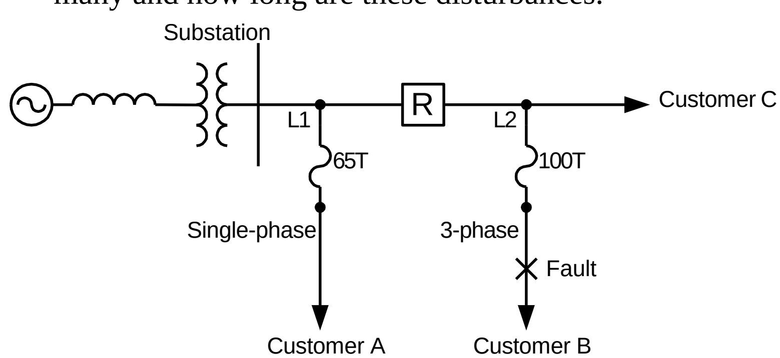
ECE528 – Fall 2016 due date: September 24
Homework 2

Some "real-world" power quality problems:

1. A large manufacturing plant experiences intermittent process interruptions. Once the process stops, it can take several hours to restart production. The 24V DC process control system consists of a variety of relays and small contactors and solenoids powered from a single DC power supply connected to 120V AC. This power supply will trip off if it cannot maintain a minimum required output voltage. Power quality recording at the 120V AC supply to this DC power supply and at the DC output showed that the DC control voltage dropped below its minimum level and the power supply tripped off once when the AC voltage sagged to 80% of nominal voltage for one cycle. Most of the time however, the DC control voltage was not affected by voltage sags on the AC side to 80% of nominal voltage for one to two cycles. The DC power supply consistently tripped off during voltage sags to 75% or less of nominal voltage for two or more cycles. The recorded voltage sags were typically between 65% and 75% of nominal voltage, with durations between two and 10 cycles.
   a. (10 pts.) Based on the lecture material, explain why the DC power supply tripped off once for a 1-cycle voltage sag to 80% of nominal voltage but "rode through" voltage sags to 80% of nominal voltage lasting up to two cycles at other times? Give a brief but complete answer. You may use diagrams if necessary.
   b. (10 pts.) What would you recommend to solve this problem? Be specific and explain the reasons for your recommendation(s).

2. In the distribution feeder illustrated below. L1 is a single-phase fused tap, and L2 is a three-phase fused tap. Fuse sizes are shown on the diagram. Recloser "R" is located downstream of L1, and upstream of L2 as shown. The recloser sequence would be two fast and two slow operations if fast-tripping (fuse saving) is enabled. The first reclose interval is 5 seconds, and the second and third intervals are 10 seconds each. Assume a 3-phase permanent fault occurs on tap L2, with a three-phase fault current of 2,000A. Use the attached time-current curves at the end of this assignment to determine the following:
   a. Assume fast-tripping of the reclosers (fuse saving) is enabled.
      i. (5 pts.) How many interruptions does customer C experience and what is the duration of each interruption?
      ii. (5 pts.) What type of disturbances does customer A experience? How many and how long are these disturbances?
   b. Assume that fast-tripping of the recloser (fuse saving) is <u>not</u> enabled.
      i. (5 pts.) How many interruptions does customer C experience and what is the duration of each interruption?
      ii. (5 pts.) What type of disturbances does customer A experience? How many and how long are these disturbances.



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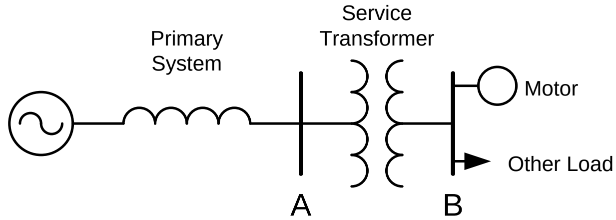
3. In the single-line diagram of a three phase system below, a 300hp motor with a NEMA code letter J is connected at bus "B" and served from a 1MVA, 5% impedance transformer. The short-circuit MVA of the primary system at bus "A" is 50MVA. Assume all impedances are entirely inductive, that conductor impedances not included in the system impedance are negligible, and that the Thevenin voltage at the source is 1 p.u. Load on the system prior to motor starting is negligible. Use conservative assumptions for the motor's locked-rotor KVA. Note: FPQ pages 112-118 may be helpful.



a. The motor is started across the line (full-voltage starting).
   i. (10 pts.) Calculate the minimum voltage in per-unit at bus B during motor starting.
   ii. (10 pts.) Calculate the minimum voltage in per-unit at bus A during motor starting. This is the voltage other customers will see when the motor starts.
b. (10 pts.) The owner of the motor is required to limit the voltage drop at bus A to 3% or less when the motor is started to avoid impacting other customers. If the motor's nominal voltage is 460V line-to-line, what is the maximum current that the motor can draw when it starts so that this limit is not exceeded?

4. A DC power supply provides a constant output voltage of 16.5V DC as long as the 1000µF internal storage capacitor's voltage is above 24VDC. Assume that the storage capacitor charges to the peak voltage of the 120V AC RMS supply each half-cycle. Ignore losses in the power supply and assume power is drawn from the DC capacitor at a constant rate of 120W.
   a. (5 pts.) If an interruption to the AC supply occurs at the instant the DC storage capacitor in the power supply is fully charged from its 120V AC RMS supply, how long, to the nearest millisecond, will it take for the DC bus voltage in the power supply to drop to 24VDC?
   b. (5 pts.) Repeat part (a), but with the power supply powered from a 240V AC RMS supply.
   c. (5 pts.) Repeat part (a), but use a 2000µF storage capacitor.
   d. (5 pts.) For the 1000µF capacitor with the 120V AC RMS supply from part (a), how much energy in Joules was stored in the capacitor when it was fully charged, and how much energy is still stored in the capacitor when it reaches 24VDC?

5. This problem is based on the paper “Are Voltage Sags Destroying Equipment”, by Ashish Bendre, et.al., IEEE, 2006.

   a. (5pts) Assume T_{60}/T_{LC}=10, and I_D=5A in a single-phase AC-to-DC power supply. I_o=3A. What is the calculated I^2T value for a for 3.5-cycle voltage sag for this power supply based on the methodology described in the paper? Does this calculated I^2T value exceed the typical rated value for a 5A diode based on this paper?
   b. (5 pts) To increase voltage sag tolerance, a new and improved version of the power supply described above is equipped with 20A diodes instead of 5A diodes. No other changes are made to the power supply parameters. In half-cycle increments, what is the duration of the longest voltage sag that this re-designed power supply can tolerate without exceeding its diodes’ I^2T ratings, based on the data in the paper? Note that I_o is still 3A.

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