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Comparative research into transients by switching of high voltage shunt reactor

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ABSTRACT

This article deals with results of performed studies of transient phenomena in application of controlled switching technique by switching high voltage 123 kV, 100 MVAr shunt reactor. First, for switching a single-pole hydraulically operated SF_6 circuit breaker has been selected and after that, one with electric motor-drive. In preparing of experimental part of studies the EMTP-ATP software has been used in computer simulations, further for analyses the cases of optimal controlled switching and switching within time deviation limits. For simulation of uncontrolled switching with current chopping and arc-reignition dynamic model of arc behavior has been implemented. The field tests with both circuit breakers have been repeated in similar network conditions for further statistical analyses. During some tests, the transient phenomena of uncontrolled switching have been observed. The achieved experimental results were compared with the computer simulations.

1. Introduction

Transients phenomena by switching-off a high voltage (HV) shunt reactor in general terms are the well known problem [1,2,4]. In the overvoltage domain they are connected with the breaking of small inductive currents, related to the switching devices, to his mechanics and type of extinguishing media [1–4]. When current chopping or arc reignition or both phenomena have occurred, they usually lead to significant switching overvoltages. Contrary, during the process of switching-on, very high inrush currents as the transients can be observed if the moment of switching is not optimal. Because of that they can be potentially very stressful for insulation and mechanical system of shunt reactor as well for other equipment [5]. Therefore they have to be prevented or mitigated. As an effective measure in prevention of such transients the controlled switching technique is in use [6,7]. Additionally, for overvoltage protection of insulation system, metal oxide (MO) arresters are generally used [8].

This article deals with and compares the part of results of performed transient phenomena studies by switching of HV 123 kV, 100 MVAr shunt reactor with two different types of SF_6 circuit breaker (CB) in one 400/110 kV substation, first with single-pole hydraulically operated (CB1) [9], and second one with electric motor-drive system (CB2), the both equipped with the proper switching controller.

2. Case studies description

First, for switching of HV shunt reactor a single-pole hydraulically operated CB has been installed. After installation, very soon some problems with instability of its mechanics have been observed resulting in the periodical incapability for switching of shunt reactor. For illustration, Fig. 1 shows the typical recorded “closing” and “opening” time of CB during some field tests. Fig. 2 depicts much more details of recorded long term deviation in the switch-time operation of the CB1, and also shows the periods of incapability for switching [9].

It was pretty clear that this time deviation in CB mechanics, more than ± 2 ms, can lead to serious cases of uncontrolled switching in despite of implemented CB controller with adaptive feedback. Therefore, the hydraulically operated CB1 has been replaced with the new one (CB2) with electric motor-drive system in order to provide much more reliable controlled switching. Prior to replacement, first experimental study (case I) of transients has been performed, in order to collect and compare the real measured data before and after the replacement. The switching of shunt reactor has been carried out in controlled and uncontrolled conditions, within different time margins. Some of the first collected data were analyzed and compared to the results of performed EMTP/ATP computer simulation and were presented in Ref. [9]. In several cases of shunt reactor switching-off the arc-reignition has been recorded with significant transient phenomena. Also, by switching-on in time out of optimal margins for controlled

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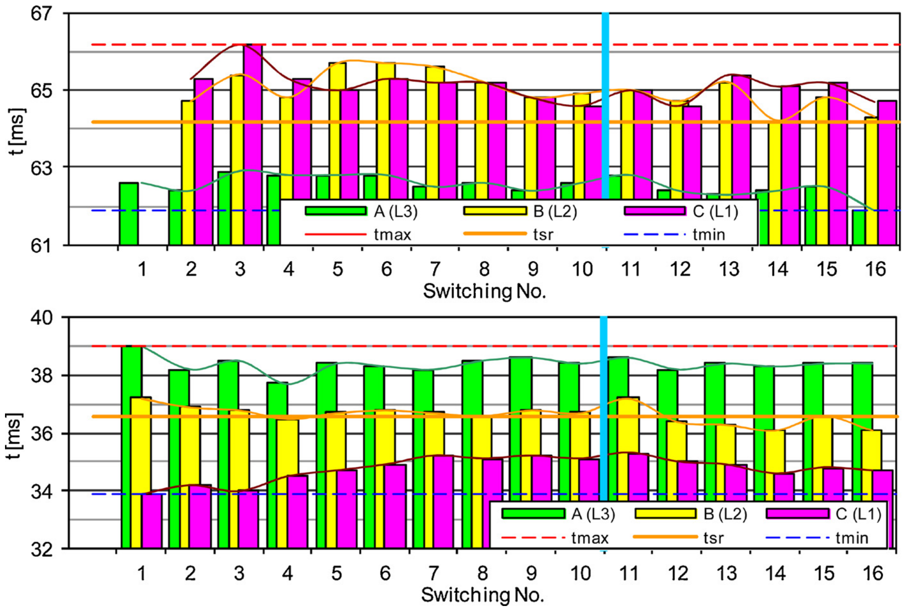

Fig. 1. Typical recorded "closing" and "opening" time of CB1.

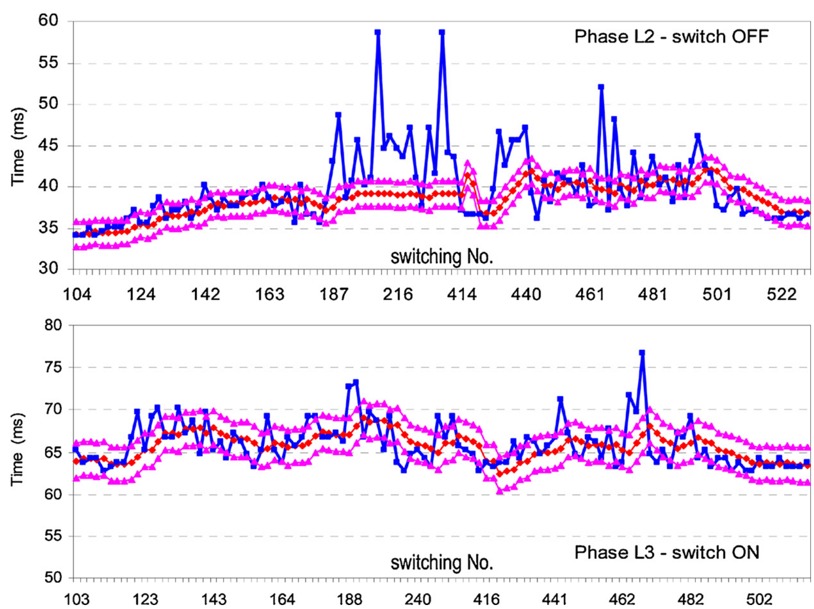

Fig. 2. Recorded long term switch-time deviation in operation of CB1 [9].

switching, high inrush currents have been expected and observed. Because of that, after replacement of CB1 with the new CB2, the second study (case II) has been prepared, much more detailed in the experimental part, as well as in the computation work.

3. Preparation of measurements (case II)

The principle schematic diagram for field measurements by switching is shown in Fig. 3. It was the same as in the previous performed field testing (case I).

In order to ensure enough data for further comparison and analyses with mathematical statistic, the shunt reactor switching has been repeated several times, in the same network, both in the controlled and uncontrolled conditions.

Due to previous observed several cases with arc-reignition during shunt reactor switching-off, in further preparation for field tests, additional analyses and reconstruction of HV voltage divider have been done, based on computation results and laboratory tests. The target was to achieve and verify the proper transfer characteristic of capacitive low-damped HV divider for field measurements according to expected amplitude and frequency spectrum of transients up to several hundred kHz [1,9]. Fig. 4 depicts the model of HV divider (HVDI) analyzed in EMTP-RV software [10] (Figs. 5 and 6).

The amplitude-frequency characteristic of the real physical models verified in the laboratory with determined upper frequency margin of ≈2 MHz, −3 dB is depicted in Fig. 7.

Also, for final verification, the standard HV AC and impulse test have been performed on both physical models of dividers before the field tests and measurements. The example of typical oscillogram of HV impulse test, performed on both dividers, is depicted in Fig. 8.

4. Computation of transients (case II)

In case II, the additional computation work has been prepared based