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Research on Server Cooling Factors Based on Analytic Hierarchy Process

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Abstract: In this paper, tidal variation, seasonal change, sea water depth and longitude and latitude are considered as four important factors affecting the heat dissipation of seabed server. The weight of each factor and heat dissipation degree is determined by analytic hierarchy process. The results show that the seasonal change factor has the greatest impact on the heat dissipation degree of server, accounting for 47%, followed by sea water depth and geographical location, it reaches 28% and 16% of the specific gravity respectively. The tidal variation has the smallest impact on heat dissipation, only 9%.

1. Introduction

For the seabed data center, how to store more servers in a limited volume and ensure the normal and fast heat dissipation to the seawater during the working process of the server is a very challenging problem. Tides and seasons will change the local water level and temperature and bring temporary seawater flow, which may have a certain impact on the heat dissipation of the data center. Please consider the influence of tide, seasonal variation and other factors on the heat dissipation effect of containers in submarine data center.

The cooling effect of the container in the submarine data center is not always the same, but is affected by different factors. Through analysis and research, it can be known that in order to maximize the cooling, there must be a certain difference between the internal temperature of the container and the external seawater temperature, and the greater the difference, the more conducive to the cooling of the server[1]. Therefore, the influence of this question on the heat dissipation factors of the data center can be understood as which factors will affect the seawater temperature. It is analyzed that depth is a major factor affecting the seabed temperature of the data center. In addition, through the search of online data, it is found that longitude and latitude (geographical location) can also affect its heat dissipation effect. This paper adopts analytic hierarchy process [2] factors to establish a quantitative model about the degree of heat dissipation.

2. Model assumptions

Hypothesis 1: all servers are in normal working state without overload or damage;

Hypothesis 2: the container is in a natural state in seawater, and there is no benthic organisms and man-made damage;

Hypothesis 3: ignoring the influence of installation difficulty on the design of heat dissipation

structure, each equipment is installed normally;

Hypothesis 4: Calculation and Research on the descent depth of container container according to the maximum tensile strength;

Hypothesis 5: ignore the influence of factors other than tide, season, depth, longitude and latitude on server heat dissipation.

3. Server cooling factors model

The heat dissipation effect of the container in the submarine data center is not always the same, but is affected by different factors. Through the analysis and research of the first question, we can know that in order to maximize the heat dissipation, there must be a certain difference between the internal temperature of the container and the external seawater temperature, and the greater the difference, the more conducive to the heat dissipation of the server, Therefore, the influence of this question on the heat dissipation factors of the data center can be understood as which factors will affect the seawater temperature. In question 3, it is analyzed that depth is a major factor affecting the seabed temperature of the data center. In addition, through the search of online data, it is found that longitude and latitude (geological location) can also affect its heat dissipation effect. See Table 1 for the specific analysis of the four factors.

Table 1: Effects of different factors on data center heat dissipation.

No	Factor	Influence effect
1	season A_1	The temperature difference between day and night varies greatly in different seasons, especially in summer. The excessive temperature makes the average temperature of seawater not too low.
2	depth A_2	The analysis shows that the depth of sea water is inversely proportional to its temperature. The deeper the container, the greater the temperature difference, and the better the heat dissipation.
3	longitude and latitude A_3	That is, geographical location. This factor is mainly related to solar radiation. The temperature in the area away from the sun all year round will also be relatively low.
4	tide A_4	The periodic fluctuation of seawater is mainly affected by the gravity of the moon and the sun, and the average temperature of seawater will be increased at full tide.

Through the above research and analysis, it can be seen that season, depth, longitude and latitude and tide are important factors affecting the heat dissipation of Seabed Data Center. This problem adopts analytic hierarchy process [2] factors to establish a quantitative model on the heat dissipation degree.

Analytic hierarchy process is mainly used to judge, compare and evaluate some complex problems that are difficult to be analyzed quantitatively. It is a multi-objective decision analysis method combining quantitative analysis and qualitative analysis. Analytic hierarchy process can divide a complex decision-making problem into smaller factors, and these decomposed small factors are combined according to a certain up-down relationship, so as to build an orderly ladder structure. Generally, the expert evaluation method is used to determine the importance of each factor in each level to the upper factor, that is, the weight value, finally, these weight values are multiplied and synthesized to obtain the weight synthesis value of the lowest layer to the highest layer. The main steps of analytic hierarchy process are as follows:

Step 1. Establishment of hierarchical structure model. After some investigation and understanding of the problems to be solved, the factors affecting their development can be divided into different orders. Generally, they are the target layer, the criterion layer and the scheme layer. The criterion layer

is the direct factor affecting the target layer. The scheme layer is the primary factor affecting the criterion layer and also the indirect factor affecting the target layer. The change of the criterion layer determines the trend of the target layer, at the same time, it also dominates the trend of the scheme layer.

Step 2. Construction of judgment matrix. Through the establishment of step 1 structural model, the class level between various factors is determined. In this paper, the 1-4 scale method is used to represent the importance of factors in the same level relative to the upper level

Furthermore, a judgment matrix is constructed to represent the degree of importance or unimportance. For example, 4 represents extremely important and 1 / 4 represents extremely unimportant.

Step 3. Weight value and consistency test. Firstly, calculate the eigenvector and corresponding eigenroot of the judgment matrix, and find out the maximum eigenroot and eigenvector of the matrix. Then the value in the eigenvector corresponding to the maximum eigenroot is the importance of each factor at the same level to the factors at the previous level, that is, the weight. The consistency index is expressed by CI. The larger the CI, the worse the consistency of the judgment matrix. On the contrary, the better the consistency effect. In order to know whether the consistency of the judgment matrix is satisfactory, the consistency ratio CR = CI / RI is introduced. If Cr is less than 0.1, the consistency result is satisfactory.

Step 4. Calculation of total weight value and consistency test. The total weight result can be obtained by multiplying the weight value obtained in step 3 with the weight value of the previous layer, and the consistency result can be verified by the same consistency test method.

According to the explanation of the principle of analytic hierarchy process and the evaluation index system of the above heat dissipation model, the hierarchical structure model is established. Since this question only discusses the impact of the four indexes of the criterion layer on the target layer, the scheme layer is simply defined.

The index acquisition of the comprehensive evaluation system judgment matrix of the model is constructed by expert suggestions. Wa is used to represent the judgment matrix of the criterion layer Al, A2, A3 and A4 for the target layer, and the weight value is calculated by taking the judgment of the criterion layer for the scheme layer as an example.

$$W_A = \begin{bmatrix} & A_1 & A_2 & A_3 & A_4 \\ A_1 & 1 & 2 & 3 & 4 \\ A_2 & 1/2 & 1 & 2 & 3 \\ A_3 & 1/3 & 1/2 & 1 & 2 \\ A_4 & 1/4 & 1/3 & 1/2 & 1 \end{bmatrix} \tag{1}$$

In this paper, the sum product method is used to calculate the subjective weight value of the criterion layer index relative to the target layer, and the weight vector is obtained through the calculation of eigenvector and eigenvalue. The calculated results need to be tested to determine the quality of the matrix:

1) Calculate the eigenvalues and eigenvectors of the comparison matrix.

From the characteristic equation $W_A - \lambda I = 0$, the maximum eigenvalue of matrix W_A is solved by MATLAB software: $\lambda_{max} = 4.03$, and the corresponding eigenvector is

$$W_0 = (0.4673 \;\; 0.2772 \;\; 0.1601. \; 0.0954) \tag{2}$$

The feature vector is the weight of the criterion layer to the target layer.

2) Consistency test

Since the order of matrix A is order 4, the random consistency index obtained by querying the data is R.I = 0.89. Calculation:

$$C.I = (\lambda_{max}\text{-}4)/(4-1) \approx 0.01 \quad (3)$$

Therefore, the consistency proportion index is $CR = C.I/R.I = 0.0112$, which is far less than 0.1. It can be seen that the matrix of the criterion layer for the target layer meets the consistency, that is, the construction of the comparison matrix W_A is reasonable and feasible. In order to understand the calculation results more clearly and intuitively, table 2 is listed.

Table 2: Characteristic values of criterion layer and case layer.

Subjective weight of criterion layer relative to target layer	A_1	A_2	A_3	A_4
	0.47	0.28	0.16	0.09
	$\lambda_{max} = 4.0300$			
Comprehensive consistency test results $CR = 0.0112 < 0.1$, model establishment qualified.				

It can be seen from the calculation results in the table that seasonal variation factors have the greatest impact on the server heat dissipation, accounting for 47%, followed by seawater depth and geographical location, accounting for 28.% and 16% respectively. Tidal variation has the smallest impact on heat dissipation, only 9%. According to the above values, for the selection of heat dissipation position of submarine container, we should first consider the area with small seasonal change. Reason: select an area with more appropriate seawater temperature in winter. When it comes to summer, the temperature in this area may rise, which will lead to the secondary release of container, resulting in unnecessary waste of manpower, time and cost. Secondly, the influence of seawater depth should be considered. Reason: when the container material allows, the better the material, the greater the tensile strength, the better the corrosion resistance, the greater the depth that can be reduced, and the heat dissipation will be strengthened. Then, considering the choice of geographical location, reason: long-term exposure to solar radiation will greatly increase the sea water temperature compared with the area away from the sun, which is not conducive to the storage of server data. Finally, due to the effect of gravity, the change of tide is inevitable. Therefore, it is more important to select an area with less gravity to make the temperature difference caused by this factor less.

4. Conclusion

Through the establishment of the model and relevant calculations, it is concluded that the server installation mode of transverse section is obviously better than that of longitudinal section, so it is recommended to adopt the server installation mode of transverse section. If the cylindrical container is used to carry the server, a large part of space resources will be wasted. If the cylindrical container is changed into a cuboid container, this problem can be solved. In addition, near the contact surface between cuboid and water, the temperature gradient is large, and the convection heat transfer coefficient reaches a high value, for the specific results, the heat dissipation method can adopt the separated heat pipe for high-efficiency cooling. Aisi 1080 carbon structural steel can be used as container manufacturing material, and its service life and price are better than other materials. Season, sea water depth, geographical location and tide will all affect the heat dissipation of the server to varying degrees. Seasonal factors have the greatest impact on server heat dissipation, accounting for 47%, followed by seawater depth and geographical location, accounting for 28% and 16% respectively. Tidal variation has the least impact on heat dissipation, only 9%.

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