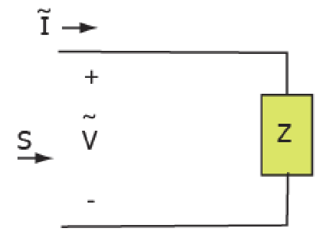
**ECE 432** **Test 1** **Sept 26 2016**

1. (20 pts)

Figure (a) shows the rms phasor voltage V, rms phasor current I, and the complex power S = P + j Q at the terminals of a network component.



(a) Original network component

Given the following measurements at the terminals:

$V := 220 \angle 0^o$ V $\quad P := 5000$ W $\quad$ input power factor is 0.8 leading

Find (a) current drawn I

(b) the equivalent impedance Z looking into the terminals of the component .

**1.** $V := 220 \times e^{j \times \frac{0}{180} \times \pi} = 220 \quad P := 5000 \quad pf := 0.8$ leading

$\phi := \operatorname{acos}(pf) \qquad S := \frac{P}{pf} \times e^{j \times (-\phi)} = 5 \times 10^3 - 3.75j \times 10^3$

Current drawn $\qquad I := \frac{\overline{S}}{V} = 22.727 + 17.045j \qquad |I| = 28.409 \qquad \arg(I) \times \frac{180}{\pi} = 36.87$

Input impedance and power factor $\qquad Z := \frac{V}{I} = 6.195 - 4.646j \qquad |Z| = 7.744 \qquad \arg(Z) \times \frac{180}{\pi} = -36.87$

$pf := \frac{\operatorname{Re}(S)}{|S|} = 0.8$ $\qquad$ leading since Q<0

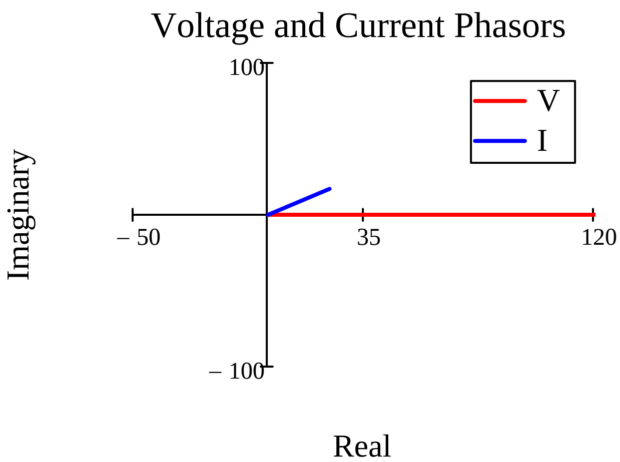
Since P absorbed is positive, component is a load drawing real power from ac supply

Q absorbed is negative, hence the component is capacitive

Specify a range variable from 0 to 1 for plotting the two phasors $\qquad i := 0..1$

Define the vectors for plotting

$$VR := \begin{pmatrix} 0 \\ \operatorname{Re}(V) \end{pmatrix} \qquad VI := \begin{pmatrix} 0 \\ \operatorname{Im}(V) \end{pmatrix} \qquad IR := \begin{pmatrix} 0 \\ \operatorname{Re}(I) \end{pmatrix} \qquad II := \begin{pmatrix} 0 \\ \operatorname{Im}(I) \end{pmatrix}$$


Voltage and Current Phasors
100
− 100
V
I
− 50
35
120
Imaginary
Real

2. (40 pts)

A single-phase, 2-winding transformer rated 25 kVA, 7620V/120V, 60 Hz has the following equivalent circuit parameters:

Combined equivalent series resistance, $r_1 + r'_2$ , on the 7620 V side is 3.06 Ω
Combined equivalent leakage reatance, $x_{l1}+x'_{l2}$, on the 7620 V side is 6.5 Ω
Core losses at rated voltage is $P_{core}$ = 400 W

Ignoring the effects of magnetizing reactance which is not given, determine

a)(18 pts) the rated current on the 7620 V side, then estimate the efficiency of the transformer delivering rated volts and current to a 0.9 power factor load connected to the 120 V side.

b)(14 pts) the per unit values of the total winding resistance and total leakage reactance using the rated values of voltages and volt-ampere of the transformer as the base;

c)(8 pts) What would be the 3-phase ratings, that is rated line-to-line voltage and total 3-phase VA, when 3 units of the above single-phase transformers are connected in Y-Y ?

$V_{1rated} := 7620$ $V_{2rated} := 120$ $S_{rated} := 25 \times 10^3$ $f_{rated} := 60$ $\omega := 2 \times \pi \times f_{rated}$

$I_{1rated} := \frac{S_{rated}}{V_{1rated}} = 3.281$ $I_{2rated} := \frac{S_{rated}}{V_{2rated}} = 208.333$

$r_{1series} := 3.06$ $x_{1series} := 6.5$ $P_{core} := 400$

Part a) rated current on the 7620 V side is $I_{1rated} = 3.281$

Winding copper losses with rated current flowing $P_{cu} := I_{1rated}^2 \times r_{1series} = 32.938$

Output power at rated voltage and current to load of 0.9 power factor lagging $pf := 0.9$

$$P_{out} := V_{1rated} \times I_{1rated} \times pf = 2.25 \times 10^4$$

Efficiency at the given operating condition $P_{losses} := P_{cu} + P_{core} = 432.938$

$$\eta := \left(1 - \frac{P_{losses}}{P_{out} + P_{losses}}\right) \times 100 \qquad \eta = 98.112$$

Part b) $S_{base} := S_{rated}$ Select base voltages for the 2 regions according to transformer ratio

$V_{1base} := V_{1rated}$ $Z_{1base} := \frac{V_{1base}^2}{S_{base}} = 2.323 \times 10^3$ $I_{1base} := \frac{S_{base}}{V_{1base}} = 3.281$

total series impedance in per unit

$$z_{seriespu} := \frac{r_{1series} + j \times x_{1series}}{Z_{1base}} = 1.318 \times 10^{-3} + 2.799j \times 10^{-3}$$

Part c) rated line voltages of Y-Y connected transformer are

$$V_{1rated} \times \sqrt{3} = 1.32 \times 10^{4}$$

$$V_{2rated} \times \sqrt{3} = 207.846$$

rated 3-phase power is

$$S_{3phrated} := 3 \times S_{rated} = 7.5 \times 10^{4}$$

3 (40 pts)

A 3-phase, round-rotor, synchronous generator, connected directly to a large power network, has synchronous reactance $X_s$ of 1.2 per unit on its own base and negligible stator resistance. The magntiude of the generator's terminal bus voltage may be assumed to be constant at 1 per unit on the generator base.

Given that the above generator is initially delivering 0.8 real power into the power network with the magntiude of its internal emf, $|E_f|$, adjusted to 1.8 per unit.

(22 pts) Calculate the power angle δ and the power factor ϕ, and sketch the phasor diagram for this initial operating condition, clearly labelling all the components of the phasor diagram.

(8 pts) At the generator terminal, is the power network appearing as a inductive or capacitive load?

(10 pts) Assuming that you have control of $|E_f|$ via the generator's excitation field and the generator's output via its input mechanical power, indicate how you would change the generator's output power factor to unity power factor while holding its active output power constant at rated value.

**Given initial operating condition:** $X_s := 1.2$ $V_t := 1 \times e^{j \times 0}$ $E_{fmag} := 1.8$ $P := 0.8$

$$\text{sin\_delta} := \frac{P}{\frac{|V_t \times E_{fmag}|}{X_s}} \qquad \delta := \text{asin}(\text{sin\_delta}) \qquad \delta_{deg} := \frac{180}{\pi} \times \delta = 32.231$$

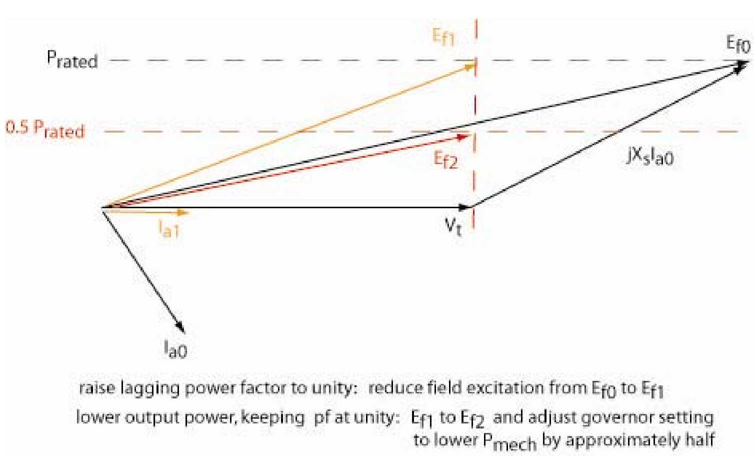
$E_f := E_{fmag} \times e^{j \times \delta}$ Output phase current: $I_a := \frac{E_f - V_t}{j \times X_s} = 0.8 - 0.436j$ current lags terminal voltage

$|I_a| = 0.911$ $\phi := \text{atan}\left(\frac{\text{Im}(I_a)}{\text{Re}(I_a)}\right)$ $\cos(\phi) = 0.878$

Alternatively Complex power output $S := V_t \times \overline{I_a} = 0.8 + 0.436j$

$Q := \text{Im}(S) = 0.436$ since Q>0, lagging power factor

Output power factor $pf := \frac{P}{|S|} = 0.878$ lagging because Q is negative



At the given operating condition, the network is absorbing inductive reactive power produced by the generator.

To change power factor from lagging to unity, holding output power constant, we lower the field excitation of the generator changing from $E_{f0}$ to $E_{f1}$ while leaving governor control untouched.