ELEMENTS OF ELECTRICAL ENGINEERING
Course Code : UE25EE141A/B

PES UNIVERSITY

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ELEMENTS OF ELECTRICAL ENGINEERING

CONDITION FOR MAXIMUM EFFICIENCY ; NUMERICAL EXAMPLES ON TRANSFORMERS

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Condition for Maximum Efficiency

i) Considering load power factor to be constant, let us find the fraction ‘x’ of the load at which maximum efficiency occurs:

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

Dividing both numerator and denominator by ‘x’ ,

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

For efficiency to be maximum, denominator in the above equation must be minimum.

Condition for Maximum Efficiency (contd..)

Hence, differentiate denominator w.r.t 'x' and equate it to zero

i.e., $\frac{d}{dx}\left(VI * cos\Phi + \frac{P_i}{x} + x * P_{cu(FL)} \right) = 0$

$$\Rightarrow \quad -\frac{P_i}{x^2} + P_{cu(FL)} = 0$$

$$\Rightarrow \quad x^2 * P_{cu(FL)} = P_i$$

i.e., maximum efficiency occurs when copper loss = iron loss

Fraction of load, x for maximum efficiency = $\sqrt{\frac{P_i}{P_{cu(FL)}}}$

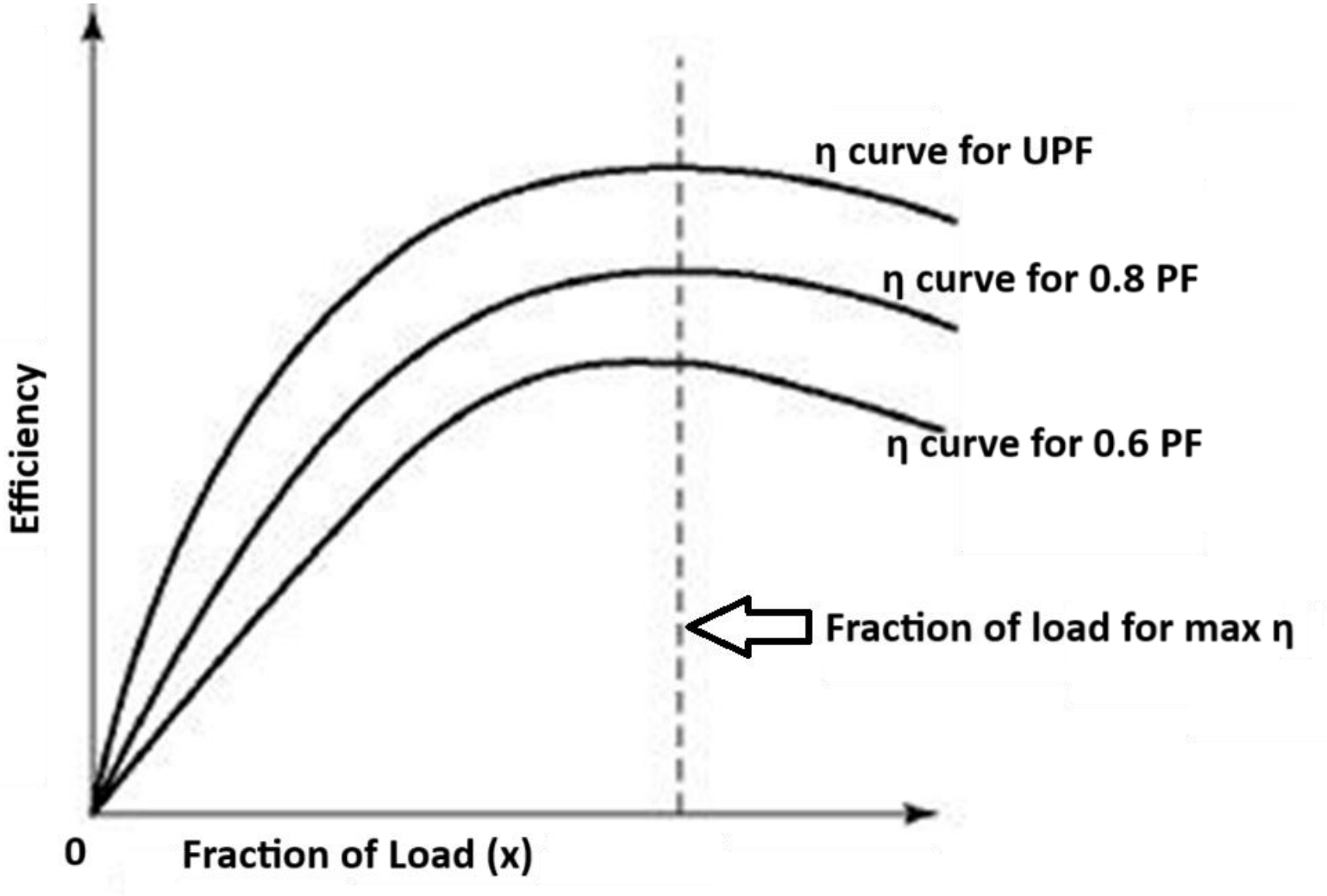
Condition for Maximum Efficiency (contd..)

Thus maximum efficiency at a given power factor occurs at 'x' fraction of load, where

$$x \text{ for maximum efficiency} = \sqrt{\frac{P_i}{P_{cu(FL)}}}$$

ii) Overall Maximum efficiency of the transformer occurs at 'x' fraction of the load (where $x = \sqrt{\frac{P_i}{P_{cu(FL)}}}$ **) and at UPF.**

Efficiency curves



Numerical Example on finding efficiency

Question:

The following is the test data for a 4kVA, 200V/400V, 50 Hz single phase transformer:

OC Test on LV side : 200V, 0.8A, 70W

SC Test on HV side: 20V, 10A, 60W

Determine

i) Full-load efficiency at 0.8 lagging power factor

ii) Efficiency under Half-load condition at 0.6 Lagging power factor

iii) Efficiency under 30% loading condition at UPF

Numerical Example on finding efficiency

Solution:

i) Full-load means x = 1

$$\text{Efficiency , } \eta = \frac{1*4000*0.8}{1*4000*0.8 + 70 + 1*60} = 96.09\%$$

ii) Half-load means x = 0.5

$$\text{Efficiency , } \eta = \frac{0.5*4000*0.6}{0.5*4000*0.6 + 70 + (0.5*0.5)*60} = 93.39\%$$

iii) 30% loading means x = 0.3

$$\text{Efficiency , } \eta = \frac{0.3*4000*1}{0.3*4000*1 + 70 + (0.3*0.3)*60} = 94.09\%$$

Numerical Example on Maximum Efficiency

Question:
The power readings obtained during OC & SC Tests on a 10kVA, 1000V/100V, 50 Hz single phase transformer are 80W & 160W respectively. Determine

i) Fraction of the load at which maximum efficiency occurs

ii) Maximum efficiency of the transformer at 0.8 Lagging power factor

iii) Overall maximum efficiency of the transformer

Numerical Example on Maximum Efficiency

Solution:

Given, P_i = 80W & $P_{cu(FL)}$ = 160W

i) 'x' for maximum η = $\sqrt{\frac{P_i}{P_{cu(FL)}}}$ = 0.707 i.e., 70.7% loading condition

ii) Maximum efficiency at 0.8 Lag power factor

$$= \frac{x * VI * cos\Phi}{x * VI * cos\Phi + P_i + x^2 * P_{cu(FL)}} = \frac{0.707 * 10000 * 0.8}{0.707 * 10000 * 0.8 + 80 + (0.707 * 0.707) * 160}$$

= 97.25%

Numerical Example on Maximum Efficiency

Solution (contd..)

iii) Overall maximum efficiency of the transformer occurs at x = 0.707 and at UPF

$$\text{Overall maximum efficiency} = \frac{0.707 * 10000 * 1}{0.707 * 10000 * 1 + 80 + (0.707 * 0.707) * 160}$$

$$= 97.78\%$$

THANK YOU

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