Research and Design of Cable Partial Discharge Online Monitoring Technology Based on GPS Clock Wireless Synchronization

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Abstract. A prototype of cable partial discharge online monitoring system was presented in this paper, including partial discharge sensor, partial discharge collector, GPS wireless synchronization system, centralized monitoring host and operation software. Real-time cable partial discharge monitoring data transmitted wirelessly, analyzed by platform software, and output information of time domain waveform, frequency waveform, discharge quantity, PRPD spectra of discharge number-discharge quantity-power frequency phase, locating information of partial discharge, history record and query of partial record and alarm severity of partial discharge.

Introduction

With the rapid development of the modern cities, 10kV or higher voltage classes’ cables are applied for electric power transmission in recent years. The civilian and industrial electricity consumption increased and the length of the electric cables were longer, which brought a huge pressure on the operation and maintenance of the electric system. Nowadays, the main method of high-voltage cables’ management in China is periodical inspection and maintenance, which consuming a lot of manpower and material resources, but the fault points can’t be found easily by naked eyes, the effect was not satisfactory. And the fault points can’t be removed rapidly, result in a low level of customer service quality. Due to the geographical condition, cables in some city areas have to be laid parallel at the same place, which leads to overheating and cable fault, reducing power supply reliability [1-4].

Based on high-frequency Rogowski Coil partial discharge pulse extraction technology, high speed sampling technology, high-speed modern wavelet-based data processing technology and GPS-based nanosecond wireless clock synchronization technology, a partial discharge online monitoring system was researched and designed for electric cable in this paper.

Research of Online Monitoring System

Application of Partial Discharge Monitoring System in Distribution Network

The partial discharge sensor is a Rogowski Coil using high-frequency ferrites as magnetic core, in other word, a core through typed current transformer with high-frequency magnetic core. First, the partial discharge pulse in cable shielding layer pass through partial discharge sensor, then detecting whether the partial discharge exists by measuring pulse signal and voltage signal in secondary coil. For convenience of field installation, partial discharge sensor applied split iron core gripper, assembled on grounded cable, real-time detecting the pulse signal from partial discharge points, coupling output, monitored and analyzed by analysis software.

GPS-based Nanosecond Wireless Clock Synchronization Technology

In order to overcome locating failure caused by cable partial discharge single-ended monitoring and pulse interference made by nearby electric devices, the signal sampling of the partial discharge
collector on both sides of the cable must be started at the same time. The locating of partial discharge is realized through time difference and the speed of partial discharge pulse in cable is $2.0 \times 10^8$ m/s, in order to ensure the locating accuracy, the paired collectors’ synchronization accuracy must be nanosecond level. But the technical difficulty of high precision clock synchronization of paired collectors with distance of hundreds meters or more can’t be solved easily. Optical fiber based nanosecond level clock synchronization technology is applied in cable partial discharge online monitoring system now. But the optical fiber laying must consider the actual conditions of the field, when optical fiber lying is not permitted, the realization of clock synchronization have to be wireless way. The main methods of wireless clock synchronization include wireless network+IEEE 1588 standard, GPS timing and synchronization technology and GPRS/3G wireless clock extraction technology. Considering the costs and clock accuracy requirement, GPS timing and synchronization technology is most suitable for our scheme.

**Locating Principle of Electric Cable Partial Discharge**

![Figure 1. Locating principle of electric cable partial discharge.](image)

**The Mass Data Wireless Transmission Technology**

Considering the actual conditions of the field, some functions, such as wireless clock synchronization and wireless data transmission, are needed in partial discharge collectors. Normally, the acquisition time of partial discharge signal sampling require at least one circle, so the capacity of collected data will be more than 2M bytes based on 100MSPS sample rate. It’s necessary to choose an appropriate public network GPRS/3G technology to transmit the data to the centralized monitoring host reliably in a short time.

**Development of Application Software Based on QT and Database**

All the data collected in the partial discharge monitoring system should be transmitted to the centralized monitoring host, after analyzing, information of time domain waveform, frequency waveform, discharge quantity, PRPD spectra of discharge number(N)-discharge quantity(Q)-power frequency phase($\Phi$), locating information of partial discharge(N-L spectra and Q-L spectra), history record and query of partial record and alarm severity of partial discharge will be output. Analysis result should be stored in database and displayed in the interface of QT development.

**Online Monitoring System and Data Analysis**

Considering the actual conditions of the filed, the function of real-time online monitoring is necessary in the cable partial discharge monitoring system. First, the centralized monitoring host sends synchronous sampling commands to the partial discharge collectors, which are synchronized by GPS
clock, and then the collectors start to collect the signals sent from partial discharge sensors. The pre-treatment of the data should be done by the collectors, and the pre-treated data should be sent to the centralized monitoring host wirelessly for further treatment by partial discharge monitoring software. The partial discharge information of the monitored loop will be analyzed, such as discharging quantity, location of partial discharge and discharge type. For the cable with more than one segment, monitoring of the partial discharge should use relay mode, the collector in the middle can send data to the neighbor collectors on both sides. The structure of the system:

![Figure 2. Structure of the system.](image)

The principle of Synchronization based on the GPS clock:

![Figure 3. Synchronization based on the GPS clock.](image)

In Fig. 3, APD120D is cable partial discharge collector[5, 6], the two collectors for synchronization arranged on both sides of the monitored cable as host and slave with a proper distance (generally 500m) and synchronized by receiving the clock information sent from GPS terminal with accuracy of 25ns. To ensure accuracy, after receiving the sampling command sent by the centralized monitoring host, the sampling data will be sent back with timestamp which generated by the collector. GPS clock system have three synchronization modes, synchronized pulse output, serial time data output and IRIG-B code[7]. In synchronized pulse output mode, the synchronous clock will send an accurate synchronous pulse with a certain time interval to the receiving device for time setting to eliminate the time error. But time information can’t be provided directly, if an error occurred in synchronous clock, the whole system will also have an error. In serial time data output mode, the time information will be output as a serial data stream to the receiving devices per second for time synchronization, but the time errors will occur in the device clock in the time interval. The serial time data output mode is more
complex than the synchronized pulse output mode, and the time that information processing cost also affects the accuracy of synchronization. Thus the major function of serial time data output mode is to add timestamp for the events. Meanwhile, to increase the accuracy of time, the synchronizing pulse signal should be given when applying serial time data output mode in the field.

Figure 4. Location performance of cable partial discharge monitoring.

Figure 5. PRPD spectra based on analysis of N-Q-Φ.

For data integration and the expansion of management services, monitoring platform should have open service interface to adapt to the communication interface of existing comprehensive monitoring system, integrated substation automation system and comprehensive cable monitoring system. The functions of dynamic analysis, correlation chart and curve display are needed for the analog quantity and digital quantity required for cable operation. The platform should meet the users’ monitoring requirement for video, image and real-time data, and the functions of interface alarm, voice notification and SMS alarm are also needed.
Summary

In this paper, a prototype of cable partial discharge online monitoring system was studied, including partial discharge sensor, partial discharge collector, GPS wireless synchronization system, centralized monitoring host and operation software. In this system, real-time cable partial discharge monitoring data transmitted wirelessly, analyzed by platform software, and output information of time domain waveform, frequency waveform, discharge quantity, PRPD spectra of discharge number (N)-discharge quantity (Q)-power frequency phase (Φ), locating information of partial discharge (N-L spectra and Q-L spectra), history record and query of partial record and alarm severity of partial discharge.

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