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Automatic location of multiple leakage points of hydropower station gate based on approximate kernel density estimation algorithm

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Abstract: *In order to accurately locate the leakage location of hydropower gates, an automatic location of multiple leakage points of hydropower gates based on approximate kernel density estimation algorithm is proposed. Based on the location structure of multiple leakage points of hydropower station gates, the early warning indicators for these leakage points have been determined. The abnormal warning features have been extracted and combined with the approximate kernel density estimation algorithm. The data execution database indicators have been set, and an automatic location normal processing structure has been built. The approximate kernel density estimation algorithm is dynamically processed to analyze the proportion of the consistency coefficient of the load distribution form of the inlet ball valve of the hydraulic turbine, so as to realize the automatic location of multiple leakage points of the hydropower station gate. The experimental results show that the flow at the starting point of valve control is gradually increasing, and the flow direction at the end point is gradually decreasing, which has good clustering effect. It can complete the clustering of different types of leakage point data, and the automatic positioning effect is good.*

Keywords: *Approximate kernel density estimation algorithm; Gate of hydropower station; Multiple leakage points; Automatic location of leakage point*

1. Introduction

The efficiency, reliability and safety of the gate of hydropower station are very important to the hydropower station [1,2]. The main purpose of the automatic location technology of multiple leakage points of the gate is to find and accurately locate the leakage points according to the pressure, flow, sound speed, sound pressure and other parameters of the gate when the gate leaks[3,4]. The main problem faced by automatic positioning technology is how to make full use of the measured parameters on the gate to locate multiple leakage points. The development of automatic positioning technology has important research significance for the integrity management of hydropower stations.

Reference [5] proposes a joint optimization operation strategy for wind energy and cascaded hydropower stations, aiming to fully utilize wind energy and minimize its fluctuation impact. This strategy considers multiple constraints such as energy storage, discharge, and output from each power station, and establishes a multi-objective short-term optimal scheduling model. To improve the shortcomings of traditional particle swarm optimization algorithms, dynamic weights and learning factors are introduced. The simulation results show that cascaded hydropower stations can effectively stabilize wind energy fluctuations, improve wind energy utilization and system power generation, and ensure stable operation of the power system. Reference [6] proposes an optimized operation strategy for cascaded hydropower stations based on the interior point method, aiming to achieve maximum power generation under limited water resource conditions. This is a nonlinear optimization problem with multiple variables and constraints, solved using an interior point method with good robustness.Reference [7] proposed the structural optimization of the surge chamber of hydropower station based on the fluid volume method, conducted model tests and three-dimensional simulation based on the fluid volume model to check the rationality of the surge chamber structure in the transient process, and proposed the optimization scheme after in-depth analysis. With the change of the shape of the impedance orifice plate and the bottom plate, the optimized scheme can provide limited water level fluctuation under load rejection and startup conditions, and effectively eliminate the stepped water level drop and air trapped eddy current, meeting the requirements of design, construction and operation.

Although the above research has made some progress, at this stage, the safety management system applied by hydropower stations in many regions is not perfect enough to accurately locate the safety risk problems faced by multiple leakage points of hydropower gates, and further research is needed. Based on the above background, the paper studies the automatic location method of multiple leakage points of hydropower station gates based on approximate kernel density estimation algorithm.

2. Design of normal treatment structure for locating multiple leakage points of hydropower station gate

2.1 Multi-leakage point positioning structure of hydropower station gate

Under the approximate kernel density estimation algorithm, the clustering coefficient of multiple leakage point data is calculated, as shown in formula (1):

$$W_H = \sum_{i=1}^{n} \alpha_i \times \frac{\theta_1 + \theta_2}{\beta - 1} \tag{1}$$

In formula (1), α_i represents the convolution error of the i, θ_1 represents the positioning time, θ_2 represents the extended positioning time, and β represents the resolution. Through the above calculation, the actual clustering coefficient can be obtained. According to the clustering coefficient obtained, the scope of multiple leakage points location and clustering of hydropower station gates is defined to expand the actual coverage area of the location [7].

2.2 Determination of early warning indicators for multiple leakage points of hydropower station gates

Before studying the location of multi-leakage points of hydropower station gates under the approximate kernel density estimation algorithm, this paper combines the location structure of multi-leakage points of hydropower stations, and according to the dispatching requirements of hydropower stations, uses the approximate kernel density estimation algorithm to determine the corresponding early warning test indicators of multi-leakage points of hydropower stations [8].

Relevant early warning indicators for multiple leakage points of hydropower station gates can be summarized and integrated first, and then gradually converted into execution instructions that can be recognized by the system in a specific format by using software. The specific indicators are shown in Table 1.

Table 1: System early warning indicator setting table

Order number	Early warning indicators	Preset standard	Measured standard
1	Response time/s	1.02	0.94
2	Control starting point	30-80	30-75
3	Control end point	40-90	40-89
4	Clustering effect/%	0.5-0.9	0.5-0.9
5	Positioning error/%	0.5	0.3

According to Table 1, the early warning indicators for multiple leakage points of hydropower station gates can be set. On this basis, combined with the approximate kernel density estimation algorithm, the instructions are set in the execution structure of the system, and combined with the intelligent voice assistance system, which can not only realize the monitoring of the daily data of the hydropower station, but also timely grasp the changes of parameters, and give the corresponding warning signals to the management personnel, laying a more solid foundation for the daily work of the hydropower station and the abnormal warning of multiple leakage points of the hydropower station gate.

2.3 Intelligent extraction of anomaly warning features

After determining the early warning indicators of multiple leakage points of hydropower station gates, the intelligent extraction of early warning features of multiple leakage points of hydropower station gates is carried out in combination with the approximate kernel density estimation algorithm . In order to reduce the possibility of daily accidents or anomalies, it is first necessary to carry out early warning and positioning. A positioning device is added to the internal execution structure of the hydropower station valve. At the same time, according to the characteristics within the scope, the detection device is used to capture the target, identify the fluctuation state of abnormal signals, determine the corresponding laws, and extract the characteristics of early warning in combination with the monitoring module.

By analyzing and checking the abnormal state of the early warning position, set it as a certain feature, and match it with gestures, so that the positioning device can capture the preset picture, and then match the corresponding early warning problem.

The feature extraction of early warning problems can be completed. At the same time, according to the template parameters stored in advance, the values and information of the relevant indicators in the hydropower station gate are adjusted to measure the similarity of the early warning feature extraction by similarity. The approximate kernel density estimation algorithm is used to locate the abnormal valve of the hydropower station, and the compression method is used to transform the analysis, further optimizing and improving the overall feature extraction range, providing a theoretical basis for the subsequent positioning processing.

2.4 Automatic positioning normal processing structure

In combination with the intelligent extraction of abnormal early warning features of hydropower stations, the automatic positioning normal processing structure is set, and the approximate kernel density estimation algorithm is combined to further refine the overall positioning structure. Generally, the automatic location model will transfer the data set information of the abnormal location of multiple leakage points of the hydropower station valves to the repository of the location structure in a special format for use. The structure of the automatic positioning model is shown in Figure 1.

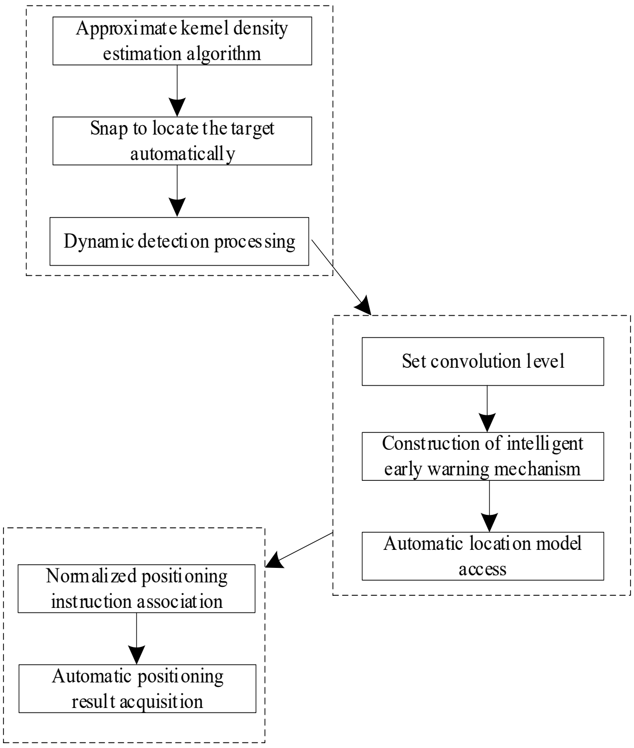

Figure 1: Structure diagram of automatic positioning model

According to the above requirements and standards, set the repository implementation indicators, as shown in Table 2.

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Table 2: Index setting table of data execution database

Order number	Valve positioning area of hydropower station	Abnormal induction times/time	Average warning time/s	Unit capture times/time
1	Fast gate	6	0.57	10
2	Penstock protection valve	3	0.25	9
3	Turbine inlet valve	3	0.41	9
4	Regulating valve	6	0.63	8

According to Table 2, you can complete the setting of data execution database indicators. In combination with the above positioning measurement status, the normal probability of positioning is calculated, which generally needs to be controlled between 85% and 92%. At this time, the measured positioning similarity of the hydropower station valve positioning area forms a reasonable automatic positioning normal processing environment, and completes the design of the automatic positioning normal processing structure.

3. Realize automatic location of multiple leakage points of hydropower station gate

3.1 Dynamic processing of approximate kernel density estimation algorithm

After completing the normal processing structure of automatic positioning, combined with the approximate kernel density estimation algorithm, this paper adjusts the basic execution environment of the automatic positioning method. Then, the measurement range of the automatic positioning method is set. The infrared ranging sensor is used to locate the nodes in the abnormal area of the hydropower station. Finally, the corresponding values and information are obtained based on the nodes, and a dynamic automatic positioning program is set using a wireless communication module. The measurement range of the automatic positioning method is gradually adjusted according to the positioning position and target changes. Instructions are issued for guidance, in order to further improve the effectiveness of automatic positioning.

After the hydropower station valve dynamic automatic positioning program is started, the program starts the system server to initialize the communication port configuration and start the communication transmission listening function. Judge whether there is a listening connection request in the current network. If there is, continue to listen. If there isn't, establish a communication connection. Then judge whether there is data on the current Sokcet port. If there is, continue to listen on the Sokcet port. If there isn't, receive the data. After decrypting the data, end the environmental monitoring data collection program. The dynamic process of approximate kernel density estimation algorithm is completed through the above steps.

3.2 Proportion of consistency coefficient of load distribution form of inlet ball valve of hydraulic turbine

Take a standard turbine inlet ball valve as an example, set the sectional switches on both sides of the turbine inlet ball valve to M_A and M_B respectively, G_A represents the power flowing through A and G_B represents the power flowing through B, use $M_B(\lambda)$ to indicate the load of the ball valve at the distance of λ from the M_B side. G represents the overall load supplied by the inlet ball valve room of the hydraulic turbine, in which the power loss along the hydropower station is not considered. From this, the distribution form of the basic load along the line of the hydropower station can be obtained, and the basic load distribution density function $\sigma(\lambda)$ of the hydropower station can be obtained on this basis:

$$\sigma(\lambda) = (M_A + M_A) \times \frac{M_B(\lambda)}{G_B} \times G \times (Z + V + B) \tag{2}$$

In formula (2), h, λ and L respectively represent the characteristic amplitude of the load distribution of the turbine inlet ball valve, the distance to the section switch side and the length of the turbine inlet ball valve. If the actual load distribution of turbine inlet ball valve is consistent with the above basic load distribution density function, then $H_i = H_{Li}$ can be determined under the corresponding load distribution conditions. However, if the actual load distribution of the inlet ball valve of the hydraulic turbine is significantly different from that of a certain type of load distribution, H_{Vi} and H_{Li} are also significantly different, and the more obvious the difference is, the more obvious the difference is between H_{Vi} and H_{Li}. Therefore, ζ can be used to represent the consistency coefficient between the actual load distribution of the turbine inlet ball valve and a certain type of load distribution. The formula is described as follows:

$$\zeta = W_H - \frac{H_{Li}}{H_{Vi}} \times \sigma(\lambda) \tag{3}$$

Under the condition that the actual load distribution of the inlet ball valve of the hydraulic turbine is completely consistent with the load distribution of a certain type, the ζ value is infinite. Therefore, the ζ value is determined according to different types of $\sigma(\lambda)$, and the load distribution with the maximum ζ value can be taken as the actual load distribution of the current turbine inlet ball valve [18].

Suppose K_b represents the weighting coefficient of a certain type of load distribution form, which can describe the proportion of the consistency coefficient of the load distribution form of the inlet ball valve of the hydraulic turbine in the overall consistency coefficient. The formula is described as follows:

$$K_b = \frac{\zeta}{\sum_{j=1}^{m} \zeta_j} \times r \times k \tag{4}$$

In formula (4), ζ_j represents the correction factor for the j th time; r represents the resistance per unit length of feeder; k represents reactance. Thus, the consistency coefficient proportion analysis of the load distribution form of the turbine inlet ball valve is completed.

3.3 Realize the automatic positioning process of multiple leakage points of hydropower station gate

On the basis of the results of the consistency coefficient of the load distribution form of the inlet ball valve of the hydraulic turbine, the approximate kernel density estimation algorithm is used for learning and training, and the final output of the automatic positioning results. The automatic positioning process of multiple leakage points of the power station gate is divided into three steps:

Step 1: Clear the influence of error information, set the triggering criteria of the diagnosis module according to the active line loss and voltage drop, and trigger the diagnosis module when the overall value of the detection alarm information is higher than the preset threshold.

Step 2: Collect the active line loss and voltage drop information of multiple leakage points of the hydropower station gate, and build the fault feature set.

Step 3: Take the fault feature set as the input of the approximate kernel density estimation algorithm, input it into the trained network model, and output the automatic location information of multiple leakage points of hydropower station gates, thus completing the automatic location research of multiple leakage points of hydropower station gates based on the approximate kernel density estimation algorithm.

4. Experimental analysis

In order to verify the application effect of this method in automatic positioning of multiple leakage points at a certain hydropower station gate, a certain hydropower station was taken as the experimental object. The total installed capacity of the hydropower station exceeds 250000 kW, including 4 sets of hydroelectric generators with a power generation time of 4396 hours and an annual power generation capacity of approximately 11.5 billion kilowatts. A simulation experiment was conducted using the MT3DMS module of GMS software, and the method was applied to the automatic positioning process of multiple leakage points in hydropower station gates, verifying the practical application effect of this method.

The approximate kernel density estimation algorithm is preferentially used to simulate and obtain the relationship between the valve control starting point and the end flow at the multiple leakage points of the hydropower station gate under different leakage conditions. The specific experimental results are shown in Figure 2 and Figure 3.

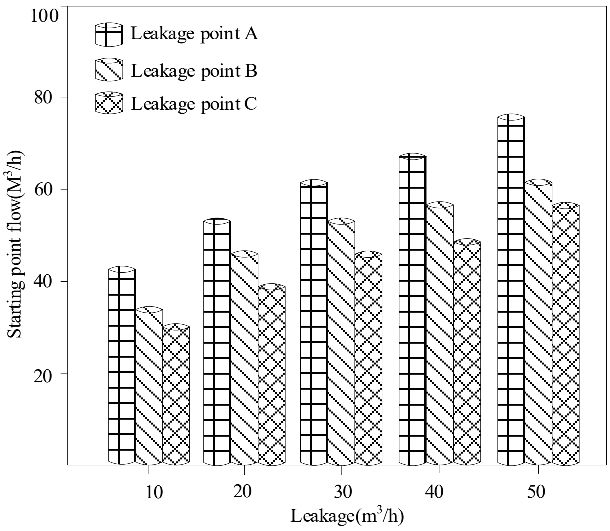

Figure 2: Effect of multiple leakage points on valve control starting point

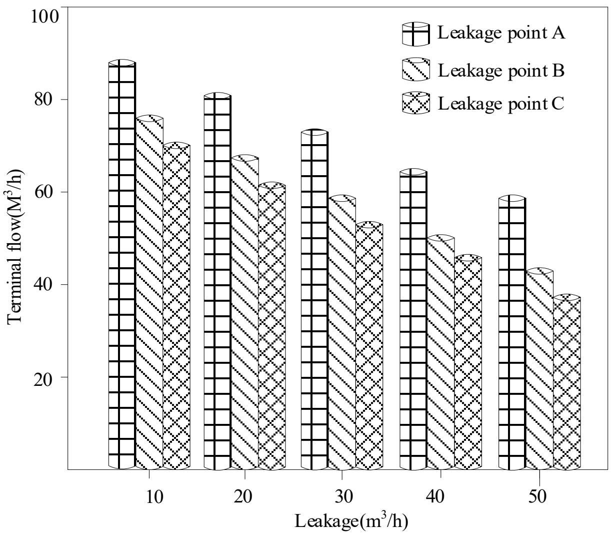

Figure 3: Effect of multiple leakage points on valve control end point

By analyzing the experimental data in Figure 2 and Figure 3, it can be seen that with the continuous increase of water leakage through the valve of the hydropower station, the flow at the valve control starting point is gradually increasing; The flow direction of the terminal point is gradually decreasing. The reason is that the method in this paper summarizes and integrates the relevant early-warning indicators of multiple leakage points of hydropower station gates, and uses software to gradually

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convert them into the execution instructions that can be recognized by the system in a specific format, and sets the system early-warning indicators, which to some extent is conducive to the rise of multiple leakage points to the valve control starting point and the decline of multiple leakage points to the valve control end point.

Three kinds of multi-leakage point data are set, which are normal data, data after physical reaction, and data after chemical and biological reaction, and are respectively represented by leakage point A data category, leakage point B data category and leakage point C data category. According to formula (1), the clustering effect of this method for different leakage point data categories is obtained, and the results are shown in Figure 4.

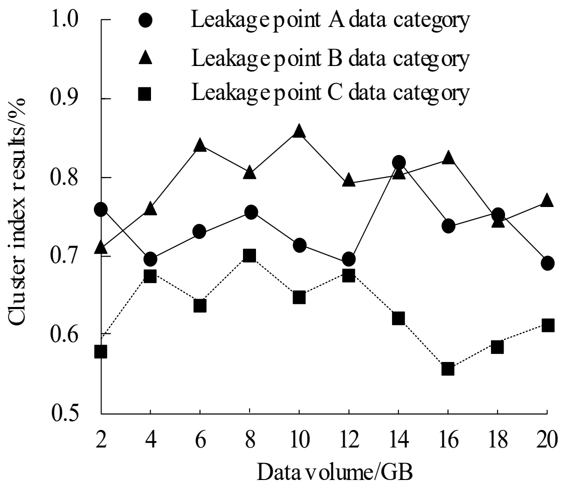

Figure 4: Clustering effect of multi-leakage point data

It can be seen from Figure 4 that the method in this paper is used to cluster the multi-leakage point data of three categories, and the clustering results are all lower than 1, the maximum value is 0.86, and the minimum value is 0.55. The method in this paper has good clustering effect, can complete the clustering of different types of leakage points data, and provide reliable results for the automatic location area calculation of multiple leakage points of hydropower station gates.

The performance of the proposed method is further verified. According to the test environment built above, the approximate kernel density estimation algorithm is integrated to verify the actual application effect of the automatic location method for multiple leakage points of hydropower station gates. Calculate the automatic positioning error of multiple leakage points of the hydropower station gate. the error comparison results are shown in Figure 5.

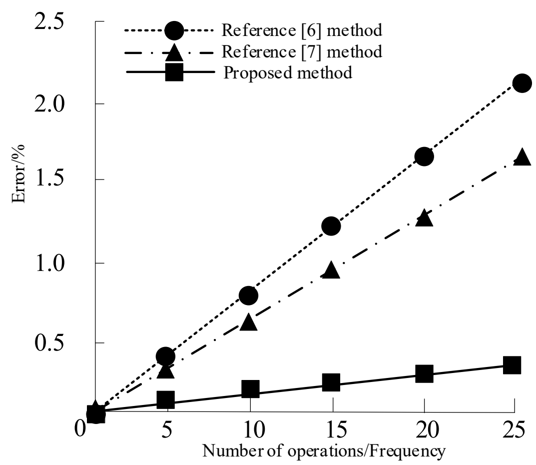

Figure 5: Comparison results of automatic positioning error of multiple leakage points by different methods

According to Figure 5, compared with the results of automatic leak point location error of the method in reference [6] and the method in reference [7], the proposed method has a small leak point location error value; The test results of automatic positioning error of multiple leakage points finally control the final error of 25 times well below 0.5%, while the error of 25 times of the reference method is finally controlled above 1.5%, indicating that the automatic positioning effect of the proposed method is better, more targeted, and has practical application value.

5. Conclusion

This paper proposes an automatic location method for multiple leakage points of hydropower station gates based on approximate kernel density estimation algorithm. The following conclusions are obtained through research:

(1) With the continuous increase of water leakage through the valve of the hydropower station, the flow at the valve control starting point is gradually increasing; The flow direction of the terminal point is gradually decreasing.

(2) The method in this paper is used to cluster the data of multiple leakage points of three categories, and the clustering results are all lower than 1, which has good clustering effect and can complete the clustering of different types of leakage points data, providing reliable results for the automatic location area calculation of multiple leakage points of hydropower station gates.

(3) The test result of the leakage point automatic positioning error finally controlled the final error of 25 times below 0.5%. The automatic positioning effect is good and has practical application value.

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