MSc Thesis
IEA Department at LTH

Popular Science Summary

Simulation of Transformer Inrush Currents and Their Impact on the Grid

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Abstract

When a transformer (an element with the ability to adapt voltage to the individual requirements of the different parts of the system) is switched in, a current inrush is drawn from the grid. The magnitude and duration of the inrush current depend on several factors, such as the size of the transformer and the network strength to which the transformer is being connected. To limit the disturbances that the energization of transformers may cause, their size is often constrained using a rule of thumb that relates the maximum transformer size to the network strength. This restriction comes from the fact that the larger the transformer is, the greater the inrush current and the deeper the voltage in the surrounding grid goes. This MSc Thesis aims to optimize the transformer sizing decision by precisely simulating the voltage dip at the energizing bus and the surrounding area. For this purpose, an adequate study of the causes and consequences of the inrush current phenomenon is conducted to design a Python model that can accurately represent these kinds of transient episodes. Afterwards, a steady-state software for power system analysis called PSS/E is used to estimate the impact on the surrounding area with limited fidelity. In conclusion, considering the limitations and assumptions made, it is possible to have some intuition on the expected impact of energizing a transformer in the grid in terms of the voltage dip in a more precise way than using the actual rule of thumb. However, some effort into verification is necessary.

Inrush currents during transformer energization are a well-known issue extensively described in the literature. Hence, modelling the equations that define its dynamics is a matter of understanding the different phenomena involved and making suitable assumptions. There are two types of transformers, but when it comes to the generation, transmission, distribution and industrial use of electrical power, three-phase transformers are dominant with respect to single-phase transformers. Still, because single-phase transformers are easier to comprehend, they are analysed first, and afterwards, the model is expanded to represent some classes of three-phase transformers. The result has excellent accuracy in comparison with other tools with superior transient analysis simulation such as Matlab Simscape or PSCAD. An example is available in Figure 1.

The next step is to find out the effect on the connected network, which relies on the PSS/E software because it is the main tool utilized at E.ON. The fact that is going to be used a steady-state program to estimate a transient effect is one of the challenges of this MSc Thesis and a limitation imposed by E.ON as they do not provide other software licenses.

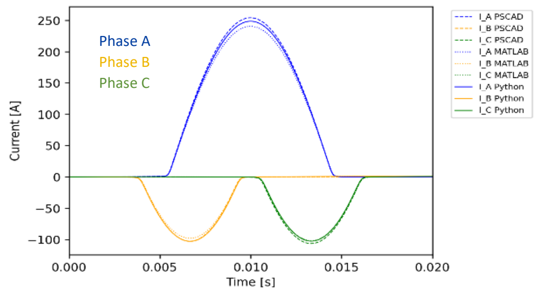

Figure 1: Inrush current waveform of a three-phase transformer compared to Matlab and PSCAD.

After developing different strategies to couple the time-simulation results with steady-state PSS/E variables and integrating everything in a Python tool, an energization study is carried out in a reduced grid. This allows us to evaluate the different alternatives and consider the most trustful ones, but the lack of measurements makes this task doubtful and non-verified.

Finally, with the information that E.ON engineers can extract from the tool designed for energization studies, it is possible to have an intuition about the voltage dip at different buses in the grid and make a transformer sizing decision given some boundary conditions imposed by grid standards or special customer requirements. Figure 2 shows the minimum voltage simulated at different buses when varying the size of the transformer being energized.

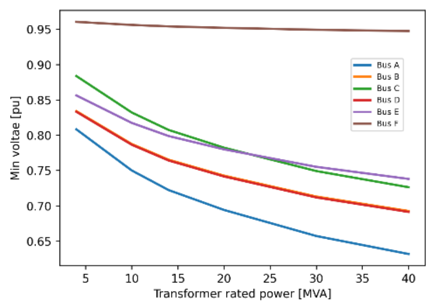

Figure 2: Simulated voltage dip at different buses