The Strategy of On-line Partial Discharge Measurement in Medium Voltage Industries

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Abstract

On-line partial discharge measurement (PDM) is applied worldwide for the preventive maintenance, and the insulation defect inside the material can be detected in advance to prevent fault event. Due to great impact of outage, there are various on-line PDM instruments developed for the extra-high-voltage (EHV) and high voltage (HV) equipments

As compared with EHV/HV equipments, the large number of equipments in a medium voltage (MV) industry costs high test fee, and the relative lower price of equipments means less maintenance fee. Restricted by the limited budget, the on-line PDM is carried out periodically rather than the adoption of a on-line partial discharge monitoring system.

Moreover, because most loads equipped with power electronics induce noise interfering on-line PDM, this paper shows simple method to distinguish partial discharge (PD) from noise. And the PD location is also illustrated in this paper for the improvement of equipment.

According to field experience, there is always failure unpreventable by the periodic on-line PDM no matter how short the period is. By analyzing the undetectable failure, these events were triggered by heat issue and undetectable by PDM. For such situation, the on-line monitoring system is necessary.

Based on the collections of case studies, the type of failures are classified according to the equipments and defects. This paper will show the classification to help tester to choose the interval of on-line PDM, and to determine to adopt on-line monitoring system or not.

Keywords: on-line partial discharge measurement, medium voltage system.

1. Introduction

The design life of high voltage equipment is usually 20 years at least, but many breakdown failure of high voltage equipment usually occurs at the in-service life less than 10 years. According to event inspections, the majority of root causes of insulation breakdown is defects inside insulation material no matter formatting in manufacture, transportation, installation, or operation, and it is hard to be detected by conventional insulation diagnostics [1,2].

So far, the most effective diagnostics of defects detections is partial discharge measurement (PDM) [1,2,3], and the on-line PDM is developed to be parts of preventive maintenance. Because of the great impact of outage and the high repair cost, there are various on-line PDM instruments developed for extra-high-voltage (EHV) and high voltage (HV) equipments. There are also lots of literatures dealing with partial discharge (PD) identification and noise elimination.

As comparing with EHV/HV equipments, the condition of medium voltage (MV) equipments is quite different. Unlike the subsystem of EHV/HV system is MV system consisting of power equipments, the subsystem of MV system consists of various production machines emitting various noise interference [4,5]. This makes on-line PDM on MV system more difficult on PD identification and noise elimination.

Moreover, test cost is also a concern of on-line PDM. The relative lower price of MV equipments (comparing with EHV/HV equipments) implies that customers do not have the willing to install a PD monitoring system with high price. Restricted by limited budget, the most possible way to carry out on-line PDM is to perform it periodic.

Based on field experience, the events initiated by heat aging can't be avoided by periodic on-line PDM, and the there is still risk of insulation breakdown. Therefore, the on-line PD monitoring system is necessary to prevent such failure, and the installation cost of such system will cost a lots.

In order to overcome the high test cost and to reduce the risk of insulation failure, this paper proposing a strategy of on-line PDM as shown inf Fig. 1. As shown in fig. 1, the quick scan can be periodic on-line PDM or simple on-line PD monitoring system according to the properties of device under test (DUT), and the most cases of noise interference could be weeded out. Then, the cases with suspected PDs could be to advanced diagnostics [5]. Once the suspected PDs is confirmed to be internal PDs, the PD location will be carried out to analyze how the defect formated [6], and the improvement can be executed.

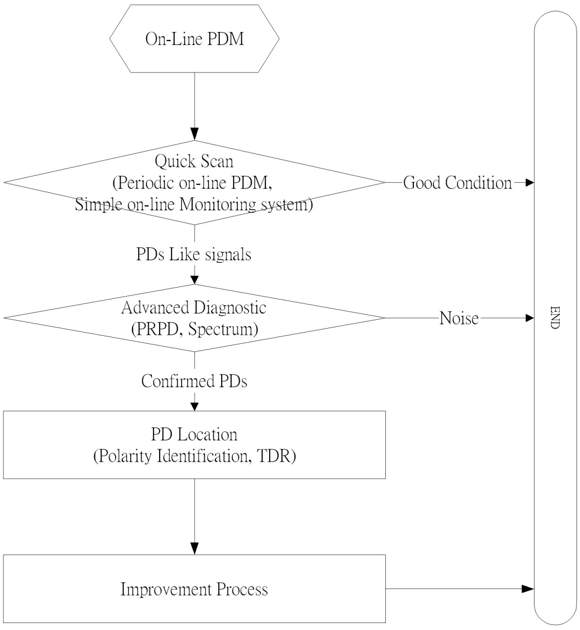


Fig. 1 the flow chart of on-line PDM on MV system

2. Quick scan

2.1 Periodic on-line PDM

Comparing with on-line PD monitoring system, periodic on-line PDM is an acceptable alternative method for on-line PDM. However, the period between on-line PDMs is an important subject. In theory, the period between test should be determined by the duration between PD inception and insulation breakdown, and there is still no decisive value from experiments. Moreover, the real defect is usually more complex than simulated one, and it takes time to perform an accelerate aging test to determine the duration between PD inception and final breakdown. Therefore, there is no literature dealing with the life time estimation of the equipment with PDs, but dealing with the risk of breakdown.

According to more than 10-year field experience, a rule of thumb in 6-month period is provided. At first 2 years, annual on-line PDM is carried out and it shows good performance. Due to customer's plan, the period of on-line PDM sometimes would exceed 12 months, and some event occurred unfortunately. Then, the 6-month period is adopted, and no unexpected event occurs in the following years.

Recently, there were few cast resin transformer (CRT) failed between two on-line PDMs, and the period of on-line PDM was shorten to be 2 months. However, the shorter period did not avoid the insulation breakdown of CRT, and similar event happened again. According to event inspection, such insulation breakdown was initiated by heat aging (poor connection), and could not be detectable before its transition to electric treeing. The aging would be fast since the heat aging transiting to electric treeing, and the 2-month period can not avoid the occurrence of such failure initiated by heat aging. Therefore, the period between on-line PDM would be 6-month by the trade-off of test cost and performance.

Fig. 2 Insulation breakdown initiated by heat aging (poor connection)

Fortunately, the failure initiated by heat aging only occurs at equipment with coils, such as power transformer and instrument transformer. Therefore, for equipment with coils, the on-line PD monitoring system is necessary to prevent failure.

Moreover, periodic on-line PDM on rotatory machine also suffers difficulty. Because insulation condition of rotatory machine is easily affected by moisture, the operation condition of rotatory machine will affect the result of on-line PDM. If the periodic on-line PDM can not carried out at same condition, the on-line PD monitoring system is also necessary for rotatory machine.

2.2 Simple on-line PD monitoring system

As mentioned above, the power equipments needing for on-line monitoring system are reduced to equipments with coils and rotatory machines. Although the amount of monitored equipments is reduced, but it still a big number. It implies that the installation cost is too high to install on-line PD monitoring system for all equipments requiring to be monitored. A simple on-line PD monitoring system is proposed, which adopts very-high-frequency (VHF)/ultra-high-frequency (UHF) measuring frequency band and monitored targe is the PD levels.

One topic of on-line PDM is noise elimination, and there are lots of algorithms to solve it. However, most algorithms developed in a simpler environment, where the samples of noises are few, and it would not suitable for high noise interference environment, such as MV industries. Because the frequency band of background noise can be up to 300 MHz as shown in Fig. 3 [5], the simple on-line monitoring system adopts the VHF/UHF frequency bands to measure PDs, and most background noise could be eliminated.

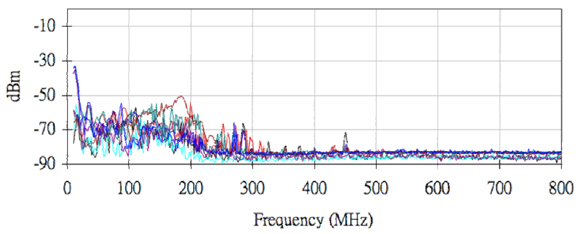


Fig. 3 Spectrum of measured background noise

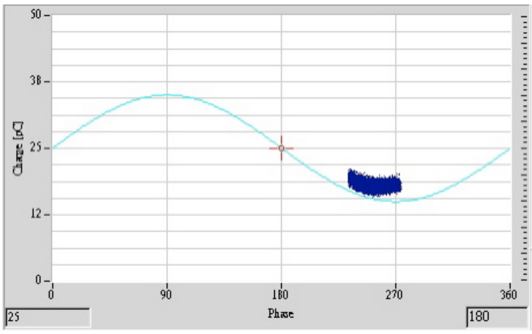
However, there are still some noise with high frequency components, which can interfere on-line PDM, such as the switching of power electric equipments and cellphones. Because the PD level grows gradually and the noise level varies a lot in a short time, the monitored target is chosen to be PD level to eliminate the interference of noises.

Because the adoption of VHF/UHF measuring frequency band and the monitored targeted of PD level, the design requirement of simple on-line PD monitoring system would be simplified, and the cost of simple on-line PD monitoring system could be lower down. Then the quick scan of periodic on-line PDM and on-line PD monitoring system could be achieved in a reasonable way.

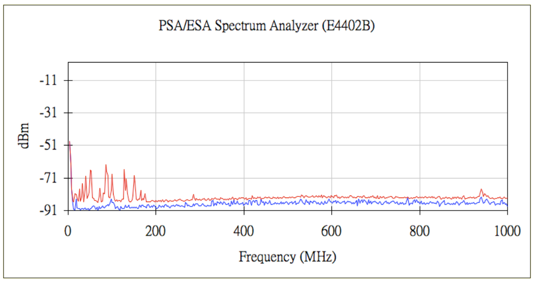
3. Diagnostics

Because the PD levels could not give enough information about defects and some background noise really have similar characteristic of PDs, the advanced diagnostics is still necessary to classify the signals as PDs or noise.

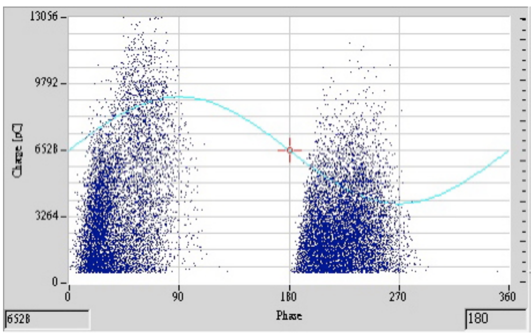
In order to achieve high accuracy of PDs identification, there are two methods of phase-resolved partial discharge (PRPD) pattern and the spectrum of PDs adopted widely []. Fig. 4 shows the experience result from [], and it shows that the PDs contains continuous span of spectrum and the PRPD pattern of triangular-form. There is always exception for the adoption of only one method, and it is suggested to confirm PDs by two more methods [5].



(a) PRPD pattern of corona discharge

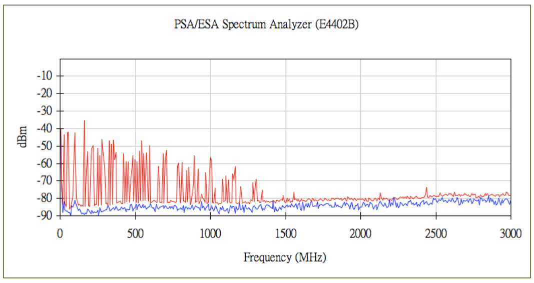


(b) spectrum of corona discharge

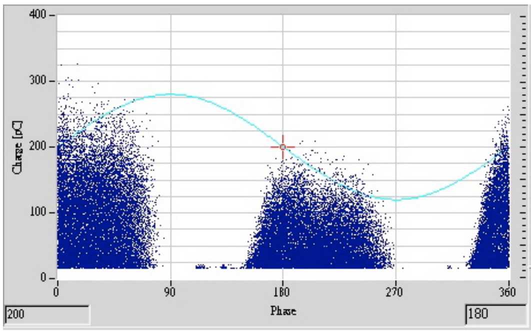


(c) PRPD pattern of external PDs

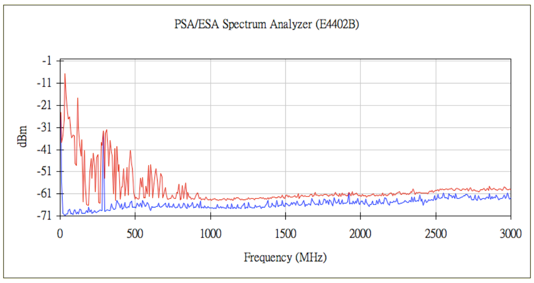
Fig. 4 the spectrum and PRPD pattern of PDs (to be cont.)



(d) spectrum of external PDs



(e) PRPD pattern of internal PDs



(f) spectrum of internal PDs

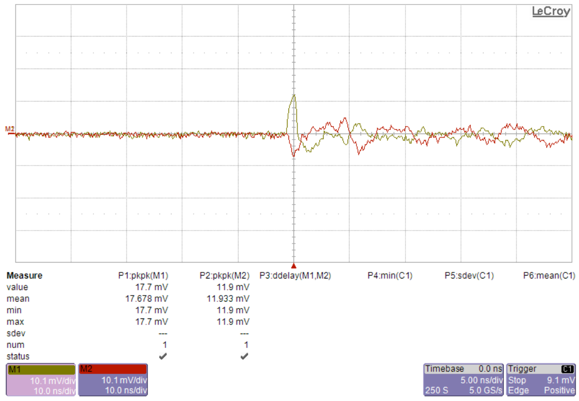
Fig. 4 the spectrum and PRPD pattern of PDs (cont.)

4. PD Location

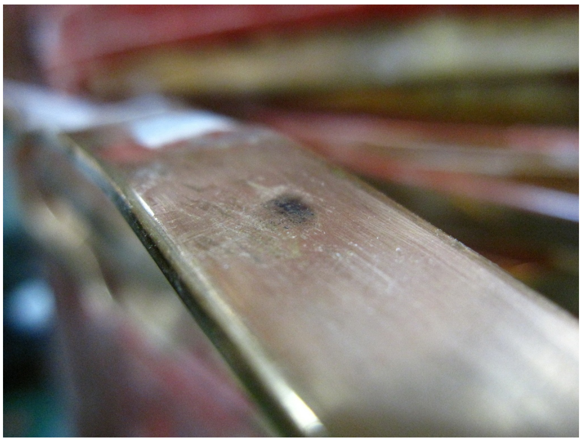
Once the PDs is confirmed, the replacement of equipments is not the only thing needed to be done, but also the identification of defect types. Only the defect type is identified, the following improvement could be carried out. For the complex equipment, the PD location is necessary for the aid of defect identification.

The polarity identification of PDs and the time-domain-reflection (TDR) are the methods suggested to locate PDs [6]. Fig. 5 and Fig. 6 illustrate the performance of them.

(a) operation

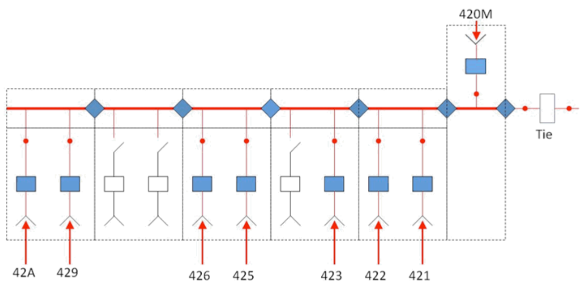


(b) pulse waveform identification



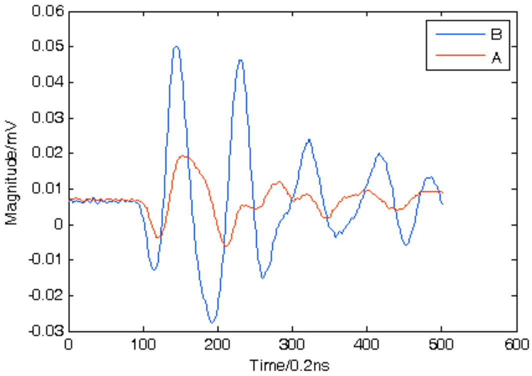
(c) The copper wire with defect

Fig. 5 Polarity identification of PDs



(a) configuration of CGIS

Fig. 6 PD location by TDR (to be cont.)



(b) TDR of PDs

(c) bus socket with defect

Fig. 6 PD location by TDR (cont.)

5. Conclusion

As on-line PDM is an effective insulation diagnostics, it suffers lots of difficulties applied on MV system, such as high noise interference, restricted test budge, combination of PDs, and etc.. All of these makes on-line PDM on MV system not so effective as that on EHV/HV system. This paper proposed a strategy of on-line PDM on MV system by the adoption of quick scan, advance diagnostic, and PD location to achieve the goal of economic effective on-line PDM.

The proper duration of 6-month periodic on-line PDM is proposed, and the structure of simple on-line PD monitoring is addressed. This part will lower down the test cost to make it possible to adopted in MV system.

The advanced diagnostics raise the accuracy of PD identification to redeem the possible misunderstand of quick scan. The PD location can aid for the following improvement.

6. Reference

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