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Design of Management System for a Variety of Marine Renewable Energy

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ABSTRACT

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The development and utilization of marine renewable energy is one of the most important measures to solve the energy crisis, protect and improve the environment. In this paper a renewable energy management system based on PDCA mode is designed to achieve the spiral increase of renewable marine energy efficiency, and achieve accurate evaluation of management system effectiveness based on entropy weight allocation theory. Taking the actual situation of marine energy utilization of a city in the last 6 years as the research data sample, in this paper, the positive impact of the PDCA management system model proposed in this paper on the improvement of the efficiency of various marine renewable energy management is analyzed.

ADDITIONAL INDEX WORDS: *Marine, renewable energy, PDCA, management system, entropy weight distribution.*

INTRODUCTION

Guaranteeing energy security and developing green low carbon economy are the important themes of sustainable development of all countries in the world today (Grecian, Inger, and Attrill, 2010; Inger, Attrill, and Bearhop, 2009; Mueller and Wallace, 2008). Facing the increasingly lack of energy resources and the grim situation of air pollution and global warming caused by burning traditional fossil fuels, all countries in the world has begun to attach importance to the development and utilization of renewable energy (Mueller and Jeffrey, 2006; Shields, Dillon, and Woolf, 2009). At present, China is experiencing the rapid development of industry, energy demand is growing, energy problems and environmental problems are becoming more and more prominent. Speeding up the development and utilization of marine renewable energy is one of the major measures to solve the problem of energy environment. Marine renewable energy has the characteristics of clean, renewable and large reserves (Alexander, Wilding, and Heymans, 2013; Wood, Bahaj, and Turnock, 2010). With the increasing maturity of marine renewable energy technology, all countries in the world are gradually expanding their development and utilization of marine renewable energy, and have achieved very good economic efficiency (Polagye, Copping, and Brownsaracino, 2014; Trapani, Millar, and Smith, 2013; Williamson, Blondel, and Armstrong, 2016). Any marine development and utilization activities will involve marine management issues. Marine renewable energy development and utilization projects need to occupy a certain area of marine space, which will cause a series of problems, for example, the right to use sea area, the legal status and safety protection of marine renewable energy facilities or structures, the impact of these related facilities and structures on maritime traffic safety, marine environment, and even national defense safety issues, *etc.* These issues need to be regulated by legislation, but the domestic legislation specifically aimed at marine renewable energy management is very little, and the provisions are not specific (Mu and Matsuda, 2016; Zheng *et al.*, 2016). Although there are many related legislations in China, they can not be applied to the development of marine renewable energy industry. Besides, some other legislative provisions are not perfect.

Because the marine renewable energy technology to reach maturity in recent years, marine renewable energy industry also is still in the early stage of development, the current researches in domestic and foreign are mainly carried out from the perspective of the industrial policy, namely how to create favorable conditions for the development of marine renewable energy industry through the tax system, development fund system, market financing system, and project management system, in order to guide and promote the rapid and healthy development of marine renewable energy industry. From the perspective of international law and integrated marine management, there are few papers and works on marine renewable energy development and utilization activities. There are various researches on marine management at home and abroad (such as marine environmental protection, marine traffic management). There are also researches on marine governance from the perspective of integrated management. These two aspects have certain reference value for this study. The model of PDCA (Plan-Do-Check-Act) is used to persist in

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continuous improvement. The enterprise applies the system to the production process, constantly evaluates the energy management performance in the process of operation, and finds the greater energy saving potential and the opportunity for improvement.

DESIGN OF VARIOUS MARINE RENEWABLE ENERGY MANAGEMENT SYSTEM BASED ON PDCA MANAGEMENT MODEL

PDCA cycle is a mode that spirally rising and continuously improving the performance of the system (Chang, 2006; Ii and Smalley, 2008), and the core management mode of it is to make reasonable arrangement for the future vision of the enterprise under the premise of ensuring the completion of the current plan, which is essentially a concept of sustainable development (Mi, Zhang, and You, 2016; Zapadka *et al.*, 2015). PDCA mode is applied to a variety of marine energy management systems to fully express the dynamics and systematization of marine energy management. The content contained in each stage of PDCA cycle in energy management system is shown in Table 1 (Saxena, Ramer, and Shulman, 2004; Vinay, Kim, and Chang, 2010; Wu, Wang, and Li, 2006).

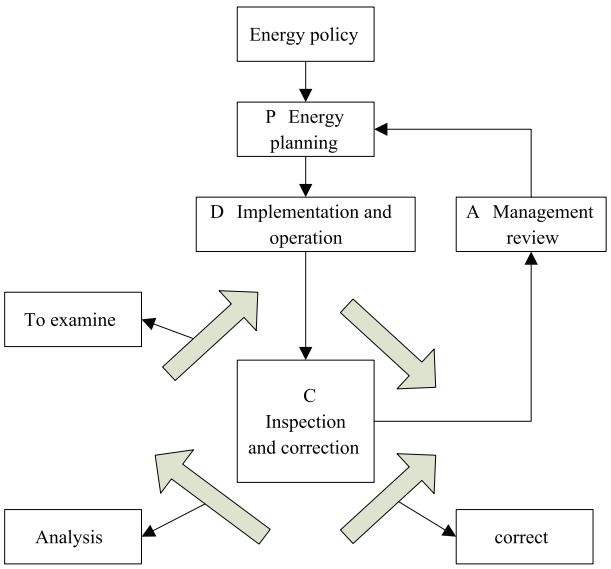

Figure 1. Design flow of management system for a variety of marine renewable energy.

The model phase and the basic content of various marine renewable energy management systems based on the PDCA cycle management model are as shown in Table 1.

At present, energy use units in China have a series of energy management, such as energy audit, energy conservation monitoring and planning, and contract energy management *etc.* These existing energy management work has overlapping contents, and the emergence of energy management system will solve this problem, which can not only integrate energy managers, but also to provide a coordinated framework for them. The key element of setting up audit framework management system for a variety of marine renewable energy is to rationally determine the weight ratio of each element of the energy management system. In this paper, entropy weight method is used to determine the proportion of these factors. Entropy weight method is a weight analysis method of management system evaluation index. It realizes objective evaluation of system performance and effectiveness based on the amount of information contained in each index value and information value. The objectivity and accuracy of entropy weight method are all strong, and can effectively realize the objective evaluation of the value of various marine renewable energy risk factors. Assuming that the marine renewable energy management system is composed of m sample data and n indicators are used for systematic evaluation, then the initialization data matrix Z of the energy management evaluation system can be expressed as:

$$Z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ z_{m1} & z_{m2} & \cdots & z_{mn} \end{bmatrix} \quad (1)$$

Table 1. *Phase content analysis of the cycle management model.*

Stage	Serial Number	Primary Coverage
Plan	1	Analysis of the state of energy utilization in Enterprises
	2	Find out the problems existing in the enterprise
	3	Building energy targets and targets, energy saving schemes and system documents
Do	4	The implementation plan of enterprise management established in the stage of execution planning
Check	5	Find out the problem during the operation, analyze it and correct it in time
Action	6	Summing up experience and lesson, refining the effect well into standard
	7	Unsolved problems are put into the next PDCA loop to improve

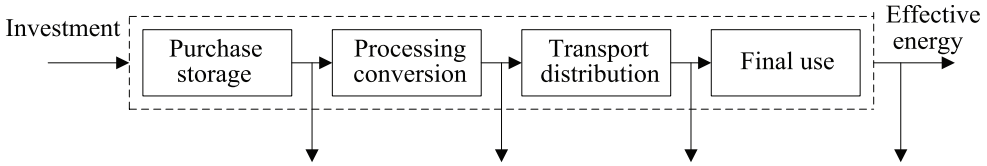

Figure 2. Conversion process of marine renewable energy.

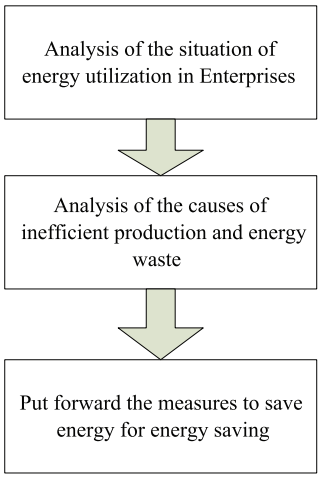

Figure 3. General ideas on the supervision and management of various marine energy sources.

Particular Year	Energy Utilization Atio (%)	
	Offshore Wind Energy	Tidal Energy
2011	35.21	23.35
2012	33.15	25.26
2013	34.14	30.12
2014	45.36	44.41
2015	51.55	48.82
2016	53.62	52.21

The index values of marine resources evaluation matrix are normalized to calculate the proportion W_{ij} of the jth indicator in the risk assessment system in the ith data:

$$W_{ij} = \frac{z_{ij}}{\sum_{i=1,j=1}^{m} z_{ij}} \tag{2}$$

Then the entropy value γ_i of the ith influencing factor in the risk assessment model can be expressed as:

$$\gamma_i = -k\sum_{j=1}^{m} W_{ij} \ln W_{ij} \tag{3}$$

At this time, we can also analyze the difference coefficient k_i of the first risk assessment model in the management system.

$$\kappa_i = 1 - \gamma_i \tag{4}$$

The weight allocation method based on entropy weight is used to determine the risk weight of various marine renewable resources ω_{ij}, which can be expressed as:

$$\omega_{ij} = \frac{\kappa_i}{\sum_{i=1,j=1}^{m} \kappa_i} \tag{5}$$

Further determining the weight ratio of the influencing factors in the marine energy management system can make the PDCA cycle mode more reasonable and effective, and improve the efficiency of various marine renewable energy sources. In the establishment and management of energy system, it should pay special attention to the conversion efficiency of energy system, and the efficiency conversion process of various marine renewable energy management is as shown in Figure 2.

Finally, we should do a good job of auditing and supervision in the process of energy management, and make clear the supervision and management of various renewable marine energy. Although marine energy is renewable energy, it needs to do well in energy conservation and promote the coordinated development of China's marine economy. Based on the PDCA model, we can see the marine energy supervision and audit process, as shown in Figure 4.

From the perspective of current development and utilization of marine renewable energy status, only offshore wind and tidal power generation technologies have reached the mature stage, and have been applied to a certain extent, while the application of wave energy, thermal energy, salt and other renewable energy technologies are still in the experimental stage. But be aware that the development and utilization of marine renewable energy is a complex activity, which relates to the protection of the project's own facilities and its related facilities, the use of the sea area, the maintenance of maritime traffic safety, the protection of the marine environment, and even the national defense safety. Therefore, the law of managing and exploiting the activities of renewable energy in the ocean must be formulated from the perspective of comprehensive management.

EMPIRICAL RESEARCH

A city is located in the coast of the East China Sea, there is use of tidal energy and offshore wind power history of this area since

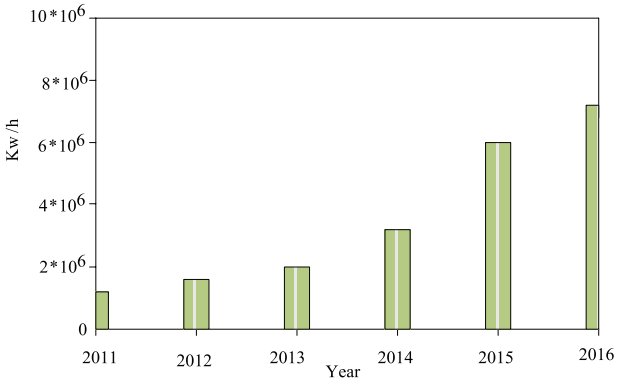

Figure 4. The trend of tidal power generation in a city.

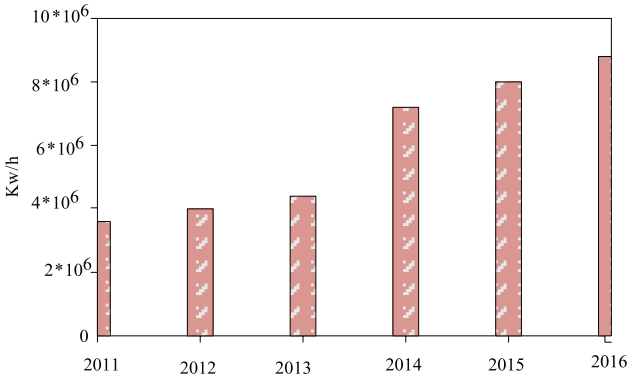

Figure 5. The trend of offshore wind power generation in a city.

ancient times, but the utilization efficiency of marine renewable energy is low, causing a large extent of manpower, material and financial resources waste. From 2014, the city has adopted the PDCA based cycle management model to establish a renewable energy management system, and reasonably use wind and tidal energy. Taking data of using marine renewable energy in this city from 2011 to 2016 as the sample data, the actual effect of PDCA cycle management mode applied in specific applications is systematically studied. First, the actual efficiencies of using offshore wind and tidal energy during 2011-2016 are counted. The statistical analysis data are from a related department of the city.

From the past 6 years, the efficiency of renewable marine energy can be analyzed. Before 2013, the efficiency of offshore wind power and tidal energy utilization is very low, which is no more than 40%. In addition to the natural factors, most of the reasons are due to lack of understanding of renewable marine resources and the lack of effective management models. Since 2014, based on PDCA, a city has adopted the eco-cycle energy utilization mode. The utilization efficiency of energy has been increasing continuously, and the utilization rate of offshore wind and tidal energy has reached 53.62% and 52.21% respectively.

In order to study the application of tidal energy and offshore wind energy in the field of power generation more directly, the changes of kilowatt hours of tidal power and offshore wind energy power in a city in recent 6 years are counted, respectively, as shown in Figure 4 and Figure 5.

From the changes of marine energy utilization efficiency in a city in recent 6 years, we can see that the PDCA cycle theory has great practical application effect in improving the efficiency of marine energy utilization.

CONCLUSIONS

After the rapid development of the economy, China has begun to bear the consequences of rapid industrialization. In recent years, haze weather has swept all over the country, and the pollution index of the major cities has remained high for several days. It is seriously endangering the health of the Chinese people. It is urgent to seek green, pollution-free energy and develop low-carbon economy. The marine renewable energy industry has provided us with such a way of development. However, we should also see that the rise of an industry is bound to bring a series of problems. We can't just pursue the huge economic benefits brought by the industry and ignore the negative effects.

We need to have this awareness in developing and utilizing marine renewable energy. We must consider comprehensively the social and environmental problems that may be caused by the development and utilization of marine renewable energy, and properly use legislation, policies and other means to solve them. We should also see that the sea is not only belonging the countries, but also in the world. Based on the "United Nations Convention on the Law of the Sea", a series of international legal documents play a role of regulating and guiding the development and utilization of seas in the world. To improve the efficiency of marine renewable energy utilization, the key is to adopt a reasonable pattern, step by step, make full use of marine energy, and promote the sustainable development of ecological environment in the surrounding areas.

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