( \eta \) is the pump efficiency, \( g \) is the gravity.

The conversion efficiency of the system:

\[ \eta = \frac{W_j}{Q_e} = \frac{W_g - W_{we} - W_w - W_c}{Q_{we} + Q_{te}} = 0.128 = 12.8\% \quad (12) \]

\( W_j \) is the net output work of the turbine. \( W_g \) is the work consumed by the working medium pump. \( W_w \) is the work consumed by the warm sea pump. \( W_c \) is the work consumed by cold sea pumps. \( Q_{he} \) is the heat absorbed by the working medium. \( Q_{we} \) is the heat of absorbing warm seawater for the working medium. \( Q_{te} \) is the heat of absorbing solar energy for the working medium.

3.2.4 Energy storage system calculation

The parameters of the battery include voltage and capacity. The nominal voltage of the battery set is 400V, the battery attenuation rate is 0.85, and the deep discharge rate is 0.8. The island residents and the system use 300kWh every day, and it can be used for 3 days. Therefore, the storage battery capacity (BC) is required:

\[ BC = \frac{300 \times 3}{0.85 \times 0.8 \times 400} = 3308 \text{Ah} \quad (13) \]

3.2.5 Power generation efficiency of multi-energy complementary integrated power generation system

According to the power generation efficiency and power generation ratio of each part of the integrated system, the integrated efficiency of the system is

\[ \eta_z = 0.5 \times \eta_h + 0.3 \times \eta_g + 0.2 \times \eta_f \]

\[ = 18.59\% \quad (14) \]

\( \eta_z \) is a multi-energy complementary integrated power generation efficiency. \( \eta_h \) is the efficiency of OTEC system supplemented by solar heating. \( \eta_g \) is the efficiency of solar cell power generation. \( \eta_f \) is the efficiency of wind power generation.

4 Further Analysis

- On multi-energy complementary OTEC

Based on the ocean thermal energy conversion, i.e., OTEC system, the system combines photovoltaic power generation, wind power generation and energy storage system to form a clean and efficient, stable power generation integrated power generation system. Give full play to their respective advantages in coordination and improve the overall power output ratio of the system. Specifically, the system has the following advantages:

1) The traditional OTEC system is inefficient, generally 1% to 2%(Heydt et al, 1993), the OTEC system uses solar complementary heating, without consuming energy of the system itself, the system thermal energy conversion efficiency to 12.8%. Theoretically the multi-energy complementary integrated power generation system has reached power generation efficiency at 18.59%.

2) This multi-energy complementary integrated power generation system, based on the ocean temperature difference energy, the use of landscape complementary power generation, and equipped with energy storage system, the comprehensive use of marine resources. It can be widely used in coastal areas or marine temperature-rich areas such as islands, providing clean and stable electricity for coastal or island residents and deep-sea engineering.

3) The pump work of the power generation supply system of the scenic complementary power generation system, compared with the traditional ocean temperature differential power generation system, does not need the external energy to be imported and self-sufficient. And the energy storage device can ensure that the whole system is working continuously, even in the evening or winter, light is not strong conditions, temperature difference power generation can still be carried out normally.

5. Conclusion

This research proposes a multi-energy complementary integrated power generation system based on ocean thermal energy conversion, i.e., OTEC. Based on its principles, the multi-energy system based-on OTEC is equipped with OTEC, solar energy, wind energy, other renewable energy power generation devices, and energy storage system to improve the overall electric energy output ratio and stability of the system. In order to improve the overall efficiency, the perovskite solar photovoltaic cells, universal wind turbines, and ocean temperature difference power generation system supplemented by solar heating were adopted, and the overall efficiency of the system can increase to 12% and above. This research provides an optimized design studies for a high
output power system that is an integrated multi-
energy system based on the ocean thermal energy conversion, OTEC. Authors have explored the feasibility of the system integration with power from wind, solar, OTEC, along with the energy storage and energy management. Based on a specific model, the energy conversion coefficient is provided and shed some light of the competitive distributed power generation in terms of efficiency, stability, and output level.

Finally, as it is shown through the previous theoretical analysis and computer modeling, this research enables the feasibility demonstration of a hybrid energy system, provides tools for the design with various necessary parameters to the engineering specification, and obtains valuable insights for the construction of the real ocean thermal energy conversion system.

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Authors' contributions (Yes, see below)
Conceived the plan: aj, jw.
Investigation:zl, js, hy, aj.
Data analysis: zl, js, hy, aj.
Wrote the paper: aj, zl, js, hy, jw.

Abbreviation:
OTEÇ: ocean thermal energy conversion
E.S.: energy storage
PV: photovoltaics
TWh: tera watt hour
MW: mega watt
KWh: kila watt hour

Declaration
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