








Integrated Maxwell–Twin Builder Co-Simulation for Transformer Fault and Reclosing Analysis

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Abstract. In this study, the transient behavior of a three-phase distribution transformer under fault and reclosing conditions is investigated using Ansys Maxwell and Twin Builder environments. The transformer is first modeled in Maxwell 3D considering realistic geometric and material parameters. The electromagnetic parameters such as winding resistance, leakage inductance, and magnetizing inductance are extracted and transferred to Twin Builder for time-domain simulation. Fault scenarios, including phase-to-ground circuits is introduced to evaluate the impact of sudden disturbances on the transformer's electrical characteristics. Subsequently, an automatic reclosing operation is implemented to restore the system after fault clearance. The transient waveforms of voltage and current before, during, and after reclosing are analyzed to observe the resulting overvoltages, inrush currents, and oscillations. The results demonstrate that the reclosing process significantly affects the post-fault recovery period and may induce temporary magnetic saturation or current asymmetry depending on the fault type and reclosing timing. This integrated modeling approach provides a practical framework for studying fault recovery mechanisms in power transformers and contributes to improving the reliability of power systems.

Keywords: Power Transformer, Reclosing, Transient Analysis, Fault, Ansys Maxwell

1 Introduction

Faults in power transformers often cause prolonged outages in electrical networks. To ensure the continuity of supply, transformer faults should be identified through predictive scenarios before their onset, or rapid intervention must occur immediately after a fault develops. As one of the fundamental components of power systems, the long-term reliable operation of power transformers is a key determinant of overall system security [1,2]. In practice, transformers may undergo reclosing operations following fault events [3]. In such cases, they must withstand a potential permanent fault that may occur after the initial disturbance.

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Automatic reclosing in transmission and distribution networks is a fundamental protection and operational technique designed to promptly isolate transient faults and re-energize the system as quickly as possible. Although reclosing is often regarded as a line-centric process due to the high incidence of temporary faults on overhead lines, three-phase transformers constitute a critical component that shapes the current–voltage transitions during reclosing. The transformer’s residual flux, magnetic saturation characteristics, winding capacitances, and leakage inductances directly influence the magnitude and persistence of transient regimes at the moment of reclosing.

Re-energizing a transformer after fault clearance produces a nonlinear magnetic response. This response may manifest as asymmetric inrush currents, saturation regions triggered by remanent flux, excessive intra-winding and inter-winding transient over-voltages, differential current impulses, and short-duration yet high-magnitude increases in electromagnetic forces [4]. The literature emphasizes that parameters such as first-pole-to-clear time, dead time, and reclosing angle play a decisive role in shaping the inrush current and transient voltages [5,6]. The transformer’s prior magnetic state, phase-angle alignment, and fault duration directly determine the transient magnitudes observed after reclosing.

The interaction between reclosing operations and transformers affects not only the reliability of protection functions but also system stability and the mechanical lifetime of equipment. Short-duration inrush currents generate sudden electromagnetic forces on the windings, increasing mechanical stress and, when repeated frequently, accelerating insulation and winding-support fatigue [7]. At higher frequencies, winding capacitances and leakage inductances become dominant, producing complex electromagnetic transient behavior—an effect particularly pronounced in high-voltage systems.

Recent IEC and IEEE standards place increasing emphasis on modeling transient conditions, evaluating different reclosing strategies (high-speed, delayed, successful reclosing window), and assessing transformer-centric impacts. However, the literature contains a limited number of studies that provide high-resolution, numerically validated analyses of current–voltage waveforms and electromagnetic forces emerging in transformers after reclosing.

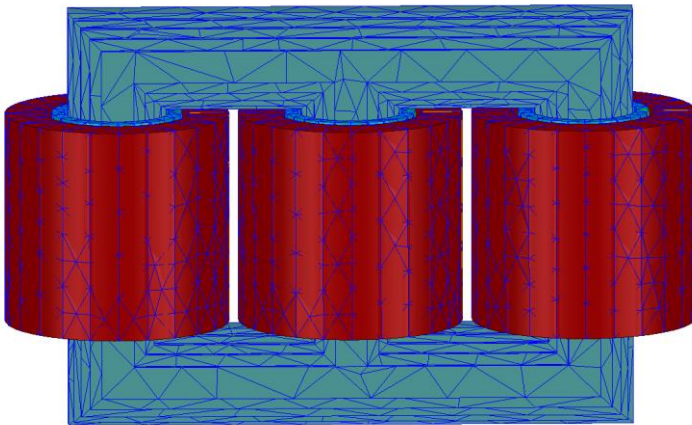
This study investigates, in detail, the transient current–voltage behavior and the variations in electromagnetic forces on the windings of a three-phase power transformer immediately following a reclosing operation. The transformer is first operated under healthy conditions. Subsequently, a fault is applied. After the fault event, switches placed on the high-voltage side operate to perform the reclosing sequence.

2 Power Transformer Model

In this study, a power transformer used in a laboratory environment was modeled in Ansys@Maxwell (Table 1). Manufacturer specifications were utilized during the modeling process. Images of the transformer are provided below (Figure 1).

Table 1. Transformer Data

Factory Info	Data
HV/LV Voltages	10,000/400 V
HV/LV connection Type	YNyn0
Number of Phases	3
Core Losses	220 W
Number of HV/LV Turns	1750/70
Conductor Material	Aluminum
No Load Loss	220 W
Load Loss	1000 W
Short Circuit Impedance	%4

**Fig. 1.** Power transformer Ansys@Maxwell Model

According to the data provided by the manufacturer, the no-load losses were measured as 220 W. The accuracy of the model was verified by comparing the simulation results with the manufacturer's specifications (Figure 2).

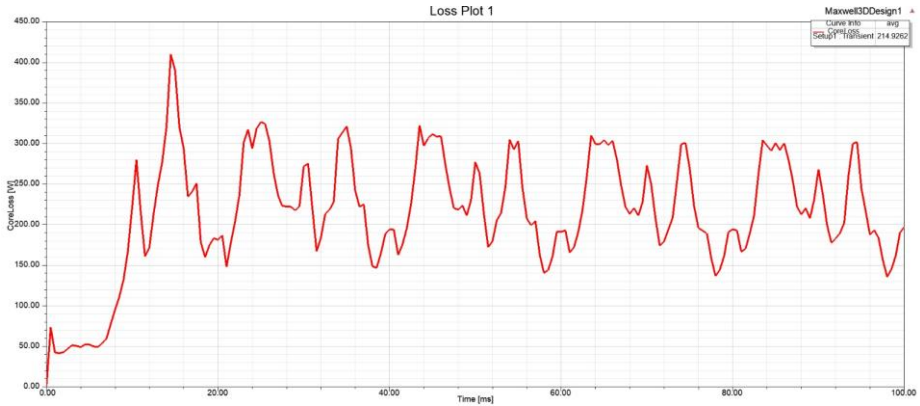


Fig. 2. Transformer No Load Core Loss

3 Fault Analysis and Reclosing

A fault was applied to the transformer, which was initially operating under normal, fault-free conditions. While the fault remained active, the reclosing switches placed on the high-voltage side first opened the circuit, de-energizing the transformer, and subsequently reclosed to restore its energization.

The simulation was executed for 0.3 s with a time step of 1×10^{-4} s. The fault was introduced at 0.05 s, and the reclosing sequence began at 0.15 s, during which the switches opened and temporarily isolated the transformer. After a predefined interval, the switches reclosed, and the transformer was re-energized. The resulting waveforms obtained from the simulation are presented below (Figures 3-5).

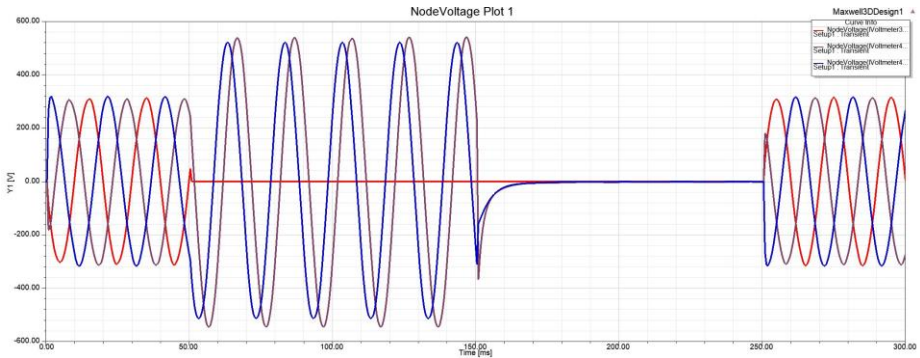


Fig. 3. Fault and Reclosing Condition Voltages

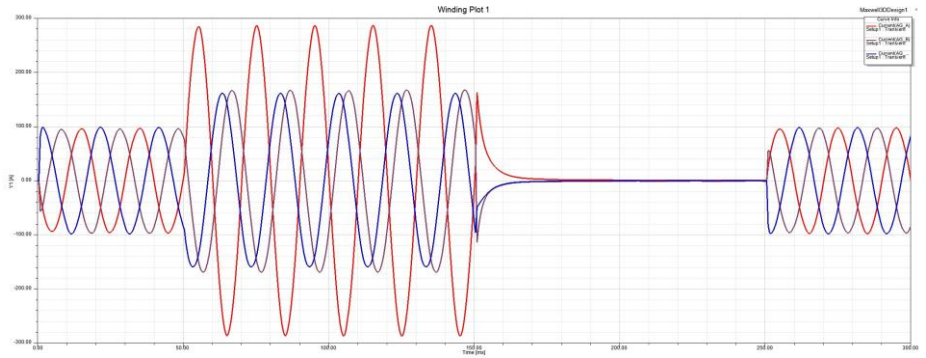


Fig. 4. Fault and Reclosing Condition Currents

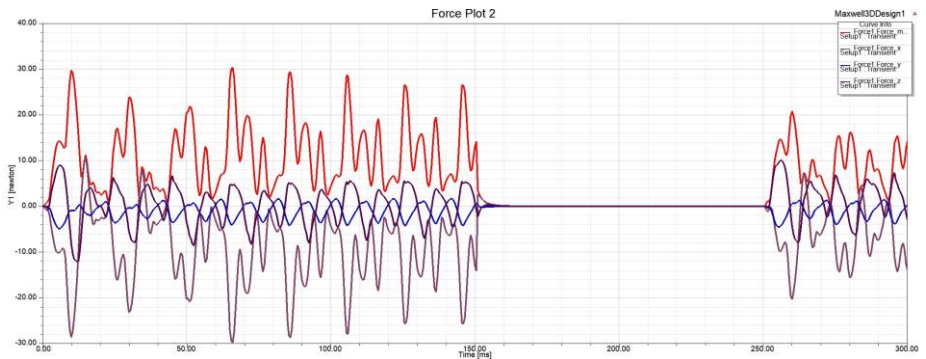


Fig. 5. Electromagnetic Force on

4 Conclusion

In this study, the transient behavior of a power transformer subjected to a single-phase-to-ground fault and a subsequent reclosing operation was examined. The simulation results indicate that the initiation of the fault produces noticeable distortions, increased amplitudes, and phase asymmetry in the force, current, and voltage waveforms. Once the recloser opens, all waveforms rapidly collapse toward zero, confirming that the transformer becomes fully de-energized and magnetically unstressed. After reclosing, the system experiences a brief inrush current, short-term force spikes, and a damped voltage recovery; however, these transients settle quickly, and the transformer resumes stable sinusoidal operation. Overall, the findings demonstrate that the applied reclosing strategy successfully isolates the fault, restores magnetic and electrical equilibrium, and enables the transformer to return to safe normal operating conditions without persistent disturbances.

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