ECE 320: Lecture 12

Notes

Votlage Regulation

Compare the secondary voltage at no load with the secondary voltage at full load (one can vary the power factor). This determines the impact of the voltage drop across the series branch.

$$VR = \left[\frac{(Vs\_noload - Vs\_full\_load)}{Vs\_full\_load}\right]\cdot 100\%$$

- Vs is the secondary voltage (or V2).
- This is calculated using the voltage magnitudes, not the angle.
- Small numbers are often considered good.
- In some cases, a larger series impedance is preferred, since it will lower fault currents. But i hurt the voltage regulation.

- Alternate form for the equation (where Vp is the primary voltage, or V1):

$$VR = \left[\frac{\left(Vp\cdot\frac{N2}{N1} - Vs\_full\_load\right)}{Vs\_full\_load}\right]\cdot 100\%$$

Vp is the voltage applied to the transformer (and is rated voltage). Assumes very small voltage drop due to magnetizing current at no load.

Vs_full_load is the voltage appearing across the load, and Vp (or V1) is voltage input to the transformer for supply the load at the given Vs value.

Efficiency

What percentage of the power in to the transformer is available at the output.

$$\eta = \frac{Pout}{Pin} = \frac{Pout}{Pin + Ploss}$$

Ploss consists of:
1. Copper losses in windings
2. Eddy current losses in core
3. Hysteresis losses in the core.

Example: Suppose the transformer tested above is supplying a resistive load of 2.88 Ohm with a voltage of 240V across the load.

Find V1, Voltage Regulation, and Efficiency.

From last time:

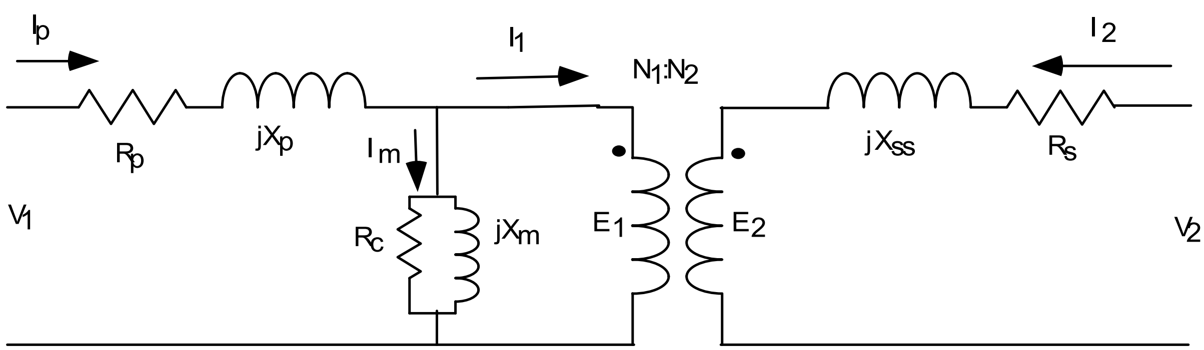
Since we don't know the exact number of turns, set N1 and N2 on relative voltage ratings.

$N1 := 8000$ $N2 := 277$

$R1 := 19.2\text{ohm}$ $X1 := 95.9\text{ohm}$ Referred to primary winding

$R2 := 0.0173\text{ohm}$ $X2 := 0.0863\text{ohm}$ Referred to secondary winding

$Xm := 38.45\text{k}\Omega$ $Rc := 160\text{k}\Omega$ Referred to primary winding



Note that any of these quantities can be referred across the ideal transformer. So for example, we could refer Xm and Rc to the secondary winding.

$$Xms := Xm\cdot\left(\frac{N2}{N1}\right)^2 \qquad Xms = 46.1\,\Omega$$

$$Rcs := Rc\cdot\left(\frac{N2}{N1}\right)^2 \qquad Rcs = 191.82\,\Omega$$

Note that when referring an impedance across the ideal transformer, the impedance will get lar when going from a higher voltage winding to a lower voltage winding, or smaller when going higher voltage winding to a lower voltage winding. This is a good way to check your results.

We are given the voltage across the load:

$V2 := 240V$

$Rload := 2.88ohm$

$Iout := \frac{V2}{Rload}$ $\quad Iout = 83.33\,A$

$Pout := Re\left(V2 \cdot \overline{Iout}\right)$ $\quad Pout = 20\,kW$ $\quad$ Loaded to rated load, with unity power factor

Transformer secondary current:

$I2 := -Iout$ $\quad$ Note that Iout and I2 have opposite polarities.

$E2 := V2 - I2 \cdot (R2 + j \cdot X2)$ $\quad |E2| = 241.55\,V$ $\quad arg(E2) = 1.71\,deg$

$E1 := E2 \cdot \frac{N1}{N2}$ $\quad |E1| = 6976.14\,V$

$Ishunt := \frac{E1}{Rc} + \frac{E1}{j \cdot Xm}$ $\quad Ishunt = 0.05 - 0.18i\,A$ $\quad |Ishunt| = 0.19\,A$

$arg(Ishunt) = -74.78\,deg$

$I1 := -I2 \cdot \frac{N2}{N1}$ $\quad I1 = 2.89\,A$

$Ip := I1 + Ishunt$ $\quad Ip = 2.93 - 0.18i\,A$

$|Ip| = 2.94\,A$ $\quad arg(Ip) = -3.51\,deg$

$V1 := E1 + Ip \cdot (R1 + j \cdot X1)$ $\quad |V1| = 7063.37\,V$

$arg(V1) = 3.94\,deg$

$Pin := Re\left(V1 \cdot \overline{Ip}\right)$ $\quad Pin = 20.59\,kW$

$$VR := \frac{\left(|V1| \cdot \frac{N2}{N1} - |V2|\right)}{|V2|} \qquad VR = 1.9\%$$

$$\eta := \frac{Pout}{Pin} \qquad \eta = 97.13\%$$

$$Ploss := Pin - Pout \qquad Ploss = 590.25\,W$$

Core losses: $Pcore := \frac{(|E1|)^2}{Rc}$ $\qquad Pcore = 304.17\,W$

Copper losses: $Ploss - Pcore = 286.09\,W$

or we could do: $(|Ip|)^2 \cdot R1 + (|I2|)^2 \cdot R2 = 286.09\,W$

Terminology

- Xm is often referred to as the magnetizing reactance, or a the excitation reactance.
- The parallel combination of Rc and Xm can be called the "shunt branch" or the "exciting bra
- As mentioned above, the secondary winding terms, Rs, Xs, Vs, Es, and Is, are the same as th denoting the secondary terms with a 2 (R2, X2, V2, E2, and I2).
- Similar comments can also be made with the primary winding, as: Vp, Ip, Rp, Xp, and Ep or those with a "1" (R1, X1, V1, E1, and I1). However, be carefull since some people label I1 a the current into the ideal transformer, and Ip as the terminal current (Ip + Ishunt)