Paris Session 2022

White / Black Box Models Accuracy

SC A2 – PS3 – Q3.7

Are white-box models being accurate enough to properly estimate transformer dielectric stresses caused by network topology changes due to the proliferation of distributed renewable energy sources? Are there some cases where black box models are a prefer ?

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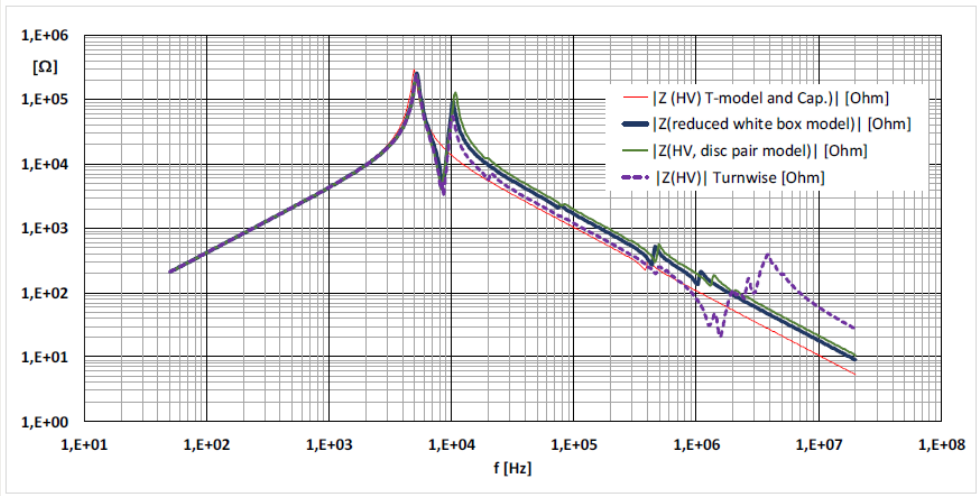
SIEMENS energy

White Box (WBM) / Black Models (BBM) - Accuracy

Are white-box models being accurate enough to properly estimate transformer dielectric stresses caused by network topology changes due to the proliferation of distributed renewable energy sources?

- WBM: Used by Manufacturer internally for design
- BBM: Terminal Equivalent representation of WB



Frequency response of different models in the range 50 Hz–20 MHz. Impedance at HV Terminal, Neutral and LV Terminals grounded. [1]

White Box (WBM):

- Number of branches (model size) pretty high to cover all relevant voltages / stresses inside the transformer.
- Frequencies covered up to >10 MHz (model size)
- The only design approach for the manufacturer !

Black Box (BBM):

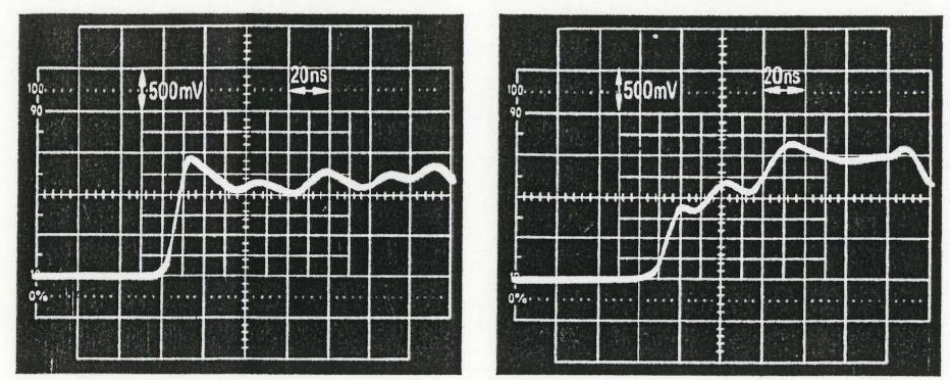
- Terminal Equivalent representation of a transformer model for network system studies (customer side)
- Generation out from WBM, any number of branches, up to the same frequency range as used by manufacturer.
- Generation from Measurements, SFRA not fully reliable in very high frequency range, BBM contains errors

White Box (WBM) / Black Models (BBM) - Accuracy

Are white-box models being accurate enough to properly estimate transformer dielectric stresses caused by network topology changes due to the proliferation of distributed renewable energy sources?

WBM – Features & Challenges:

- Representation up to single turns automized, thousands of branches for a Large Power TX
- Separate Bushing Model for f>1MHz advisable, hundreds of branches



Steep Front Wave at the Terminal versus at the Winding Entrance. Bushings have a damping effect to very high frequencies [2]

- Standard Design Criteria based on Full Wave (BIL) and Short Time factors covering up to 1 MHz.
- Design Criteria for f>1 MHz: much literature, not fully applicable in transformer design → extra margin to be considered.
- WBM should cover frequencies up to 10 MHz (Depending on Customer Need).
- Detailed evaluation of any dielectric stress is possible, signals provided by customer (from simulation or measurement)
- In addition to international literature Test Series for a better coverage of transformer internal insulation setup would be helpful

White Box (WBM) / Black Models (BBM) - Accuracy

Are there some cases where black box models are a prefer ?

BBM – Features / Challenges:

- Terminal Equivalent representation of a trans-former model for network studies @ customer site
- Generation out from measurements contains potential measurement errors
- BBM generation out from WBM is adjustable in model size and mirrors the manufacturers model
- Good way to include a frequency dependent transformer model into customer site studies

[1]: Verification of Withstand Capability for Very Fast Transients of a 200 MVA, 500 kV GSU-Transformer by Modelling and Testing. Alexander Rabel (Siemens AG Austria, Transformers Research) , Jian-Jason Zhou (Siemens China, Transformers Research)

[2]: Verhalten von Hochspannungswicklungen für Transformatoren bei Steilwellen mit Fronten im Nanosekundenbereich. Walter Müller, Werner Stein, Siemens-Energietechnik 5 (1982)