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Validation of short-circuit current calculations in electric power system

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Abstract. The determining factor for the selection of electrical equipment and switching devices is the short-circuit currents (SCC), for which the electrodynamics and thermal resistance is checked for the first, and for the second the switching capacity and wear-resistance. Also, the fault current is calculated for setting the relay protection and automation threshold. As is known, different digital simulation tools are used for calculating the SCC, in which inevitably use simplifications and limitations of mathematical models of equipment and EPS in whole. In this connection, the calculated values of SCC comprise, in some cases, significant error, so the validation is needed for used simulation tools. Proposed to use specialized hybrid software and hardware system for validation as the source of data needed to compare the simulation results of verified tools. It helps to determine their actual properties and capabilities, as well as to increase the reliability of decisions made on the basis of the calculated SCC, by understanding the causes and possible level of errors that arise.

1 Introduction

The task of calculating the short-circuit currents (SCC) is one of the most important in the research, design and operation of electric power systems (EPS). The solution of this problem is necessary for the selection and verification of electrical equipment in accordance with the conditions of electrodynamic and thermal stability, the design and setting of relay protection, automation and et al. Therefore, the evaluation of reliability the SCC calculations, especially their maximum values, is extremely important and urgent. The maximum instantaneous value of SCC, called the peak current, is found at the steady-state value of initial symmetrical short-circuit (SC) and the largest value of the dc short circuit component. The value of the dc component is approximately calculating with the help of a constant factor (k) reflecting the damping of the dc component according to an exponential law with a certain time constant and determined by the formula [1]:

$$k = 1,02 + 0,98 \cdot e^{\frac{-3}{\omega \cdot T_{dc}}}, \tag{1}$$

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where ω – synchronous angular frequency of voltage; T_{dc} – the time constant of the damping of dc component of the SCC.

2 The problem of calculation of short circuit currents and an alternative way to solve it

For a branched network, the theoretically rigorous method of calculating the dc component of SC and its time constant in any branch is the application of the Laplace transform. Such a general and rigorous path of solution is possible in principle, but it is obvious that for a complex scheme it is inapplicable. Therefore, an equivalent network time constant is used, for the determination of which there are several methods [2, 3]. However, the determination of the equivalent time constant in real power system with respect to each faults point with using of these methods is an extremely complex task, the solution of which does not provide a significant increase in reliability in the calculation of SCC due to the approximations of the indicated methods. So, for practical calculations, the time constant is not determined, but takes for it some mean value depending on the location of the fault and the corresponding value of the constant factor.

For SCC calculations are used various software tools (CAPE, PSS/E, PowerFactory, etc.). However, despite the existing differences, they are united by a common approach to SCC calculations, namely the calculation of only steady-state emergency modes, since the accuracy of solving algebraic equations is high and does not cause doubts, in contrast to the solution of differential equations. In this case, the changing during the transient process values are taken into account by means of common coefficients, in particular the constant factor. With this approach, single-line equivalent circuits are used for calculating, the calculation of currents and voltages in asymmetric modes is performed by the method of symmetric components, and in order to simplify the EPS model only the main harmonic component is accounted for, the models of synchronous machines (SM) are given in the form of a constant EMF behind the resistance. In this case, the EMF SM (super-transient or transient) and the internal angle are assumed to be unchanged throughout the calculation. They are assumed to be numerically equal to the value at the time preceding the fault and determined by the known formula [4, 5].

For complete replacement of large-scale data, for understandable reasons, the created in the research and development laboratory of Electric power system simulation of Tomsk Polytechnic University Hybrid real time power system simulator (HRTSim) is used to evaluate the reliability of SCC calculations. HRTSim is intended for continuous methodically accurate three phase simulation of quasi-steady state and transient processes in equipment and EPS in whole for all possible operating conditions and any electric disturbance, including overvoltage [6], on an unlimited range and guaranteed instrumental accuracy. The possibility of obtaining complete and reliable information on the full significant spectrum of quasi-steady and transient processes in EPS using the hybrid tool is confirmed by comparing the results of simulation with full-scale data [7, 8], as well as a number of successfully performed applied works [9-12].

3 Experimental studies and discussion

The EPS of Tomsk region was used as a test model for simulation. The initial topology and the mode of the test EPS correspond to the validated dispatching measurements formed on the data of Tomsks EPS supervisory control and data acquisition (SCADA). For carrying out of experimental researches the most widespread in Russia tool for calculation of SCC - ARM SRZA has been chosen. In each simulation tools, the test model of EPS with the

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identical topology and parameters of the main equipment is modelling within the limits of the capabilities of used in them mathematical models.

Since in the tools in which the possibility of calculating SCC is declared, static mathematical models of equipment and EPS as a whole are used. It excludes the effect of the network on the dc component of SCC, on the reliability of reproduction of which depends mainly the maximum value of the total SCC. For determining the degree of influence of different values and the trend of the dc component, the three-phase faults at the generator are simulated, at which the influence of the network on the peak current from the generator side is eliminated, and at remote faults in the network, when this influence is significant. For determining the peak current in the ARM SRZA the obtained value of the initial current is multiplied by the constant factor, depending on the fault location [13]. For comparison from the oscillograms of the phase SC obtained in the HRTSim, one should choose those at which the phase value of the voltage is maximally close to zero at the moment of short-circuit. Example results in HRTSim simulation is shown in Fig. 1.

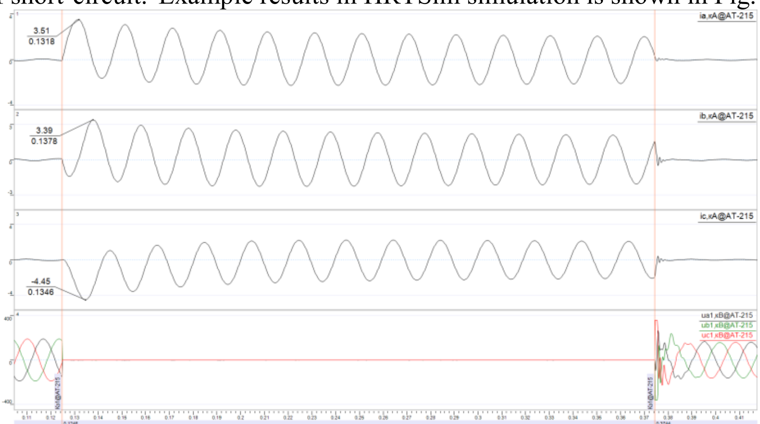

Fig. 1. Oscillogram of instantaneous values of phase currents and voltages of 220 kV AT-215 transmission line with the three-phase short-circuit.

For comparison, the simulation results are summarized in Table 1, in which the error of the peak current (ΔI_p) is determined with respect to HRTSim.

Table 1. Comparison of the peak currents values for three-phase faults obtained in HRTSim and ARM SRZA.

The fault location as the fault point is electrically removed from the sources	HRTSim	ARM SRZA	ΔI_p,%	k
	RMS value of peak currents, A			
Faults on the 110 kV bus TPS-3	6872	6449	6.16	1.965
Faults on the 110 kV bus SHC	7714	6386	17.22	1.965
Faults on the 220 kV transmission line AT-215	3144	3259	-3.65	1.78
Faults on the 220 kV transmission line T-211	3005	3186	-6.00	1.78
Faults on the 220 kV transmission line AT-214	4770	4289	10.07	1.78
Faults on the 220 kV transmission line CHP-223	1306	1440	-10.2	1.78
Faults on the 220 kV transmission line TV-221_2	2571	2896	-12.6	1.78
Faults on the 220 kV transmission line T-218	4398	5218	-18.6	1.78
Faults on the 110 kV transmission line C-40	2069	2458	-18.8	1.717
Faults on the 110 kV transmission line C-7B	3137	2223	29.13	1.717
Faults on the 110 kV transmission line C-7A	3409	4711	-38.1	1.717

The following conclusions can be drawn from these results:

1. As the short-circuit point is removed from the sources, the relative error of the peak current increases, which confirms the significant role of the network in the formation of the dc component of SC and the impossibility of an accurate calculation of its magnitude and trend with the help of the common coefficient, since in each specific case the attenuation rate is individual and formed by all elements networks.

2. The results show (in Table 1, the first and second points of the short-circuit), that the error introduced with the assumption of the constant EMF and its calculation by the parameters of the pre-emergency mode can reach significant values and basically depends on the magnitude of the dc component that discarded when applying the principle of constancy of flux linkages.

3. Since real EPS are complex networks, it is absolutely impossible to make an equivalent, and there will always be an error related to this. In addition, the drawback of such transformations is that in the common case, the power of the sources and energy receivers in the real circuit are not equal to the corresponding powers in the equivalent circuit.

4 Conclusions

The conducted experimental researches confirm that the use of the constant factor does not allow to determine reliably the maximum value of the peak current, and in view of the impossibility of accurately calculating the time constant of the dc component for real EPS, the only way to increase the reliability of the calculation of SC is the validation of the software tools. HRTSim can be used as a source of data for the validation of software tools.

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