ELEMENTS OF ELECTRICAL ENGINEERING
Course Code : UE25EE141A/B

PES UNIVERSITY

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ELEMENTS OF ELECTRICAL ENGINEERING

TRANSFORMER EFFICIENCY CALCULATION USING OC & SC TESTS ; CONDITION FOR MAXIMUM EFFICIENCY

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Losses in a Transformer

Transformer losses include

i) Core (or) Iron Losses (P_i)

These losses include Hysteresis & Eddy current losses

Hysteresis loss is due to the reversal of magnetization of the core of the transformer as the current in the transformer winding reverses. Hysteresis loss is given by the following empirical formula:

$$P_h = K.B_m^{1.6}.f \quad \text{(Watts)}$$

Where, K is called Steinmetz constant
B_m is the maximum flux density in the core
f is the supply frequency

Losses in a Transformer (contd..)

Eddy current loss occurs in the core due to rate of change of flux in the core. These losses are given by

$P_e = K_1 . B_m^2 . f^2 . t^2$ (Watts)

Where t is the thickness of laminations.

Eddy current loss can be reduced by laminating the core.

ii) Copper Losses (P_{cu})

These losses occur in the primary and secondary windings of the transformer due to winding resistances.

Total copper loss = $I_1^2R_1 + I_2^2R_2$

Where I_1 , I_2 , R_1 , R_2 represent Primary & secondary currents and Primary & secondary winding resistances respectively.

Finding Efficiency of a Transformer

Efficiency of a Transformer can be found by one of the following two methods:

i) By Direct Loading

In this method, transformer is loaded under different loading conditions (No-Load to Full-Load) and different power factor loads to find its efficiency under various conditions. This method can be used for small transformers but not viable for large transformers.

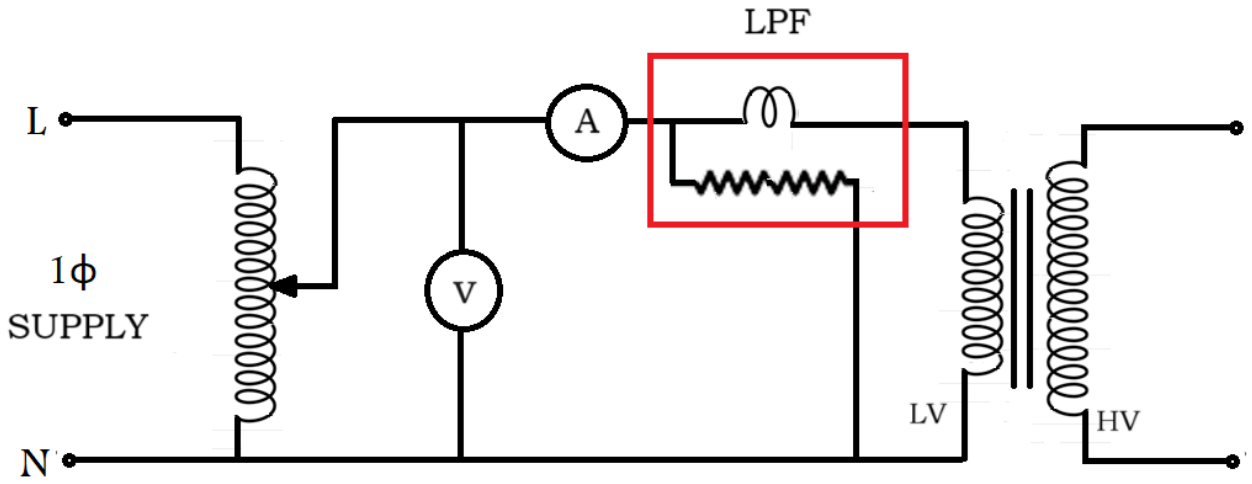
ii) By Conducting Open Circuit (OC) & Short Circuit (SC) Tests

In this method, by conducting OC Test, core loss in the transformer can be found. By conducting SC Test, Rated copper loss can be found. Using this data, the efficiency of transformer can be predetermined under different loading conditions and different power factor conditions.

Open Circuit or No-Load Test on a Transformer

Open Circuit (OC) Test on a Transformer is performed to determine core losses in the transformer.

The connections for OC Test are as follows:



During OC Test, rated voltage rated frequency supply is applied on LV winding with HV winding kept open.

Open Circuit or No-Load Test on a Transformer (Contd..)

Open circuit Test is usually conducted on LV side due to the following reasons:

i) Arranging rated Low Voltage supply is easier than arranging rated High Voltage supply.

ii) Voltmeters and Watt meters of lower voltage range can be used.

iii) It is safer work on LV side than HV side.

In this test, after applying rated voltage rated frequency supply on LV side, following readings are noted:

i) No-Load Voltage, V_0 (indicated by the voltmeter)

ii) No-Load Current, I_0 (indicated by the ammeter)

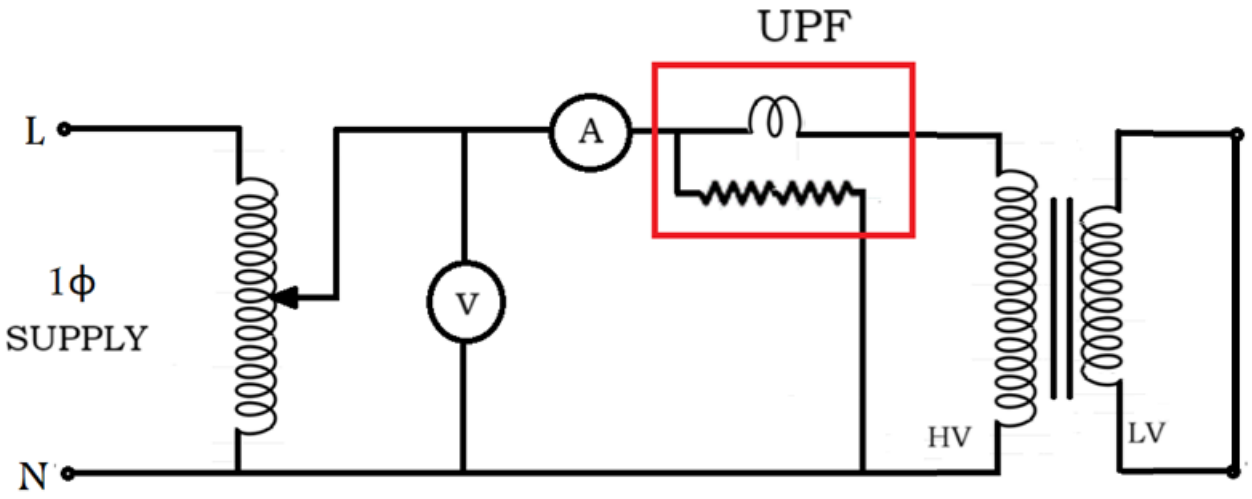
iii) No-Load Power, P_0 (indicated by the wattmeter)

It is observed that No-Load current is just 2 to 5% of rated current of the winding. So, copper losses during OC Test are negligible. Hence power reading indicated by the wattmeter is equal to the Core (or) Iron Loss i.e., P_i in the transformer.

Short Circuit on a Transformer

Short Circuit (SC) Test on a Transformer is performed to determine copper losses in the transformer.

The connections for SC Test are as follows:



During SC Test, variable voltage rated frequency supply is applied on HV winding with LV winding shorted.

Short Circuit Test on a Transformer (Contd..)

In this test, low voltage rated frequency supply is applied on HV side and the voltage is gradually increased until the current flowing in HV winding becomes equal to its rated current. The following readings are noted:

i) Short Circuit Voltage, V_{sc} (indicated by the voltmeter)
ii) Short Circuit Current, I_{sc} (indicated by the ammeter)
iii) Short Circuit Power, P_{sc} (indicated by the wattmeter)

Short circuit Test is usually conducted on HV side since rated current of HV winding is less than rated current of LV winding. Hence, Ammeter and Wattmeter of lower current rating can be used.

It is observed that 5 to 10% of rated voltage of the HV winding is enough to circulate rated current. So, iron loss during SC Test is negligible. Hence power reading indicated by the wattmeter is equal to the Full-Load (or) Rated Copper Loss i.e., $P_{cu(FL)}$ in the transformer.

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Finding Transformer Efficiency by OC & SC Tests

By conducting OC Test, iron loss P_i in the transformer can be found. By conducting SC Test, Rated (or) Full load copper loss $P_{cu(FL)}$ can be found. Using the losses data, efficiency of the transformer can be found as:

$$\text{Efficiency , } \eta = \frac{Output\ Power}{Input\ Power} = \frac{Output\ Power}{Output\ Power + Total\ Losses}$$

$$= \frac{x * VI * cos\Phi}{x * VI * cos\Phi + P_i + x^2 * P_{cu(FL)}}$$

Where, x = Fraction of Load on the transformer (= 1 under FL condition)

VI = Rated Apparent Power in VA/kVA/MVA

$cos\Phi$ = power factor of the load

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ELEMENTS OF ELECTRICAL ENGINEERING

Text Book & References

Text Book:

1. "Basic Electrical Engineering" S.K Bhattacharya, 1st Edition Pearson India Education Services Pvt. Ltd., 2017
2. "Basic Electrical Engineering", D. C. Kulshreshta, 2nd Edition, McGraw-Hill. 2019
3. "Special Electrical Machines" E G Janardanan, PHI Learning Pvt. Ltd., 2014

Reference Books:

1. "Engineering Circuit Analysis" William Hayt, Jack Kemmerly, Jamie Phillips and Steven Durbin, 10th Edition McGraw Hill, 2023

2. "Electrical and Electronic Technology" E. Hughes (Revised by J. Hiley, K. Brown & I.M Smith), 12th Edition, Pearson Education, 2016.

THANK YOU

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