UHF 기술을 이용한 온라인 부분방전 모니터링

論 文
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On-line Insulation Diagnostic by PD Monitoring Field Practical of UHF Technique for On-line PD Monitoring

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Abstract - A field-oriented UHF system for on-line PD monitoring of transformers is designed, which has been installed inside the oil tank of transformer in a substation by two ways: on-line installing mode through the oil-valve and pre-installing mode through the man hole/hand hole cover. This system has successfully captured long intermittent discharge signals that hadn't been detected through conventional techniques, and solved the problem successfully. The results demonstrate that UHF technique has great advantages for on-line PD monitoring of transformers. By adopting the peak detection technique, it becomes easy and effective for the transplantation of the phase-resolved pattern recognition technique from conventional method to UHF method, and then to realize continuous on-line monitoring, source characterization and trending analysis.

Key Words : Power Transformer, On-line Monitoring, Partial Discharge, UHF; Field Test

1. Introduction

As a new partial discharge detecting method, UHF technique has been developed rapidly since 1980s. Because the wave-guide structure of GIS, which is extremely appropriate for the propagation of UHF signals, the application of UHF PD detecting technique on GIS has become great successful, and its on-line sensitivity can reach 1 pC. In the UK, diagnostic couplers are specified for all new GIS, and UHF techniques are used extensively in factory testing, site commissioning and during the service life of the GIS. So far, UHF technique has been applied in the PD detection of many power equipment, such as cable, generator and transformer, etc[1].

The studies of UHF partial discharge detection technique mainly concentrate on the following aspects: sensor design、optimization and calibration [2-6], UHF radiation and propagation mechanism, PD source characterization and fault location[7-8]. In addition, some researchers use UHF method as an anti-interference tool for the conventional technique. Of course, most of the researches are specially developed for GIS, but as a matter of fact, many of the above techniques can be used to transformers. In 1996, Rutgers firstly explored the feasibility of using UHF technique in transformers[9].

After that, many people made deep researches into this project, and good results is obtained both in laboratory and field practices [10-14]. As for practical use, phase-resolved pattern recognition and trending analysis are the most useful tools for UHF method, just as it is for traditional technique. But because the original UHF signal is very fast, only lasts for the magnitude of nano seconds, it is extremely hard to correlate it with power cycle. At present, people mostly fulfill this function by using the POW mode of the spectrum analyzer, but it's a rather luxury approach and inconvenient at the same time. The peak detection technique is very effective to condition the UHF signal and can accomplish the same function as SA quite easily.

This paper adopts the peak detection technique in the field-oriented UHF on-line PD monitoring system of transformers, then the two practical working instances are introduced in detail, the results indicate the effectiveness of the UHF technique and its superiority over conventional methods.

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2. Experimental

2.1 The configuration of the system

The system includes two main parts: the stationary continuous-working equipment that deals with the UHF peak detection signals, and the movable instrument that analyzes the original UHF signals in time domain as well as frequency domain. The stationary equipment is a self-developed industrial PC system, which is made up of a fast DAQ card and real-time analyzing software. While the movable part is a high quality digital oscilloscope that works in "plug and play" mode. Fig.1 shows the diagram of the system configuration.

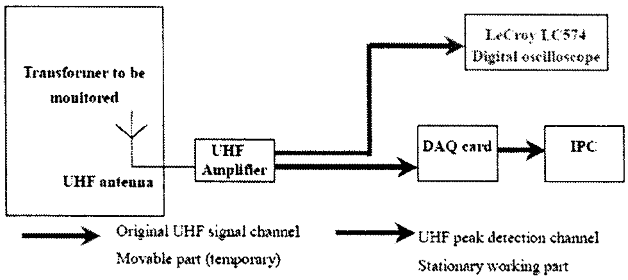


Fig. 1 Block diagram for field UHF PD on-line monitoring system.

2.2 Hardware Components of The System

The hardware components mainly consist of UHF sensor, UWB amplifier with peak detection module, RG142/U cables, high-speed DAQ card, IPC and digital oscilloscope, the bandwidth ranges from 400M~1500M Hz. UHF sensor is a self-compensative Archimedes antenna fed by a 50Ω coaxial cable, which is matched through a 4:1 wide band ferrite-core transformer. Figure 2 shows the SWR property of the UHF sensor. The gain of the amplifier is 40dB with the same working frequency band, and there're two channels output, one is the original UHF signal and the other is the UHF peak detection signal. The function of DAQ card is to sample the UHF peak detection and the reference phase signal with the max sampling rate 20MS/s per channel. The oscilloscope is LeCroy 574A model with 4GS/s single-shot sampling rate and 1GHz analog bandwidth, which is used to process the original UHF signal.

2.3 The UHF Peak Detection Technique

Usually in the practices of UHF, the phase information of the PD is obtained by using a SA that is set to POW mode. When considers the cost factors and the convenience reasons, the SA does not suitable to be used as a component of the stationary equipment, so the peak detection technique is adopted to condition the original UHF signals, which not only maintains the phase and magnitude info, but also lower the requirements for the digital sampling rate greatly. By doing this, the cost of the device is reduced to the maximum extent, and the traditional phase-resolved pattern recognition technique can then be transplanted to the UHF method.

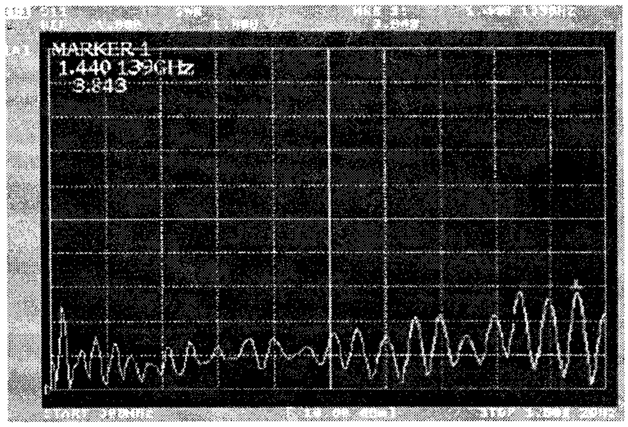


Fig. 2 The SWR attributes of the UHF sensor.

2.4 Main Functions of the System

The two parts of the system work independently. The stationary device will be installed on the equipment during its service life, and its main functions are: continuously monitoring the target, then decide whether there're PD or not; making phase-resolved statistical analysis of the UHF peak detection signals to plot charts, which is to make source characterization; recording important PD parameters and making trending analysis. The stationary part provides reserved port for the movable device to be connected in. A high-speed oscilloscope is used temporarily to make frequency domain analysis of the original UHF signals, which includes making pattern recognition by the UHF spectra and estimate the approximate time-flight information from different sensors, but these kind of work has be done by qualified researchers at present.

2.5 Installing Modes

According to the different installing modes of the sensors, two implementing schema of the system are designed. One way is on-line installation by inserting the sensor into transformer tank through the oil valve, this is the "plug and play" mode; the other way is by pre-installing the sensor onto the manhole or hand hole cover, which must be carry on before the oiling of the transformer, in this way the sensor will be as a part of the cover and will work with the transformer permanently after installation. Special oil-proof design is required for both of these two ways, so as to guarantee the safety service of the transformer; besides, it's necessary to increase the sensitivity of the sensor while installation requirement is satisfied.

3. Results and Discussion

3.1 Anti-interference Measures

The background noises level inside the oil tank is very low (about 25mV), which is about two times lower than the outer environment (about 50mV). A stable and continual signal was found and recorded by the oscilloscope, see Figure 3. In order to find out its source, several layers of aluminum foil was wrapped onto the apertures at where the flange joints and all the signal lines were screened by a soft spiral iron pipe, which intention is to ensure good screening of the whole measuring system. After convinced that the interferences could be totally removed by the screening, we found that the signal still exists, then the sensor was withdrawn out of the transformer, still the signal existed, so we concluded that the signals are interferences brought about by the switched power of the amplifier.

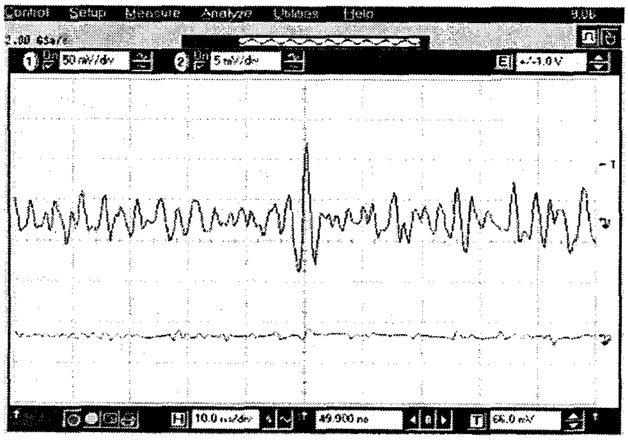


Fig. 3 Typical noise signal from the power system.

During the period of monitoring, three intensive signals were captured by the measuring system. The amplitudes of the signals were about 400mV, which were much higher than that of the background noises (see Figure 4). When each signal was captured, the operations of the transformer tap changer could be excluded definitely. The time intervals between two signals were seven hours approximately. The time domain waveform of the signals indicated that they were much likely to be discharges, but it was kept uncertain whether they were generated inside the transformer oil tank or other electrical equipments' operation coupled into the transformer from the power lines.

3.2 Site Testing Results

In the inspection period of the transformer, two types of sensors are designed and pre-installed permanently onto the oil tank, and all the wires and cables are screened with metal pipe. In the on site PD test before the transformer was put into service, we did experiments with both the UHF system and conventional PD method at the same time, and the current pulse signals and UHF signals were recorded synchronously for comparison studies. During the experiments the maximum UHF signal was saved and set as the threshold of warning when the transformer was in the normal service state. The power spectrum of the UHF by FFT can be compared with those obtained in the laboratory, so as to get the source type information.

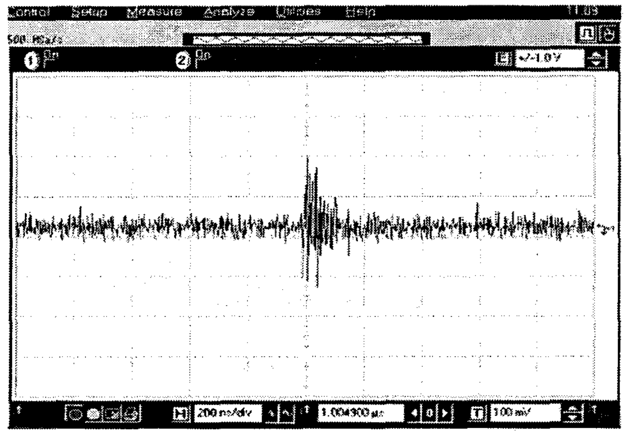


Fig. 4 A typical suspicious discharge signal.

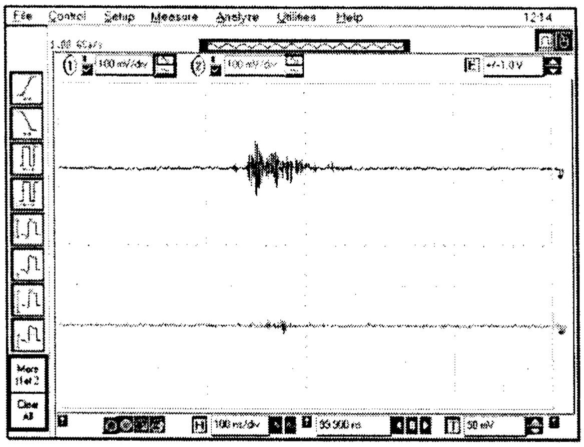
As in the conventional PD test, the procedure is to apply 1.3 times of normal voltage for 30 minutes to each phase one by one. The conventional results are shown in Table 1. The typical UHF PD signals of the R phase are shown in Figure 5. It shows that the background of the manhole antenna is about 30mV, while the PD signal is approximately 150mV. Besides, each time the waveform of the signal almost keeps the same, which indicate that it is a monotype discharge. The case of the hand hole antenna is analogous as the manhole antenna, but the signals are much smaller. Because the signals become steady and low in a few minutes, we conclude that it is gas cavity discharge in oil or corona discharges on small conductor burrs which soon be melted down by the PD energy. The results demonstrate that the sensitivity of the UHF system is high enough to detect very small discharges in transformers.

4. Conclusions

The practical applications in field demonstrate that the UHF technique is very effective for on-line monitoring. By putting the UHF sensor inside the transformer tank, both high sensitivity and anti-interference characteristics can be achieved at the same time, which are the most advantages of UHF over conventional methods. Peak detection technique makes it easier and cheaper for UHF method to import conventional phase-resolved pattern recognition technique and trending analysis, which makes it more practicable for on-line utilization of UHF technique.

Table 1 Apparent discharges recorded with conventional method.

Apparent charge [pC]	Applied voltage [kV]	R phase	S phase	T phase
Maximum	189	2,000	800	1,200
Steady	189	100	130	110



(a) Manhole antenna (b) Hand hole antenna

Fig. 5 Typical PD signals from Manhole and hand hole antenna when the R phase is energized.

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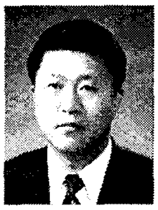

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