SIMULATION OF THREE-PHASE SHORT CIRCUIT CONDITION ON A SYNCHRONOUS MACHINE

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Abstract: The paper deals with three-phase short circuit current of a synchronous machine. Transient phenomena of the machine during short circuit condition are described in the text. Simulations of this fault were carried out in two different pieces of software – PSCAD and PSS Sincal. Results of simulations are compared to a measurement on a real machine and discussed.

Keywords: synchronous machine, short circuit, PSCAD, PSS Sincal

1 INTRODUCTION

Nowadays, simulation tools provide a suitable and commonly used solution for power system analyses for different purposes – e.g. short circuit analysis, stability calculations, development plans or research. There are different pieces of software available for these purposes, such as Matlab, ATP, PSS/E, PSCAD, PSS Sincal and many others [1]. However, the user always has to keep in mind that the simulation is performed only on a model and results need not correspond exactly to the reality.

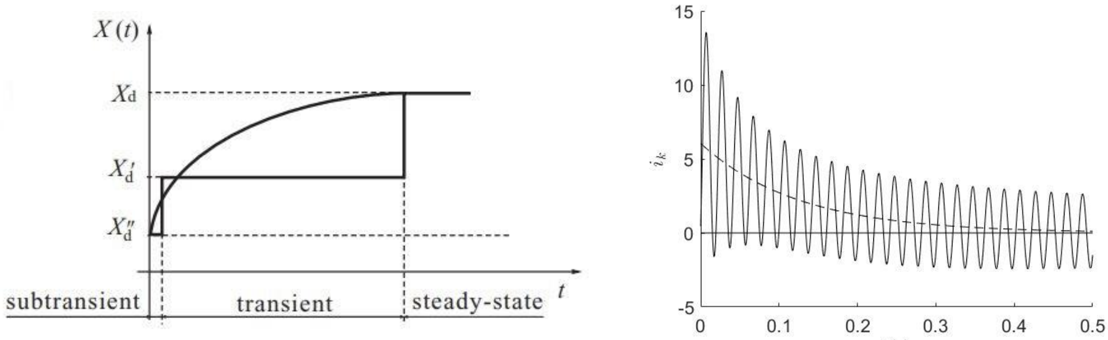
In this paper, the three-phase short circuit at the terminal of a synchronous generator will be examined. This fault was chosen because the three-phase short circuit is generally considered as the gravest fault in power grids, but at the same time, synchronous machines are tested by this fault accordingly to the standard IEC 60034-4 [2].

The aim of this paper is to compare the short circuit current waveform obtained by measurement on a real machine with the results of simulations in two pieces of software – PSS Sincal and PSCAD. Assuming that the user has set up the standard synchronous machine model in both pieces of software with basic parameters obtained from measurement or datasheet, this article compares whether the obtained current waveform correspond to the reality. In other words, the goal is to assess whether the usage of built-up synchronous machine model in PSS Sincal and PSCAD with basic parametrization leads to credible results in case of three phase short circuit.

Concerning synchronous machines, comparison of simulation results and data from measurement is not frequently done as the modelling approaches are considered to be accurate enough (as the machine theory is highly-developed). A simple comparison was done for Matlab software in [3], but for PSCAD and PSS Sincal, no such study was found.

2 SYNCHRONOUS MACHINE UNDER SHORT CIRCUIT CONDITION

The short circuit current of the synchronous machine has a specific waveform, which is caused by the electromagnetic transients in the machine itself. A complex explanation of this issue is done in [4]. In view of electrical properties, generator is said to be changing its reactance during the short circuit condition from the lowest one, the subtransient reactance x_d'', through the transient reactance x_d' to the biggest one, synchronous reactance x_d. This is depicted in the Figure 1(a). As the reactance of the machine is rising, the short circuit current diminishes over time. The current waveform can be expressed as a sum of 4 components: subtransient (damping with subtransient time constant T_d''), transient component (damping with transient time constant T_d'), steady-state component and aperiodic component (direct current damping with time constant T_a) [5]. The example of the current waveform of the synchronous machine is given in the Figure 1(b). All above mentioned reactances and time constants are crucial for setting up a machine model in software.



(a) (b)

Figure 1: Machine reactance (a) [4] and current (b) during the short circuit.

3 TEST MACHINE AND ITS MODELLING

A small laboratory generation unit was used for testing. The unit is composed of a synchronous generator on the same shaft with an induction engine (as a supply) fed from the invertor and equipped with regulator to maintain the constant value of machine speed. It is important to denote that the synchronous machine is excited from the external source that keeps the excitation current constant so the excitation regulator does not influence the transient.

For this paper, the synchronous generator is the key element. It is a mass-produced machine of 6 kW. Parameters of this machine, which are essential for its modelling (as was mentioned in previous section), are stated in the following Table 1. Most of them were taken from the datasheet [6], only values of transient and subtransient reactances were taken from [3] as they were assessed more precisely. Note that the rated voltage of the machine is 400 V L-L, which is equal to 230 V L-N, but the test was done only with reduced voltage 69 V L-N with respect to measurement devices.

S (kVA)	U_r (V)	P (kW)	n (r. p. m.)	x_d (%)	x_d' (%)	x_d'' (%)	T_d' (ms)	T_d'' (ms)	T_a (ms)
7.5	400	6	1500	140	8.61	6.81	40	3.7	6

Table 1: Parameters of the test machine

In PSCAD, a standard synchronous machine from the library called Machines was used for modelling. It is a standard 6-th order model, which parametrization and settings were analysed and described in detail in [7]. For this case, values from Table 1 were used for parametrization. In order to respect operating conditions of real machine, no speed governor or excitation regulator were modelled – machine was simulated as rotating at synchronous speed without a torque on the shaft (no-load) and with constant excitation giving 69 V L-N on machine terminals.

In PSS Sincal, a synchronous machine model was used. In this software, it is important to choose the simulation mode correctly. For objectives of this paper, the mode dynamics/electromagnetic transients was used. In this mode, the machine is represented by 6-th order model. This model was parametrized according to Table 1. Similarly to PSCAD, in PSS Sincal machine was modelled without excitation regulator (with constant excitation) and without speed governor. The setting of the model is described in Help [8]. However, comparing to PSCAD, set up and initialization of the model is simpler.

4 TEST AND SIMULATION RESULTS

The short circuit current measurement was done on the previously described test machine. The machine was rotating at synchronous speed, with no load and the excitation current was set to get 69 V L-N at machine terminals (30 % of rated voltage; as previously explained, it was due to measurement devices). After this initialization, the sudden three-phase short circuit was applied. Voltage and currents in all phases were measured during the transient with oscilloscope Yokogawa DL850 equipped with current sensors for measurement. The voltage was measured only to determine the angle when the fault was applied to simulate it identically. The measured current waveform is in the following Figure 2.

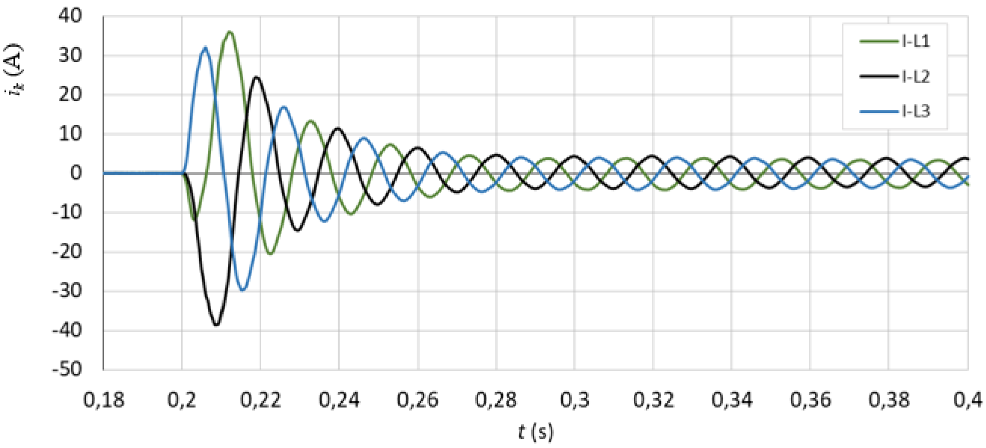


Figure 2: Shor circuit current waveform obtained by measurement

The short circuit test under the same conditions, which was done on a real machine, was simulated in PSCAD and PSS Sincal. Waveforms obtained by simulations are in the following Figure 3 and Figure 4.

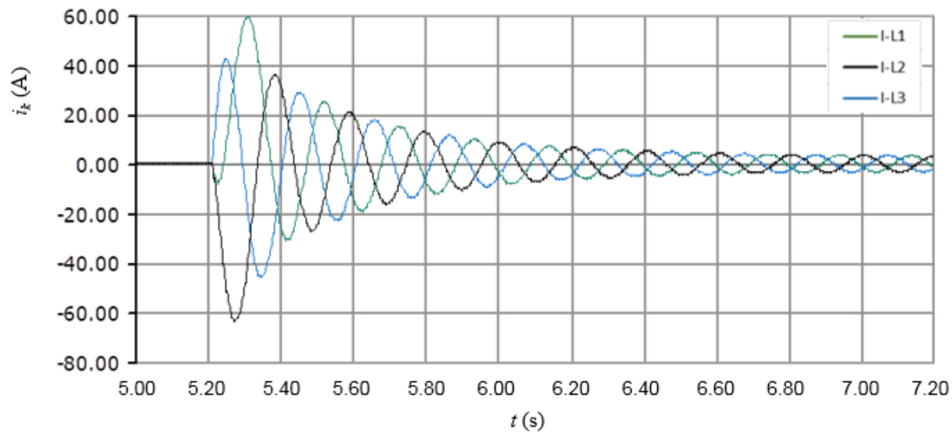


Figure 3: Short circuit current waveforms from PSCAD

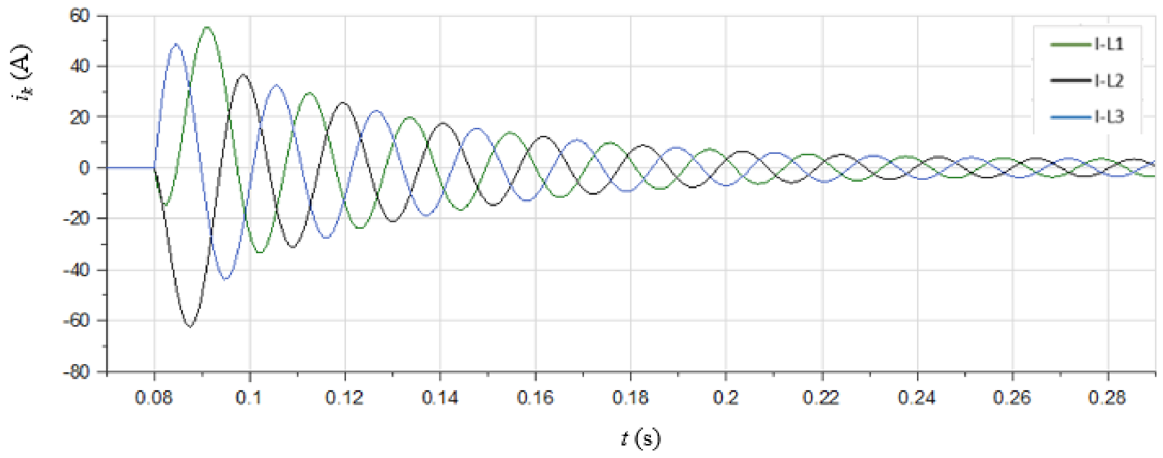


Figure 4: Short circuit current waveforms from PSS Sincal

From Figures 2 - 4 can be seen that the short-circuit current has the same waveform in all three graphs and results obtained in different pieces of software are almost the same. Comparing to the measurement, steady-state short-circuit current has practically the same value. However, the magnitude of current during the subtransient state (1st peak) is different – value obtained by simulation is significantly higher (in phase L2, measured value is almost 39 A, whereas results from simulations are almost 63 A).

Even though the results can be assessed as pessimistic and in reality, the short circuit peak current will be smaller, more accurate results would be expected. In addition, machine model parametrization and set-up was done clearly in both pieces of software.

Machine modelling remains the biggest source of uncertainties. Firstly, machine parameters tolerance needs to be taken into account. At least, the values of transient and subtransient reactance were modified due to the testing, but other parameters, such as time constants, were used from [6]. It would be better to assess them also from tests done accordingly to [2], but it is more complicated to determine them comparing to determination of reactances. Values of the parameters can be also influenced by the reduced voltage, which was used due to measurement devices possibilities.

Then the saturation effects of the machine should be considered. For simulations, saturation effects are often neglected as the saturation curve is not known. Nevertheless, saturation effect neither can be assessed for the test machine as its design does not allow measure it (measurement of the excitation current is not possible).

Other uncertainties can be caused by the measurement devices, especially by the current sensors and the signal conversion as the measurement of current is indirect. However, the difference of more than 20 A cannot be caused only by devices errors and is more influenced by previously mentioned machine modelling problems.

5 CONCLUSION

Simulation software is a powerful tool to study power systems dynamics. In this article, PSCAD and PSS Sincal were used to simulate the three-phase short circuit current waveform and results were compared to the measurement. It can be concluded that simulated waveforms are close to the measured one, but values of the peak current are bigger comparing to the measurement. To make the simulation more accurate, more detailed analysis of modelling or usage of different (more detailed) model would be required.

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