Avoiding the Pitfalls of Generators and Large Motors

CPS ENGINEERING, INC.
MECHANICAL AND ELECTRICAL ENGINEERS

Overview

One of my clients recently asked me to investigate an ongoing issue with their standby generator operation. The problem concerned the starting of a 1,000 ton chiller whenever their building was running on onsite standby power.

The building owner never had a problem starting the chiller on utility power. He also knew that under worst case summertime conditions, this particular chiller would overload the generators, and so never attempted to start it on standby power.

During a recent shutdown period, the owner tried starting the chiller with a relatively lightly loaded bus in a power outage scenario, and then tried starting the chiller with no other loads on the generator bus. Both attempts failed.

The Facts

1. The chiller has a full load of 86 amperes at 4160 volts, 555 kW and 619 kVA.
2. The starter is a reduced voltage auto-transformer type.
3. Starting inrush current was measured at 381 amperes, or about 4.4 times running amps.
4. The two generators, when paralleled, have a capacity of 4,000 kW and 5,000 kVA at 0.8 power factor. Because the building operates close to a 0.9 power factor, the maximum kVA rating of the standby system is reduced to 4,500 kVA.
5. Alternator sub-transient reactance is 12.5 percent.

In both cases, there was ample reserve capacity in the generators for the chiller to operate at its full load rating of 555 kW. Both failures involved an industrial-grade undervoltage relay that resided in the starter for the chiller.

The generator vendor was called in to check and adjust the settings on the protective devices at the engine but they could not find anything that was grossly out of parameter. The next step was to bring in a testing company to measure load readings. At that point the owner called me in to review the facts and to see if I could offer a solution.

Background

There have been a myriad of papers and technical articles in trade magazines over the past 25 years about overloading standby engines during motor starting events, and most generator vendors even provide basic software to calculate the maximum allowable motor horsepower to prevent overloads. The typical situation is that a generator operating at some known load will shut down on underfrequency or undervoltage when trying to start the motor.

Neither of these situations were evident at this site. The protective devices on the generator system failed to register an event and the generator service technician declared a "not-my-problem" situation.

Because the situation did occur when on utility power, my first inclination was to focus on the voltage drop conditions. Generators are not considered a "stiff" source when compared to utility alternators. Utility generation equipment may be rated in the thousands of megawatts with multiple sources feeding into the grid; on-site generators at this location totaled four megawatts. The ratio of starting kVA for a 1,000 ton chiller to available kVA is much greater and this ratio is reflected in the corresponding voltage drop when applying the load to the bus.

There are various problems that can occur when starting on the utility as well as on an onsite generation system. With utility power available, the problems usually involve improper protective relay settings. Because the normal building operation is with the utility available, these kinds of problems tend to crop up shortly after installation and are dealt with by tweaking various relay settings on the protective devices. When the problems finally go away, they hopefully go away for good.

Unfortunately, most standby power installations for important buildings never seem to undergo enough testing to uncover the subtle errors that may take years to manifest. Generator installations for existing buildings require shutdowns for the tie-in of new equipment. Typically, the shutdown periods are for a weekend, or a 24 hour period, or even less. There are many tasks that need to take place before testing the generators. If time becomes short, the installers and owners compromise the final tasks, such as testing. The owner inherits the potential "gremlins" when the tie-ins are completed and everyone walks away.

Marginally sized generators and large motors have a dynamically intertwined relationship, so testing becomes paramount, as well as the designer having a full working knowledge of the other systems in the building.

Potential solutions

In this case, the goal is to make sure there is spare capacity in the generator for the starting kVA of the chiller. This chiller has a starting kVA of 2,442. Therefore, the maximum load on the generator bus prior to chiller start cannot exceed 2,058 kVA. This assumes that there is no overload capability in the generator system, which is a mandatory assumption given the competitive nature of generator manufacturers. Any load in excess of 2,058 kVA will cause the engine to lose speed and trip on underfrequency protection.

Witnesses claimed that the generators were seeing about 1,558 kW of load when they made the first attempt to start the chiller. Furthermore, the second attempt was made with no other loads on the generator bus, and yet the second attempt failed as well.

If a generator cannot handle the voltage dip during starting, it will trip itself off line on a safety in the voltage regulator. Using the sub-transient reactance of 12.5 percent, and assuming the generators are paralleled, the voltage dip during a chiller start would be about 7.6 percent with no other loads on the generator bus. This number is elevated compared to the utility system voltage drop, but is still at a level where other building equipment would not be adversely affected. If there was already a 1,558 kW load on the bus, the voltage drop at that point during starting would be about 11.8 percent. This level may cause a noticeable indication with light flicker, but should not be a cause for a building shutdown.

If undervoltage protection on the main or on the feeder circuit breaker is set too low, one or both trip. We would classify this condition as a nuisance trip because neither the chiller nor the electrical system would be damaged if the undervoltage condition was allowed to remain for the few seconds that it would require to start the chiller. If this event occurred, my recommendation would have been to adjust the pickup and time-delay values in the relay(s) to the point where the parameters do not enter the protective envelope of the chiller.

The undervoltage protection in the chiller starter causes a safety shutdown of the starter circuit. According to the testing company technician, this condition did occur. The starter is equipped with an industrial grade undervoltage relay that apparently dropped out during an attempted chiller start. Getting around this involves the cooperation of the chiller manufacturer. The fix is relatively simple: adjust the settings on the existing relay, or replacing the relay with one having a range of setpoints and time delays that eliminate this condition. The chiller vendor should be advised of the modifications and should also give their approval. Even if this modification solved the immediate problem, the owner still could not start the chiller with a bus load greater than 1,558 kW.

It may be possible to adjust the starting characteristics of the chiller starter. The autotransformer starter reduces the inrush current for a few seconds using an intermediate tap on an autotransformer. Since chillers normally start very lightly loaded, there is considerable leeway available to reduce the voltage during starting. In an autotransformer, it is possible to adjust the tap setting to a lower value if the autotransformer has multiple taps. Again, the chiller manufacturer would need to be give their approval to whatever is done with starter modifications.

An autotransformer starter is considered to be the best type of starter in medium voltage applications from a torque/horsepower perspective. At the low voltage level (208 and 480 volt), the closed-transition wye-delta, or the solid-state soft-start are typically used because either one provides better lower inrush than an autotransformer. The wye-delta starter is not readily available for 4,160 volt motors, and soft-start electronic starters are prohibitively expensive at this voltage level as well.

If the starting current was reduced to, say 300 percent or 258 amperes, the maximum load on the engine bus could increase to 2,335 kW before an overload occurs due to chiller start, rather than 1,558 kW today. As with before, all other voltage drop conditions would have to be satisfied, including the adjustment of the troublesome voltage relay in the chiller starter.

The next best solution is to convert the chiller to variable frequency drive (VFD) operation. In this case, the chiller inrush can be as low as 100 percent of full load, at which point all undervoltage and overload conditions are eliminated. Whether or not this chiller can be converted is a question for the chiller vendor, but at a minimum, the motor would have to be replaced with a 480 volt unit, a step-down transformer is required, and there would be numerous changes to the chiller and its controls. Other changes to the chilled water plant may be required as well.

To eliminate the need for load management, and to guarantee fully automatic operation, perhaps the ultimate solution is to consider the installation of a third 2,000 kW engine. This solution would provide more than sufficient reserve capacity as well as allowing a reasonable amount of growth in load.

CPS Engineering, Inc. 90 National Drive Glastonbury, CT 06033
Tel. 860-657-8118 Fax 860-657-8999
www.cpsengineering.com info@cpsengineering.com