rated power

rated voltage

Tutorial 4

1) Open circuit and short circuit tests are performed on a single phase, 50kVA, 2400/240 V distribution transformer. The following results are obtained:

rated voltage on LV

	Voltage applied (V)	Current (A)	Power (W)
HV side open	240	4.85	173
LV side shorted	52	20.8	650

rated current on HV

a) Calculate exciting admittance (G_c and B_m) referred to the HV side.

b) Calculate equivalent series impedance (R_{eq}, X_{eq}) referred to the HV side.

txfr rated power & voltage

fancy term for a distribution line that feeds a load i.e. conductor

2) A single phase, 50 kVA, 2400/240V distribution transformer is used as the step down transformer at the load end of 2400V feeder with series impedance of 1+j2 Ω. Equivalent series impedance of the transformer is 1+j2.5 Ω referred to the HV side. The transformer is delivering rated load (50kVA) with 0.8 pf lagging at rated secondary voltage. You can ignore the transformer excitation branch.

rated voltage of the line

a) Calculate the voltage at the transformer primary (HV) terminal.

b) Calculate the voltage at the sending end of the feeder

c) Calculate the real and reactive power delivered to the sending end of the feeder.

A comment on <u>rated</u> vs. <u>operating</u> voltage

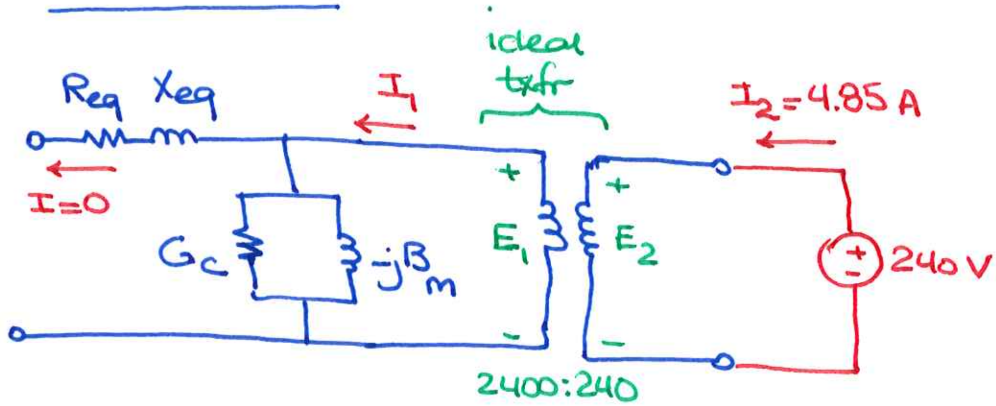
The phrase "2400 V feeder" or "2400/240 V transformer" provides the <u>rated</u> voltage of that device. i.e. it is designed and insulated to operate at or near these values. Typically, the equipment can handle voltages that are 10-20% above the rated values. It does not mean that the device is necessarily <u>operating</u> at those voltages.

The <u>operating</u> voltage depends on the system conditions and is not a static value (i.e. it changes if the system conditions change). In a healthy system, the operating voltages are somewhere within 90-110% of the rated voltage values. The operating values are either given to us in a question or need to be calculated. For example, we were told that the transformer secondary (LV) side was operating at the rated voltage (240 V) in question 2. The operating voltage at the HV winding was calculated to be 2448 V. (i.e. a little higher than the rated voltage of 2400 V).Similarly, the operating voltage of the 2400 V feeder was calculated to be 2490 V at the sending end and 2448 V at the receiving end (i.e. it was different than the rated value).

What about $\mathbf{V_{base}}$? A really good choice would be to use 240 and 2400 V as the V_{base} values on LV and HV side of the transformer, respectively. However, any set of V_{base} values that are related by the 240/2400 V ratio would work, e.g. V_{base} of 100/1000V, or 300/3000 V, etc.

Tutorial 4

1) OC Test



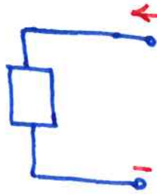
$E_2 = 240\text{ V}$ (KVL on the right loop)

$\therefore E_1 = 240 \times \frac{2400}{240} = 2400\text{ V}$

$I_1 = 4.85\text{ A} \times \frac{240}{2400} = 0.485\text{ A}$

$P_{oc} = \frac{E_1^2}{R_c} = E_1^2 . G_c$ $\qquad$ $G_c = \frac{1}{R_c}$

$\therefore G_c = \frac{P_{oc}}{E_1^2} = \frac{173\text{ W}}{(2400\text{ V})^2} = 3 \times 10^{-5}$ ℧



I_1 : total current into exc'n branch

E_1 : voltage across exc'n branch

$Y = G_c - jB_m$

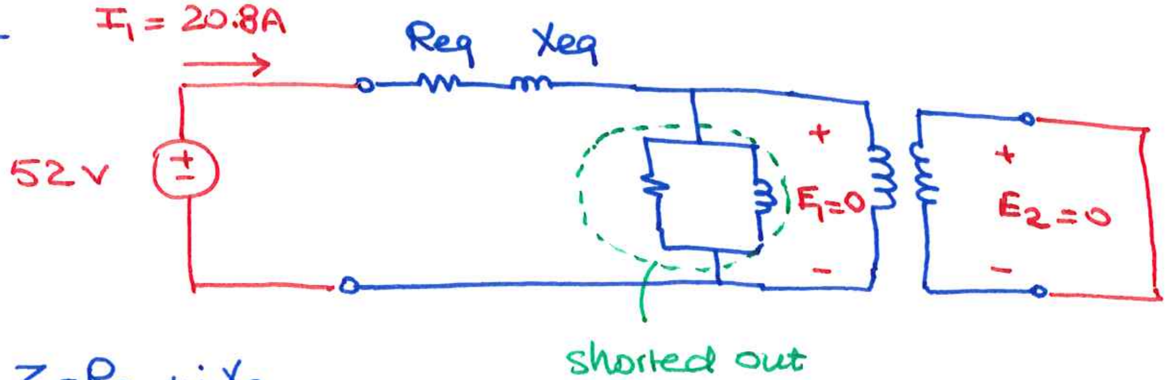
eq. admittance of exc'n branch

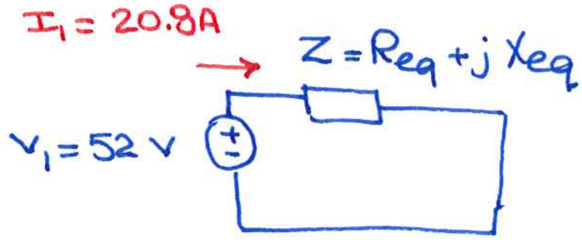
$Y = \frac{\overline{I_1}}{\overline{E_1}}$. Using magnitudes only, $|Y| = \frac{I_1}{E_1} = \frac{0.485\text{ A}}{2400\text{ V}}$

$= 2.02 \times 10^{-4}$ ℧

$B_m = \sqrt{|Y|^2 - G_c^2} \simeq 2 \times 10^{-4}$ ℧

SC Test





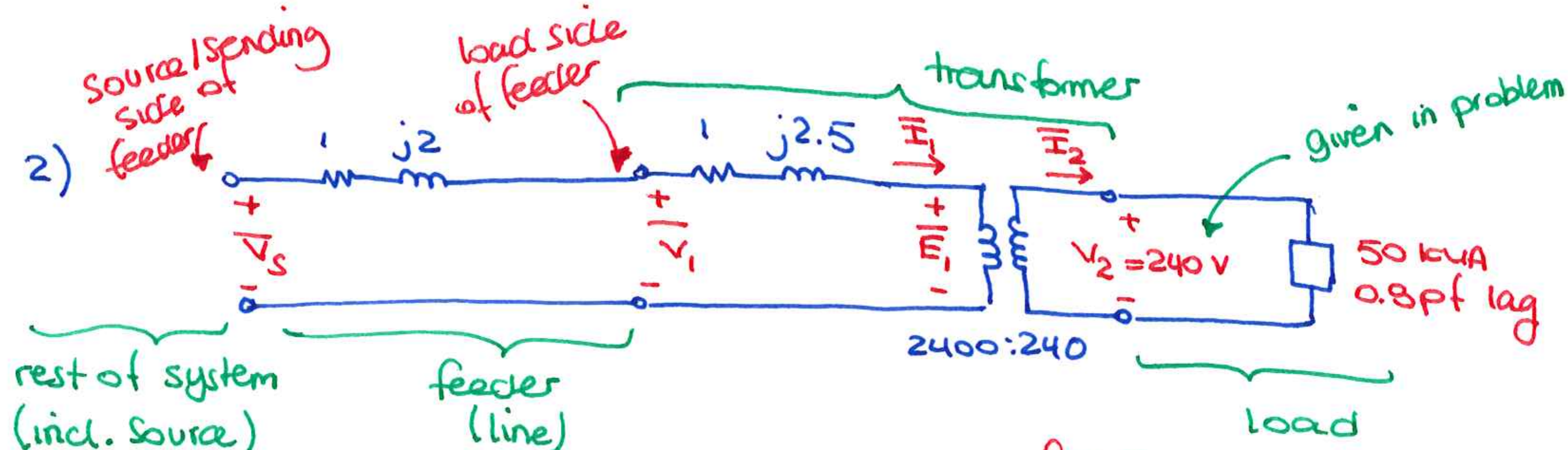
$$P_{sc} = I_1^2 . R_{eq}$$

$$\therefore R_{eq} = \frac{P_{sc}}{I_1^2} = \frac{650\ W}{(20.8\ A)^2} = 1.502\ \Omega$$

From Ohm's Law: $\bar{Z} = \frac{\bar{V}_1}{\bar{I}_1}$ $\therefore$ $|Z| = \frac{V_1}{I_1} = \frac{52\ V}{20.8\ A} = 2.5\ \Omega$

$$X_{eq} = \sqrt{|Z|^2 - R_{eq}^2} = 2\ \Omega$$

2)



a) $\bar{S}_{load} = \bar{V}_2 . \bar{I}_2^*$ $\therefore$ $\bar{I}_2 = \frac{\bar{S}_{load}^*}{\bar{V}_2^*} = \frac{50 \angle -36.87^\circ}{240 \angle 0}$

from *

arbitrarily assigned

$$= 208.3 \angle -36.87^\circ\ A$$

$$\bar{I}_1 = \bar{I}_2 \times \frac{240}{2400} = 20.83 \angle -36.87^\circ\ A$$

$$\bar{E}_1 = \bar{V}_2 \times \frac{2400}{240} = 2400 \angle 0^\circ\ V$$

$$\bar{V}_1 = \bar{E}_1 + \bar{I}_1 (R_{eq} + j X_{eq}) = 2448 \angle 0.68^\circ\ V$$

from KVL!

b) $\overline{V_S} = \overline{V_1} + \overline{I_1}\,(1+j2) = 2490\angle 1.15^\circ$ V

c) $\overline{S_S} = \overline{V_S}\cdot \underbrace{\overline{I_S}^*}_{\overline{I_1}^*} = (2490\angle 1.15^\circ)(20.83\angle +36.87^\circ)$

$= \underbrace{40.87\times 10^3}_{P = 40.87\ \text{kW}} + j\,\underbrace{31.95\times 10^3}_{Q = 31.95\ \text{kVAr}}$