ECE471 INDUSTRIAL POWER SYSTEMS
Motor Starting Studies

In ECE370 we saw a steady-state model for induction motors that was based on the motor running at its operating speed (slip) with a fully-energized magnetic field. This model has to have two major adjustments when the motor is being started. Since the magnetic field has not built-up, the parallel elements have to be neglected. Also, since the speed is zero the slip is 1.0 and the load resistor is a short-circuit. This results in a very simple model that is just a series resistance and leakage reactance. The appropriate values to use are given in the “ANSI Contribution” page of SKM, which we have already seen in fault analysis.

Example

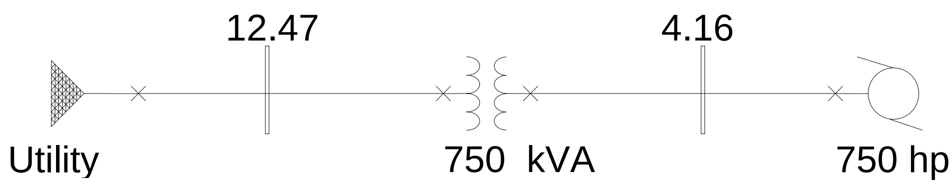
In the system shown below, the utility bus has a three-phase fault level of 15.041 kA with an X/R ratio of 12:1. The transformer is 750 kVA with 0.5% winding resistance and 6% leakage reactance. The 750 hp motor operates at 90% efficiency and 0.83 lag and has a starting impedance of 0.25 pu on a 750 kVA base with an X/R ratio of 12:1.

a) Draw the single-phase equivalent diagram and determine the percent drop in its terminal voltage if the motor is line-started.

b) Repeat part (a) with a starting capacitor bank whose impedance is equal to the motor impedance.

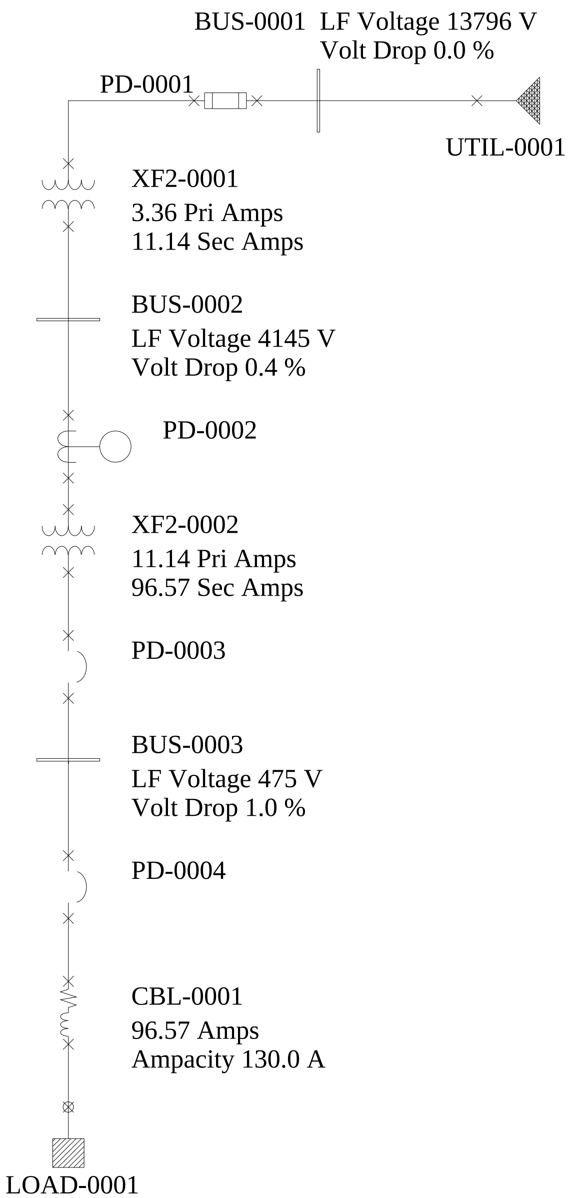
c) Ditto, if X_C is increased by 150%.

d) Determine the nominal kVAR of the bank in (c).



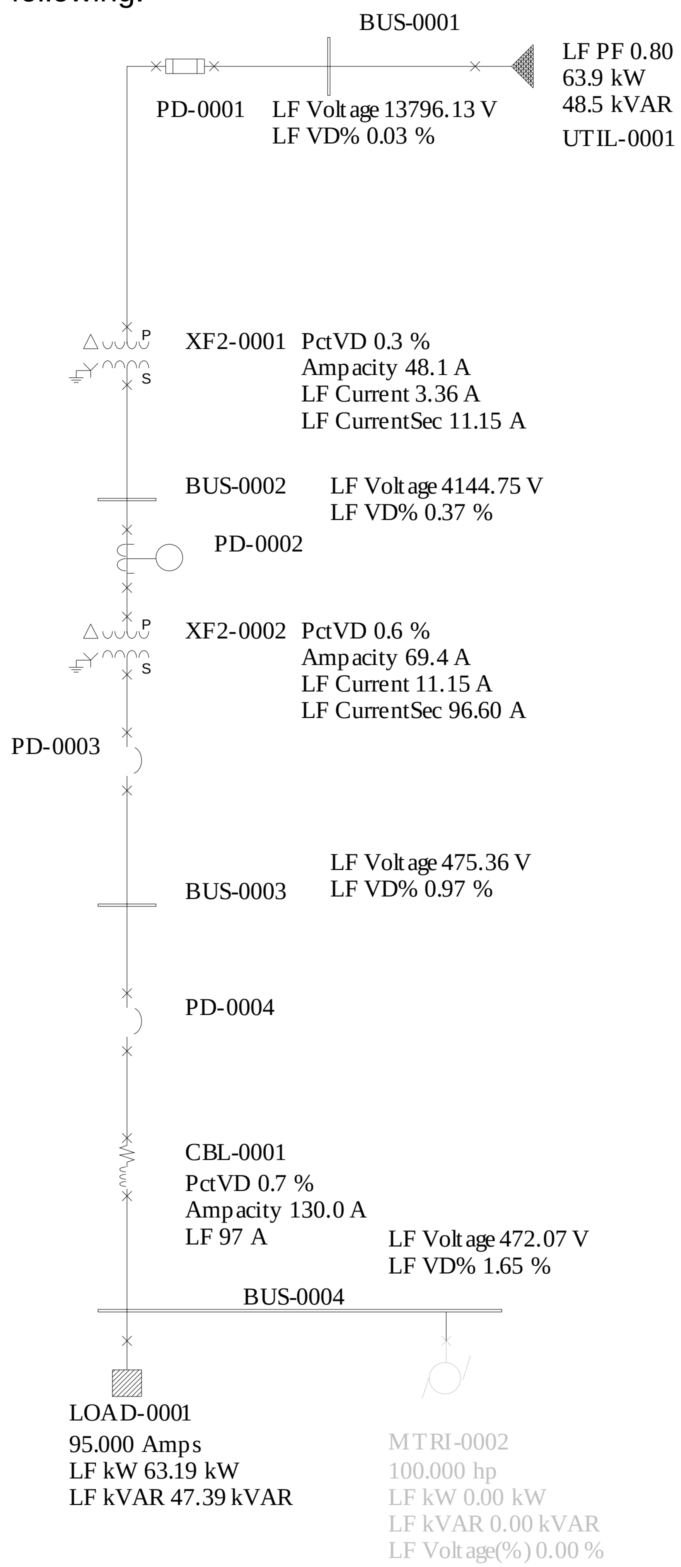
PowerTools Tutorial

We'll begin with the radial system that was used for load-flow and TCC analysis. It is reproduced below.



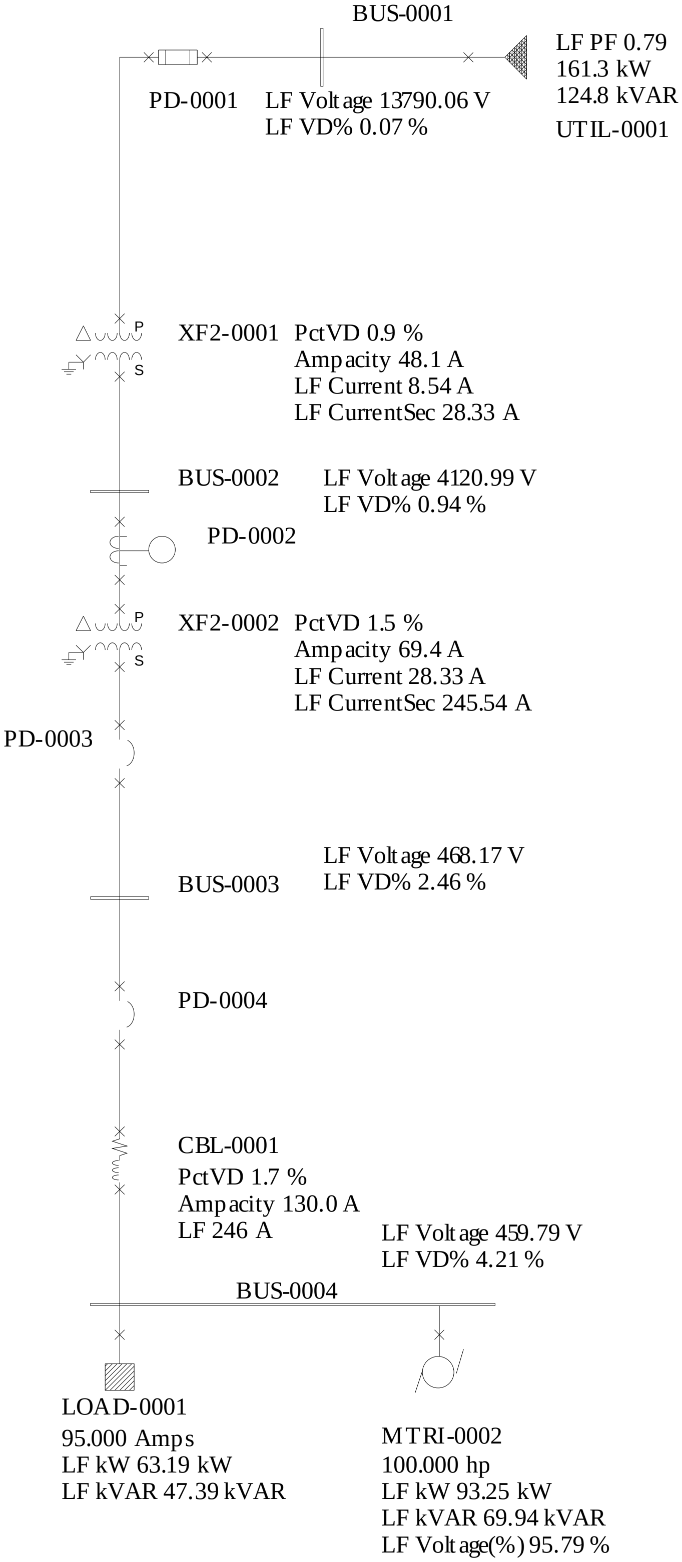
Now we have to add a motor to the load bus so we'll convert the node to a regular bus. Select it by drawing a box around the dot, then click on the "One-Line" tap and select "Convert to Bus". Stretch the bus and insert a 100 hp, 480 V motor with 0.8 pf and η. Uncheck the "In Service" box for the time being.

Run load flow and datablock and you should get results similar to the following.

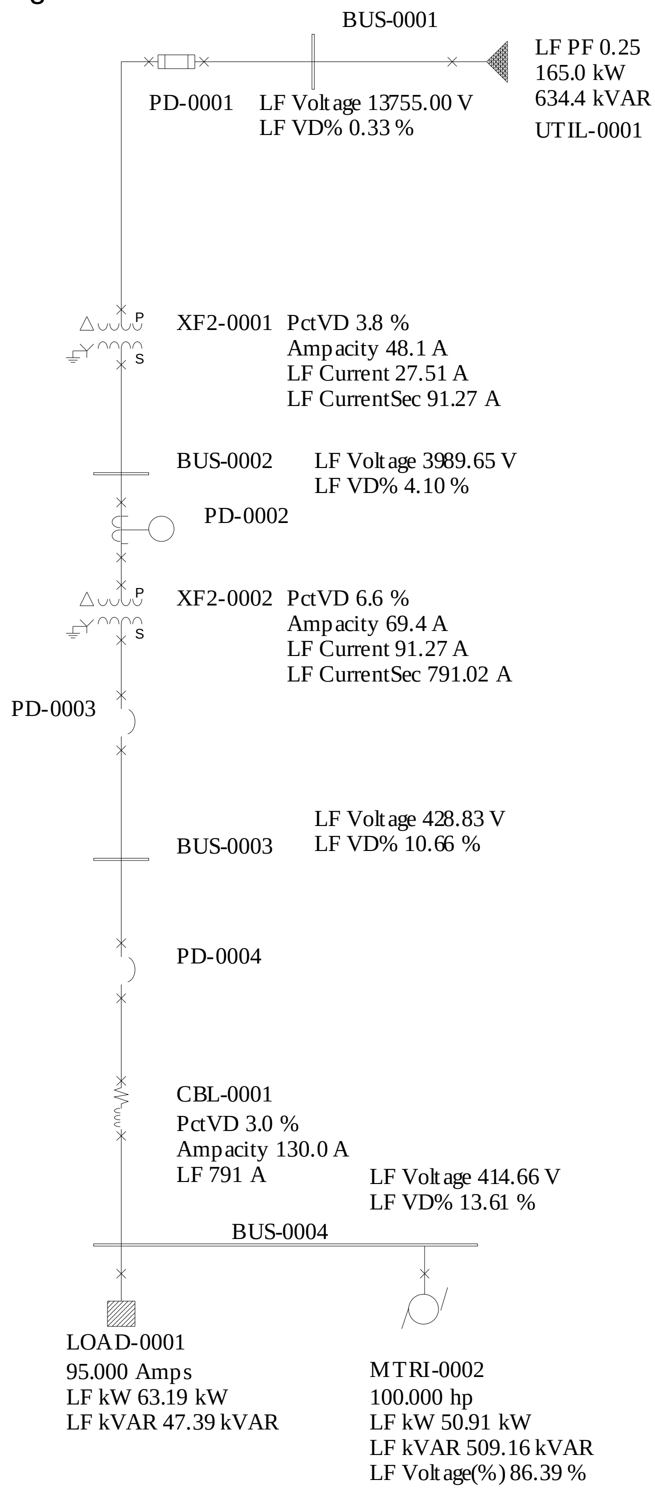


This should be the same results that were obtained previously.

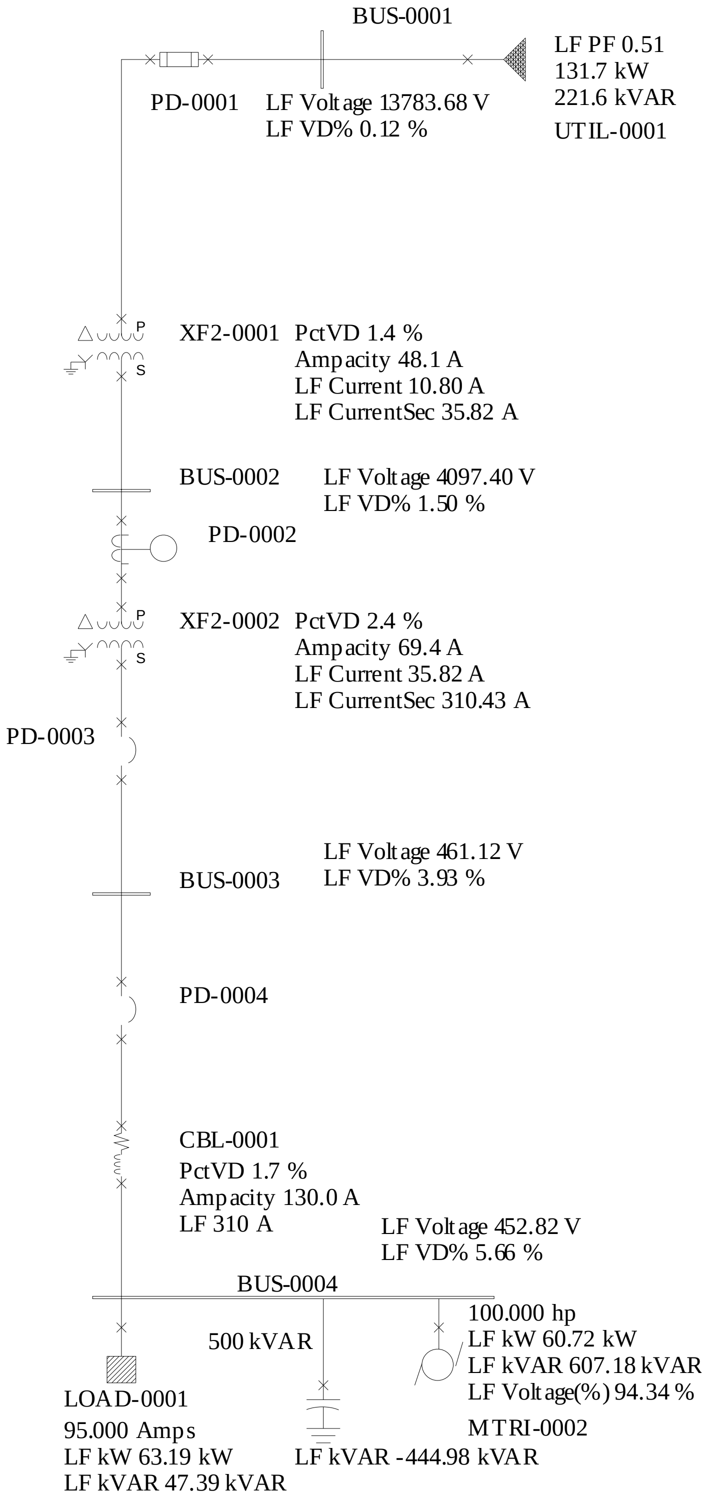
Go back to the component editor and check the "In Service" box on the motor. Run load flow and datablock again to produce the following.



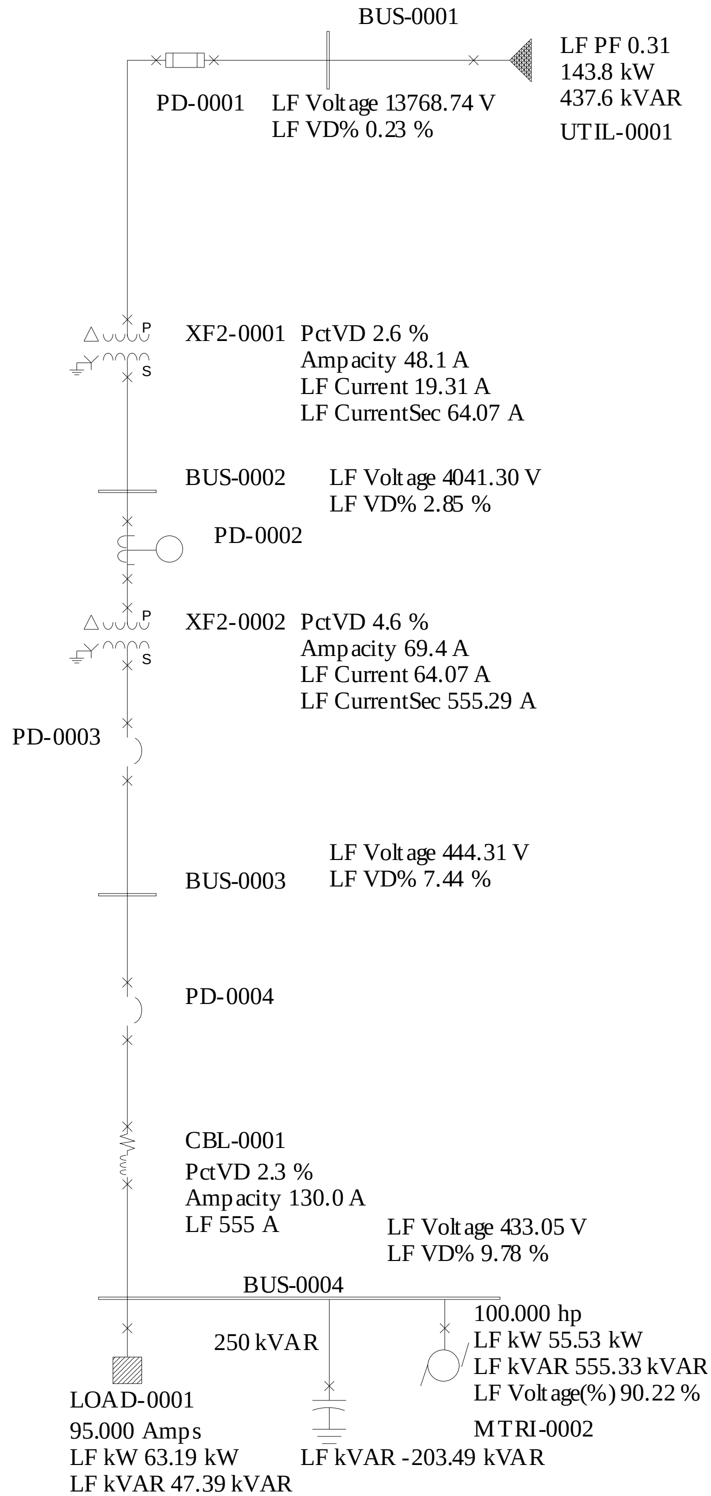
The voltage drop at the motor bus is 4.21%, which is acceptable. However, this only applies once the motor has reached its steady-state operating speed. To see what happens during start-up, go back to the component editor and change the motor from "Running" to "Starting". Once again run load flow and Datablock.



The starting voltage declines by 13.6%, which exceeds the 10% industry standard. Since most of the starting voltage drop is due to reactive power flow, a capacitor will improve things. Since the motor is drawing 509 kVAR on start-up, let's start by inserting a 500 kVAR bank at the BUS-0004 and re-run.



The voltage decline is only 5.66%, which is good but we may have overcompensated, so let's re-run with 250 kVAR.



This results in a decline of 9.78%, which is within the 10% standard, but only just!!