TECHNICAL INFORMATION

TITLE: DFT FILTERING IN GROUND-FAULT RELAYS

Adjustable-frequency drives, rectifiers, and other static loads can contribute zero-sequence current that is not the result of a ground fault. This contribution can be significant in a resistance-grounded system and it can interfere with ground-fault coordination. The following discussion exposes the source of zero-sequence current that is not the result of a ground fault. Once this is understood, ground-fault relays with the appropriate response characteristics can be applied with confidence in resistance-grounded distribution systems.

In a three-phase system in which harmonics are not a problem, it is necessary to measure only the power-frequency component of zero-sequence current to achieve coordinated ground-fault protection. Zero-sequence current can be measured at the transformer neutral or by a current transformer with all phase conductors through its window. The zero-sequence component of current in each line is equal to one-third the sum of the three line currents. If the transformer neutral is not connected, the sum of the three line currents must be zero and there can be no zero-sequence current regardless of how unbalanced the load is or what the phase voltages may be. If the transformer neutral is connected to ground through a neutral-grounding resistor, zero-sequence current in the neutral is equal to the sum of the zero-sequence components of the line currents. Neutral current must return through ground and it has only two sources—current flowing to ground as a result of a ground fault, and current flowing to ground through the systems distributed capacitance. Capacitive current returning to the neutral results only from unbalanced voltage and/or unbalanced capacitance to ground. Current flowing to ground through the systems distributed capacitance can be responsible for sympathetic tripping during a ground fault and its unbalance can be responsible for nuisance tripping during normal operation. Sympathetic tripping can be avoided by setting the operating value of the ground fault relays higher than the sum of the capacitive currents to ground in the largest feeder[1]. Since the sum of the capacitive currents to ground in the largest feeder is usually larger than the unbalanced capacitive current returning to neutral during normal operation, this usually eliminates nuisance tripping as well.

If harmonics exist in the phase voltages, achieving coordinated ground-fault protection without nuisance or sympathetic tripping can be a little more difficult. Capacitive reactance decreases with increasing frequency; and harmonic current, especially at the triplen frequencies, can add significantly to zero-sequence current. The phase voltages for each triplen harmonic are in phase so that all capacitive current to ground at all triplen frequencies adds to zero-sequence current. Other harmonics contribute to zero-sequence current in the same manner as the fundamental—capacitive current returning to the neutral results only from unbalanced voltage and/or unbalanced capacitance to ground. Harmonic current in the load does not contribute to zero-sequence current. Harmonic current in the load can cause zero-sequence current in an unfaulted system only by creating harmonics in the phase voltages that force currents to flow in the capacitive reactances to ground.

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Most ground-fault relays are calibrated to sinusoidal current at 50 to 60 Hz. The response of a relay to harmonically rich current at other power frequencies is a function of both the current transformer's characteristic and the relay's filtering. The responses of three Startco products with ground-fault capability, used on the load side of a Model CIMR-P5U27P5 Saftronics GP5 5HP drive, are shown in Figure 1. The current required to trip the relays increases below 20 Hz due to the frequency response of the current transformers. The variation in trip levels in the 30- to 60-Hz range is due to the influence of harmonics.

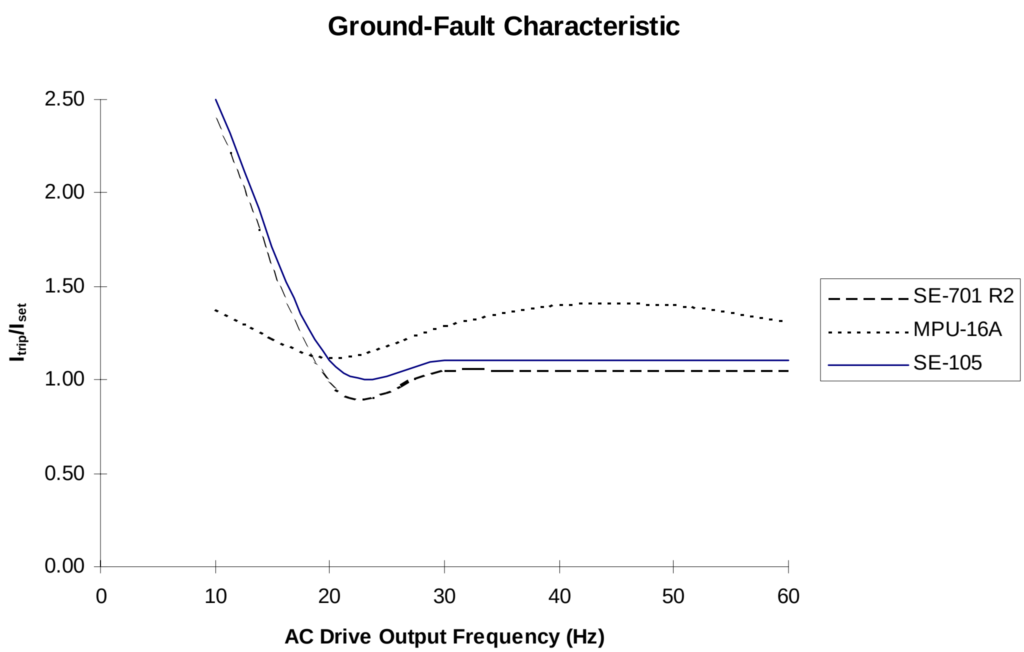

FIGURE 1

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The SE-701 DFT uses a discrete Fourier transform to derive the power-frequency component of zero-sequence current and suppress zero-sequence harmonics. Application examples are trailing cables feeding large static loads and plant supplies feeding adjustable-frequency drives. The SE-701 DFT will maintain an acceptable tripping ratio, without nuisance tripping, in the presence of quiescent, zero-sequence harmonic current that exceeds the power-frequency set point. When used on the supply side of a rectifier or an adjustable-frequency drive, a SE-701 DFT will respond only to a supply-side ac fault—a load-side dc fault produces predominantly 3rd harmonic zero-sequence current. The response characteristic of this relay is shown in Figure 2 and the non-DFT response is shown for comparison.

Ground-Fault Characteristic

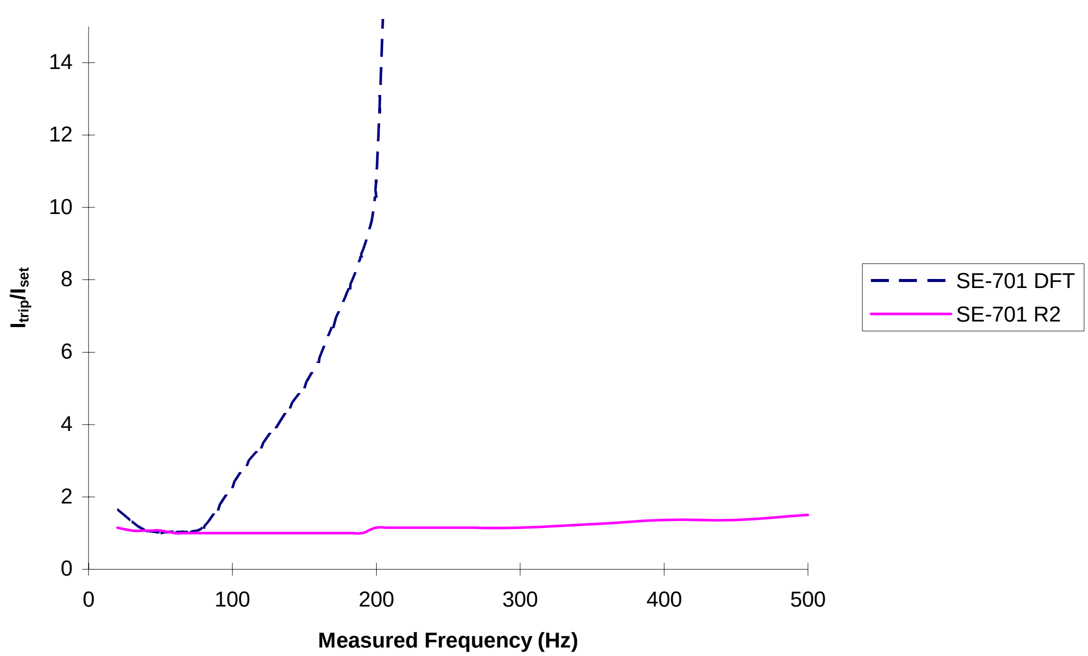

FIGURE 2

[1] G.E. Paulson, "*Monitoring Neutral-Grounding Resistors*". Presented at the Mechanical Electrical Symposium in Victoria, British Columbia, February 21-23, 1989.