Development Of Transformer Digital Twins Using Multiphysics Simulation Tools

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Abstract

In the past, the grid conditions were quite stable and thus, the transformers were considered to operate under stable conditions in a centralized power grid. Due to the stable load conditions, many transformers had a long lifetime. However, today the world is changing, and the power grid continues to increase in complexity by integrating intermittent renewables, distributed energy resources, electric vehicle charging stations, data centers, etc. All these factors are resulting in more dynamic loading of the transformers. Irrespective of the changing generation and demand trends, transformers are expected to last for 30 - 40 years. However, manufacturers and asset owners feel pressure to ensure competitiveness and effective allocation of capital and operational expenditures. Therefore, better insights are needed in order to ensure sound decisions on transformer design optimization, maintenance, repair, or new investment. These challenges can be addressed by implementing smart and digital technologies, such as a transformer digital twin. In recent years, few transformer manufacturers made efforts in power asset digitalization and asset digital twin developments. Such development activities regarding the digitalization of transformers support and remove uncertainty during design and configuration while supporting applications and ensuring availability and reliability through condition monitoring and advanced services.

In contribution to this necessity, this article presents the benefits and development process of transformer digital twin applications to manage the current and future challenges to the transformer industry. Computer-aided engineering (CAE) tools such as the finite element method (FEM) simulations play a vital role in the development of transformer digital twins. HTT has developed DryTrafo, a digital twin application for cast resin transformers using COMSOL Multiphysics® simulations. There are different twin applications under the portfolio of DryTrafo such as DryLoss and DryHeat, a graphical illustration is shown in Fig. 1. DryLoss twin application computes AC and DC losses using the AC/DC Module, it also provides a visual assessment of magnetic and current density fields to identify high and low-loss pockets in the transformer geometry, which facilitates design optimization. DryHeat twin application analyses the thermal behavior of cast resin transformers based on the CFD Module, including the identification of the hotspot temperature. DryTrafo offers insight into the designs and allows engineers to provide a complete optimization of transformer design within minutes.

Finally, a three-phase rectifier transformer unit, 2000 kVA 10500/720 V is used to explain the development and working principle of the twin simulations under the portfolio of DryTrafo. These transformer digital twins can provide value in several stages from planning, and realization, to field operations to help produce efficient designs, forecasting the transformer thermal behavior under different load cycles, visualizing maximum permissible overload capabilities, and remaining useful life estimation.

Keywords: digital twin; cast-resin transformer; multiphysics simulation; FEM

Figures used in the abstract

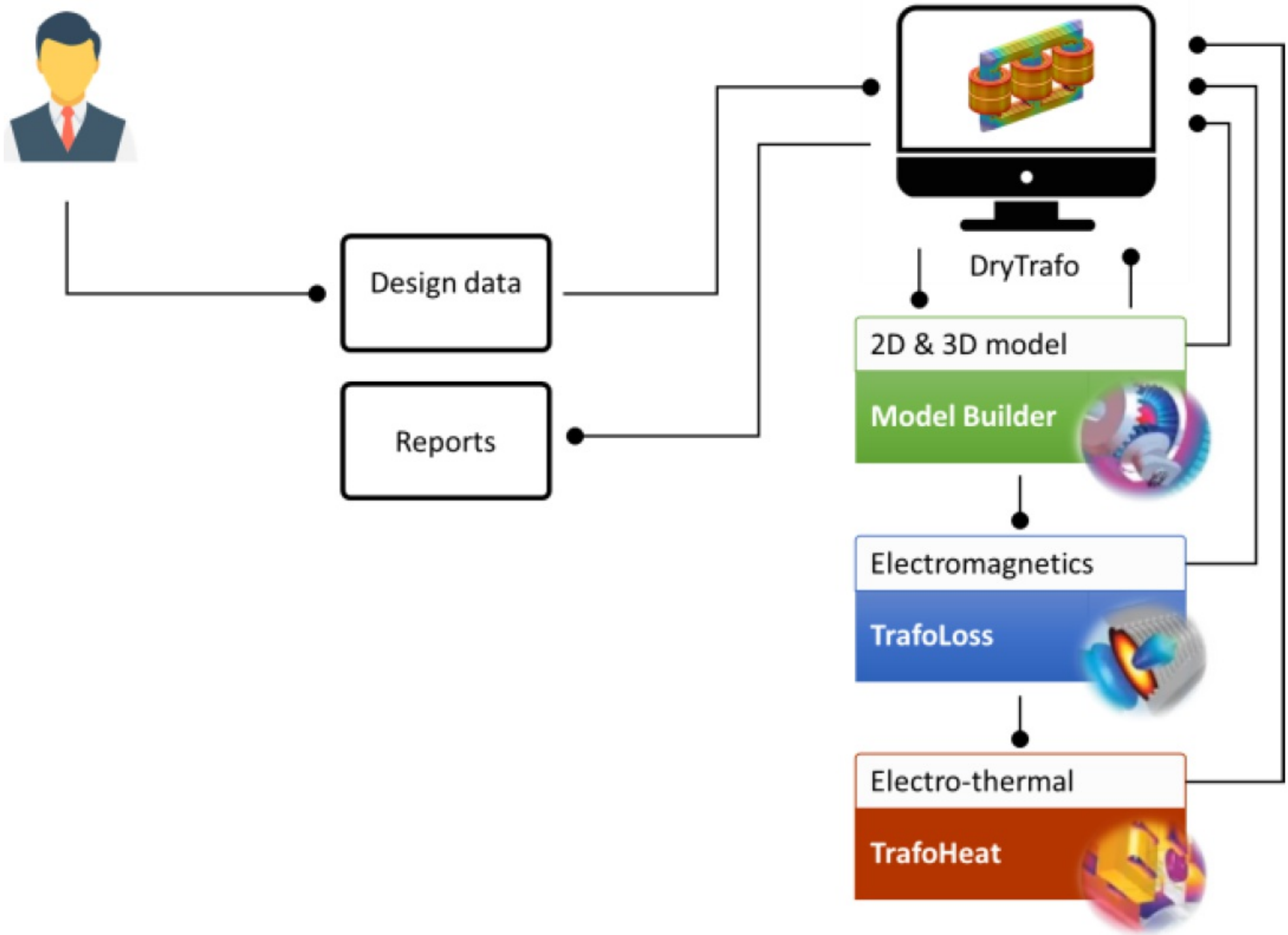

Figure 1 : Graphical illustration of DryTrafo twin application.