A STUDY ON THERMAL AND ELECTRICAL STRESSES OF POWER TRANSFORMERS

By

Eng. Rehab Ahmed Saad Elshourbagy

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electrical Power & Machines Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

Prof. Dr. Osama El-sayed Gouda

Electrical power and Machine Dept.
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Title of Thesis:

A Study on Thermal and Electrical Stresses of Power Transformers

Key Words:
Top oil temperature ; Hotspot temperature; Transient over voltage; Transformer Life time

Summary:
Power transformers are intended to withstand system abnormalities such as over voltages and overloads. Diagnostics and monitoring of transformer are the effective methods to prevent failures and ensure the network reliability. The solid insulation of power transformers is a function of time which depends on the temperature, moisture amount, acids and oxygen in the insulation system. This thesis focuses on thermal and electrical stresses that affect the insulation of power transformer and hence cause aging of power transformer. IEEE loading guide and IEC 60354 equations were modeled and thermal model is studied to estimate transformer top oil and hotspot temperature. Transient overvoltage is studied also to show how the power transformer can be exposed to electrical stresses causing insulation overheating. Remaining service life of the transformer is estimated through degree of polymerization of paper (DP) insulation.

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Nomenclature

TS	Tensile Strength
IEC	International Electro-technical Commission
IEEE	Institute for Electrical and Electronics Engineers
DP	The degree of polymerization
HST	Hot-spot temperature
Θ_A	Ambient temperature, °C.
$\Delta\Theta_{TO}$	Oil temperature rise over ambient, °C
$\Delta\Theta_H$	Hot spot temperature rise over top oil temperature, °C.
Θ_H	Final hot spot temperature, °C.
$\Delta\Theta_{TO-R}$	Top oil temperature rise over ambient at rated load
R	Ratio of load losses at rated current to no load losses
K	Load factor (supplied load/rated load)
n	An empirically derived exponent that relies on the cooling method
H	Hot spot factor due to the increased eddy losses at the winding end
g	Average winding to average oil temperature rise at rated load
m	An empirically derived exponent that depends on the cooling method
$\Delta\Theta_{TO,U}$	Ultimate top oil temperature rise over ambient temperature
τ_{TO}	Top oil rise time constant
$\Delta\Theta_{H,U}$	Ultimate hot spot temperature rise top oil temperature
τ_H	Hot spot rise time constant
q_{Tot}	Heat generated by total losses, W
C_{th-Oil}	Oil thermal capacitance W.min/° C,
R_{th-Oil}	Oil thermal resistance° C/W,
Θ_{Oil}	Top oil temperature, ° C
I_{pu}	Load current per unit power
q_w	Heat generated by losses at the hot spot location, W
C_{th-H}	Winding Thermal Capacitance at the hot spot location, W.min/° C
R_{th-H}	Thermal resistance at the hot spot location ° C/W
$P_{EC-R(pu)}$	Rated eddy current losses at the hot spot location
P_{TL}	Transformer Total Losses
P_{NL}	No Load Losses
P_{LL}	Load Losses
P_{Ω}	Losses due to Load current and Dc Winding Resistance
P_{EC}	Winding Eddy Losses
P_{OSL}	Other Stray Losses