Multi-Physical Tracking and Sensing Technology of Switchgear Partial Discharge Based on Edge Computing and Smart Gateway

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Abstract. In view of the high bottleneck of current partial discharge detection technology, strong professionalism and heavy detection tasks, the partial discharge process is greatly affected by the equipment operating environment and condition factors. The paper proposes a switching device partial discharge multiphysics based on edge computing. Research on perception and state tracking technology. The article aims at the edge computing technology of multi-physical partial discharge signal feature extraction, the construction of multi-physical tracking over-limit early warning model, and the development and trial production of intelligent gateway technology. The research found that the edge computing algorithm proposed in the paper can effectively reduce the cost and power consumption under the premise of ensuring the performance of the detection system.

Keywords. Edge computing, smart gateway, switch equipment, physical tracking and sensing technology.

1. Introduction

The construction of the power Internet of Things is an important content of the country's new digital infrastructure, and an important measure for the country to promote industrial transformation and upgrading and drive the economy to achieve leapfrog development. High-voltage switchgear is a key component of power system control and protection, especially the distribution network switchgear equipment is large in quantity and wide-ranging, the equipment types are many and scattered, the cost is low, the reliability is poor, and the distribution network operation and maintenance force is weak, resulting in the failure rate of the distribution network equipment high [1]. Partial discharge detection is an important core method for insulation monitoring and state operation and maintenance of high-voltage switchgear. It has the obvious advantages of high sensitivity and strong timeliness.

In order to effectively prevent defects in switchgear caused by insulation aging and deterioration, which may cause production accidents, in accordance with the requirements of the State Grid Corporation of Chinese major anti-accident measures, in-depth research on the multi-physical perception and analysis technology of partial discharge based on the Internet of Power Accurate identification of insulation status and early warning of faults are very important for improving the
reliability and economy of switchgear operation, ensuring the safety of power production, promoting the transformation of power grid enterprise management and operation and maintenance, business upgrading, and improving user experience and corporate social image meaning [2]. Therefore, how to effectively reduce costs and reduce power consumption under the premise of following the scientific laws of partial discharge detection and ensuring the performance of the detection system, and using the Internet of Things technology to solve the problems of partial discharge intelligent perception and status warning is the project that needs to be faced and solved. The key problem. This paper discusses the edge computing technology based on the edge computing and diagnosis model for the feature extraction of multi-physical partial discharge signals. At the same time, it proposes the construction of the multi-physical tracking over-limit warning model, which realizes the low cost of the switchgear partial discharge multi-physical tracking and sensing system and high-efficiency.

2. Switchgear partial discharge multi-physical sensing and state tracking technology

Ultrasonic, high-frequency current and ground wave smart terminals are designed with a unified hardware architecture, and each smart terminal is synchronized through wireless phase, based on the LoRA communication method to realize the communication connection between the smart terminal and the edge computing gateway, and the signal conditioner of different principles the module is integrated in the single board system [3]. The hardware architecture of the integrated intelligent terminal is shown in Figure 1.

![Figure 1. Hardware architecture design of integrated smart terminal](image)

The low-power MCU adopts K64 series processing, has ultra-low standby power consumption, and a high-bandwidth AD acquisition controller, which can ensure low power consumption while meeting the terminal's acquisition requirements; Lo-Ra plans to use SX1268 and use the 470mHz frequency band for communication, the design receiving sensitivity is -127dbm, and the transmission power is up to 20dbm, and the line-of-sight from the terminal to the gateway can be more than 2000m. The key consideration in the design of this smart terminal is based on the random and intermittent characteristics that may appear in the partial discharge of solid insulation defects under the operating voltage for a long time, emphasizing the real-time nature of embedded processing, that is, it can realize the sequence pulse capture mode to achieve arbitrary Non-lost acquisition of occasional pulses. In order to realize the effective acquisition of sparse discharge, an adaptive variable time length acquisition reprocessing algorithm based on the present number of pulses is proposed, which greatly improves the accurate detection of sparse discharge and effectively avoids sudden flashovers [4]. The occurrence of the failure.

3. Research on in-situ extraction technology of simplified state features of partial discharge multi-physical signals

The simplified state characteristic data set of high-frequency/TEV signal, extract the phase and amplitude (ϕ, V) of the discharge pulse, form a two-dimensional number table of length N, and upload it to the edge computing gateway. In addition to extracting the phase and amplitude (ϕ, V) sequence of
the discharge pulse, the simplified state present feature data set of the ultrasonic signal also needs to further extract the first 5 main frequencies of the signal and its corresponding peak value. Form two two-dimensional data tables and upload them to the edge computing gateway.

3.1. The multi-physical characteristics of the partial discharge development process of the typical defect model of the switchgear

This project intends to build a typical partial discharge model of defects based on the above-mentioned switchgear defect statistical analysis [5]. By applying constant AC voltages of different voltage levels, three methods of high frequency, TEV, and ultrasound are used to detect the signal from the beginning to the breakdown of the defect. Obtain the statistical characteristics of multi-physical quantities in the whole process of typical defect discharge, study the changing laws and characteristics of these characteristic quantities, and perform early warning of dangerous discharge based on the identification of the development stage state of the discharge characteristic parameters, as shown in picture 2.

![Diagram](image)

**Figure 2.** Multi-physical characteristics research on the whole process of partial discharge development of the typical defect model of switchgear

3.2. Data analysis

Figure 3 shows the variation process of the statistical parameters of the number of discharges with time under four voltages [6]. Among them, the number of test discharges with an applied voltage of 90% breakdown voltage is irregular, and the overall number of discharges fluctuates greatly, with a downward trend; The test discharge times with applied voltage of 85%, 75% breakdown voltage, and 70% breakdown voltage show significant phase characteristics, and the different phases correspond to the normal discharge degradation and high breakdown risk phases respectively.
4. Research on smart gateway technology based on edge computing and diagnosis model

4.1. Edge Computing Technology

Develop algorithm modules with the following functions on the intelligent gateway of the aggregation unit: data collection and storage management module, data upload module, horizontal statistical analysis of different intelligent terminal data, and risk assessment algorithm module based on status identification of the discharge phase.

The Sobel operator is one of the most commonly used operators in edge detectors. It uses neighborhoods to avoid calculating gradients at interpolated points between pixels. Usually, two convolution kernels $h_1$ in equation (4) are used. And $h_2$ respectively detect the horizontal and vertical edges of the image.

$$
\begin{align*}
    h_1 &= \begin{pmatrix}
        1 & 2 & 1 \\
        0 & 0 & 0 \\
        -1 & -2 & -1
    \end{pmatrix},
    h_2 &= \begin{pmatrix}
        -1 & 2 & 1 \\
        -2 & 0 & 2 \\
        -1 & 0 & 1
    \end{pmatrix} \\
\end{align*}
$$

(1)

If the response of $h_1$ is $x$ and the response of $h_2$ is $y$, the amplitude can be obtained according to the following formula:

$$
\sqrt{x^2 + y^2} OR |x| + |y|
$$

(2)

And the direction is $\tan^{-1}(y/x)$. The result of the calculation is an edge amplitude image.

Laplace operator is based on the two-dimensional equivalent of the second derivative based on the above principle. The Laplacian formula of the function $f(x, y)$ is:

$$
\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}
$$

(3)

Use the difference equation to approximate the second-order partial derivatives in the x and y directions as follows:

$$
\frac{\partial^2 f}{\partial x^2} = \frac{\partial (f[i,j+1]-f[i,j])}{\partial x} = (f[i,j+2]-2f[i,j+1]+f[i,j])
$$

(4)
This approximation is centred on point \([i, j + 1]\) and replace \(j\) with \(j - 1\) to get:

\[
\frac{\partial^2 f}{\partial x^2} = (f[i, j + 1] - 2f[i, j] + f[i, j - 1])
\]

(5)

It is an ideal approximation of the second-order partial derivative centred on point \([i, j]\), similarly,

\[
\frac{\partial^2 f}{\partial y^2} = (f[i + 1, j] - 2f[i, j] + f[i - 1, j])
\]

(6)

Combining these two expressions into one operator becomes the following template that can be used to approximate the Laplacian operator:

\[
\nabla^2 \approx \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}
\]

(7)

4.2. *Construction of multi-physical quantity tracking over-limit early warning*

Based on the extraction and selection of characteristic parameters of discharge data, the diagnosis of discharge development stage is based on support vector machine (SVM). The specific operation steps are as follows: (1) From the discharge data of each stage of each group of tests in each, 80% of the data are selected as training samples, and the other 20% are used as identification samples. (2) Perform feature extraction and feature selection for training samples and recognition samples. (3) Use training samples as the input of SVM to train the model and save the trained samples. (4) After the recognition data is normalized, it is used as the input of SVM, and the trained model is used for recognition. The recognition effect is shown in Table 1 below:

| Training data          | Test Data               | Number of test samples | Recognition accuracy |
|------------------------|-------------------------|------------------------|----------------------|
| Discharge data under 85% Ub | Normal degradation stage | 300 groups             | 92.54%               |
|                        | High risk stage         | 300 groups             | 97.93%               |
| Discharge data under 80% Ub | Normal degradation stage | 300 groups             | 98.33%               |
|                        | High risk stage         | 300 groups             | 95.33%               |
| Discharge data under 75% Ub | Normal degradation stage | 300 groups             | 93.68%               |
|                        | High risk stage         | 300 groups             | 99.33%               |
| Discharge data under 70% Ub | Normal degradation stage | 300 groups             | 97.66%               |
|                        | High risk stage         | 300 groups             | 90.41%               |

It can be seen from the above table that the diagnostic accuracy rate of all types of creeping discharges in the development stage is above 90%. Therefore, it can be considered that the feature parameters, feature selection methods, and classifiers used in this project plan are useful for the diagnosis of the development stage of air gap discharge Better recognition effect [7].

4.3. *Lo-Ra Data Gateway*

The gateway is planned to use high-performance ARM to support 3G/4G and wired network communication functions. The Lo-Ra part matches the terminal Lo-Ra function. The functional block diagram is shown in Figure 4.
Figure 4. Block diagram of the smart gateway

The gateway has no sleep and low power consumption mechanism, maintains an online monitoring state, and can send and receive data in real time. The gateway uses external power supply and uses a continuous working mode to monitor the messages sent by the terminal in real time, and forward it in real time, so that the cloud can receive the data and analysis results collected by the terminal in a timely and accurate manner; the terminal adopts a low-power timing working mode, the terminal has several built-in timers, which are collected by the timer trigger device [8]. When the timer is triggered, the terminal starts and continuously collects several time data, then analyses and processes the data, and finally sends the processing results to the gateway. After a successful transmission, it immediately enters the low-power working mode until a timer trigger.

5. Conclusion
Intelligent sensing terminals are the key infrastructure for the transition from the traditional power grid to the energy Internet. The realization of the re-technical innovation of traditional sensing through edge computing technology is conducive to the rapid development of the industrial Internet industry. This paper studies the edge computing technology for intelligent sensing, discusses the framework of intelligent sensing edge computing, the optimized transmission method of multi-parameter sensing data, and the cloud-side collaboration mechanism, and proposes the design method of multi-parameter sensing algorithm. Parameter tracking perception application. Practice has proved feasible. In the future energy Internet construction, it is necessary to further optimize the cloud-side collaboration mechanism, expand the application range of edge computing technology, continue to enrich the algorithm warehouse in the field of power generation, transmission, transformation and distribution, and implement demonstration applications in related scenarios.

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