Frequency Response of Current Phasor Estimators in the UR Family of Relays

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This document considers the frequency response of the current phasor estimators on the UR family of relays and estimating the impact of superimposed components (both harmonics and inter-harmonics) on accuracy of current measurement.

The UR family of relays uses a full-cycle Fourier filter for current phasor estimation. The current waveforms are pre-filtered using a modified MIMIC filter. The MIMIC filter is a Finite Impulse Response (FIR) filter that ensures accurate rejection of any DC components that may be present in the current signals. The filter guarantees that a transient overshoot in the estimated current magnitude is below 2% for any time constant of the DC component(s) that may be contained in current signals. This allows for very low security margin when setting current based protection elements such as an Instantaneous Overcurrent (IOC) element, as far as the relay accuracy is considered.

At the same time the filter has much better filtering properties for higher frequencies as compared with the traditional MIMIC filtering technique.

Figure 1 on the following page shows a combined frequency response of the MIMIC filter and the full-cycle Fourier algorithm (i.e., an actual frequency response of the UR relay in the current channels). For each frequency, one may read a "gain" of the estimator. That gain indicates how much of a given component is perceived by the relay as an operating fundamental frequency signal (i.e. 60 Hz or 50 Hz). The gain for the fundamental frequency (1 pu) is 1.00. This means that the filters are tuned to a 60 Hz or 50 Hz signal. As the fundamental frequency in the system changes, the frequency tracking mechanism follows the actual frequency and adjusts the sampling rate accordingly. As a result, the (1 pu frequency, 1.00 gain) point follows the actual system frequency providing for maximum accuracy under off-nominal system frequencies.

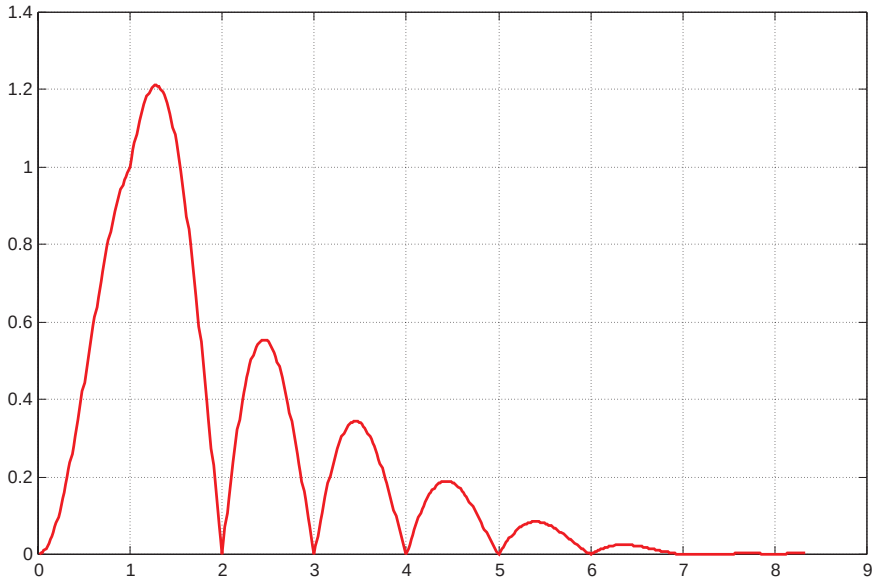

FIGURE 1. Frequency response of the UR phasor estimator for current signals

It is clear from the above figure that harmonics do not "leak" to the fundamental frequency component at all. That means that any amount of higher harmonics is filtered out perfectly by a UR relay.

Inter-harmonics, however, affect the accuracy of estimation to certain extent. For example, a signal of 3.5 nominal frequency would leak to the fundamental frequency estimate with a gain of 0.34; that is, 34% of its magnitude may get added or subtracted depending on the phase relation from an actual fundamental frequency component. For example, if 0.2 A of 60 Hz x 3.5 = 210 Hz is permanently superimposed on a 1 A, 60 Hz signal, then 0.34 x 0.2 A = 0.068 A would leak to the 60 Hz measurement. Thus, the 1 A, 60 Hz signal would be seen by the relay as a reading between 1 – 0.068 A = 0.932 A and 1 + 0.068 A = 1.068 A depending on the phase angle relation between the two components in the current signal (1 A, 60 Hz and 0.2 A, 210 Hz).