In-Service Partial Discharge Measurements on Power Cable Terminations

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ABSTRACT

This paper first describes the various types of cable terminations and termination failures encountered in transmission and distribution networks in SPPG. Then introduces a portable in-service non-conventional electromagnetic Partial discharge (PD) measurement system and practical PD measurement methodology in time and frequency domains. The procedures to pin point the location of PD among transformers, switchgears and GIS cable terminations, to identify the defect using frequency spectrum, PD clustering, PD patterns, PD pulses, time-of-flight measurement techniques, as well as with the help of GIS on-line PD Monitoring system, are proposed.

KEYWORDS

In-service; Cable termination; Partial discharge; PD clusters; PD patterns.

1. INTRODUCTION

Electrical grid in Singapore adopts fully underground cable systems. Due to space constraint, power assets like transformers and shunt reactors in substations often placed nearby or on different floors and are connected to the Gas Insulated Switchgear (GIS) by cable terminations with short cables. These terminations are immersed in the oil tank or installed in GIS compartments and are seldom maintained in service life after commissioning tests [1]. Cable termination failures, especially inside oil-filled transformer and shunt reactor cable boxes, can be very critical, possibly result in high risks of transformer or shunt reactor fires.

Cable terminations incipient faults possibly initiate PD signals, the PD signals will travel between GIS, cables, transformers and other equipment in substation, from upstream to downstream substations through grounding, cable sheath and conductors. On the contrary, if there are defects in these equipment and cable joints, the PD signals will propagate to terminations. It makes the PD location much more complicated. Since the off-line termination PD detection is not convenient in this configuration after the cable commissioning tests, usually periodical in-service or on-line PD measurement is the most appropriate method to assess the insulation condition of cable terminations [2].

Convectional IEC 60270 as reference for such PD measurements is not applicable as it cannot be calibrated by measuring the apparent charges by picoCoulombs (pC) in the frequency range up to 1 MHz [3], non-conventional PD measurement methods dominate in on-site testing for in-service assets by detecting other PD signal's properties and physical characteristic in mV or dBm [4] [5]. Electromagnetic and acoustic detections are two of such methods, categorized based on detected PD current pulse frequency ranges of:

- High Frequency (HF 3-30 MHz)
- Very High Frequency (VHF, 30-300 MHz)
- Ultra-High Frequency (UHF, 300 MHz-3 GHz)
- Acoustic (20 kHz-250 KHz)

The challenges of reliable in-service PD measurement, interpretation and location in cable terminations are:

a) Overcome high background noises, such as power electronic pulses from surrounding equipment, spotlights, radio signal and equipment and other unknown interferences.

b) Pin-point and narrow down to the PD source among the interconnected power assets within the substation, from downstream or upstream substations.

c) Intermittent PD signals that could be influenced by environmental conditions, transition over-voltages, such as switching operation, transformer energization in network, and load changes.

d) Evaluate the severity of PD activities and defects inside terminations.

To overcome the above challenges, a portable in-service and on-line PD measurement system using different sensors is introduced. it analyzes PD signals in time and frequency domains, applies PD clustering, creates Phase-Resolved PD (PRPD) patterns and performs time-of-flight measurement to pin point the location of PD among transformers, switchgears and GIS cable terminations.

Comparing detecting PD in the HF and VHF bands, UHF technique, which has only a few known discrete interferences (such as 940 MHz and 1.8 GHz in Singapore) and has the advantage of the distance selectivity of several meters, can be perfectly used for location of cable terminations with sensitivity of a few pC [5].

This paper first describes the various types of cable terminations and its failures modes encountered in networks of Singapore, then introduces a portable in-service non-conventional electromagnetic PD measurement system and practical PD measurement methodology in time and frequency domains. It compares the PRPD patterns obtained in laboratory with on-site tests, under single phase and three phases voltage respectively. Specially focus and case study are given on the PD detection and location by UHF method.

2. TYPES OF CABLE TERMINATIONS

Driven by the ease of installation and removing the risk of leak, dry type plug-in (with slip-on stress cone) terminations are gradually replacing old wet type (or fluid filled) terminations in most HV and EHV networks in Singapore. However, the different generations of various terminations are still around and will be in service for a long time.

The typical cable terminations and its connection with GIS and transformers are shown in Figure 1. The terminations have various types. Dry type and wet type plug-in terminations in transmission networks are shown in Figure 1(a), separable connector (or Branch, Elbow), bare and shrouded heat shrinkable terminations only used in MV