PQ SYNERGY 2017

Thermal Modeling of Oil Immersed Transformer Using Temperature Rise Data

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POWER QUALITY ENGINEER

PEA.

N1

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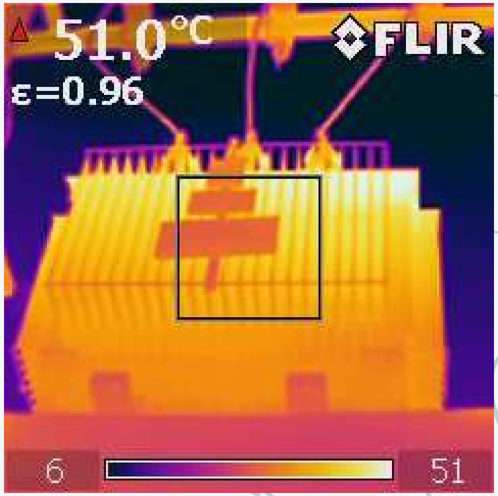
INTRODUCTION

IMPORTANT PART
in distribution system

IMPORTANT PARAMETER
is Hot Spot Temperature

For steady state

Hot Spot Temperature
= function (Top Oil Temperature Rise)



INTRODUCTION

Top Oil Temperature

Max. Top Oil Temperature

ALARM 80-90 C

TRIP 90-100 C

Top Oil Temperature Indicator

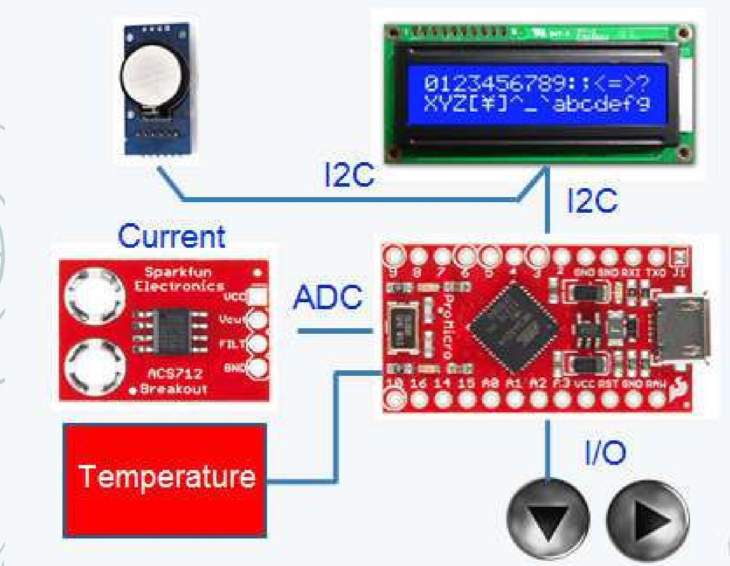
Ambient Temperature is not recorded.

For light load condition, Hot Spot can not be detected.

INTELLIGENT TRANSFORMER

CONDITION BASED MAINTENANCE

ASSET MANAGEMENT



- LOW COST
- SMART DEVICE
- ONLINE CONDITION MONITORING
- EASY COMMUNICATION

INTELLIGENT TRANSFORMER
INTELLIGENT BRAIN

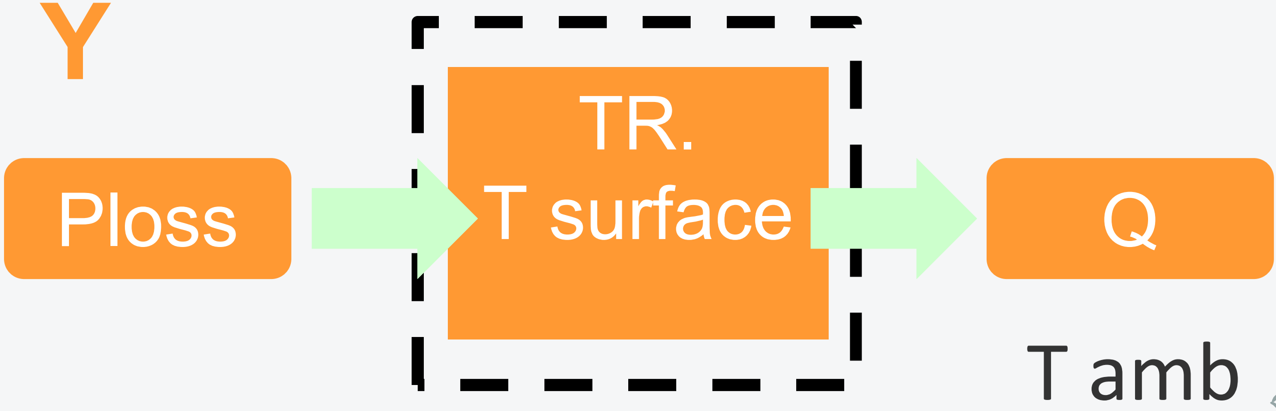
We need to know the relationship between

load and temperature rise.

OBJECTIVE

To Study Thermal Modeling of Oil Immersed Transformer in PEA. Distribution System

THEORY

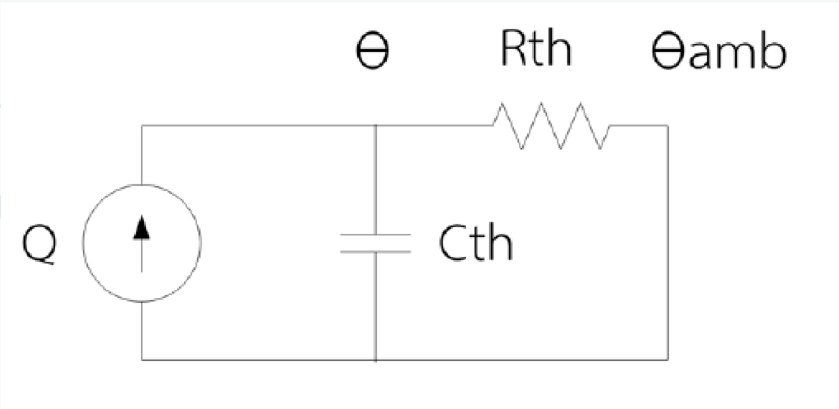


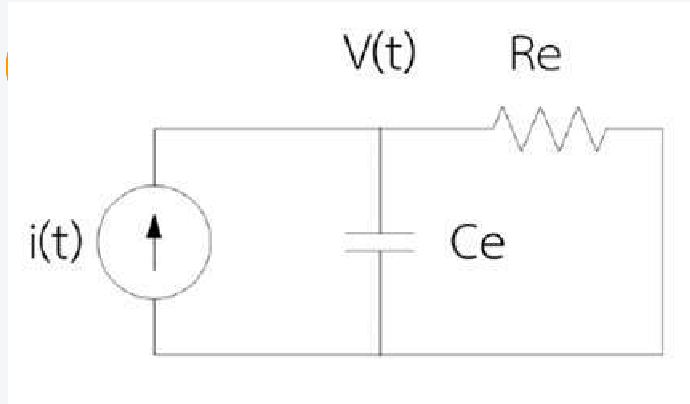
1st Law of Thermodynamic

Energy rate in = accumulated energy +Energy rate out

$$Q = C_{th} \frac{d\theta}{dt} + \frac{1}{R_{th}} (\theta - \theta_{amb})$$

THERMAL-ELECTRICAL

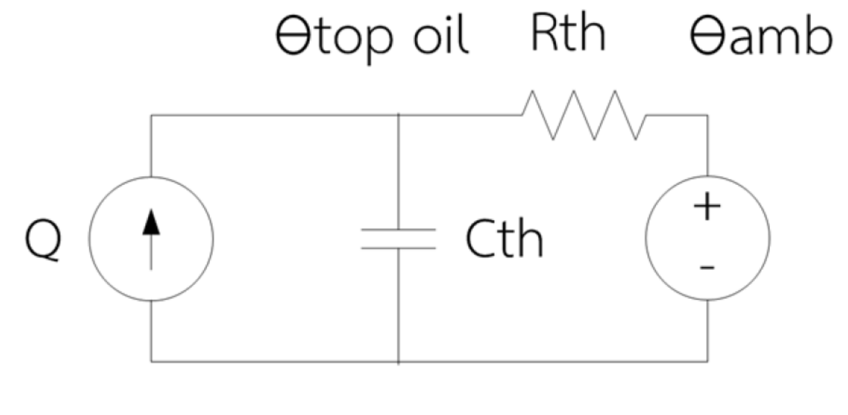




Thermal process
Heat flow rate Q, [W]
Thermal resistance Rth,[K/W]
Thermal capacitance Cth,[J/K]
Temperature θ, [K]

Electrical circuit
Current i(t), [A]
Resistance Re, [Ω]
Capacitance Ce, [F]
Voltage V(t), [V]

TRANSIENT PROCESS



$$Q = C_{th}\frac{d\theta_{top\ oil}}{dt} + \frac{1}{R_{th}}\left(\theta_{top\ oil} - \theta_{amb}\right)$$

$$\theta_{top\ oil} = (\theta_u - \theta_i)\left(1 - e^{-\frac{t}{\tau}}\right) + \theta_i$$

$$\tau = R_{th}C_{th}$$

EXPERIMENTAL WORK

1. FIND TIME CONSTANCE
2. FIND THERMAL RESISTANCE
3. FIND THERMAL CAPACITANCE
4. ENJOY YOUR WORK!!!!

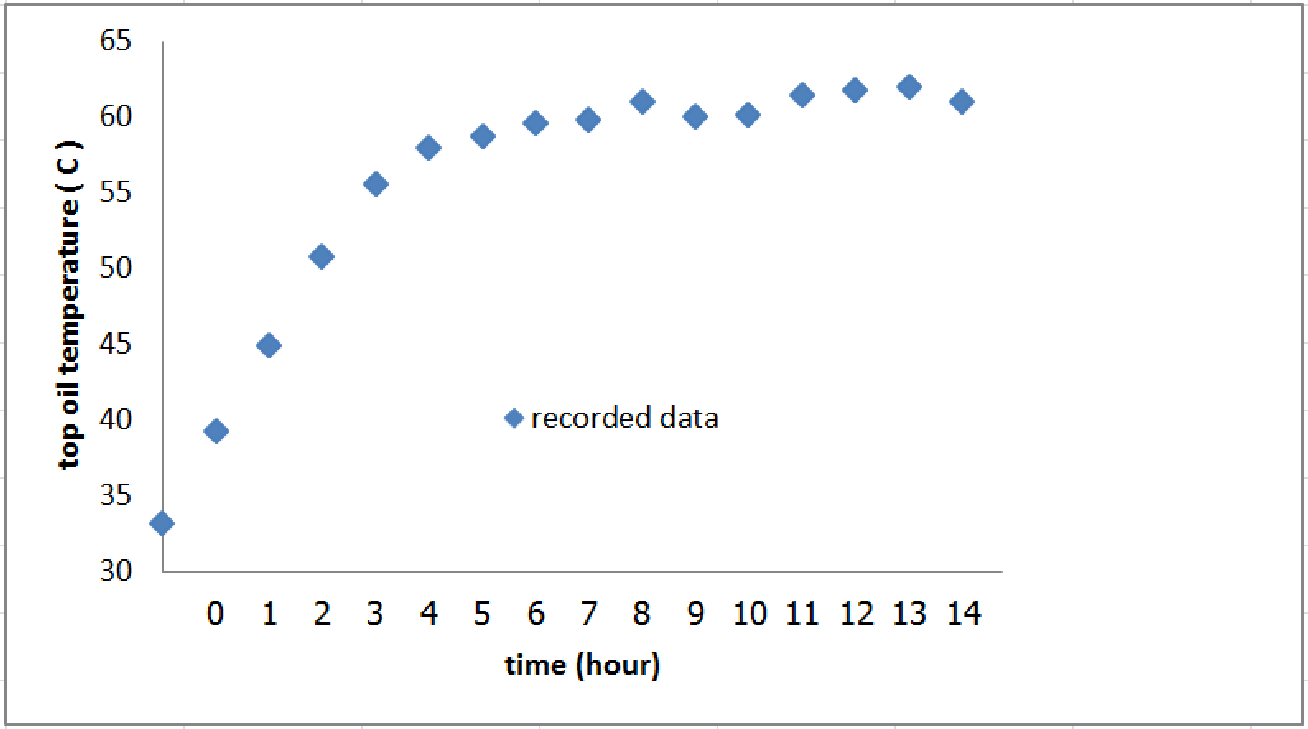
TRANSFORMER DATA

Sample	unit	A	B	C	D	E	F
Capacity	kVA	50	50	100	100	160	160
Voltage		22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V

CONSIDER 3 SIZES OF TRANSFORMER
… 50 100 160 kVA

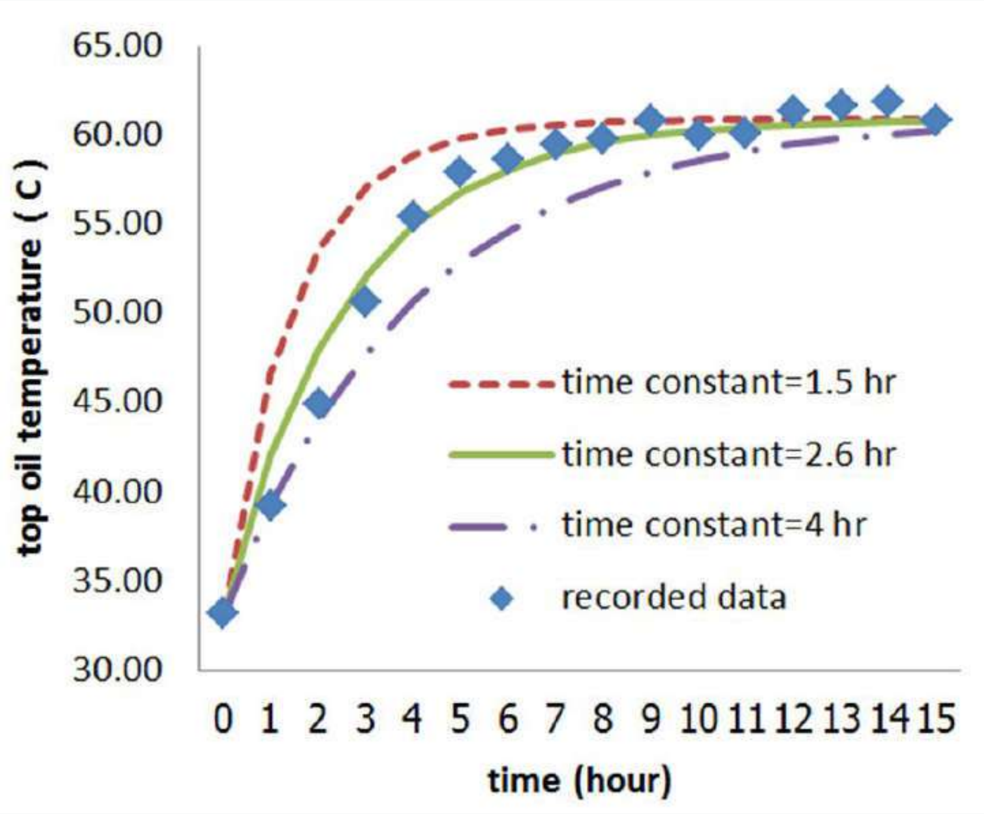
2 MANUFACTURER FOR EACH SIZE

TEMPERATURE RISE REPORT



1. SET SHORT CIRCUIT TEST
2. VARY SUPPLY TO RATED TRANSFORMER LOSS
3. RECORD OIL AND AMBIENT TEMPERATURE

FIND TIME CONSTANCE

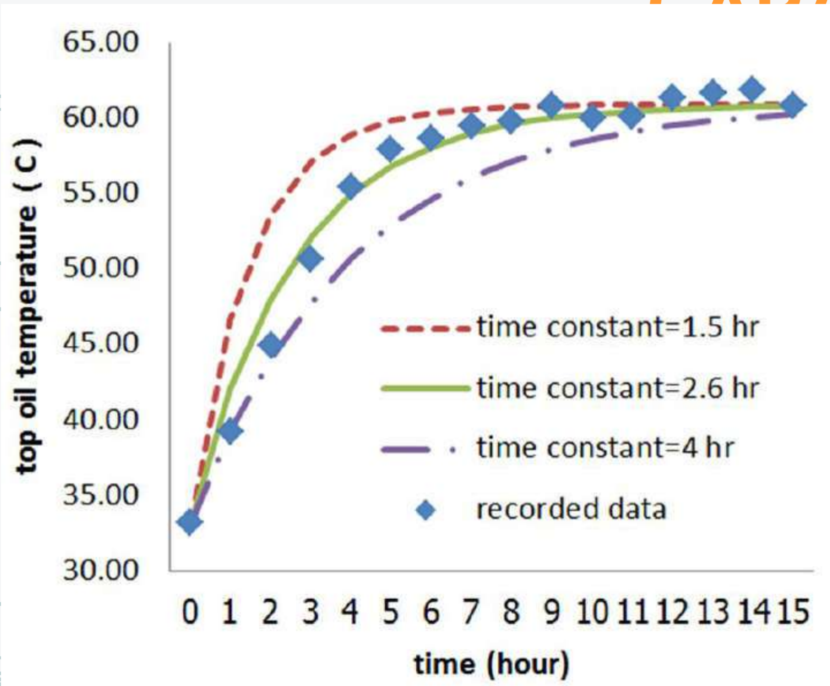


1.VARY TIME CONSTANCE FROM 1.5 TO 4 HRS.

2.TIME CONSTANCE=**2.6HRS.**

3.BEST FIT , AVERAGE PERCENTAGE DEVIATION = 1.836%

FIND THERMAL RESISTANCE AND CAPACITANCE



FOR STEADY STATE

$$Q = \frac{1}{R_{th}} (\theta_{top\ oil} - \theta_{amb})$$

$$\tau = R_{th} C_{th}$$

1. CONSIDER STEADY STATE, **Rth = 0.0305 K/W**
2. TIME CONSTANCE=2.6HRS.
3. **Cth = 306.67 kJ/K**

RESULT

Sample	unit	A	B	C	D	E	F
Capacity	kVA	50	50	100	100	160	160
Voltage		22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V
temperature rise	K	35.40	35.70	43.10	41.20	42.40	38.10
Loss during test	W	1,014.70	1,069.00	1,767.00	1,687.00	2,439.00	2,368.00
Time constance	hrs	2.10	2.60	2.80	2.50	2.00	2.00
Thermal C	kJ/K	216.70	280.28	413.26	368.52	414.17	447.50
Thermal R	K/kW	34.89	33.40	24.39	24.42	17.38	16.09
APD.	%	2.13	0.84	1.15	0.56	0.39	0.78

1. TEMPERATURE RISE = **35– 45 K**

2. TIME CONSTANCE= **2.0 – 2.8 HRS.**

RESULT

Sample	unit	A	B	C	D	E	F
Capacity	kVA	50	50	100	100	160	160
Voltage		22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V	22kV / 400V
temperature rise	K	35.40	35.70	43.10	41.20	42.40	38.10
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APD.	%	2.13	0.84	1.15	0.56	0.39	0.78

3.THERMAL CAPACITANCE = 200-450 KJ/K

4.THERMAL RESISTANCE= 15-35 K/KW

DISCRETIZATION , EASY EQUATION

$$Q = C_{th}\frac{d\theta_{top\ oil}}{dt} + \frac{1}{R_{th}}(\theta_{top\ oil} - \theta_{amb})$$

FIRST ORDER

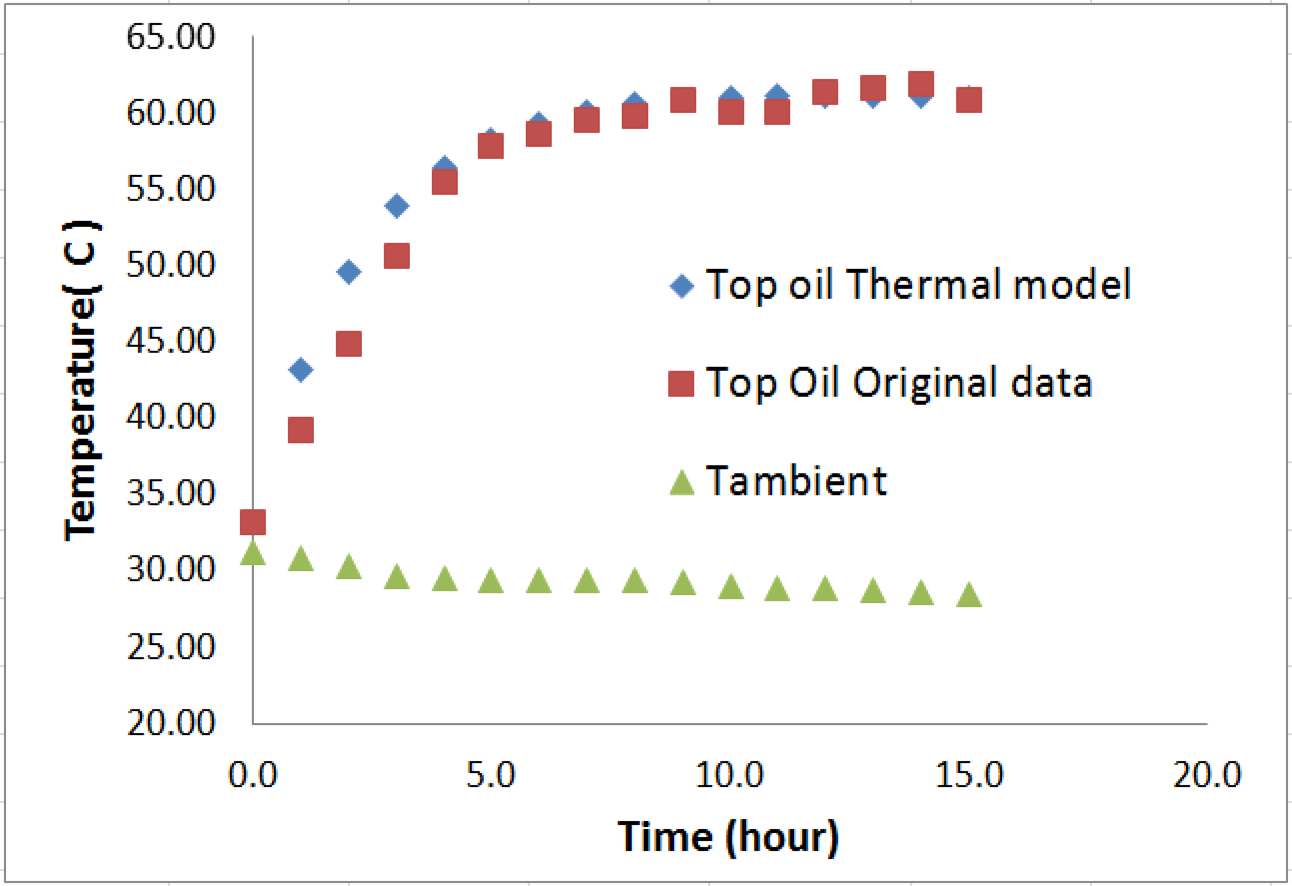
DISCRETIZED WITH SMALL TIME STEP

$$Q = C_{th}\frac{\Delta\theta_{top\ oil}}{\Delta t} + \frac{1}{R_{th}}(\theta_{top\ oil} - \theta_{amb})$$

$$\Delta\theta_{top\ oil} = \theta_{top\ oil,t+time\ step} - \theta_{top\ oil,t}$$

RECHECK THERMAL MODEL

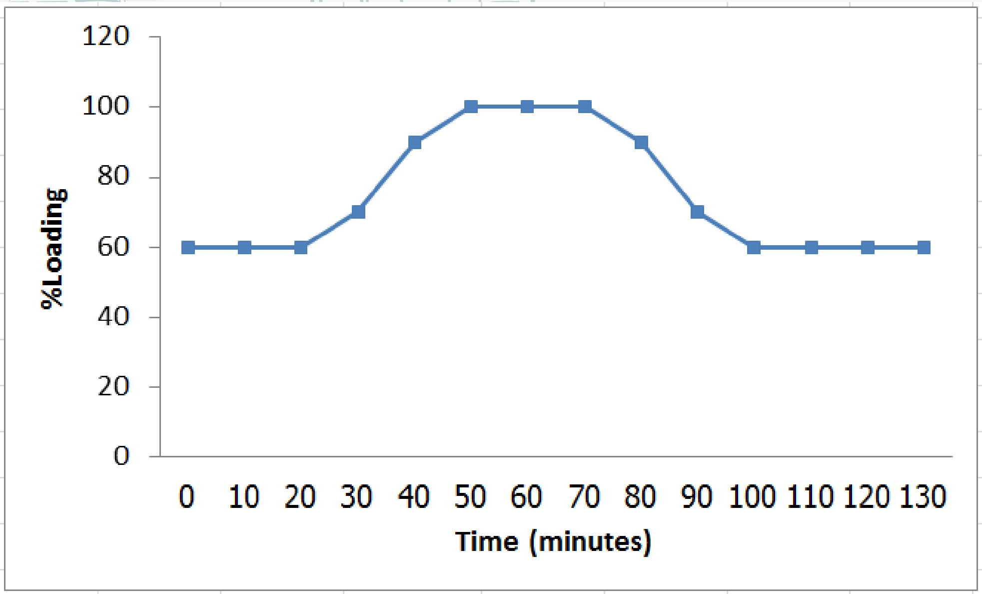
$$Q = C_{th}\frac{\Delta\theta_{top\ oil}}{\Delta t} + \frac{1}{R_{th}}(\theta_{top\ oil} - \theta_{amb})$$

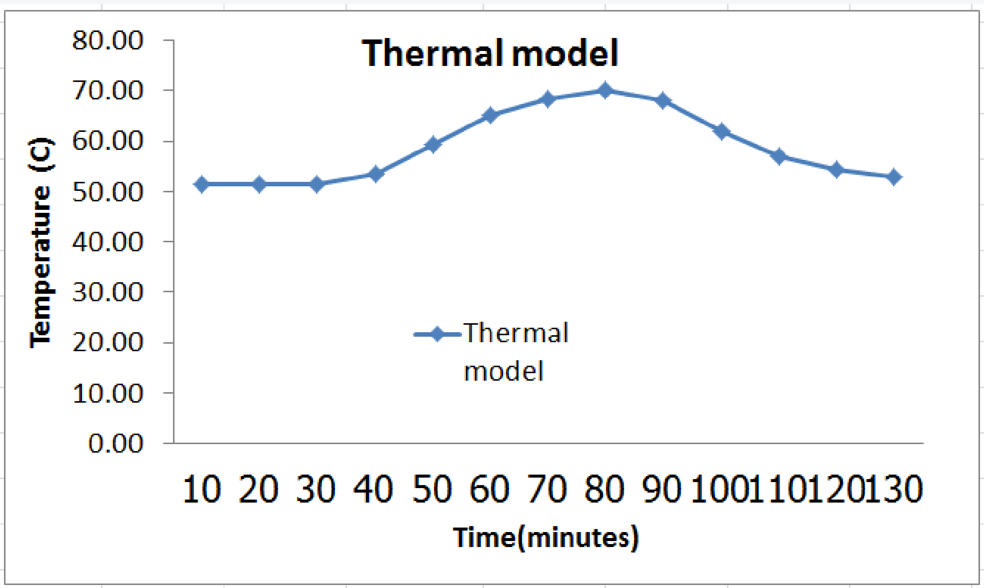


AVERAGE PERCENTAGE DEVIATION APD.=2.41%

TIME STEP = 10 MIN.

SIMULATION





%LOAD RANGE 60-100 %

SIMULATION

RECALCULATE EVERY 60 MIN

USING DISCRETIZED EQUATION FOR MICROCONTROLLER

CONCLUSION

1. **Thermal model** of oil immersed distribution transformer was derived using raw data from transformer **temperature rise test.**

2. **Dynamic and Discretized** Thermal model that is in simple form. It is good for micro controller.

Credits

Special thanks to all the people who made and released these awesome resources

CUSTOMER DIVISION PEA.N1

TRANSFORMER DIVISION PEA.HEAD OFFICE

Thanks!

Any questions?

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