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Power Quality and Generators – Part 1: Sizing and Code Issues

Editor's Note: This is the first installment in an ongoing series that will cover basic engineering and code issues for standby generators. In a subsequent column, the author will address harmonic effects on generators.

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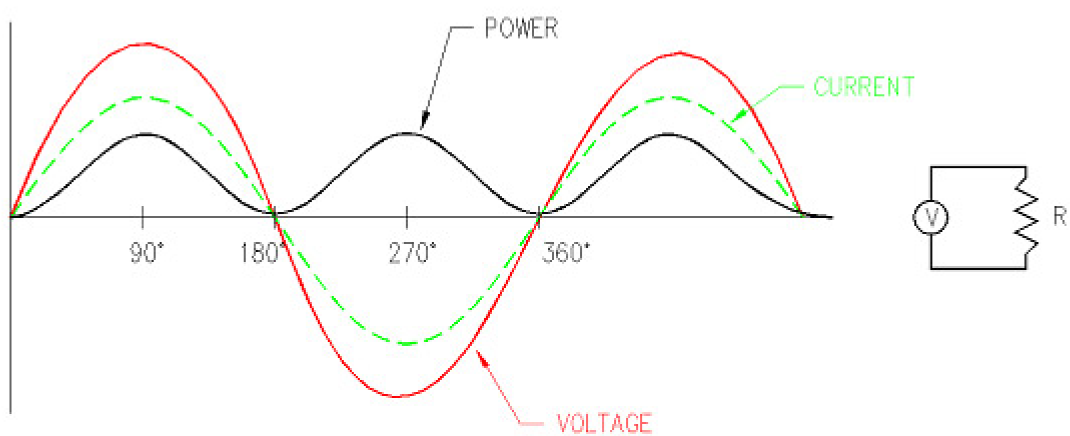
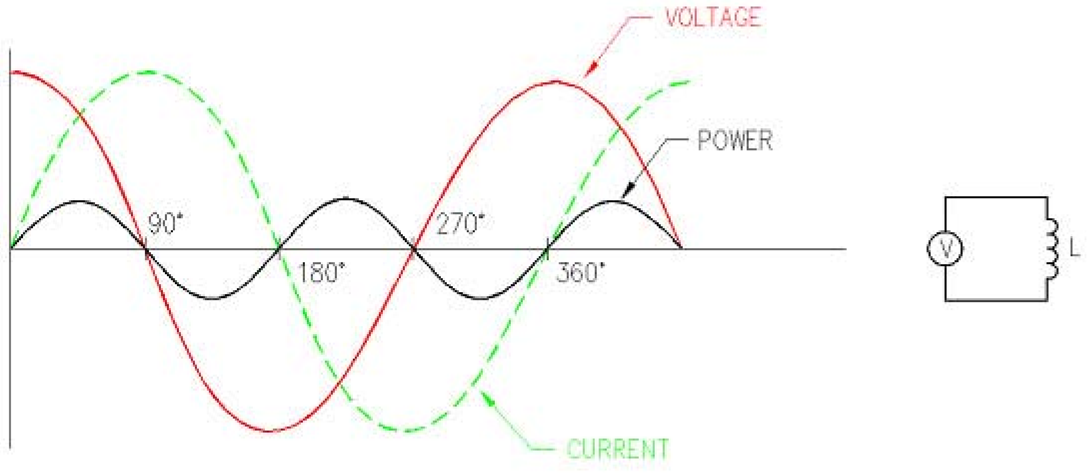
The need for continuous electrical power and life-safety systems has increased for many installations. Critical installations that require reliable power quality typically include a standby generator for essential loads. In addition, these generators can provide power to code required life safety or legally required standby loads.

There are important sizing and code issues involved in effectively designing and specifying a standby generator. Generators are typically specified with a kW rating and an associated power factor. Together, these values indicate the maximum kW (real power) and kVA (apparent power) that the generator will produce.

Mathematically, power factor is the ratio between kW and kVA (PF = kW / kVA). It is a measure of how efficiently the current is being converted into useful work. At low power factors, more current will be required to provide the same amount of power.



PURELY RESISTIVE LOAD. CURRENT IS IN PHASE WITH VOLTAGE, POWER IS ALWAYS POSITIVE. POWER IS ALWAYS BEING DISSIPATED BY RESISTIVE LOAD.



IN A PURELY INDUCTIVE LOAD CURRENT LAGS THE VOLTAGE BY 90°. POWER ALTERNATES EQUALLY BETWEEN CYCLE OF POSITIVE AND NEGATIVE. THIS MEANS THAT POWER IS BEING ALTERNATELY ABSORBED AND RETURNED TO THE SOURCE. IF THE SOURCE IS A MECHANICAL GENERATOR, IT WOULD TAKE (PRACTICALLY) NO NET MECHANICAL ENERGY TO TURN THE SHAFT BECAUSE NO POWER WOULD BE USED BY THE LOAD.

An engineer must consider both the engine and generator individually and as a system. Engines produce the real power (kW) or horsepower and control frequency. Generators change the mechanical energy into electrical energy (kVA) and must satisfy magnetization current (kVAR) within an electrical system.

Often times a more critical parameter in sizing a generator is the maximum skVA (starting kVA) and maximum skW (starting kW) allowed. The skVA is dependent on the maximum allowable voltage drop during starting and will be lower for more sensitive critical loads, or where lower maximum voltage drops are required by code.

It is common for a systems stating kVA and maximum allowable voltage drop to drive the size of the generator. Motors can draw six times the full load amps during start up. High efficient motors can draw ten times the full load current or more. This means that the starting of motors can dramatically effect the skVA required and may exceed the maximum skVA of a generator that would otherwise be large enough to serve the steady state load. This could require an oversized generator based solely on the motor starting requirements.

Staggering the starting of large motors and/or providing soft starters or variable frequency drives (VFD) can mitigate the voltage drop problem by reducing the inrush current and kVA. Staggering the starting of large motors can reduce the peak starting kVA to within limits of a smaller generator. When providing steps between loads, the designer must be aware of all codes and maximum allowable starting time delays for life safety and legally required standby loads.

Soft starters or VFD’s can reduce the starting inrush current and kVA to half of that of an across the line starter. On the down side, these devices also utilize SCR’s (silicon controlled rectifiers) to chop up the AC waveform and will provide a non-linear waveform. This non-linear waveform (harmonics) will cause voltage distortion across the
reactor of the generator and can cause unacceptable transient performance. This will adversely affect the performance of the entire system. Voltage drop and voltage distortion will be much higher when a facility is under generator power than when on utility power. Typical generators will have 15-20% internal reactive impedance, whereas utility transformers will typically have between 2-5% internal reactive impedance.

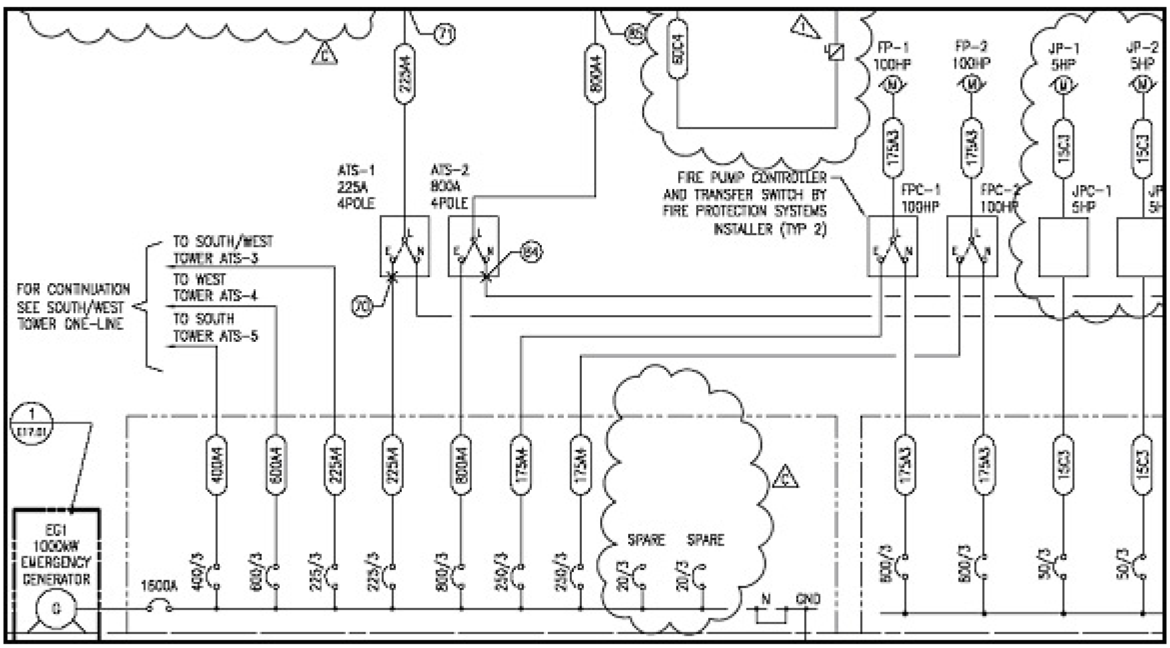
Waveform notching caused by this voltage distortion can be detrimental to solid state timing devices that rely on zero crossing switches. To compensate for the voltage distortion from non-linear loads, a larger generator with reduced impedance can reduce the effects caused by the non-linear load.

The design engineer must be aware of the intended use of the on site generator. Depending on the load factor, typical application, typical peak loading and typical hours per year, the generator will require either a standby rating, a prime rating or a continuous rating. In addition, code issues will drive the required rating of an on-site generator. Operating a generator beyond it rating will result in a shorter life and more expensive operating costs. It is important to reference a generators intended use to manufacturers warrantee restrictions in regard to run time per year.

Regenerative loads such as conveyors, cranes and elevators can rely on the power source to absorb power during breaking. These types of loads in the system can affect the size and type of generator. In addition planning loading and stepping to ensure that other loads are connected that can absorb the regenerative power can help solve this potential problem.

It is possible to have a single generator feed life safety and non-life safety loads. The National Electric Code (NEC 700.5 B) will allow an alternate power source to supply emergency, legally required standby and optional loads, where automatic selective load pickup and load shedding as needed is implemented to ensure adequate power to life safety, legally required standby and optional loads, in that order. This can be achieved by providing a separate automatic transfer switch (ATS) for each of the three branches of loads (life safety, legally required standby, optional).

As a side benefit, the three branches of automatic transfer switches can provide convenient load stepping during generator startup. This will typically reduce the required size of the generator. The transfer switches must be timed to reduce the maximum skVA and meet all NEC transfer time parameters for life safety and legally required standby loads.



Standby power systems can be complex. Effectively designing electrical systems with multiple automatic transfer switches and multiple types of loads requires a thorough understanding of generator sizing criteria and of the various applicable codes.

Conservatively over sizing a generator from not clearly understanding sizing requirements will not only add undo expense to a project, but can also be detrimental to the reliability of the system. Most manufacturers recommend that diesel engines should not be run at less than10% of rated load for extended periods and in general recommend that loads do not drop below 30% of the rating of the generator. Check manufacturer recommendations for specific installations.

The engineer must also be aware of the minimum amount of on site fuel supply required for an internal combustion prime mover serving as a power source for emergency systems. A minimum amount of on site fuel storage is identified in section 700 of the National Electric

Code. For large generator, the minimum amount of on site fuel supply can exceed the limits set forth by building and/or fire codes and can lead to additional system requirements including; separate fuel supply systems, Class H, Division 3 occupancies or UL 2085 tanks with integral secondary containment.

Many jurisdictions are now requiring generators to be UL 2200 (Stationary Engine Generator Assembly) listed and labeled. This standard represents a national product safety requirement for generators. These requirements cover stationary and fixed generators rated 600 volts or less and are intended for installation and use in ordinary locations in accordance with the National Electric Code. This requirement has only been enforced in the past few years. Owners and engineers considering utilizing used generators should ensure UL 2200 compliance and coordinate with local code officials.

Generator system design and sizing can be complex. To effectively design and size generator systems, an engineer needs to understand the effects of different components in the electrical system and be able to navigate through the various electrical, building and NFPA codes.

Future installments in this series will provide more in-depth analysis of other critical engineering and code issues involved in effective design and specification of generator systems.