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Timings of high voltage circuit-breaker

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ABSTRACT

The reliability of an electrical power system is influenced by the operation of circuit-breaker (CB). A good indicator of circuit-breaker condition is its switching time. Based on it some of the critical circuit-breaker irregularities can be detected and removed before they develop to a failure. In this paper, the evaluation of time measurements (timings) in case of different failures will be carried out for two circuit-breaker solutions, i.e. with spring and hydraulic drive. Moreover, the relationships between switching time and failure type/location will be derived. Thereby, the influence of failure trend will also be taken into account.

1. Introduction

Nowadays, the reliability of an electrical power system gains on importance. The circuit-breaker (CB) is one of the most important elements of the electrical power system and its reliability is crucial. Therefore, to evaluate CB condition special on-line and off-line measurement systems are used [1]. Their task is to report any changes in operation of the breaker. However, the breaker is a device that operates at very different conditions like rated/short-circuit current or high/low ambient temperature and its operation time is not equal in all cases. Hence, the faulty conditions have to be distinguished from normal operation conditions. However, this task appears not to be a trivial one [2].

The detection technique considered in this paper is the measurement of the switching time, so called timing [3]. In order to detect a failure, time measured during unusual operation will be compared with reference time measurement.

Although this detection method is quite old, there is very little experience about failures that can be detected with use of it. This situation is partially caused by very small failure rates which amount about 6 failures per 100 CB and year [4]. Having such small number of failures, gaining of the knowledge has significantly been slowed down. In order to speed up the learning process, the theoretical considerations like in this paper have to be done. Here, the time measurements during unusual operations will not be carried out on real CB but they will be simulated with use of digital models. For this purpose, digital models of two different 110 kV SF_6 CB have been created. One of CBs has spring drive (SD) the other one is driven by hydraulic drive (HD). In order to consider cases that occurred in reality, the failures for simulations have been selected from the extended failure database which is in possession of the Institute of Electrical Power Systems at TU-Darmstadt.

2. Sensors and definition of timings

The time measurements can be done in many ways. The easiest way is to measure the time difference between the signals from the auxiliary contacts, which every breaker posses. However, these contacts are not directed for such measurements. Yet their task is to define the actual breaker position or the amount of stored energy. Therefore, the obtained results can be burden with errors. The other possibility would be to use the position transducers (linear or angular) to define the stroke-time characteristic (Fig. 1) and then to read-out the switching times. Because the breaker elements bend during switching, the location of named transducers has also a meaning. Normally, the sensors (resistive/capacitive transducers) are installed on the low voltage side of the breaker. However, the measurements of exact contact position can only be done if sensors are installed in their vicinity. This requires the application of expensive optical position transducers. The variety of sensors has been more exactly described in [1]. The digital models allow the generation of stroke characteristic for any moving element and, therefore, for exact timings.

In order to avoid the measurement inadequacy and to get the unambiguous start and stop measuring points, two auxiliary values: 99% and 1% of stroke have been defined. None of them should be equal to the extreme positions due to final oscillations of contacts but they have to be located as close as possible to them. Setting

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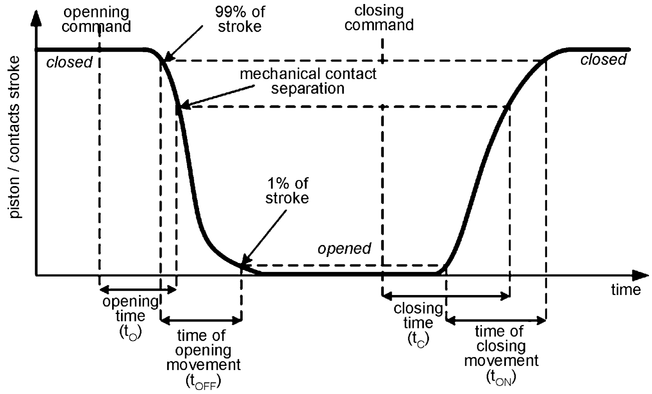

Fig. 1. Definition of switching times.

event points too wide can lead to loss of important information like damping efficiency.

Four times are defined on Fig. 1:

- t_O – opening time – time between the release signal and mechanical separation of breaker contacts. (inherit time),
- t_{OFF} – time of opening movement – time between selected points of 99% and 1% on the stroke characteristic,
- t_C – closing time – the time between the close signal and mechanical connection of the breaker contacts (also named inherit time),
- t_{ON} – time of closing movement – similar to the t_{OFF} but the stroke direction changes.

3. Digital models of CBs and reference timings

The failure effects will be considered in two digital models of 110 kV SF_6 high voltage CB with SD and HD. Both models have been created in MATLAB/SIMULINK program. The mechanical environment has been modeled with use of toolbox SimMechanics. Other breaker parts like motor, control circuits, release coils or oil flows have been created using standard toolboxes.

It is important to mention that the intention of this paper is not to compare the CB solutions but to analyze the failure effects. Moreover, the timings presented here do not include the arc influence during switching. It has been assumed that the CB switches only rated currents and that the timings are done during periodical off-line maintenance actions.

The exact description of models is not relevant for considerations of this paper and therefore it will be omitted. Additional data to this topic can be found in [5,6].

3.1. Reference timings of CB with SD

Fig. 2 shows a model of CB with SD. The energy required for close switching is stored in a spiral spring located in the drive, which is tensed by an electrical motor. During a close switching, the spiral spring drives an eccentric lever that moves the pull rod system causing motion of contacts and tensing of opening spring, which stores the energy for open switching. Under the influence of high transmission forces the pull rod bends during operations. This rod property is modelled by elasticity components. It is important to notice that energy for switching is delivered from two different locations (closing spring– drive; opening spring – pole 3). The relevance of this fact for timings will be explained in next paragraphs.

Fig. 3 shows the stroke of breaker contact (Pole 1) and angle of eccentric lever in drive for Open–Close sequence. It can be noticed that the stroke oscillates more than the eccentric lever angle at the end position. Additionally, during the closing the contact stroke is

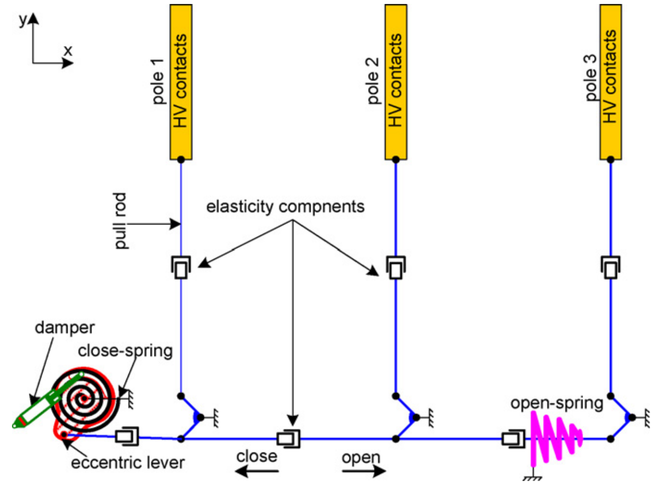

Fig. 2. General model of CB with SD.

Table 1
Timings of a reference switching of CB with SD during Open-Close switchin

	t_O (ms)	t_{OFF} (ms)	t_C (ms)	t_{ON} (ms)
Cs - pole1	18,208	29,110	25,996	29,794
Cs - pole2	18,196	26,771	26,278	29,233
Cs - pole3	18,174	26,698	26,509	28,874
ELa - drive	18,219	31,317	25,952	31,859

Cs – h.v. contacts stroke, ELa – eccentric lever angle.

higher than the steady state value (@135 ms on Fig. 3). This is caused by elasticity of the pull rods and over-travel of eccentric lever.

The switching times of CB with a SD have been read-out from the simulated stroke characteristics, according to Fig. 1. The stroke of high current contacts in every pole and angle of eccentric lever have been acquired separately. The results of time measurements have been shown in Table 1.

Considering Table 1, the first dependencies on time can be defined. The time of open movement t_{OFF} of the first pole is relatively longer comparing to the other poles. The reason for this is the location of the drive. During switching-off, all the masses in the system will move downwards. In order to avoid collisions of mechanical elements in drive, the speed of these moving masses has to be reduced. This is done by damper that is connected to the eccentric lever in the drive. This is also the reason why the t_{OFF} for

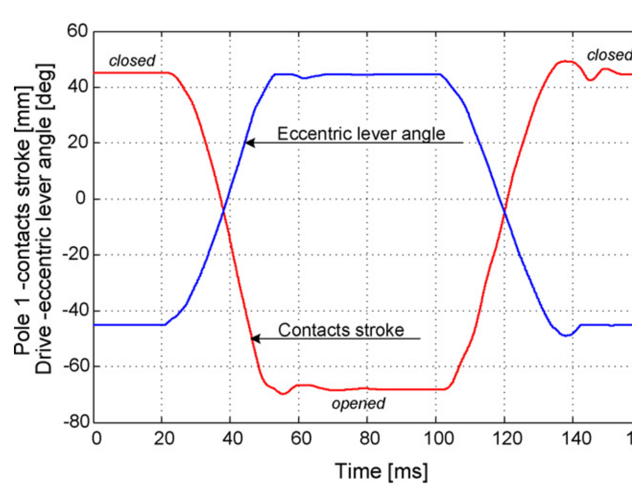

Fig. 3. General model of high voltage CB with SD.