Research on Transformer Relay Protection System Based on Ubiquitous Power Grid Technology

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Abstract. Things are ubiquitous power system as the core power, combined with intelligent sensor terminal, a communication network, the network flow system more complicated artificial intelligence technology and internet cloud configuration, having a holographic perception, ubiquitous connection, open sharing, innovative features fusion. Where the grid-based networking technology, system components paper analyses imprecision transformer relay fuzzy theory, a reliability model corresponding relay, and more truly reflect the reliability of the system.

1. Introduction
Things are ubiquitous power system as the core power, applied in the power system, and its essence is to achieve a variety of sensing devices to share information and resources of the communication information, so as to form a physical entity having a self-identification, intelligent sensing and processing. Synergy and interaction between entities, objects related to each other so that perception and feedback control, a more intelligent form of electricity production and living system. Therefore, the combination of Things technology will be ubiquitous existing power system built into the pan in the power of Things is the future development trend of electric energy systems, as well as the current stage of the national grid most urgent and important task.

2. The basic concept and system architecture of ubiquitous power IoT

2.1. Basic concepts
Pan in the power of things can be defined as: The "Big Clouds move Chi" and other modern information technology and advanced communications technology, energy power line connected to people of all sectors of production and consumption, machine, material, carrying through the production of grid operation, business data flow and business flow management and external customer service, state of the power system to achieve a comprehensive perception, information processing and efficient, convenient and flexible application of a new generation of information and communication systems [1].

2.2. Ubiquitous power IoT system architecture
Ubiquitous things as power is applied to the grid industrial things, in its architecture extension layer followed perception of things, the underlying network transport layer and application layer internet on the three-tier structure, the edge computation layer increases. As shown in Figure 1.
In the context of a high proportion of renewable energy, electricity market reform, and "Internet +" smart energy, a large amount of basic small data needs to be connected, and the value density of a single data is low, but massive data has great value, and UPIoT is to achieve an important way to connect basic data. These large amounts of data mainly include small data connections on the user side of energy and power and small data connections in various links of energy and power transmission and distribution. There are many types of small data on the user side, mainly involving households, various buildings, agricultural and industrial enterprises, public infrastructure, etc. Energy consumption main body; The small data of transmission, transmission, distribution and distribution mainly involve environmental data, equipment status data, auxiliary facility status data, electrical facilities micro-meteorological data, etc. Figure 2 shows the relationship between the ubiquitous network, the Internet of Things, and the sensor network. It can be seen from this that UPIoT is based on the Internet of Things.

Figure 1. Basic architecture of ubiquitous power IoT
2.3. **Key technologies of ubiquitous power IoT**

2.3.1. *Smart chip.* With the continuous development of the power system, more and more equipment such as metering, protection, transformation, control, monitoring, and power consumption are connected to the power system. The operation of various power equipment generates a large amount of data. At present, most on-site data collection equipment is still the industrial acquisition device based on transmission that has poor data reliability and low accuracy, which also makes the terminal equipment less intelligent. Micro-intelligent sensors and intelligent terminals based on smart chips can fully solve this problem. They have high precision and low power. The features of consumption, miniaturization and intelligent computing can, on the one hand, complete the collection, extraction and transmission of device information; on the other hand, through local edge computing, the terminal can be intelligent and complete the local self-control, thereby eliminating the need for telemetry without the remote control function.

2.3.2. *Internet of Things platform.* With the massive data of the power system connected to the integrated data platform, through the rational analysis and deep mining of large amounts of data, the effective use of power information can be realized. The integrated data platform should have big data processing and cloud computing, as well as artificial intelligence capabilities to realize landscape forecasting and power system fault diagnosis. At present, Baidu's "Tiangong" intelligent IoT platform, mobile One NET IoT platform, Ali link IoT platform and other integrated data platforms have been successively applied in production practice. Mobile One NET cooperated with "Hi" Electric to help them solve the problems of "equipment status detection", "equipment location supervision", "equipment information management" and "reverse control equipment".

3. **Key technology of transformer relay protection system based on ubiquitous power Internet of Things**

Driven by the energy revolution, a high proportion of intermittent renewable energy sources such as wind power and photovoltaics with randomness and volatility will bring challenges to the safe and stable operation of the power system. It is the current generation, transmission, transformation, distribution the four major business scenarios need to be solved urgently. The construction of the ubiquitous power Internet of Things should obtain meteorological environment data in real time by widely deploying sensor devices such as anemometers, wind vanes, and illuminance collectors, and apply machine learning, big data analysis and other technologies to achieve renewable accurate prediction of energy output, based on comprehensive monitoring of the operating status of the source, network, load and storage, combined with real-time analysis of ultra-real-time calculations on the entire network information, online dynamic calculation of power flow, quantitative assessment of system security situation and wide-area intelligent collaborative control To improve the safety and economy of high-ratio renewable energy power systems.
In addition, the intelligent operation and maintenance business of generator sets, transmission lines, substations and distribution networks are also one of the construction priorities of the ubiquitous power Internet of Things in the field of system operation control. Ubiquitous Power Internet of Things can issue fault warnings in time based on the system's comprehensive perception and monitoring data, and use fuzzy theory to intelligently diagnose the source of the fault, while quickly isolating the fault and achieving self-recovery, combined with network topology information, considering personnel skills constraints, materials Available constraints, through an intelligent optimization algorithm, make a repair plan. At present, the Ningxia power transmission equipment and line status monitoring system demonstration project has achieved real-time diagnosis and risk assessment of the status of power transmission and transformation equipment. The demonstration project of the Fujian power transmission line UAV intelligent patrol system is also based on the UAV sensor system. A special UAV flight control system suitable for the inspection of mountainous power grids is developed [2]. The overall system architecture is shown in Figure 3.

![Figure 3. Overall structure](image)

In the transformer relay protection system, the cloud integration solution of the CLAA alliance is adopted, and the black boxed IoT terminal in the unlicensed frequency band is adopted to realize the rapid, flexible, low-cost, wide-coverage, and low-power UPIoT deployment. The core work of UPIoT is to complete the function of data distribution between IoT terminals and applications to ensure reliable and low-cost data transmission. Both applications and terminals need to register with the Internet of Things Centre to establish associations. At the same time, multi-service applications share a unified Internet of Things, reducing construction and operating costs. The above functions and requirements can be realized through different network elements. Such network elements are as follows: Internet of Things base station (IWG), multi-service platform (MSP), flexible UPIoT cloud, authentication centre...
(AUC), network management system (NMS), location Computing server (LCS), business operation support system (BOSS), business roaming exchange server (SRX). The core architecture of the CLAA relay protection system based on Lora is shown in Figure 4.

Figure 4. LoRa-based CLAA relay protection system core architecture

The terminal node samples the data to be collected, and transmits the collected data to the Lora base station through the Lora terminal radio frequency module. The parameters to be collected change with the application scenarios of UPIoT. The parameter types include electrical parameters, non-electrical parameters and other types of parameters. Electrical parameters include AC quantity (4 Bytes), DC quantity (4 Bytes), and switching quantity (1 Bit), and state quantity (1 Bit), control quantity (1 Bit). Non-electrical parameters include analog (4 Bytes) and state (1 Bit). Other types of parameters include measurement data (4 Bytes), gear data (1 Bytes or multiple Bytes). By collecting these data, wait until the system is running, and get the best control decision. The sensor collects the data and transmits the related data to the base station via LoRaWAN after processing. The base station implements protocol conversion and transmits it back to the server via GPRS or Ethernet. There are two main ways to report data from the terminal collection node: one is to report data regularly, generally less than 10 minutes, and several hours or one day; the other is that the master station actively calls the terminal node to upload data, and the collection terminal responds to the master Commands issued by the station to upload data. The data transmission rate is related to the data type and collection frequency, and the data traffic being transmitted changes with different application scenarios. Table 1 shows the network capacity of one base station in the CLAA network [3].

Table 1. Network load and capacity example table

| Data length | Packet frequency | Channel load | Spreading factor | Air delay / ms | Transmission rate / (kbit / s) | Network capacity |
|-------------|-----------------|--------------|-----------------|---------------|-------------------------------|-----------------|
| 8           | 60 times / h    | 30%          | 7               | 36.1          | 5.47                          | 3 989           |
| 16          |                 |              | 7               | 51.5          | 5.47                          | 2 796           |
| 32          |                 |              | 7               | 71.9          | 5.47                          | 2 003           |
|             |                 |              | 12              | 1 155.1       | 0.29                          | 125             |
|             |                 |              | 12              | 1 646.6       | 0.29                          | 87              |
4. Modelling and simulation of transformer relay protection system

4.1. Model building and simulation analysis

In the dual-machine system shown in Figure 5, Me and En are the potentials of the two systems, Zm and Zn are the system impedance, and R and XL are the line resistance and reactance, respectively. A single-phase ground fault occurs at point k in the line, and it is simulated. The required parameters can be freely selected [4].

![Figure 5](image)

**Figure 5.** When the power system fails

The data of the fault voltage and current obtained by the sampling system is a periodic function. The periodic function contains not only the fundamental component, but also the DC component and each harmonic component. Suppose the obtained signal periodic function is \( f(t) \). If \( f(t) \) satisfies Dirichlet condition, then \( f(t) \) can be expanded into a triangular Fourier series. The expression is:

\[
f(t) = a_0 + \sum_{n=1}^{\infty} \left( a_n \cos n\omega_0 t + b_n \sin n\omega_0 t \right)
\]

(1)

Among them

\[
a_0 = \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} f(t) dt
\]

(2)

\[
a_n = \frac{2}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} f(t) \cos n\omega_0 t dt
\]

(3)

\[
b_n = \frac{2}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} f(t) \sin n\omega_0 t dt
\]

(4)

\( \omega_0 = \frac{2\pi}{T} \) is the fundamental frequency, sometimes referred to as fundamental frequency.

1) Take the single-phase ground short-circuit fault as an example, in the case of A-phase metallic ground short-circuit

\[
\frac{U_{m}}{Z_{m}} = (I_{z} + K \times I_{k}) z_{L} L_{k}
\]

(5)

The measured impedance calculated by \( U_{m}, I_{m} \) can accurately reflect the distance of the fault, so that the fault section can be compared and judged.

2) Two-phase ground fault

When a metallic two-phase ground short-circuit fault occurs in the system, the voltage of both ground phases at the fault point is 0. Taking A and B phase grounding as an example, there are

\[
\frac{U_{m}}{I_{m}} = z_{L} L_{k}
\]

(6)
Both formulas have the same form as (6), so the measurement and judgment made by these voltages and currents can correctly reflect the fault distance.

In addition, subtracting (7) and (8), we can get

$$U_{m1} - U_{mB} = (I_{m1} - I_{mB})zIL$$

Let $U_{mAB} = U_{mA} - U_{mB}$, $I_{mAB} = I_{mA} - I_{mB}$, also get the same form as equation (8), so using them as the distance protection measurement voltage and measurement current can also correctly determine the fault distance.

### 4.2. Operation result

Set phase A to have a single-phase ground short-circuit fault within 0.2-0.3s. The first line of the sampling diagram is the time vector, the second line is the collected voltage vector, the fifth line is the current vector, and the collected voltage and current are visually represented in the form of a graph. Changes in current.

![Three-phase current waveform](image)

**Figure 6.** Three-phase current waveform

The simulation waveform is shown in Figure 6. From the figure, it can be seen that when a single-phase ground fault occurs in phase A, the current in phase A increases significantly, while the current in two phases B and C remains basically unchanged, and it is still the load current; The voltage has a significant voltage drop, while the B and C phase voltages remain basically unchanged [5].

### 5. Conclusion

The intelligent operation inspection management system of relay protection based on the Internet of Things technology uses the application mode of mobile terminals closer to the smartphone, which achieves the purpose of "easy to use, easy to use and practical" of the system; and uses real-time interactive means and network Information technology realizes the process management and control of the standardized operation of intelligent transportation inspection. The system greatly improves the safety and efficiency of on-site work and improves the safe operation of the power grid. With the further application of the Internet of Things technology, it will promote the revolutionary development of
intelligent transportation inspection and lay a solid foundation for the final realization of the global energy Internet.

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