SUBJECT: Using Emergency Power with DSD Elevator Drives

Diesel-Generator sets can be used as a power source for DSD-412 DC drives. However, there are potential problems that need to be discussed, understood, and avoided.

1. Typical power generators (3-phase alternators) including those used for emergency power are sized by a Kilowatt (KW) rating at a specific Power Factor (PF), usually 0.8. At 0.8 PF the generator Kilo-Volt-Ampere (KVA) output will be 1.25 x KW. The diesel engine must produce the real, or KW, power. The alternator must be able to handle the electrical KVA. Typical generators will have 15-20% internal reactive impedance. This is much higher than the local utility connection where the source impedance is established by the closest distribution transformer, with only 2-4% impedance being typical.

2. The voltage regulation characteristic of the generator by itself is rather poor. As electrical load amps are added or removed, voltage at the output terminals will fluctuate significantly. Part of the voltage sag with increasing load is caused by the internal electrical impedance, but other internal magnetic effects also cause an additional need to increase generator field strength (excitation) as electrical load is increased. A typical generator regulator/controller will monitor voltage output at the generator terminals and automatically adjust the excitation as necessary to maintain either a constant voltage or a constant volts/Hz output. This control is a closed loop, with all the typical closed loop characteristics of regulation, response time, sag, recovery, overshoot, and potentially, oscillation. It is usually capable of working with up to 20% of Total Harmonic Distortion (THD) voltage at the generator [industry standard].

3. Diesel engine speed directly determines and holds the generator output frequency at the desired 50 or 60 Hz. But speed regulation of the engine itself with load changes is poor. There is always a closed loop control (governor) to monitor engine speed and adjust fuel flow to maintain the desired operating electrical frequency. Again, this has its own regulation, response time, sag, recovery, overshoot, and potential for oscillation characteristics.

4. The drive will draw harmonic current from the power line, regardless of the source of power. This is typical of all types of solid state power converter drives. The DSD-412 DC drive is a reversible 6-SCR design. Typical AC line current will include 20% 5^{th}, 14% 7^{th}, 9% 11^{th}, and 8% 13^{th} harmonics. Both the fundamental and harmonic line currents will create voltage droop effects when passing through the impedance of the source, aggravating the issue of generator voltage regulation.

5. However, the magnitude of line current (and therefore the degree of I x X sag) and KW power will vary greatly depending on the demands of the load. An elevator will typically demand 250% of "rated" current during acceleration, and almost no current while waiting at a landing. During deceleration, the DSD-412 drive will regenerate a significant amount of energy, up to 250% of rated current for a short period of time, back to the power source. But of course a "constant" voltage is always expected at the drive input terminals. The drive must make adjustments to accommodate a change in line voltage or frequency on the fly.

6. Several interfering issues when local generators are used to provide power are:
   A. The elevator operation is cyclic causing large fluctuations in the elevator drive load.
   B. The generator impedance is relatively high which can cause the voltage to fluctuate.
   C. The diesel engine rpm may fluctuate causing a frequency and (V/Hz) voltage change.
   D. When the line voltage and frequency fluctuate, the drive has to follow them in order to maintain the proper voltage/current output to maintain the desired elevator speed profile.

   It should be easy to visualize that suddenly applying a large load (like starting to accelerate an elevator) will cause a sag in generator voltage and frequency which should eventually be corrected by engine-generator controls. If the sag is too severe, the drive may trip out on an undervoltage or changing frequency (SyncLoss) fault. When the elevator reaches running speed, the high ampere load will just as suddenly be removed, causing a voltage and frequency overshoot. At best, as the drive attempts to draw variable power from the lines it must also adapt to a continually changing line voltage and frequency as those respective regulators adjust themselves. The expected result is that the drive should be able to act normally as long as the supplied voltage from the generator remains within the specified normal operating region (rated line volts, +/-10%). As it turns out, the time constants of the engine, generator, and the dynamic tuning of their respective regulators, are the primary factors which define the performance behavior of the overall system with a changing load. The rate of change of power demand of a typical elevator in operation is faster than the regulating control loops for a typical diesel-generator set. It should be apparent that the size of the elevator load "disturbance " to the engine-generator will become less important as the size of the engine-generator set is increased. Therein lies the first clue to avoiding problems.

RECOMMENDATIONS

1. Ensure that the diesel-generator is adequately sized.
Diesel-generator sets have almost no overload capacity to produce KW or KVA beyond their continuous rating while maintaining line voltage and frequency at rated values. Sizing the gen-set to just meet the average nameplate power of the elevator motor will cause unacceptable overload sags and surges at times of elevator acceleration. Line impedance will also be too high for the DSD drive to operate during regeneration (specified at 8% max). Sizing the gen-set to just meet the KVA & KW power of a single elevator during acceleration (2.5 x motor rating) will technically not overload the gen-set and may meet drive requirements for line impedance, but will fail to hold output voltage at the rated value at the beginning and end of elevator accelerations causing system instability, and still fail miserably during regenerative elevator stops. **The minimum recommended size for the gen-set is 4-5 times the Peak KVA necessary to accelerate the largest elevator in the system.** Yes, this

is 10-12 times the largest elevator motor nameplate rated KW (or drive isolation transformer KVA) capacity. This sounds like overkill, but when the elevator accelerates the worst step change in power demand will be only 20-25% or less of the diesel-generator set rating. It should have no problem maintaining output voltage and frequency within normal "utility" ratings during elevator starts and stops. Other attached loads or normal gen-set losses will be able to absorb elevator regenerative stop energy. The effective impedance of the generator as seen by the drive will be diminished by the drive/generator KVA size ratio and will be low enough to be ignored. If other building loads are to be attached, ensure that rated power of the generator is larger than the sum of those loads plus the peak KVA elevator demand.

2. Stagger elevator starts.
When emergency power generators are used to power more than one elevator in a system the elevator car controller(s) should control elevator cycling so that only one elevator is allowed to start at a time. This will ensure that the diesel-generator will not be hit with large 'block load' disturbances that would cause unacceptable voltage or frequency sags. This is less important if the gen-set size is larger than the minimum size recommended above.

OTHER OPTIONS

If one must use a gen-set that is smaller than the recommendation above, the following suggestions may help.

A. **Modify the elevator acceleration profile** when on emergency power to reduce the rate of change of electrical load and the peak power demand. Note that this is not the same as simply reducing the maximum elevator running speed.

B. **Work closely with the diesel-generator set manufacturer and the specifying agent** so that the effects of transient load changes can be quantified and designed to meet the requirements. Regulating systems with load measuring anticipatory controls do exist. Flywheels can be built into the equipment. The goal is to maintain output voltage and frequency within the elevator drive cycle load change profile.

C. **Provide a harmonic trap filter** at the drive. This can remove most drive current harmonics from the generator and reduce the voltage distortion at the generator regulator feedback terminals caused by those harmonics. However it WILL NOT reduce the effect of a heavy load suddenly applied to or removed from the diesel-generator. The diesel generator must be able to keep up with the power demand changes without excessive sags or surges. Also note that a harmonic trap filter is meant to be operated at a fixed line frequency. When the generator frequency sags or surges it becomes less effective.

D. **The use of a power factor correction device is NOT RECOMMENDED.** The electrical power factor of a DSD drive powering an elevator varies widely during the normal elevator cycle. A fixed amount of capacitive KVAR correction will be incorrect most of the time. When the elevator is at rest, leading KVARs can cause generator control instability. A variable compensation device is not likely to keep pace with elevator cycling and cause more problems than it cures. Even if such a device could correct the power factor to be unity, all of the time, it WILL NOT reduce the effect of a heavy load suddenly applied to or removed from the diesel-generator.