EE 137A Homework #6

due Thursday, Oct 18, 2018

1. Per-Unit Quantities

A generator is rated 500 MVA, 20 kV. The windings are Y-connected with impedance 1.1 p.u.

(a) What are the base quantities for P, Q, S, R, X, Z, and I?

(b) Find the impedance in ohms.

(c) Suppose the same generator is being used in a circuit for which S_{BASE} = 200 MVA and V_{BASE} = 22 kV. What is the per-unit value of the impedance in the new base?

2. Simple Transformer

A single-phase transformer rated 7.4 kVA, 1.2kV / 120V has a primary winding (on the high-voltage side) of 800 turns.

(a) How many turns are in the secondary winding?

(b) What are the currents in the primary and secondary windings when the transformer is operating at full rated power and rated voltage? Ignore losses (treat the transformer as ideal).

(c) For the following steps, suppose the transformer is delivering 6 kVA at its rated voltages and p.f. = 0.8 lagging. What is the impedance Z_2 connected across the 120-V terminals?

(d) What is the impedance Z_2' referred to the primary side? Write a sentence explaining why you would expect Z_2' to be greater or less than Z_2.

(e) Using Z_2', find the primary current and power supplied. Does it agree with your expectations?

3. Realistic Transformer

A single-phase transformer rated 1.2kV/120V, 7.4 kVA has winding resistance $r_1 = 0.8\Omega$ and $r_2 = 0.01\Omega$ and leakage reactance $x_1 = 1.2\Omega$ and $x_2 = 0.01\Omega$ on the primary and secondary side, respectively.

(a) Why do you think these quantities are larger on the primary side?

(b) Find the transformer impedance – that is, the combination of winding resistance and leakage reactance from both sides – in ohms, referred to the primary side.

(c) Find the transformer impedance in ohms, referred to the secondary side.

(d) Find the transformer impedance in per-unit.

(e) If the turns ratio is a = 10, what is the actual primary voltage when the transformer delivers 7.4 kVA at 120V and unity power factor to the secondary side? (Hint: it will be slightly greater than 1.2kV because the transformer is not ideal.)

(f) Suppose the primary voltage stays constant at the value you found in (e). But now the load is disconnected, so the secondary current drops to zero. What is the secondary voltage? (Hint: it was 120V at full load, so at no load it will increase a bit.)

(g) What is the "voltage regulation" in percent?

(h) Suppose that while the transformer is operating at rated conditions (full load), a fault occurs on the secondary side, reducing the load impedance and the voltage to zero. Assume the only source impedance present is due to the transformer itself, and no circuit breaker trips. What would be the secondary current in this hypothetical situation?

4. Transformer Thought Experiments

A transformer is connected to an a.c. voltage source on the primary side, while the secondary side has no load connected to it: that is, the secondary winding is an open circuit.

(a) Suppose this were an ideal transformer. What is the current in the primary winding? Explain in your own words.

(b) Now assume this is a practical (real-life), not an ideal transformer. What determines the current in the primary winding when the secondary winding is an open circuit? How is this represented in the transformer model?

(c) Discuss what would happen if you accidentally connected a practical transformer to a d.c. voltage source. *Do not try this at home.*

(d) Finally, consider the question, "What would happen if you connect an ideal transformer to a d.c. source." Does this question even make sense? Discuss.

5. Load Tap Changer in PowerWorld

Open the Case: Example 3-12 in PowerWorld.

(a) In Edit mode, change the transformer label to 13.8/345 kV.

(b) Right-click on the line dialog box. What information does it contain about the line and the transformer?

(c) Go into Run mode and click on Solve (green button under the Tools tab). Set the load tap changer (LTC) to manual. At the default load (500 MW, 100 MVAR), what is the range of voltages the LTC transformer can supply at Bus 2? How many tap changes correspond to the entire range? Express the Bus 2 voltage in kV and p.u. when the LTC is at the center (1.00000), minimum and maximum taps.

(d) Return to the center tap and change the load. For what real and reactive load is the bus voltage closest to 1.0 p.u.? How does the bus voltage change as you vary the real and reactive load? Comment.

(e) Set the LTC to auto. Leaving the reactive load at 100 MVAR, increase the MW until you reach the line thermal limit. How many steps does the LTC take? Now decrease the load MW and observe the LTC operation. What do you notice, and why do you think it is controlled this manner?

(f) Leave the real load at 100 MW and now increase the load VAR. What do you notice about the LTC operation? What is the voltage when you reach the line thermal limit? Discuss.

(g) Repeat f. but make the load capacitive, keeping it at 100 MW and increasing the negative VAR. Discuss your observations.

(h) What can you conclude about the operating range of this LTC?

For next week:
While you're in PowerWorld, you may want to peek ahead at next week's problems:
GOS 5.43 and 5.44 (Example 5-4).