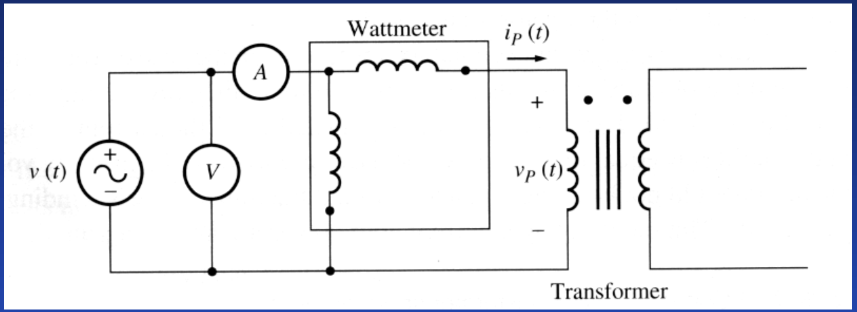
Determining the values of components

The open-circuit test.

Full line voltage is applied to the primary side of the transformer. The input voltage, current, and power are measured.



From this information, the power factor of the input current and the magnitude and the angle of the excitation impedance can be determined.

To evaluate R_C and X_M, we determine the conductance of the core-loss resistor is:

$$G_C = \frac{1}{R_C} \tag{4.33.1}$$

The susceptance of the magnetizing inductor is:

$$B_M = \frac{1}{X_M} \tag{4.33.2}$$

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Since both elements are in parallel, their admittances add. Therefore, the total excitation admittance is:

$$Y_E = G_C - jB_M = \frac{1}{R_C} - j\frac{1}{X_M} \tag{4.34.1}$$

The magnitude of the excitation admittance in the open-circuit test is:

$$\left|Y_E\right| = \frac{I_{oc}}{V_{oc}} \tag{4.34.2}$$

The angle of the admittance in the open-circuit test can be found from the circuit power factor (PF):

$$\cos\theta = PF = \frac{P_{oc}}{V_{oc} I_{oc}} \tag{4.34.3}$$

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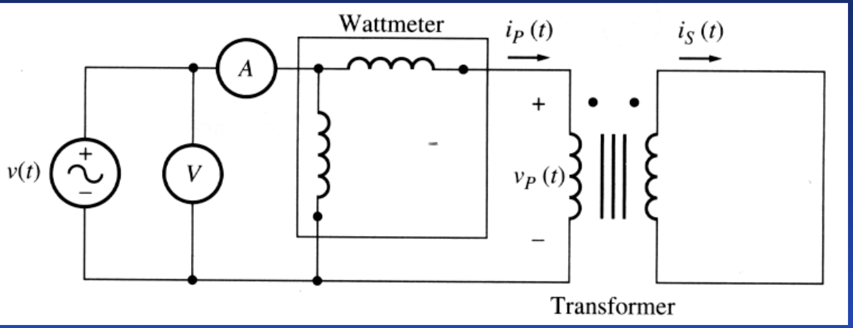
In real transformers, the power factor is always lagging, so the angle of the current always lags the angle of the voltage by θ degrees. The admittance is:

$$Y_E = \frac{I_{oc}}{V_{oc}} \angle -\theta = \frac{I_{oc}}{V_{oc}} \angle -\cos^{-1} PF \qquad (4.35.1)$$

Therefore, it is possible to determine values of R_C and X_M in the open-circuit test.

Determining the values of components



The short-circuit test.

Fairly low input voltage is applied to the primary side of the transformer. This voltage is adjusted until the current in the secondary winding equals to its rated value.

The input voltage, current, and power are again measured.

Since the input voltage is low, the current flowing through the excitation branch is negligible; therefore, all the voltage drop in the transformer is due to the series elements in the circuit. The magnitude of the series impedance referred to the primary side of the transformer is:

$$|Z_{SE}| = \frac{V_{SC}}{I_{SC}} \quad (4.36.1)$$

The power factor of the current is given by:

$$PF = \cos\theta = \frac{P_{SC}}{V_{SC} I_{SC}} \quad (4.36.2)$$

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Therefore:

$$Z_{SE} = \frac{V_{SC}\angle 0^\circ}{I_{SC}\angle -\theta^\circ} = \frac{V_{SC}}{I_{SC}}\angle \theta^\circ \qquad (4.37.1)$$

Since the serial impedance Z_{SE} is equal to

$$Z_{SE} = R_{eq} + jX_{eq} \qquad (4.37.2)$$

$$Z_{SE} = \left(R_p + a^2 R_S\right) + j\left(X_p + a^2 X_S\right) \qquad (4.37.3)$$

it is possible to determine the total series impedance referred to the primary side of the transformer. However, there is no easy way to split the series impedance into primary and secondary components.

The same tests can be performed on the secondary side of the transformer. The results will yield the equivalent circuit impedances referred to the secondary side of the transformer.

Determining the values of components: Example

Example 4.2: We need to determine the equivalent circuit impedances of a 20 kVA, 8000/240 V, 60 Hz transformer. The open-circuit and short-circuit tests led to the following data from primary side:

$V_{OC} = 8000\ V$	$V_{SC} = 489\ V$
$I_{OC} = 0.214\ A$	$I_{SC} = 2.5\ A$
$P_{OC} = 400\ W$	$P_{SC} = 240\ W$

The power factor during the open-circuit test is

$$PF = \cos\theta = \frac{P_{OC}}{V_{OC} I_{OC}} = \frac{400}{8000 \cdot 0.214} = 0.234 \ \ lagging$$

The excitation admittance is

$$Y_E = \frac{I_{OC}}{V_{OC}} \angle -\cos^{-1} PF = \frac{0.214}{8000} \angle -\cos^{-1} 0.234 = 0.0000063 - j0.0000261 = \frac{1}{R_C} - j\frac{1}{X_M}$$

Determining the values of components: Example

Therefore: $$R_C = \frac{1}{0.0000063} = 159\,k\Omega; \quad X_M = \frac{1}{0.0000261} = 38.3\,k\Omega$$

The power factor during the short-circuit test is

$$PF = \cos\theta = \frac{P_{SC}}{V_{SC} I_{SC}} = \frac{240}{489 \cdot 2.5} = 0.196 \;\; lagging$$

The series impedance is given by

$$Z_{SE} = \frac{V_{SC}}{I_{SC}} \angle \cos^{-1} PF = \frac{489}{2.5} \angle 78.7°$$

$$= 38.4 + j192\,\Omega$$

Therefore:

$$R_{eq} = 38.3\,\Omega; \quad X_{eq} = 192\,\Omega$$

The equivalent circuit