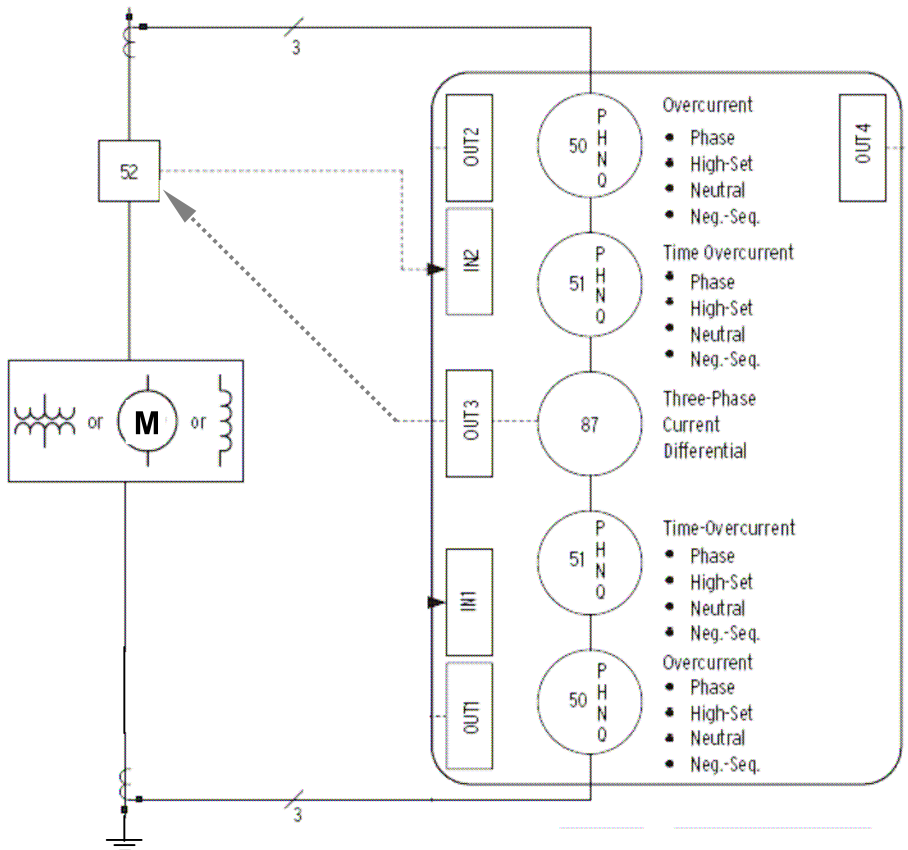
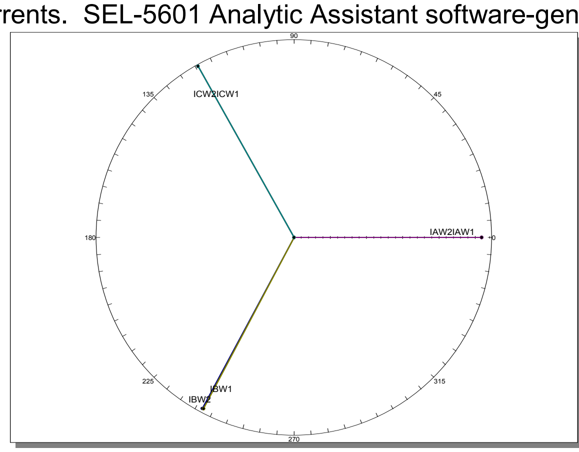
1st Operation

This 87T device is connected around an induction motor as a motor differential. The terminal side of the motor has CTs, and the neutral side of the motor has CTs; each are brought into the differential relay. Connection should be something like the following:



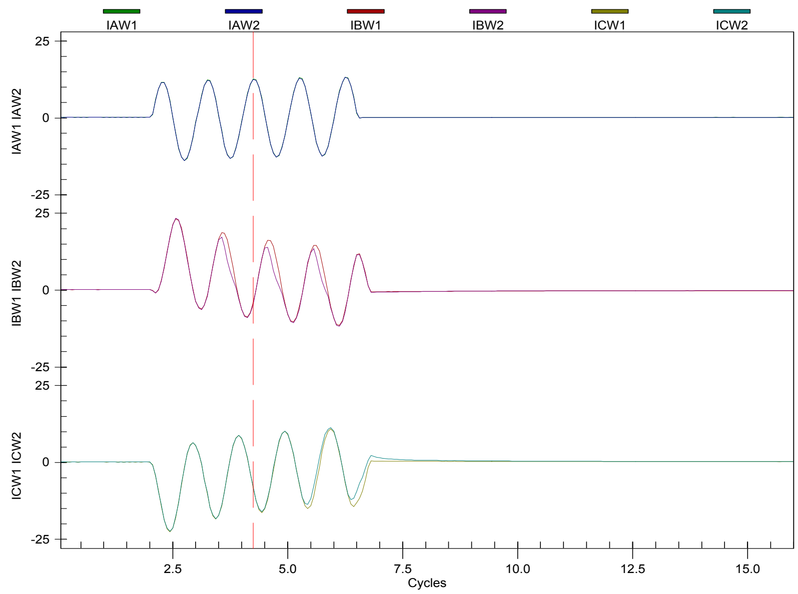
One set of three phase CTs is connected to the SEL-587 Relay with reverse polarity (that is, reverse polarity on all three phases). With the motor energized, the currents should enter on the terminal side and exit on the neutral side and the differential CTs should be connected such that neutral currents are 180 degrees out of phase with the terminal currents. SEL-5601 Analytic Assistant software-generated phasor diagram:



The terminal or high-side CTs on the motor were found to be reverse-polarity.

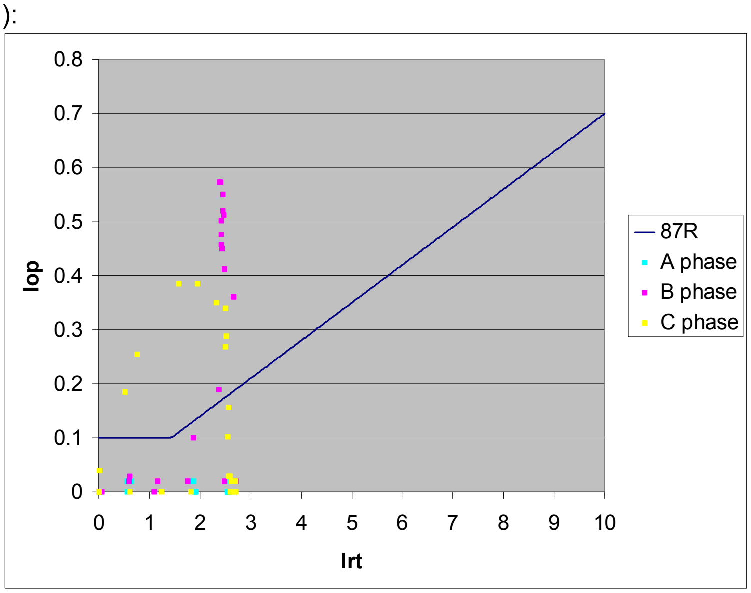
2nd Operation

After the CT polarity problem was fixed, the motor was re-energized. We do not have that event report. However, we have from the previous trip the raw event data. Looking at it, we have a suspicion of what might be wrong during the 2nd trip (and any motor start). Looking at the raw waveforms (again, noting that the polarity of the terminal side CTs is wrong, so the currents signals on each side of the motor are in-phase), we note that there are signs of CT saturation which could also present a problem given the very, very sensitive differential settings. Notice a little saturation/error in the B and C phases:

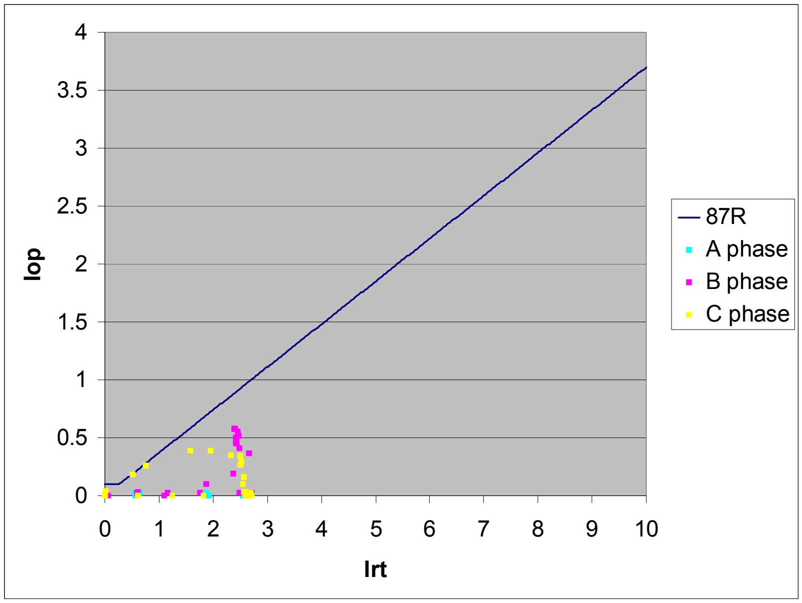


IBW2 shows very clear signs of saturation. C phase is showing some error at the end of the waveform.

Getting creative here, the SEL application engineer wanted to see what the effect of this saturation would do to the sensitive differential settings, so using the standard, filtered event report data, he mathematically reversed the polarity on one set of CTs and calculated the operate and restraint quantities for each of the three differential elements and compared it to the 7% slope setting. Results show that the CT saturation/error would put the B and C phase elements in the operate region (i.e. misoperate, even if the CT polarity had been fixed):



From this data, he calculated the worst case slope required to overcome this and wound up with a slope of about 37%. Here is the same plot only with a slope setting of 37%:



Raising the slope to 37% does reduce the desired sensitivity of 80 amps tripping for running and 200 amps tripping for starting. With 37%, the running trip level would be about 137 amps and the starting trip level would be about 1076 amps.

Another option would be to add a 10 millisecond delay before tripping, as this would help override any CT saturation (along with the built-in security counts on the 87 elements) and might allow you to keep a more sensitive slope setting. The only change you would need in your settings would be MTU1 = 87R * XT + 87U * XT.

Credit to Bill Fleming, Field Application Engineer for SEL, for the detailed analysis and relay algorithm modelling involved here.