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Techno-Economic Feasibility of PV-wind-diesel-battery Hybrid Energy System in a Remote Island in the South China Sea

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Abstract

This paper explores the techno-economic feasibility of renewable power generation in a remote South China Sea island, seeking to substitute the existing diesel generator with a PV-wind-diesel-battery hybrid energy system (HES). First, the authors assessed the availability of local renewable energy resources, elaborated the dispatch strategy of the HES, and introduced the load curve, system configuration, techno-economic specifications of the major components. Then, the Hybrid Optimization of Multiple Energy Resources (HOMER) software was employed to simulate and optimize the HES. In order to identify the optimal configuration of the system, different combinations of the HES were simulated before comparing the economic and operation information of the feasible alternatives. Through the simulation and optimization, it is concluded that the HES can provide sufficient and reliable power to the study area. Finally, the economic and resources sensitivity analysis was performed to identify how the optimal design is to change with the sensitivity variables.

Key words

Hybrid energy system, Techno-economic feasibility, Hybrid Optimization of Multiple Energy Resources (HOMER).

1. Introduction

As a major coastal country, China holds a vast sea area of about 3,400,000km^2, dotted with 6,500 islands greater than 500m^2 [1]. Since "building a maritime power" became a national strategy in late 2012 [2], China has embarked on developing remote islands, particularly those located in the South China Sea.

With the gradual perfection of the infrastructure, electrical demand in remote islands also grow rapidly. However, due to geographic inaccessibility, it is impossible to supply power to these areas via conventional grid. Most of these islands have to rely on the stand-alone power supply system (SPSS), which is mainly composed by diesel generator [3]. The SPSS generates power by continuous burning of fossil fuel, creating massive emission of greenhouse gases. What is worse, the shipment of fuel is often delayed or cut off by the perilous weather conditions, not to mention the global shortage of fossil fuel.

A possible solution to the energy blight lies in the abundance of renewable energy resources, as most of the remote islands are located in the equatorial belt [4, 5]. In this regards, introducing fuel free alternative power generation system based on renewable energy cannot only tackle the aforementioned environmental problems, but also meet the growing electrical demand in the future [6]. However, in contrast to diesel generators, the power output of renewable energy system (RES) is highly dependent on the atmospheric condition, leading to an unpredictable fluctuation of energy production, which severely affects the stability and security of power supply [7]. This gives birth to the hybrid energy system (HES), which realizes more consistent power supply through the optimal integration of the RES with conventional energy system and energy storage system [8]. The superiority of the HES over conventional energy systems has been validated by a number of recent studies [9-11].

Abdullah et al. [12] suggested that the HES offers a much more reliable and sustainable electricity supply plan than the stand-alone PV system for rural tech centers during prolonged cloudy and dense haze weather. Chauhan and Saini [13] analyzed the techno-economic feasibility of micro hydropower (MHP)-biomass-biogas-wind-solar-battery hybrid system for an isolated area in India, and compared the HES with each system based on a single energy against the economic, technical and social criteria. The results show that the HES is undoubtedly the best choice, featuring the least net present cost, levelized energy cost, the smallest battery storage, and the greatest employment potential. Through simulation and comparison, Nema et al. [14] observed that the HES reduced nearly 80% of the fuel consumption, CO_2 emission, and harmful gas exhaust from those of the conventional diesel-powered system, indicating that the HES is an environmentally friendly power solution to cope with climate change and environmental pollution. Patil et al. [15] looked for the optimal sizing of an integrated RES in four different scenarios, it was found that MHP-biomass-biogas-PV-energy plantation-wind turbine based configuration, which containing the most various types of renewable energy resources had the lowest cost of energy and was considered as the most cost-effective option for power supply. Sinha and Chandel [16] concluded that the HES outperforms single resource-based system in reliability, efficiency, energy storage, and levelized energy cost. Sigarchian et al. [17] found that the HES with biogas engine boasts cheaper energy cost and lower CO_2 emission than that with diesel engine.

For the reliability and cost-effectiveness of the HES, the sizing of the system must be determined in light of resource availability and electrical demand [18, 19]. Several softwares have been developed for the design and assessment of the HES [20]. In this research, the Hybrid Optimization of Multiple Energy Resources (HOMER) software is adopted to analyze the techno-economic feasibility and achieve the optimal design of the proposed system. Originally created by National Renewable Energy Laboratory (NREL), HOMER is widely recognized as a powerful tool for simulation, optimization and sensitivity analysis [21]. To the authors' knowledge, there are few comprehensive studies on the HES development in China's remote islands. Therefore, this paper mainly aims to examine the techno-economic feasibility of the HES in the study area, Yongxing Island, and find the optimal HES design for reliable, sustainable and cost-effective power supply. The research starts with the availability assessment of local renewable energy resources. Subsequently, the authors elaborated the dispatch strategy of the HES, and introduced the load curve, system settings and techno-economic specifications of the major components. Then, the HOMER software was employed to identify the optimal scale of the system. Finally, the sensitivity analysis was performed to identify how the optimal design responds to the sensitivity variables.

2. Overview of Study Area

2.1 Location

Yongxing Island (16°50′3″N, 112°20′15″E) was taken as the representative of the remote islands in the South China Sea. As shown in Fig.1, the tiny island (2.6 km^2) is separated from the Chinese mainland by a distance of about 339km. As the center of Sansha City, the island has shops, hostels, a hospital, a post office and even an airport. In 2012, there were about 1,000 residents living on the island. The flat terrain makes the island an ideal local for PV and wind farms.

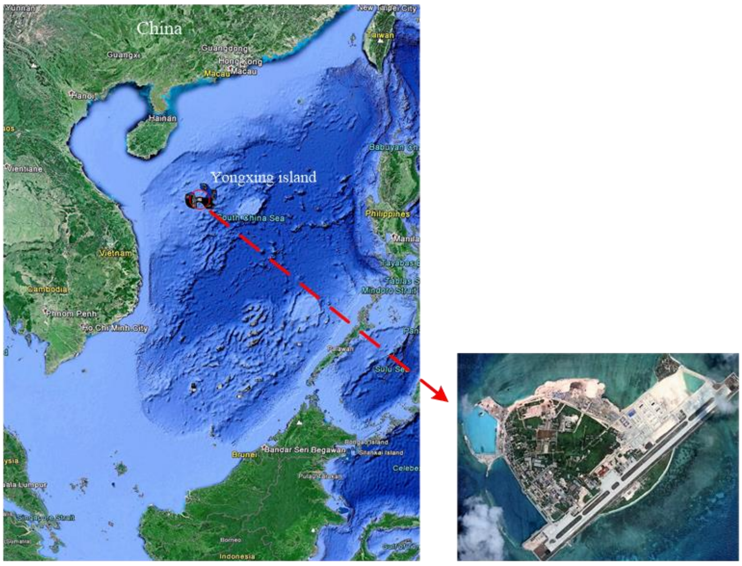

Fig.1. Location of Yongxing Island

2.2 Load Curve

The typical daily load curve of Yongxing Island was obtained from the energy management system (EMS) of the current power system. As shown in Fig.2, the load curve remains in the vicinity of 500kW from 0:00a.m. to 6:00a.m., accounting for 50% of the total capacity of the system. This is because many air-conditioners works around the clock under the high annual average temperature (26.1 ℃); since the working hours start at 8:00a.m. and end at 6:00 pm, the power demand grows in the morning and stays at high levels in the afternoon; the load curve peaks at 7:00p.m. when most residents return home and turn on lights, water heaters and air-conditioners.

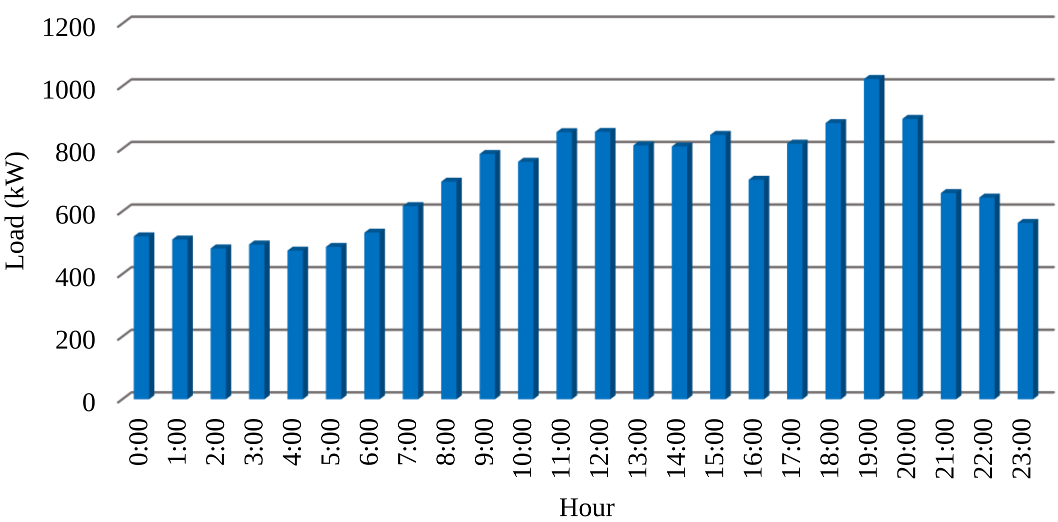

Fig.2. Typical Daily Load Curve of Yongxing Island

3. Assessment of Renewable Energy Resources

As mentioned above, HES is a proper, green power supply solution to remote islands by optimal combination of renewable energy resources. Hence, it is critical to evaluate the availability of renewable energy resources in the early phase of system design [22]. In this chapter, the potential of solar energy and wind energy of Yongxing Island is evaluated based on meteorological data obtained from NASA atmospheric database [23].

3.1 Solar Energy

3.1.1 Monthly Average Solar Irradiance

Fig.3 illustrates the monthly average solar irradiance of the study area. Located in the equatorial belt, Yongxing Island is exposed to intense solar irradiance all year around. The irradiance increases steadily from January to March until reaching the peak at 6.92kWh/m^2/day in April. Then, it gradually decreases to the lowest point of 3.91kWh/m^2/day in December. It is worth mentioning that the annual average solar irradiance is averaged at 5.57kWh/m^2/day, more than any other sunny city in China, such as Lhasa (5.53kWh/m^2/day) and Lanzhou (4.43kWh/m^2/day).

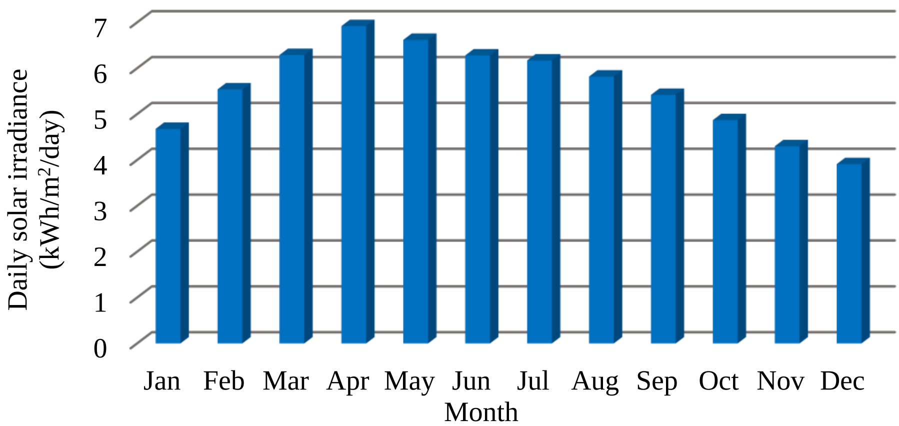

Fig.3. Monthly Average Solar Irradiance of Yongxing Island

3.1.2 Total Solar Irradiance

The total solar irradiance (TSI), defined as the sum of irradiance in a whole year, can be calculated with the following equation:

$$E_{total} = \sum_{i=1}^{12} E_i \cdot N_i \quad (1)$$

where E_{total} is the TSI (kWh/m^2/year); E_i is the monthly average solar irradiance (kWh/m^2/day); N_i is the number of days in each month; i is the number of each month. By this equation, the TSI of Yongxing Island is calculated as 2,032 kWh/m^2/year.

According to the *Assessment Method for Solar Energy Resources* (QX/T 89-2008) issued by China Meteorological Administration [24], the TSI is the most important criterion for solar power classification (Table 1). In view of the abundant solar resource, large-scale solar energy system is very suitable for Yongxing Island.

Tab.1. Solar Power Classification.

Solar power class	Potential	Total solar irradiation (kWh/m^2/year)
1	Very good	>1850
2	Good	1750-1850
3	Fair	1400-1750
4	Poor	<1400

3.2 Wind Energy

3.2.1 Monthly Average Wind Speed

Thanks to the East Asian monsoon, Yongxing Island is blessed with a good potential in wind energy [25]. The monthly average wind speed of the island stands at 10m above the Earth's surface (Fig.4), and the annual average wind speed is 6.23m/s. Moreover, the wind speed varies from the southwest monsoon (SWM) season and the northeast monsoon (NEM) season in the range of 4.12m/s~9.05m/s. The SWM lasts from April to September, and the NEM lasts from October to the next March.

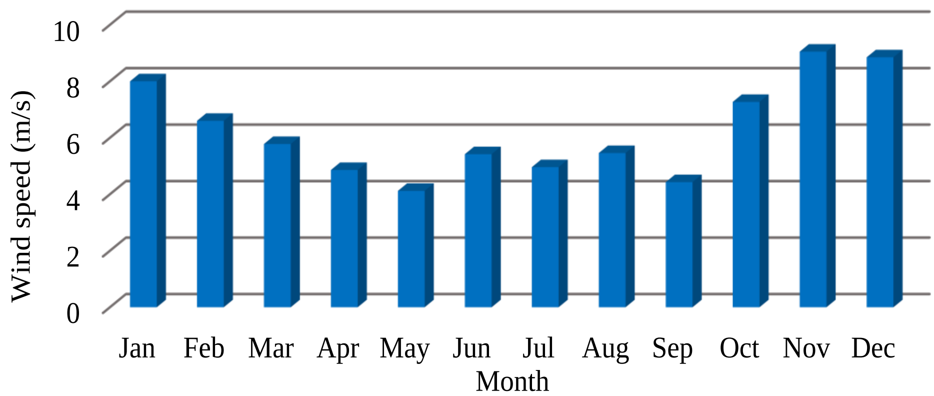

Fig.4. Monthly Average Wind Speed at 10m Above the Earth's Surface of Yongxing Island

3.2.2 Wind Speed Probability Distribution

The wind speed probability distribution is an important indicator of the statistical characteristics of wind energy [26]. In this paper, the two-parameter Weibull probability density function is adopted with the following equation:

$$f(v)=\frac{k}{c}\left(\frac{v}{c}\right)^{k-1}\exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{2}$$

where f(v) is the probability of wind speed at v; k is the shape factor, a determinant of the shape of the density curve; *c* is the scale factor correlated to the average wind speed.

For proper selection of wind turbine, it is imperative to know the wind speed probability less than or equal to a particular wind speed. Hence, the Weibull cumulative distribution function should be obtained by taking the integral of probability density function:

$$F(v)=1-\exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{3}$$

In this research, the Weibull shape and scale factors are calculated by the Wind Energy Resource Analysis (WERA) software [27]. According to the monthly average wind speed in the given time (Table 2), the shape and scale factors of the Weibull distribution were obtained as k=4.56 and c=6.76, respectively.

Tab.2. Monthly Average Wind Speed in Indicated Time

Time (GMT)	Wind speed (m/s)											
	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1:30	7.58	6.14	5.36	4.49	3.76	5.17	4.68	5.23	4.07	6.64	8.37	8.32
4:30	7.35	5.97	5.21	4.42	3.72	4.94	4.53	4.95	3.96	6.49	8.06	8.00
7:30	7.06	5.76	5.10	4.43	3.80	4.82	4.40	4.76	3.97	6.52	7.90	7.80
10:30	7.26	5.96	5.25	4.46	3.80	4.80	4.28	4.65	4.17	6.87	8.22	8.08
13:30	7.73	6.34	5.47	4.51	3.79	4.86	4.34	4.72	4.32	7.12	8.69	8.56
16:30	7.82	6.41	5.59	4.65	3.93	5.16	4.62	5.10	4.29	6.90	8.61	8.56
19:30	7.61	6.12	5.42	4.48	3.89	5.44	4.91	5.49	4.20	6.64	8.37	8.32
22:30	7.53	6.07	5.31	4.42	3.78	5.37	4.90	5.50	4.15	6.56	8.30	8.40

3.2.3 Wind Power Density

The wind power density is the best criterion for the assessment of wind resource potential [28]. Based on the Weibull probability density function, the wind power density can be calculated as below:

$$P = \frac{1}{2}\rho\int_0^\infty v^3 f\left(v\right)dv = \frac{1}{2}\rho c^3 \Gamma\left(1+\frac{3}{k}\right) \tag{4}$$

where P is the wind power density (W/m^2); ρ is the air density (kg/m^3); Γ is the gamma function. With the shape and scale factors obtained earlier, the wind power density was calculated to be 179.6W/m^2.

In accordance with the *Methodology of Wind Energy Resource Assessment for Wind Farm* (GB/T 18710-2002), the wind power is divided into 7 classes by the annual average wind speed and the wind power density (Table 3) [29].

Tab.3. Wind Power Classification at 10m Above the Surface.

Wind power class	Potential	Wind power density (W/m^2)	Annual average wind speed (m/s)
1	Poor	<100	4.4
2	Marginal	100-150	5.1
3	Moderate	150-200	5.6
4	Good	200-250	6
5	Excellent	250-300	6.4
6	Excellent	300-400	7

7	Excellent	400-1000	9.4

According to the classification standard, Yongxing Island falls to the moderate class of wind power density, making it reasonable to set up a small-scale wind power system on the island.

4. Description of the Proposed Hybrid Energy System

In the proposed HES (Fig.5), the distributed generators (e.g. PV panel, wind turbine and diesel generator) are connected to the AC bus, the battery bank is placed in a separate DC bus, and the AC and DC buses are interconnected via an AC/DC bidirectional converter. The detailed techno-economic specifications of each component are presented in the following sections.

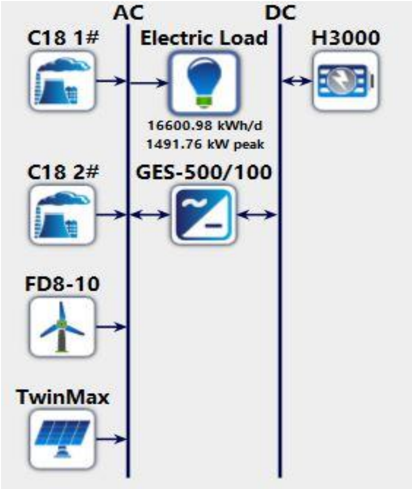

Fig.5. System Configuration of the Proposed HES

4.1 Major Components

4.1.1 PV Panel

It is urgent to improve the power density of PV panel due to the limited land area of the island. The bifacial PV panel, capable of enhancing the power output of the PV system, stands out as a viable option [30]. Hence, the TwinMax bifacial PV panel (Yingli Solar) was selected for simulation. The techno-economic specifications of the panel are given in Table 4.

Tab.4. Techno-economic Specifications of Selected PV Panel in HOMER Model

Description	Specification
Derating factor (%)	90
Life time (year)	30
Temperature coefficient of power (%/□)	-0.38
Nominal operating cell temperature (□)	46
Efficiency at standard test conditions (%)	21.2
Initial capital cost ($/kW)	2000
Replacement cost ($/kW)	2000
Operation and maintenance cost ($/kW/year)	0

4.1.2 Wind Turbine

The wind speed probability distribution (Table 5) of Yongxing Island was calculated according to equation (4). It can be inferred that the wind speed of the island ranges from 4m/s to 8m/s in about 90% of the time of a year. This means a small wind turbine (cut-in speed: 2.5m/s~3.5m/s; rated power: 1kW~25kW) is suitable for the island [13].

Tab.5. Wind Speed Probability Distribution of Yongxing Island at a Height of 10m.

Wind speed (m/s)	1	2	3	4	5	6	7	8	9	10	11
Frequency (%)	0.07	0.88	3.65	9.51	17.9	24.69	23.65	14.23	4.68	0.7	0.04

Based on the above analysis, FD8-10 (Shanghai Ghrepower) was chosen as the wind energy conversion system (WECS). The small-scale wind turbine has a rated power of 10kW and a hub height of 13m. With the permanent magnet synchronous generator (PMSG) as wind generator, the wind turbine realizes high power factor and efficiency through variable speed constant frequency (VSCF) operation, and reduces the weight, volume and fault rate of the WECS by removing the gearbox. The techno-economic specifications of the selected wind turbine in HOMER model are shown in Table 6.

Tab.6. Techno-economic Specifications Of Selected Wind Turbine in HOMER Model

Description	Specification
Rated power (kW)	10
Hub height (m)	13
Life time (year)	20
Cut-in wind speed (m/s)	3
Cut-out wind speed (m/s)	25
Rated wind speed (m/s)	10
Initial capital cost ($)	45000
Replacement cost ($)	45000
Operation and maintenance cost ($/year)	900

4.1.3 Diesel Generator

The HES often requires a diesel generator as a back-up system for a sudden increase in the load demand or an unexpected decline of renewable output. In this research, the liquid-cooled Caterpillar (CAT) C18 diesel generator (rated power: 508kW) is selected for the simulation. Two of such generators were arranged in the system to meet the peak load. The techno-economic specifications of the selected diesel generator are displayed in Table 7 [3]. The diesel price was set to USD 2 per liter, considering the high transport cost.

Tab.7. Techno-economic Specifications Of Selected Diesel Generator in HOMER Model

Description	Specification
Rated power (kW)	508
Life time (hour)	120000
Initial capital cost ($)	120000
Replacement cost ($)	110000
Operation and maintenance cost ($/hour)	0.025
Minimum load ratio (%)	30

4.1.4 Battery Bank

The battery bank is widely accepted as the key component of the HES, thanks to such attractive functions as mitigating the intermittency of renewable power generation [31]. In this research, Hoppecke 24 OpzS 3000 battery (rated capacity: 3,000Ah; rated voltage: 2V; round-trip efficiency: 86%; minimum state of charge: 30%) is selected for the simulation in HOMER. The economic specifications of the selected battery are exhibited in Table 8 [32]:

Tab.8. Economic Specifications of Selected Battery in HOMER Model

Description	Specification
Initial capital cost ($)	2171
Replacement cost ($)	1953
Operation and maintenance cost ($/year)	217

4.1.5 Converter

In this research, a bidirectional AC/DC converter is introduced to connect the AC bus with the battery bank. The PV panel and wind turbine were not connected due to the inverter embedded in the system. The GES-500/100 converter (efficiency: 95%; service life: 15 years) was chosen for the simulation. The techno-economic specifications of the selected converter are listed in Table 9.

Tab.9. Techno-economic Specifications of Selected Converter in HOMER Model

Description	Specification
Size (kW)	100
Initial capital cost ($)	92000
Replacement cost ($)	92000
Operation and maintenance cost ($)	0

4.2 Dispatch Strategy

Depending on the tasks of diesel generator, HOMER provides two dispatch strategies that oversee the HES operations: the load following strategy (LFS) and the cycle charging strategy (CCS). In the LFS, the diesel generator produces exactly the amount of electricity to meet the load demand, and the battery bank is charged by renewable energy resources. Therefore, this strategy is appropriate to systems with abundant of renewable energy resources. In the CCS, once the state of charge (SOC) of battery bank falls below the set value, the diesel generator will start to operate at full capacity to charge the battery bank until the SOC reaches the set value. Overall, the CCS is a good choice for a system poor in renewable energy resources, as it reduces the number of charge-discharge cycles, lengthens the service life of battery, and lowers the cost of battery replacement. In pursuit of the optimal dispatch strategy for the HES, both the LFS and the CCS were subject to simulation.

5. Techno-economic Assessment Criteria

Based on component specifications, input parameters and system constraints, the HOMER was utilized to perform energy balance calculation for every possible configuration of the proposed HES. Then, each feasible configuration was sorted by the techno-economic assessment criteria, including the total net present cost (TNPC) and levelized cost of energy (LCOE).

5.1 Total Net Present Cost (TNPC)

As the main techno-economic assessment criterion of HOMER, the TNPC comprises all the profits and costs incurred in the life cycle of the system. The parameter can be calculated as follows:

$$TNPC = \frac{C_{ann,tot}}{CRF(i, N)} \tag{5}$$

where $C_{ann,tot}$ is the annualized cost of the system, that is, the sum of the annualized capital cost, replacement cost, operation cost and fuel cost; CRF(i, N) is the capital recovery factor (CRF), a ratio used to convert the present value into annualized cash flows. For a specific real interest rate *i*, the CRF can be calculated as:

$$CRF(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1} \tag{6}$$

Where *N* is the number of years.

5.2 Levelized Cost of Energy (LCOE)

The LCOE is defined as the average cost per kWh of available electricity generated by the HES. The parameter equals the quotient of dividing the annualized system cost by the total electric load served:

$$LCOE = \frac{C_{ann,tot}}{E_{served}} \tag{7}$$

where E_{served} is the total electric load served (kWh).

6. Simulation and Optimization

In this section, the proposed configuration of HES would be simulated in HOMER, using the aforementioned meteorological, techno-economic specifications. The simulation process would determine whether the HES is feasible by judging the system could meet the electrical demand or not. Both the economic information and operation information were calculated for each feasible configuration to sieve out the most profitable alternative.

6.1 The Optimal System

Table 10 listed the optimization results of each categorized HES configuration, which includes optimal configuration, dispatch strategy (DS), TNPC, LCOE and renewable fraction (RF). Obviously, these configurations demonstrate the feasibility of HES development to Yongxing Island, with the LFS being the most suitable dispatch strategy.

Tab.10. Optimization Results of Each Categorized HES Configuration

PV (kW)	FD8-10	C18 (kW)	H3000	DS	TNPC ($)	LCOE ($/kWh)	RF
3000	60	1016	600	LFS	27,061,298	0.314	0.71
3000	0	1016	600	LFS	29,353,508	0.341	0.58
0	60	1016	200	LFS	42,338,192	0.493	0.16
0	0	1016	200	LFS	45,704,041	0.534	0

In terms of environmental protection, Fig.6 illustrates the contribution of energy resource in each feasible HES configuration. It can be seen that renewables are the major contributor to power generation in the first two configuration (71% and 58%). This means the two configuration can significantly reduce the dependency on diesel fuel. Compared to the conventional diesel-powered system, the three HES can lower the diesel consumption by 70.9%, 56.9% and 15.5%, respectively, and cut the annual CO_2 emission by 2,894ton, 2,323ton and 631ton, respectively.

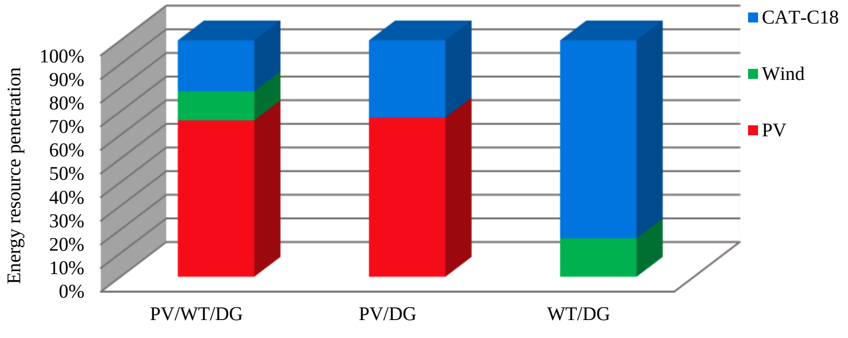

Fig.6. Contribution of Energy Resource in Each Feasible Configuration (%)

On the economic front,Fig.7 and 8 show the TNPC and LCOE of all feasible configurations. It is clear that the HES is more profitable than conventional diesel-powered system, and the PV-wind-diesel-battery configuration is the most cost-effective system (TNPC: $27,061,298; LCOE: $0.314/kWh).

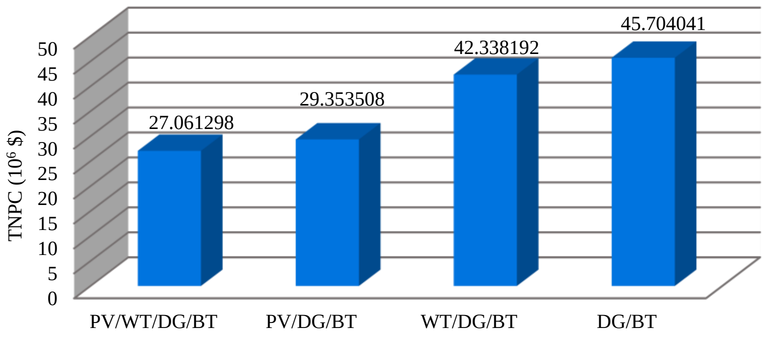

Fig.7. The TNPC of All Feasible Configurations

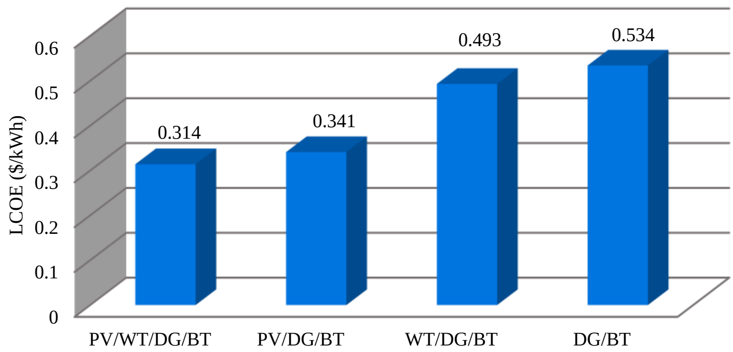

Fig.8. The LCOE of All Feasible Configurations

In view of the cost-effectiveness and low CO_2 emission, the PV-wind-diesel-battery configuration was selected as the optimal system for Yongxing Island. In this scenario, the monthly average generating capacity is given by Fig. 9. By virtue of the abundance of solar energy resource on the island, the electricity generated by PV panel amounts to 5,305,159kWh/year, taking up 66.16% of the total output of the system; the annual average output power of PV panel reaches 605kW, with a standard deviation as low as 63.66. The results reflect that the PV panel can provide a stable power supply to the HES all year around. By contrast, the output by the wind turbine fluctuates significantly under the seasonal variation of wind energy resource. During the NEM season, the wind turbine generates plenty of electricity. With the arrival of SWM season, however, the output of the wind turbine plunges, and the diesel generator work for prolonged hours to keep the power balance of the system.

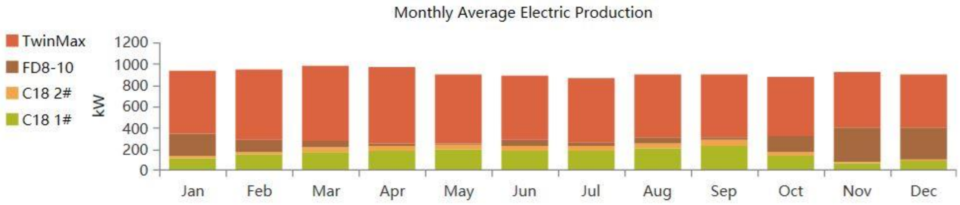

Fig.9. Monthly Average Generating Capacity

6.2 The Importance of Battery Bank

The optimal configuration (PV-wind-diesel-battery) was contrasted with the configuration without battery bank (PV-wind-diesel) in terms of initial capital cost, the TNPC, power surplus, and power shortage (Table 11). The purpose is to demonstrate the importance of the battery bank in enhancing the economy and reliability of the HES.

Tab.11. Comparison Between the Optimal System with and without Battery Bank

Configuration	Initial capital ($)	TNPC ($)	Excess electricity (kWh/year)	Capacity shortage (kWh/year)
PV/wind/diesel/battery	10,794,600	27,061,298	1,730,726	5,247
PV/wind/diesel	8,940,000	28,298,300	2,889,911	45,396

Despite a higher initial capital cost resulted from the high price of battery, the optimal configuration features a 4.4% smaller TNPC than the configuration without battery bank. A possible reason lies in the fact that the battery bank can improve the system efficiency through peak loading shifting, and lower the operating cost by shortening the operation hours of diesel generator. Moreover, battery bank reduces the power shortage by 88.4%, which greatly enhances the reliability of the HES.

7. Sensitivity Analysis

The sensitivity analysis attempts to identify the optimal design responds to the sensitivity variables, including major meteorological data and techno-economic parameters. The analysis results are displayed in the spider graphs of Fig. 10 and 11. The sensitivity variables fall within +30%~-30% of the best estimate. It is observed that the TNPC is more sensitive to the cost of PV panel and battery, wind speed and diesel price, as the corresponding curves are steeper than those of the other variables.

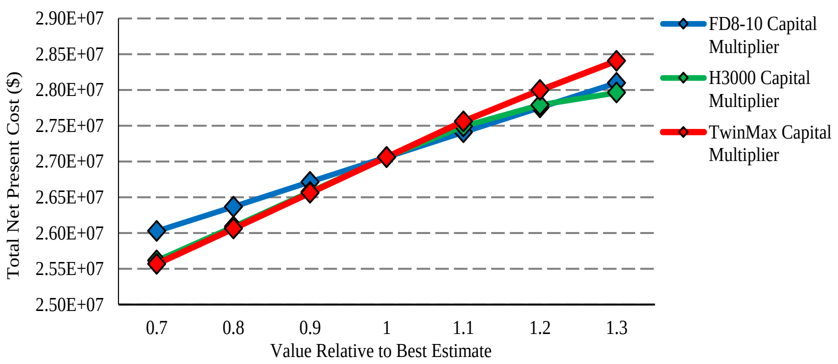

Fig.10. Economic Sensitivity Analysis

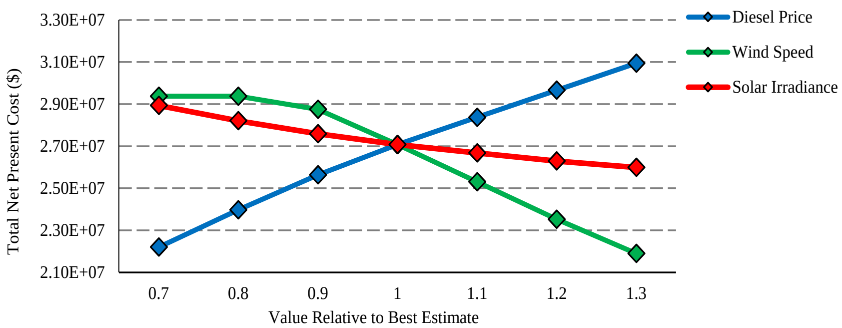

Fig.11. Resource Sensitivity Analysis

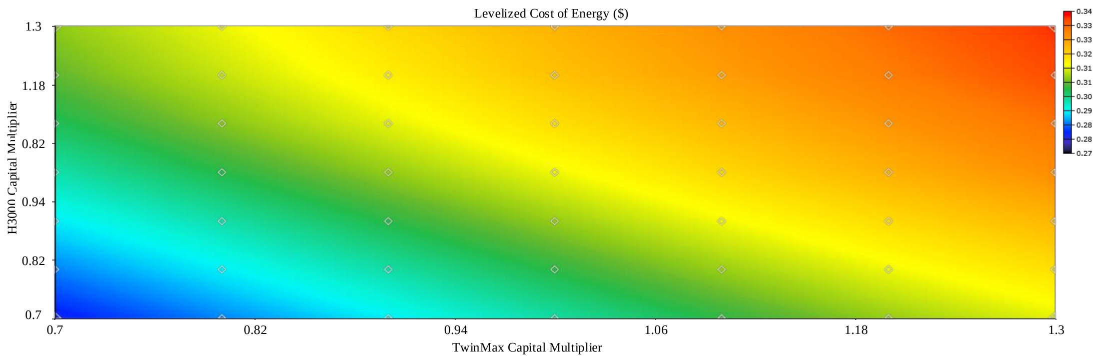

Fig.12. LCOE vs. the cost of PV Panel and Battery Cost

Fig. 12 shows the variation of the LCOE with the cost of PV panel and battery. It can be seen that the LCOE becomes increasingly affordable with the decrease of the cost of PV panel and battery. Under the continuous development of renewable energy technologies, the price of PV panel and battery is bound to drop in the foreseeable future, further enhancing the cost-effectiveness of the HES in Yongxing Island.

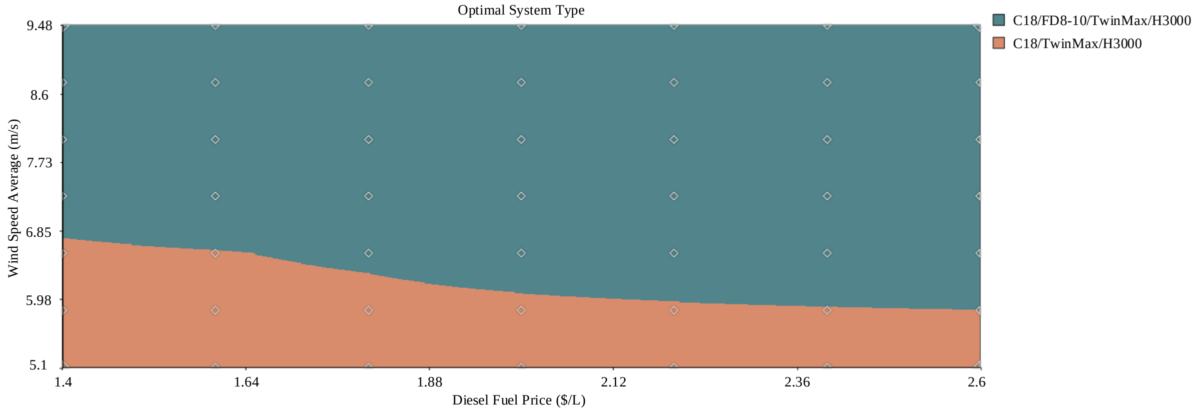

Fig.13. Optimal System Type for Wind Speed vs. Diesel Price

Fig. 13 displays the optimal system type for wind speed vs. diesel price. As shown in the figure, wind turbine is a favourable way to tackle both the growing wind speed and the rising diesel price. Hence, the wind turbine should be integrated into the HES as the substitute of diesel generator, as long as the system is deployed in remote southern islands like Yongxing.

Conclusion

This paper investigates the techno-economic feasibility of renewable power generation in Yongxing Island, seeking to substitute the existing diesel generator with the HES. Through the simulation and optimization, it is concluded that the proposed PV-wind-diesel-battery hybrid system can provide sufficient and reliable power to the study area; Compared to the conventional diesel-powered system, the proposed system can relieve the dependency on diesel fuel, and operate in a more cost-effective manner. In addition, as the key component of the HES, the battery bank is able to significantly enhance the cost-effectiveness and reliability of the entire system.

According to the results of sensitivity analysis, the TNPC is most sensitive to the cost of PV panel and battery. Hence, the economic competitiveness of the HES will be further improved with the continuous price reduction of these major components. In terms of energy resources, the TNPC is most sensitive to the wind speed and diesel price, indicating that the wind turbine must be integrated into the HES as the substitute of diesel generator, as long as the system is deployed in remote southern islands like Yongxing. Suffice it to say that the research findings provide new insights on the design, optimization and development of the HES in the South China Sea.

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