外部放電のリスクアセスメント

○　李長興（台湾震江（株））、邱敏彦（台湾震江（株））、黄智賢（台湾震江（株））顔世雄（工研院）

Risk Assessment of External Discharge

Lee Chang-Hsing (PDS), Chiu Min-Yen (PDS), Huang Chih-Hsien (PDS), and Yen Shih-Shong (ITRI)

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1. Introduction

Insulation diagnostics of high voltage equipment is always an important issue. However, the insulation failure can’t be effectively prevented until the realization of on-line partial discharge measurement (PDM). Based on the experience of Power Diagnostic Service Co., Ltd. (PDS), the failure rate is obviously decreased from 0.258 % per unit-year to 0.024 % per unit-year as the adoption of on-line PDM.

However, a successful on-line PDM is not only based on the advanced technique of the instrument adopted, but also executed via the well-experienced engineers. Therefore, on-line PDM is always cost time and money, and it is not easily popularized to every high voltage equipment. In order to overcome this difficult, PDS developed a novel method to simplify the measurement, which distinguish internal PD signals from noise/external discharge signals via the existence duration [1].

Because the internal defect won’t disappear but become worse and worse, the worst condition would be internal discharge phenomenon and no one can predict when it will breakdown. Therefore, it is usually classified as medium/high risk. Oppositely, the external discharge phenomenon is easily influenced by environment condition, and is less relationship with insulation condition. Hence, it is usually classified as no/low risk.

However, there was flashover between phase-to-ground in a switchgear panel, which was already classified as low risk due to external discharge phenomenon. Due to this unexpected situation, the review of risk assessment about external discharge phenomenon is taken place, and the discussion is shown in this paper.

2. Characteristics of external discharge phenomenon

Once, the breakdown voltage of surrounding air decreases, the external discharge phenomenon may occur. If the breakdown voltage of surrounding air increases, the external discharge phenomenon may disappear. Because the breakdown voltage of surrounding air is influenced by environment condition, the trend of PD level of external discharge is unstable (shown in fig. 1). In beginning stage, the external discharge is considered harmless. However, if this situation lasts for long period, it would possibly form a tracking on the surface of insulation material, and the PD trend would be stable, as shown in fig. 2(a). Eventually, the serious tracking would possible cause flashover between phase and ground (shown in fig. 2(b)). In other words, before the external discharge forms the tracking on the surface, most external discharge would be harmless, and could be classified as no or low risk. Once, there is visible tracking on the surface, the risk level would be increased due to the increasing possibility of flashover.

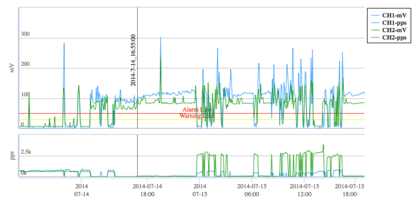
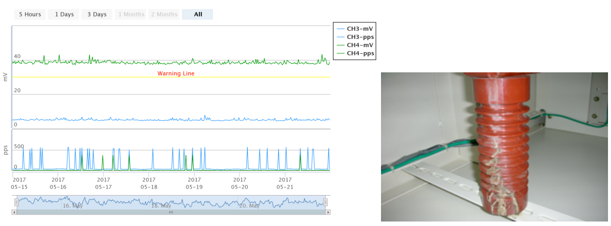


Fig. 1　typical PD trend of external discharge without tracking



(a) PD trend　　(b) tracking on surface

Fig. 2　the typical PD trend of external discharge with tracking

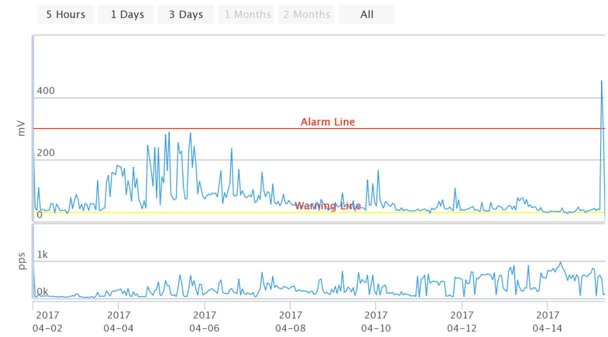
3. Harmful external discharge

Based on past field experience, the external discharge would not cause insulation breakdown, and it rarely causes flashover in the air-conditioned environment. Therefore, the progression of external discharge to flashover is unknown in real cases, and no effective criteria can be used to indicate the risk level of external discharge.

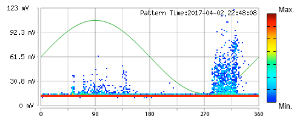
By the advantage of monitoring system, the development of harmful external discharge was recorded (fig. 3(a)). One switchgear panel showed external discharge phenomenon with unstable trend of PD level (fig. 6(b)), and it was classified as low risk. After 3 days, a different phase-resolved partial discharge (PRPD) pattern occurred, and its PD trend was still unstable (fig. 3(c)). Therefore, it was still classified as low risk. However, PD area was wider at day c (fig. 3(d)), but the PD trend is still unstable. Therefore, it is still classified as low risk with external discharge. Unfortunately, this situation lasted for 8 days, and the external discharge suddenly initiated a flashover between phase and ground (fig. 3(e)).

Figure 4 shows the faulted switchgear, and the circuit breaker (CB) is in the out-of-service position. The fault area is on the surface of bushing and shuttle, and no insulation material is damaged. Inside the bushing, there are watermark on the surface and verdigris around the conductor (fig. 4(b)). The metal shuttle is two pieces (fig. 4(a)), and there is protrusion at the edge.

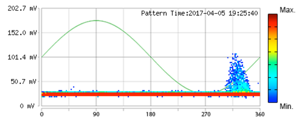
The watermark and verdigris implies high humidity inside the chamber. The out-of-service CB means the humid air is blocked from flowing out by the closed metal shuttle. This condition forms the environment with lower breakdown voltage of humid air. The electric field would be enforced at the protrusion at the edge of metal shuttle, and it would possibly initiate the external discharge. Then the decoupled electrons further ignite the surface discharge around watermark. Eventually, the closed space is full of decoupled electrons, and a slight disturbance of system voltage trigged the flashover between conductor and ground (metal shuttle).



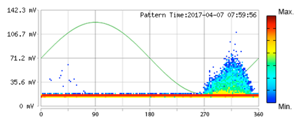
(a) PD trend



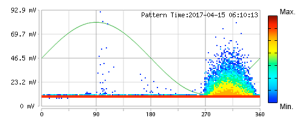
(b) PRPD pattern at day a



(c) PRPD pattern at day b



(d) PRPD pattern at day c



(e) PRPD pattern at day d

Fig. 3 PD trend of switchgear with external discharge

(a) inside panel

(b) inside bushing

Fig. 4 Faulted switchgear panel

4. Conclusion

In most case, external discharge is considered without immediate risk, and there would be enough time to repair the situation. However, in the situation mentioned in section 3, it would be a medium risk with flashover between conductor and ground, and previous experience can’t be applied to identify the correct risk level. Fortunately, based on the monitored PD data, there is an obvious change in the PD properties before it gets worse: more stable trend of PD level and wider area of PRPD pattern, and the unwanted flashover could be avoided by monitoring its behavior.

5. Reference

[1] 李長興、邱敏彥、黄智賢、顔世雄, ”部分放電監視で観測された部分放電信号の持続特性”, 第３４回　電気設備学会全国大会。