Design and simulation analysis of offshore tidal energy generating set system based on sensor network

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Abstract
Tidal energy refers to the potential energy and kinetic energy of tidal changes. It is a kind of energy that hides a huge amount of energy and can be regenerated endlessly. Tidal energy as an energy source is purely renewable energy. The tide rises and falls every day, and the energy is constant, so it will be endless. Power generation through tidal energy can not only alleviate the energy shortage but also become the main additional energy source for people to carry out economic construction and development in areas near the sea. Because tidal power plants are usually built-in offshore areas with relatively small populations, they will not cause complicated problems such as flooding of farmland and immigration. In view of the shortage of energy and fuel in the world and the increasingly serious environmental and pollution problems, tidal energy has received widespread attention and influence all over the world due to its infinite reserves, lack of environmental pollution, and high predictability. Based on the submarine acoustic wireless sensor network platform, we have developed an experimental submarine acoustic ray sensor network platform, which provides an effective platform for testing and evaluating the submarine acoustic ray sensor network. This paper determines the capacity of TCF, the layout design of TCF in TCT, and the research on the collection system. Based on the underwater acoustic wireless sensor network platform, the underwater acoustic network experimental test system platform is being developed, and a feasible research plan is proposed for the detection and evaluation of the underwater acoustic wireless sensor network.

Keywords
Sensor network · Sea tidal energy · Generator set · System design

Introduction

Principles of tidal power generation

Under the influence of the tidal force of celestial bodies (especially the moon and the sun), water will rise and fall in stages, which is called tidal activity. Tidal energy refers to the potential energy and kinetic energy of tidal changes. It is a kind of energy that hides a huge amount of energy and can be regenerated endlessly (Abd El Razik 1972). The main use of tidal energy is to generate electricity. Usually, a dam is built at regular intervals to separate the offshore estuary or bay from the open sea to a natural reservoir (Abdel Moneim 2004). The turbine generator is installed in the gap of the dam. As the tide rises, the water level in the reservoir will be less than the water level in the seawater. The huge seawater enters the reservoir through the hole, and the kinetic and potential energy in the seawater can be converted into mechanical energy of the turbine, thereby prompting the generator to rotate (Abu Al-Izz 1971). When the tide is closed, the water level in the reservoir will be greater than the sea surface, and when sea water is injected into the sea from the reservoir, it will cause the turbine to rotate in the opposite direction (Abu El-Magd et al. 2020). Therefore, the generator generates continuous power. Tidal power generation is very different from hydroelectric power generation (Akgun and Turk 2010). The main reason is that the water level difference in hydroelectric power generation is relatively large, while the water level difference in tidal power generation is relatively small. Therefore, the water level difference in the turbines of tidal power plants is small and large. The current is suitable (Alexander 1993).
Advantages and disadvantages of tidal power generation

Advantages

Tidal energy as an energy source is purely renewable energy. The tide rises and falls every day, and the energy is constant, so it will be endless (Alizamir et al. 2018). Power generation through tidal energy cannot only alleviate the energy shortage but also become the main additional energy source for people to carry out economic construction and development in areas near the sea (Babajide and Saeed 2016). Because tidal power plants are usually built-in offshore areas with relatively small populations, they will not cause complicated problems such as flooding of farmland and immigration (Baeza and Corominas 2001). In addition, companies such as the chemical industry and aquaculture can develop rapidly, which largely alleviates the problems of larger populations, less land, and scarcity of arable land in coastal areas. These problems do not require the construction of high dams for tidal power plants and water levels (Betrie et al. 2013). Tidal energy is a kind of economic energy, without other fuel and transportation costs, but compared with other traditional companies and Tongfeng Hydropower Plant, it has a large amount of secondary energy investment (Breiman et al. 1984). Therefore, tidal power generation has the same advantages as hydroelectric power plants in rivers, such as a large amount of investment and less electricity production costs. From the perspective of long-term development, the various effects of tidal power generation are still very good, which can greatly reduce the use of other energy sources (Chen and Guestrin 2016).

Disadvantages

The tidal range and sea level rise often change throughout the day, and the tidal range may even change twice a month; therefore, in the absence of special supervision measures, the guaranteed production time is short and the annual service life of the installed system is short, the power generated by the generator is short, the fixed, and the electric energy is relatively poor. The tidal power plant is usually built in Haikou Port. Compared with general hydroelectric power plants, the construction of tidal power plants is difficult to construct due to the depth of the dam, the length of the dam, and the difficulty of foundation treatment and anti-siltation (Chen et al. 2019). Therefore, the construction cost is high and the investment is high. Because tidal power stations have low lifts and large flows, large turbines using a large amount of steel must be selected, and the building structure is complicated, and because it is submerged by sea water for a long time, it is necessary to be aware of the risk of these buildings being eroded by sea water (CONOCO 1987). In short, through the analysis and research of tidal power stations by scholars and experts from various countries in the world, tidal measurement technology has been relatively mature, and it has made great progress in reducing investment, increasing economic and social benefits, and having broad development opportunities (Costache 2019).

Materials and methods

Layout planning model of offshore tidal energy generating units

This article points out the modeling based on TCT planning, which is used to determine the capacity of TCF and the layout of TCT to minimize the total production cost per ton (Costache et al. 2020). The tidal energy unit takes into account the planning and operating costs. The energy system using tidal energy in the objective function, including the input cost of TCT, the operating cost of the grid after TCF is connected to the grid (grid loss and the production cost of the unit in the grid), and indoor gas conditioning costs (Dai and Lee 2001). Therefore, use two-level programming theory to create a model for TCF layout planning. The model consists of two layers, and the specific structure is shown in Fig. 1.

The emergency combination and variable transfer rules of the upper and lower models are: the upper part mainly optimizes the content of TCF and the layout of TCT. Following the original TCT layout plan in the upper model, taking into account the changes in the tidal effect and attention effect of TCT, the output power of the TCF is obtained and transmitted to the lower planning model as the input capacity (Eggensperger et al. 2013). The overall objective function of the TCT layout in the upper model, the optimization result of the upper model becomes lasting, which will affect the production cost of the equipment in the network in the lower model, greenhouse gas charging fees, and network losses (Eker et al. 2015). Let us assume that the sea area in the TCF construction plan is shown in Fig. 2.

In the figure, the sea area is set as a square area composed of nxm squares, where the center of each grid is the orientation of the TCT, and the inset shows the diameter of the TCT blade. According to the minimum distance between adjacent TCTs, the transverse length and length width of each grid are set to 4 times and 6 times the diameter of the TCT blade. The position in the figure is the position of W station TCT. X and Y respectively represent the horizontal and vertical coordinates of the corresponding position in the TCT positioning network. In order to improve the content of TCF and the layout of TCT, this paper establishes a top-level main optimization model. The goal is to minimize the total power generation cost per ton of tidal energy.

$$\min F(x_w, y_w) = (C_{TCT} + C_e + C_o)/E_T$$ (1)
The limitations of the above model include two aspects. The first negative side is the boundary of TCF, and its formula is as follows:

\[
\begin{align*}
    x_{\text{min}} < x_{w} < x_{\text{max}} \\
    y_{\text{min}} < y_{w} < y_{\text{max}}
\end{align*}
\]  
\( \quad (w = 1, 2, ..., N_{T}) \)  

\( C \) is the daily investment cost of the same efficiency of all TCTs in TCF, and the following formula can be used:

\[
C_{CT} = N_{T} \times C_{\text{unit}} \times \frac{r(1 + r)^{l}}{(1 + r)^{l-1}} \times 365
\]  

(3)

It is the weighted sum of the daily TCF power generation calculated using the following formula:

\[
E = \sum_{e=1}^{k} \left( E_{T} \times p_{e} \right)
\]  

(4)

\( CE \) is the weighted sum of the daily processing costs of greenhouse gases of devices in the network. The following formula can be used:

\[
C_{e} = \sum_{e=1}^{k} \left( C_{\text{environment}} \times p_{e} \right)
\]  

(5)

The scheme of TCTS grouping is shown as in Fig. 3. A two-dimensional rectangular coordinate system is built in TCF. The fixed field of the coordinate origin indicates the offshore substation, and the point in the coordinate system indicates the position of the TCT.

In the figure, \( a \) represents the angle between the line between the \( i \) TCT and the coordinate type and the positive axis of the \( x \)-axis, \( i = 1, 2, ..., N_{T} \), which represents the number of \( x \).

Linek represents the \( k \)th line starting from the origin of the coordinate, which is the core of the \( k \)th group (El Haddad et al. 2020). The angle between Linek and the half axis of the \( X \)
axis. $X$ and $Y$ represent the horizontal and vertical coordinates of the $i$th TCT, and $X_0$ and $Y_0$ represent the specific orientation of the TCF offshore substation.

**Underwater acoustic wireless sensor system and hardware design**

Based on the submarine acoustic wireless sensor network platform, we have developed an experimental submarine acoustic ray sensor network platform, which provides an effective platform for testing and evaluating the submarine acoustic ray sensor network (El-Fakharany 1998). The specific framework of the platform is shown in Fig. 4.

The platform is composed of system application layer, monitoring network layer and subsea node layer. The system application layer includes saving, processing, and analyzing the data transmitted by the monitoring network layer, and setting the dynamic working parameters and the status of the uawsn node (El-Hussaini et al. 1990). The software can perform graphics functions to complete display, set node parameters, simulate interference communication, detect errors, and simulate. The monitoring network layer can also forward the execution instructions issued by the system application layer to the sensor nodes. By monitoring the network layer, sensor nodes can also perform data extraction and download applications (El-Rakaiby 1990). The submarine node layer is the submarine node layer composed of sensor nodes. The sensor nodes communicate with floating-point nodes through Dart, and the submarine sensor nodes upload the received data to the water level, and the floating sub-nodes pass it to the system application layer to test the system topology and water under the acoustic communication situation (Fan et al. 2018).

The structure of the wireless sensor used to detect the micro energy system. The system architecture of the system must include a transmitter and a receiver. The receiver in this article uses a built-in receiver module, and the circuit development related to this is not explained here. This article focuses on the hardware circuit of the transmitter. The hardware system of the wireless sensor network node transmitter of the micro-thermoelectric generator is shown in Fig. 5.

As shown in Fig. 5, the transmitter structure consists of a micro energy harvester, a thermoelectric energy harvester, a booster circuit with MPPT function, an energy slower and a wireless sensor network node operated by the system load. The collector is composed of various energy conversion equipment (thermoelectric generators). The energy production materials can be determined based on the environmental energy attributes of the actual place of use and the electrical energy required to meet different operating conditions. The power management IC is mainly composed of MPPT module, power interface, charger, and energy slower. The energy mitigation circuit is composed of a super capacitor, a comparison circuit, and a voltage regulator circuit. The load is mainly the processing of the data obtained by the sensor and the transmission through the radio control module. The circuit converter designed based on the bq25505 ultra-low voltage boost converter in this paper includes the following features: tracking the strongest power, DC-DC boost conversion, and energy slowing. See Fig. 6.

In the hardware circuit of this article, a company’s bq25505 power management chip is mainly used to obtain power from the ultra-low power thermal energy conversion module. As shown in Fig. 7, these 16 branches are distributed in a counterclockwise direction again.

In Fig. 8, the circuit a is mainly composed of the current control chip bq25505 and its related circuits. TEG is a micro-thermoelectric generator that generates voltage through thermoelectric conversion. The TEG output is connected to the VIN-CombiDC terminal of bq25505 through a resistor R; R passes high connect the frequency shock LBST to the LBST terminal.

**Generator set collection system planning model and algorithm**

The design of the TCF collector system is a non-linear optimization combination, which can be effectively solved using genetic algorithms. In genetic algorithm optimization, a sequence of binary numbers is usually used to encode lines in the topology of the collector system.
Fig. 4 Experimental test platform

Fig. 5 The hardware circuit architecture of the transmitter of the micro energy harvesting wireless sensor network node
The example shows that after the crossover and mutation operations, the tree topology encoded by the control sequence can still guarantee the radial shape and connection of the topology. In Fig. 9, after the cross-mutation operation, the topological structure encoded by the Prufer sequence still shows the characteristics of radial shape and connection.

Source and processing of tidal velocity data

The tide speed data used in this example is located in two different locations: one is located in a certain country, which is called area A in the example. The speed data comes from the Business Center of the Oceanic and Atmospheric Administration of a certain country. The website of the center has many years of monitoring data information from multiple places in a certain country, which can be used for free; the other location is in a certain country, and the name is B in the example. The data comes from the energy center of a certain country; Table 1 shows the specific geographical indications of regions A and B.

Using K-means clustering technology, the diurnal variation curve of tidal action was simulated, and the tidal data samples of area A and area B were analyzed accordingly. The obtained diurnal variation curve of tidal action is shown in Fig. 10 and Fig. 11.

The figure shows that the typical tidal diurnal variation curves of area A and area B naturally have different changes, and the tidal changes of area B are relatively fast. The method of using the unified planning model proposed in this paper to determine the capacity of the TCF and to check the layout of the TCT is to connect the TCF to the simulation analysis of the IEEE31 node detection system, and add the data of the IEEE31 node system in the appendix. Table 2 shows the specific parameters of the equipment used in the detection system in the network. In the example, considering the maximum...
hourly load curve including a 24-h period, the daily peak load is 283.5 MW. Table 3 shows the parameters of TCT.

Results

Wireless sensor system test results

Detection requirements: the transmission power parameter is 20%, the data packet transmission interval is 20 s, the mutual communication, the communication distance is 20 m, 30 m, and 40 m, each distance checks 200 data packets, as shown in Fig. 12.

Comparative analysis of layout planning of tidal flow energy generating units

For example, TCF is built in the sea area of 0.4861 km² (divided into 20 × 20 square), then TCF is connected to the IEEE31 bus test system. Based on the tidal speed data measured from area A and area B, the following two tables are designed for simulation experiments: Table 1:

![Diagram](image1)

**Fig. 8** DC-DC boost circuit with MPPT function and energy storage circuit schematic diagram

![Diagram](image2)

**Fig. 9** The changing process of Prufer sequence coding topology
Considering the total cost of system planning and operation, the TCF, TCF content, and TCT layout are determined. Attached Table 2: Only consider the investment cost of TCT to plan TCF content and TCT layout. Compared with Table 1, Table 2 does not consider operating costs and the greenhouse gas processing costs of the equipment in the network. The simulation analysis of Table 1 and Table 2 is carried out using the tidal influence of area A and area B. The content of TCF is shown in Table 4 (Figure 14).

Experimental results show that if you do not consider changes in greenhouse gas regulation costs and grid operating costs, TCF revenue will be reduced. It can be concluded that regardless of whether the daily output is in area A or area B, the grid operating costs are useful for TCF planning to fully exploit the tidal current generation potential. The unit (CE + CO)/ER determined by the planning model in Table 1 is lower than the cost determined by the planning model in Table 2. This shows that the method proposed in this paper for tides with different changing characteristics is appropriate (Table 5).

### Table 1 Geographical information of area A and area B

| Name   | Location                        | Dimension | Longitude |
|--------|---------------------------------|-----------|-----------|
| Area A | Certain place, certain country  | 55° (N)   | 167° (W)  |
| Area B | A certain area, a certain country| 58° (N)   | 3° (E)    |

Comparative analysis of construction area of different TCFs

Study the effect of different TCF plans on the TCT layout model, and determine the appropriateness of testing the method. In the different situations of Table 1 and Table 2, the model in this paper is used to simulate and analyze the following three ocean areas using different planning areas: (1) It is assumed that TCF km2 is built in the sea area of 0.1222, and the area is divided into 6 × 6 square. (2) TCF is set up in an ocean area of 0.3111 km², and the area is divided into 9 × 9 squares. (3) It is assumed that the TCF is built in the sea area of 0.4861 km², and the area is divided into 11 × 11 squares. TCF is connected to the IEEE31 node detection system. Under different circumstances, the acquired TCT layout is shown in Fig. 15. The TCT layout for sea level planning is 0.1216 km² and 0.3111 km². Case (3) gives the TCT layout of 0.4861 km² sea area. Table 6 shows the production capacity of TCF under three different conditions. Table 7 shows the total production cost of TCF and other optimization items in three different situations. Experimental data shows that with the expansion of the planned area of TCF, the production capacity of TCF has also shown an increasing trend, and the total power generation cost has been reduced. Experiments show that the design of a larger area of TCF can obtain higher benefits after being connected to the grid. For the three different sea area TCF plans, the total power generation cost in Table 1 is less than that in Table 2. The proposed unified plan for determining TCF production capacity and TCT layout can achieve better economic results than the optimization model that only considers TCT investment costs.
Simulation results of power collection system planning for generating sets

(1) In Example 1 of this example, TCF covers a sea area of 4 × 4 square kilometers. The public node, that is, the location of the substation is in the center of the TCF. There are 31 TCTS connecting the submarine cable to the public node. First, radial grouping of TCTS in TCF is performed, and then a simulation experiment is performed on the TCTS in each group of TCTS packets, and the collector system plan of the maximum number of TCTS in each packet. The TCT is connected to the power system in the form of a machine and a transformer. According to the current on the high voltage side of the transformer and the maximum current capacity on the line, the number of TCTS in a group is expressed as 31i. The capacity of the TCT unit is 4 MW, and the rated voltage of the collection system is 36 kV, which is calculated by formula (6):

\[
I = \frac{S}{732U} = 500
\]

where \( S \) is the capacitance of the TCT, \( U \) is the rated voltage in the collector system, and \( I \) is the current on the high-voltage side of the transformer. After the maximum power consumption of the cable, the maximum number of TCTS that can be connected to the cable is 9.25; the maximum number of TCTS that can be connected is 8. There are 31 TCTS groups in TCF, and then find each TCT group, the specific results are shown in Fig. 16.

| Group number | Maximum output (MW) | Minimum output (MW) | \( \gamma \) | \( \beta \) | \( \alpha \) | \( a \) | \( b \) | \( c \) |
|--------------|---------------------|---------------------|------|------|------|------|------|------|
| 1            | 300                 | 50                  | 0.0127 | -0.91 | 22.984 | 0.00376 | 3.0 | 0   |
| 2            | 90                  | 16                  | 0.0300 | -0.11 | 25.314 | 0.01751 | 1.8 | 0   |
| 3            | 60                  | 20                  | 0.0271 | -0.02 | 25.506 | 0.06251 | 2.0 | 0   |
| 4            | 36                  | 20                  | 0.0291 | -0.006 | 24.901 | 0.00835 | 3.26 | 0   |
| 5            | 40                  | 20                  | 0.0291 | -0.005 | 24.701 | 0.02501 | 4.0 | 0   |
| 6            | 50                  | 20                  | 0.0272 | -0.0056 | 25.301 | 0.02501 | 4.0 | 0   |

Table 3 Parameters of tidal flow energy generator set

| Symbol | Unit parameters | Numerical value |
|--------|-----------------|-----------------|
| \( C_P \) | Capacitation factor | 0.46 |
| \( v_{\text{out}} \) | Cut out flow rate | 3.6 m/s |
| \( v_{\text{rated}} \) | Rated flow rate | 3.1 m/s |
| \( v_{\text{in}} \) | Cut-in flow rate | 0.8 m/s |
| \( P \) | rated power | 1.3 MW |
| \( C_T \) | Blade thrust coefficient | 0.8 |
| \( D \) | Blade diameter | 189 m |
| \( r \) | Discount Rate | 0.02 |
| \( l \) | Economic life of a machine | 30 years |
| \( C_{\text{unit}} \) | One investment cost | 799,713$ |

![Fig. 12 Communication results at different distances](chart_image)
According to the TCT grouping situation in the figure, use the method of this article to experiment and analyze the TCT in each group. The topology of the collection system is shown in Fig. 17. The MST algorithm is also used for simulation and analysis of TCT after grouping. Figure 18 shows the topology, Fig. 17 and Fig. 18 show the line, and the number displayed indicates which cable is used for the line.

The indicators obtained by the two methods are listed in Table 8, including the total cost, the annual investment cost of the cable used, the cost of the collector transmission power loss, and the total length of the path. Table 9 shows statistical information about the quantity. From example 1, it is shown that the total cost of the collector system obtained by this method is reduced by 34.12071.

First, compared with the MST algorithm, the cable length of the optimized collector system has increased by 36.11071, resulting in a cable investment cost increase of 34.02071, which shows that the cable length is the main factor affecting the solvency system investment cost, but according to the results in Table 9 it is shown that although the result of using this method is an increase in cable investment, the cost has increased. Although the length of the cable used by this method is longer, the demand for high-power cables is lower than that of cables produced by this method. The increase in the length of the MST algorithm route may not completely correspond to the increase in the economic cost, and the cross-sectional area of the route also has an effect on the investment cost. When optimizing the planning of the acquisition system, not only the length of the path must be considered but also its impact on the path; second, compared with the MST algorithm, the transmission capacity of the acquisition system obtained by the method is reduced: an increase of 41.12%. Under the condition of determining the topology, the current loss transmitted is the line proportional to the square of the current flowing through the line. It can be deduced from Table 9 that the topological result obtained by the method in this paper is that the current flowing through each line is very small, so the transmission current loss of the line is significantly reduced. This is a direct result of the total cost determined by the proposed method the exponential effect has distinct advantages.

Example 2 is the situation of the TCT layout obtained in this example. TCF covers an ocean area of 0.487 km². The public node is located in the middle of the TCF. Fifty-two TCTS are connected to public nodes through submarine cables. First, radial grouping of TCTs in TCF is performed, and then an experimental analysis is performed on the collector system plan of TCTs in each group. (1) The TCT optimization software package first determines the number of TCT software packages and the

| Table 4 | Tidal flow power plant capacity of area A and area B under different scenarios |
|---------|---------------------|
|         | Plan 1   | Plan 2   |
| Area A  | 78.1 MW  | 46.9 MW  |
| Area B  | 61.3 MW  | 38.5 MW  |

| Table 5 | Simulation results of area A and area B under different scenarios |
|---------|---------------------|
| Scale   | Index   | Plan 1       | Plan 2       | ΔCv   | ΔCp   |
| Area A  | $F$      | 150.842     | 221.419     | −70.578 | −31.89% |
|         | $C_{TCT/ET}$ | 30.139     | 23.862     |  6.278  |  26.32% |
|         | $(Ce + Co)/Er$ | 120.704    | 197.558    | −76.855 | −38.91% |
| Area B  | $F$      | 82.144     | 124.376    | −42.232 | −33.97% |
|         | $C_{TCT/ET}$ | 13.934     | 12.185     |  1.749  |  14.36% |
|         | $(Ce + Co)/Er$ | 68.211    | 112.192    | −43.981 | −39.21% |
maximum number of TCTS in each software package. The unit capacity of TCT is 1.3 MVA. The calculated transformer high voltage current is as follows:

\[
I = \frac{S}{1.732U} = \frac{1.2 \times 1000}{1.732 \times 35} = 19.705447 A
\]  

(7)

Approximately 21A, according to the maximum current capacity of the cable, a maximum of 23.2 cables can be connected, of which the total number is 23 units. There are a total of 2 TCTS, which can be grouped and then analyzed for each TCT group. The specific results are shown in Fig. 19.

(3) Based on the TCT grouping situation in the figure, experiments and analysis are carried out on the best plan of the collection system through the model, algorithm and MST algorithm. The topology of the collection system is shown in Fig. 20 and Fig. 21. The number of each line in the figure indicates what kind of cable the line uses. Table 10 and Table 11 show the corresponding indicators obtained from the simulation in Example 2.

It is shown from example 2 that the total cost of the method in this paper is reduced by 24.04071, which corresponds to example 1. As shown in the figure, the maximum number of TCTS in the package is 9, and the maximum length sequence code of the inspector is 7 bits, which is used to indicate the possible topology in the collector system; example 2 is the maximum number of TCTS in 23 packets, the maximum length of the main sequence code is 21 bits to indicate the possible topological structure in the power system. The two TCFs in the package with different detection areas, TCTS distance and TCTS number are used to simulate the best plan for the energy supply system. The results show that it is effective to introduce Priifer sequence into genetic algorithm to encode the topology of the collection system to solve the planning model of the collection system. Following the radial grouping in example 1 and example 2, the topology of the collector system obtained by the proposed method and MST algorithm shows that the lines are not crossed, which indicates that the TCT grouping proposed in this paper completely solves the line crosses.
Discussion

Functional requirements and design principles of sensor networks

Before designing the hardware system of the uawsn node, you must first set its functions according to the task of the subject, and then propose its hardware according to the functions (gateway nodes, relay nodes, and sensors).

Functional design of sensor nodes

The basic function of the sensor node is to process information, underwater acoustic communication, and energy management data collection. The sensor network studied as a communication platform in this project can be connected to various sensors, including the dart communication module and IAP function module, making troubleshooting easier.

Status quo of development and utilization of tidal energy at home and abroad

Status quo of foreign development and utilization

In the early twentieth century, Germany first built the first tidal power plant. There are many design concepts for waiting for

Table 6 Planning capacity of tidal flow power plant

| Scale  | Plan 1 | Plan 2 |
|--------|--------|--------|
| 6 × 6  | 6 × 6  | 21.7 MW | 8.5 MW |
| 9 × 9  | 9 × 9  | 46.9 MW | 25.3 MW |
| 11 × 11| 11 × 11| 61.3 MW | 38.5 MW |

Fig. 15 Layout scheme of tidal flow energy generating units

Table 7 Simulation results of tidal current power plants in different planned areas

| Scale | Index | Plan 1 | Plan 2 | ∆Cv | ∆Cp |
|-------|-------|--------|--------|-----|-----|
| 6 × 6 | F     | 238.147| 422.043| -183.896| -43.58%|
|       | C<sub>TCT</sub>/E<sub>T</sub> | 15.134 | 12.185 | 2.949 | 24.21% |
|       | (C<sub>e</sub> + C<sub>o</sub>) / E<sub>r</sub> | 223.014 | 409.858 | -186.845 | -45.58% |
| 9 × 9 | F     | 105.428| 190.384| -84.957 | -44.63% |
|       | C<sub>TCT</sub>/E<sub>T</sub> | 13.996 | 12.185 | 1.812 | 14.36% |
|       | (C<sub>e</sub> + C<sub>o</sub>) / E<sub>r</sub> | 91.432 | 178.198 | -86.769 | -48.68% |
| 11 × 11| F    | 82.144 | 124.376 | -42.232 | -33.96% |
|       | C<sub>TCT</sub>/E<sub>T</sub> | 13.933 | 12.185 | 1.749 | 14.36% |
|       | (C<sub>e</sub> + C<sub>o</sub>) / E<sub>r</sub> | 68.211 | 112.192 | -43.981 | -39.21% |
tidal power plants, but few have implemented them. By the 1960s, the first major tidal power plants appeared. Subsequently, power plants gradually increased and became more and more mature.

**Status of domestic development and utilization**

In the 1950s, China built many small tidal power plants in the southern region. However, due to the conditions at the time, there are still many problems. It was gradually lost. It was not until the new century that our country began to attach importance to tidal power plants, and they were established in many places in the south. As conditions became more and more mature, tidal power plants began to take shape and achieved great development, especially energy conservation and emission reduction. Since its implementation, the tidal power plant has played an irreplaceable function and began to be widely used.

**Future development trend of tidal energy development**

**Policy aspects**

Encourage diversified operations and promote the full use of renewable ocean energy. For example, tidal energy considers aquaculture, and wind generators are installed.

Table 8  Example 1: Simulation results of the collection system of tidal flow energy power plant

|                          | Method of this article | MST algorithm | The result of this paper is an improvement of the minimum spanning tree | Percentage increase |
|--------------------------|------------------------|---------------|------------------------------------------------------------------------|---------------------|
| Comprehensive cost ($)   | 85,390.31              | 129,606.91    | −44,216.61                                                             | −34.13%             |
| Cable investment cost ($)| 27,424.87              | 20,463.97     | 6960.91                                                                | 34.03%              |
| Network loss cost ($)    | 64,183.95              | 109,142.91    | −44,959.01                                                             | −41.18%             |
| Total line length (m)    | 17,674.88              | 12,985.88     | 4688.98                                                                | 36.12%              |
on top of wave generators for a wide range of applications. At the same time, scientific breeding and development of the tourism industry are also carried out to promote the wide application of marine energy. In addition, environmental protection laws and regulations are formulated to evaluate the development of renewable energy in the offshore sector.

Technical aspects

Research on effective energy conversion and offshore renewable energy facilities rely on safety and stability to study renewable energy equipment used at sea, especially some equipment that effectively fights typhoons. Because some equipment has been immersed in sea water for a long time, it is necessary to strengthen the research of anti-corrosion material technology and anti-sticking technology for underwater renewable energy devices.

Table 9  Example 1: The statistical results of the number of cables used in the collection system

| Cable type number | Number of cables used in the method in this article | The number of cables used by the MST algorithm |
|-------------------|-----------------------------------------------------|-----------------------------------------------|
| 1                 | 25                                                  | 9                                             |
| 2                 | 0                                                   | 8                                             |
| 3                 | 0                                                   | 9                                             |
| 4                 | 0                                                   | 7                                             |
| 5                 | 0                                                   | 1                                             |

Conclusion

In view of the shortage of energy and fuel in the world and the increasingly serious environmental and pollution problems, tidal energy has received widespread attention and influence all over the world due to its infinite reserves, lack of environmental pollution, and high predictability. This paper determines the capacity of TCF, the layout design of TCF in TCT, and the research on the collection system. Based on the underwater acoustic wireless sensor network platform, the underwater acoustic network experimental test system platform is being developed, and a feasible research plan is proposed for the detection and evaluation of the underwater acoustic wireless sensor network.

Table 10  Calculation example 2: simulation results of tidal current power plant collection system planning

|                     | Method of this article | MST algorithm       | The result of this paper is an improvement of the minimum spanning tree | Percentage increase |
|---------------------|------------------------|----------------------|-------------------------------------------------------------------------|---------------------|
| Comprehensive cost ($) | 31,687.44              | 41,714.81            | −10,027.41                                                               | −24.05%             |
| Cable investment cost ($) | 13,080.89              | 7727.85              | 5353.05                                                                  | 69.28%              |
| Network loss cost ($)   | 18,606.56              | 33,986.97            | −15,380.41                                                               | −45.26%             |
| Total line length (m)   | 7658.83                | 4047.99              | 3610.85                                                                  | 89.21%              |
Declarations

Conflict of interest The authors declare that they have no competing interests.

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