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Monitoring of transient overvoltages on the power transformers and shunt reactors – field experience in the Croatian power transmission system

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Abstract

Power transformers and shunt reactors may be subjected to various dielectric stresses such as lightning and switching overvoltages. Since the exposure of equipment to overvoltages during operation and the overvoltage amplitudes are usually unknow, an on-line overvoltage transient recorder is used with the ability to sample, analyze and store transients at transformer terminals in real-time. In this paper, transient overvoltage monitoring system is presented. Overvoltages are measured on the outside measurement terminal of the shunt reactor and transformer bushing. Field experience regarding the application of monitoring system in Croatia is described including different cases of lightning and switching overvoltages. Lightning overvoltages recorded by monitoring system are correlated with data from the lightning location system (LLS). Switching overvoltages recorded on the shunt reactor are compared with numerical simulations in EMTP-RV software. Collected data about overvoltage stresses can be used as the basis for the assessment of the transformer and shunt reactor insulation condition and estimation of health index.

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Keywords: Transient overvoltage monitoring system; lightning location system; lightning and switching overvoltages; power transformers; shunt reactors; EMTP-RV

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1. Introduction

Overvoltages are one of the often causes of faults and outages in the transmission power system. Magnitude and rate of rise of overvoltages due to lightning strikes on transmission lines is an important consideration for substation insulation and the strategy adopted for limiting these overvoltages. The transmission line faults caused by a lightning can be classified as a backflashover or a flashover due to the shielding failure. Both events cause overvoltages which travel towards the substation from the striking point. Attenuation due to high frequency nature of the lightning overvoltages is caused by corona losses and skin effect. Therefore, usually lightning strokes that are close to the substation are considered when assessing overvoltage protection requirements and the associated risk of failure of the substation equipment. Insulation faults on a transmission line in front of the substation can provoke short circuit currents with high magnitudes. In case of an insulator flashover, a surge with a very steep front is formed. It enters the substation and causes insulation stress especially on windings of power transformers and shunt reactors [1].

Modern LLSs report the location of the lightning impact and the lightning peak currents which are estimated from the measured electromagnetic field peaks. The available technology for detection and location of the cloud-to-ground (CG) lightning has significantly improved over the last decades. LLS data have the advantage of covering extended areas on a continuous basis [2]. Data from LLSs can be used only to determine if the fault, e.g. short circuit caused by an insulator flashover on the transmission line, was caused by the lightning. However, amplitudes and waveforms of the overvoltages at the power transformer terminals are usually unknown. For that purpose, an overvoltage transient recorder is used with the ability to sample, analyze and store transients in real-time.

Switching overvoltages during deenergization of the shunt reactor can impose a severe duty on both the shunt reactor and its circuit breaker due to current chopping that occurs when interrupting small inductive currents. Switching overvoltages can be dangerous for the equipment if the peak value exceeds the rated switching impulse withstand voltage of the shunt reactor. However, overvoltages resulting from the deenergization are unlikely to cause insulation breakdown of shunt reactors as they are protected by surge arresters connected to their terminals. The severity of the switching duty increases when single or multiple reignitions occur. Such flashovers create steep transient overvoltages on shunt reactor with the front time ranging from less than one microsecond to several microseconds and may be unevenly distributed across the winding. These steep fronted transient voltages are stressing the entrance turns in particular with high inter-turn overvoltages [3]. Switching transients on shunt reactor are measured by using the transient overvoltage monitoring system.

In this paper, transient overvoltage monitoring system for power transformers and shunt reactors is presented. Overvoltages are measured on the outside measurement terminal of the shunt reactor and transformer bushing. Field experience regarding the application of monitoring system in Croatia is described including different cases of lightning and switching overvoltages recorded on power transformers and shunt reactors. Data from transient overvoltage monitoring system are correlated with data from the LLS. Switching overvoltages recorded on the shunt reactor are compared with numerical simulations in EMTP-RV software. Collected data about overvoltage stresses can be used as the basis for the assessment of the transformer and shunt reactor insulation condition and estimation of health index.

2. Transient overvoltage monitoring system

Overvoltages in power network can be caused by CG lightning strokes, switching operations and faults. Power transformers and shunt reactors can be exposed to such transients during the operation. Transient overvoltages with steep wave front have an impact on dielectric stresses of the insulation of first few winding turns. The number and amplitudes of overvoltages which stress the insulation depend on various parameters such as the lightning stroke density in the considered area, since it determines how often the transformer is stressed by lightning overvoltages. Since the overvoltage amplitudes at transformer terminals are usually unknown, an on-line overvoltage transient recorder is used with the ability to sample, analyze and store transients in real-time. Collected data can be used as the basis for the assessment of the transformer insulation condition, especially if combined with other transformer data such as dissolved gas analysis (DGA). This fact was the driving force for upgrading the existing transformer monitoring system with transient overvoltage monitoring system (TMS). Overvoltages, as well as voltages, are