

5th Harmonic resonance

Application Note



Power Quality Case Study

Measuring tools: Fluke 43B Power Quality Analyzer

Operator: Water plant electrical engineer

Features used: Voltage, harmonic spectrum

Problem description

A small city gets its water from a mountain lake 30 miles away. A pumping system at the lake brings water up a short incline and into a long gravity pipeline that feeds the city's water distribution system.

Before entering the pipeline, the water passes through a filter that removes debris. When the differential pressure across the filter gets too high, a large backwash pump reverses the flow momentarily to clear the filter. The backwash flow carries debris to a settling pond.

Powering this backwash pump is a 650 hp, 3-phase motor equipped with a soft start. A "negative sequence detector" helps protect this important motor by shutting it off upon the loss of a phase, or when voltage distortion exceeds a predetermined level.

The power to this motor comes via a 30-mile utility line originating in the city. A power factor correction capacitor near the backwash pump improves power factor and reduces voltage loss at the end of that 30-mile line. For a long time, this configuration worked with no problems.

After a small earthquake in the nearby mountains, questions arose regarding the continuation of the water supply in the event of a power interruption. How would the city get its water if the utility connection were lost due to an earthquake? The answer was a generator. Subsequently, the city added a diesel-powered engine generator and transfer switch to the system (see Fig. 1).

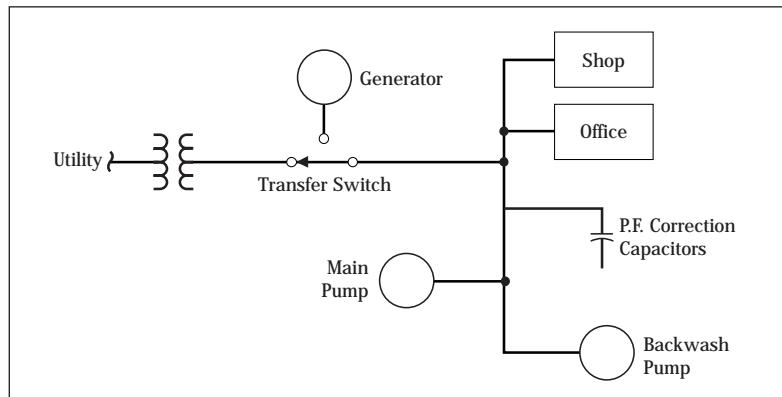


Fig. 1 One-line diagram of the water plant

System testing under generator power revealed a problem. The backwash pump would suddenly stop part way through the start sequence. And it was stopping because the negative sequence detector was putting out a stop signal to the motor controls. What electrical anomaly was the negative sequence detector protecting the motor from? Was it a phase loss? Excessive voltage distortion? What were the characteristics and source of this anomaly? Unfortunately, the city engineer was unable to answer these questions with his existing test equipment. After some research to identify a device that would allow him to see what was going on, he purchased a Fluke 43B.

Measurements

The engineer suspected voltage distortion, so he connected the Fluke 43B phase-to-phase across the input to the soft start and selected "Harmonics." During the start sequence, the

Fluke 43B displayed 5th harmonic distortion rising to 80 % of the fundamental prior to the stop signal.

Theory and analysis

The ideal displacement power factor (DPF) is 1.0. This occurs when the current and voltage are "in-phase." Inductive motor loads cause the current to lag, thereby lowering the DPF. This usually results in a penalty charge from the utility, so many users install a capacitor to provide DPF correction.

However, the combination of inductance and capacitance will form a resonant circuit that may result in high circulating current at the resonant frequency. It's standard practice to size a capacitor at a value large enough to correct the DPF to at least 0.9, but not so large that it makes the voltage lag the current. The resulting configuration yields a resonant frequency between the 5th and 7th harmonic.

Problems can occur if the circuit has a source of harmonics near the resonant frequency. In the case of the backwash pump, the source of harmonics was the semiconductor switching operation of the soft start.

Why did the circuit work fine when powered by the utility, yet not work when powered by the generator? The difference is the source impedance. The low impedance of the utility means it can absorb harmonic currents without causing severe voltage distortion. The impedance of the generator is much higher than that of the utility. Harmonic currents flowing into the generator caused enough voltage distortion to trigger the negative sequence protection circuit to produce a stop signal.

Solution

The city engineer solved the problem by moving the capacitor to the utility side of the transfer switch. With this configuration, the generator never sees the capacitor and the resonance condition does not exist when the generator powers the circuit.



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