GENERAC
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POWER

WHITE PAPER

Sizing Considerations for Commercial and Industrial Generators

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INTRODUCTION

Sizing a generator for industrial applications involves a variety of factors that can influence the specification and purchasing process. To ensure the optimal power solution for your application, it is highly recommended that you work with your local generator representative to ensure accurate sizing for your project. While many manufacturers provide sizing programs, it is important to understand how and why selections are made. This paper will cover the vital aspects of the sizing process.

Determining the scope of the project is one of the first steps. Different application types, such as manufacturing, wastewater treatment, data centers, and hospitals, have unique requirements. Location can also determine emissions, sound levels, derating due to elevation and temperatures, and acceptable fuel types. It is important to be familiar with federal, state, and local code requirements as well.

For new construction sites, determining whether your loads are considered essential or optional loads are important factors to consider. Paralleling can also be a great tool to avoid exceeding budget while still having expansion capabilities after day one requirements. Paralleling is also beneficial when space allocated for installation is tight and a minimal footprint is required.

For existing buildings, peak load levels can be gathered from billing history. If necessary, unique load characteristics (transients or harmonics) can be observed using power analyzers.

When sizing generators, there are three main occurrences you need to take into account. Unlike utility power, the generator is not an infinite source. Therefore, the amount and types of loads can cause frequency dip, voltage dip, and harmonic distortion.

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FREQUENCY DIP

Frequency dip is when the engine cannot supply enough power (kW) to support the load demand, causing a reduction in engine RPM. When frequency dips occur, the generator will sense a need for more fuel to increase RPMs and will bring it back up to speed (typically 1800 rpm's for 60 Hz or 1500 rpm's for 50 hertz). The lag time to recover as well as a drop in hertz is referred to as a frequency dip. Most loads are tolerant of a frequency dip up to 10 Hz, but some technologies can be more sensitive.

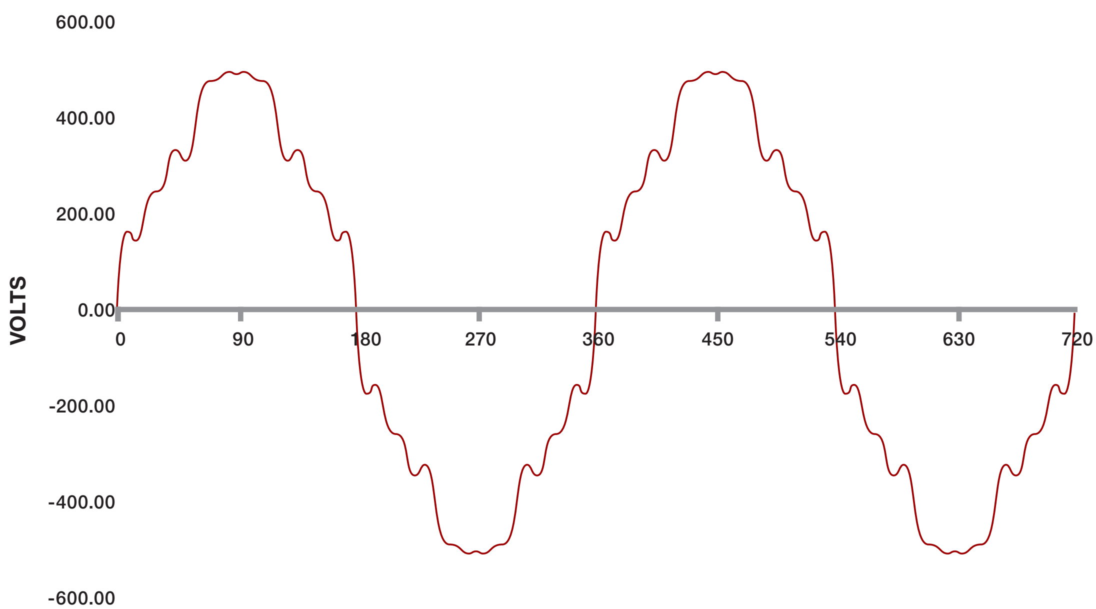
VOLTAGE DIP

Voltage dip occurs when there is a decrease in voltage for a short duration. This is generally caused when the alternator experiences high inrush currents upon motor startup. Most NEMA motors can withstand voltage dips up to 30 percent. However, general facility loads beyond 15 percent can cause some loads to reset.

HARMONIC VOLTAGE DISTORTION

Harmonic Voltage Distortion is caused when loads have impedance changes with applied voltage. These loads are called non-linear loads and include anything that involves AC/DC conversion (rectifiers). The changing impedance means the current drawn will not be a sine wave, even if it connected to a sine wave voltage source. Therefore, if you look at the sine wave you will see the amount of voltage distortion to the waveform. Total harmonic voltage distortion should be limited to a maximum of 10 percent in accordance with IEEE 519, which is shown below:

Figure 1. Selected Harmonic Profile Sinewave



Total Harmonic Distortion (THD) can affect the generator due to harmonic currents produced, which in turn flow through the alternator, taking up capacity and creating heat. Two ways to address this is to utilize filtering devices or reduce the source impedance by upsizing the alternator or adding other loads.

Load Analysis

Load analysis, including starting profiles and normal operating conditions, is an important step in determining the cumulative effect of each individual load. As each load type can tolerate different deviations, requirements and individual settings can vary from one load to the next.

To ensure the proper application is employed for identified loads, applications may require a solution in which loads are stepped onto the generator in certain sequences.

Motor Loads

The starting kVA required to energize the field, overcome the locked rotor, and bring a motor up to speed is a key characteristic that plays a significant role in the generator sizing process. Almost all U.S. motors have a motor nameplate that includes the NEMA starting code, which determines the skVA required for each.*

TABLE 1: Motor Loads

Letter Designation	kVA per hp
A	0 - 3.15
B	3.15 - 3.55
C	3.55 - 4.0
D	40. - 4.5
E	4.5 - 5.0
F	5.0 - 5.6
G	5.6 - 6.3
H	6.3 - 7.1
J	7.1 - 8.0
K	8.0 - 9.0
L	9.0 - 10.0
M	10.0 - 11.2
N	11.2 - 12.5
P	12.5 - 14.0
R	14.0 - 16.0
S	16.0 - 18.0
T	18.0 - 20.0
U	20.0 - 22.4
V	22.4 and up

**Exceptions would include IEC motors, specialty motors and submersible pumps.*

Per Table 1: NEMA Code G 100HP motor would need a 600 skVA alternator to start. However we only need 100kVA to run the motor.

For NEMA Code G motors:	**skVA ~ HP x 6**	**starting**
	rkVA ~ HP x 1	**running**
For engine kW:	**skW ~ HP x 2**	**starting**
	rkW~ HP x .85	**running**

Twice the horsepower is required for startup: 200 kW
And just .85 of the HP is needed to keep running: 85 kW

Three 100 HP motors started in unison would take two 300 kW units approximately 600 kW to start. Each unit started individually in sequence would reduce the starting kW required by 40 percent.

M1 starting 2x100~200 kW
M2 starting M1 85 kW + 200 kW ~ 285 kW
M3 starting M1 85 kW + M2 85 kW + M3 200 kW ~ 370 kW

Several alternative methods have been widely used to minimize the effects of motor loads on generator sizing:

Reduced Voltage Starters

Reduced voltage starters electromechanically provide a lower voltage to the windings of the motor and reduce the skVA required to spin it up to speed. However, if the torque provided at that voltage is not sufficient for full speed, the motor will switch to full voltage and normal skVA when it runs out of torque. This is commonly an issue when the reduced voltage motor is the only load.

Soft Starters

Soft starters electronically control the voltage applied. With different types available, awareness of operational characteristics is paramount. Some soft starters have the ability to start at low voltage and ramp up to full voltage. In this configuration, generator excitation and governor response is such that there are no voltage or frequency transients. Some soft starters ramp voltage until a preset current limit is reached. This preset current limit will determine the size of generator required. Stepping the voltage, as opposed to ramping, may result in load steps, which can create transients.

Variable Frequency Drives

A Variable Frequency Drive (VFD) varies voltage and frequency, which allows them to control starting and stopping rates. While harmonics were commonly an issue with VFD's in the past, IGBT technology has improved performance, quality, and cost.

ADDITIONAL LOAD CONSIDERATIONS:

IGBTs

Insulated Gate Bipolar Transistors have been widely implemented wherever rectifiers and inverters are needed. They have greatly improved harmonics including VFDs and UPSs.

Regenerative Loads

Regenerative loads, such as elevators and cranes, actually send power back to the generator that can cause shutdown. This can be overcome by adding an offsetting load such as building load, a break resistor, or load bank.

Uninterruptible Power Supply

With various manufacturers and UPS types available in the industry today, checking a manufacturer's specification for harmonics and loading is imperative. IGBTs have also made a tremendous improvement in Total Harmonic Distortion (THD). Be sure to include recharge requirements of UPS batteries in your sizing calculations.

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Leading Power Factor

Generators can handle 0.8 lagging to unity power factor. Leading power factor can cause voltage instability and/or over-voltage trips. Some sources of a leading power factor can be a lightly loaded UPS, high intensity discharge lighting, and power factor correction capacitors.

Lagging power factor loads or switching loads off when on generator power can offset leading power factor situations.

CONCLUSION

In conclusion, there are many factors involved in selecting the right generator, including application type, location, and applicable codes, as well as types of loads and their tolerance for transients. Your local generator manufacturer is the best source to partner with to ensure you have the optimal solution for your project.

Author Background

Rick Slavens is a power solutions manager for Generac Power Systems' Industrial Division with over 30 years of engineering experience. Over the last 12 years, Slavens has focused on the Mission Critical industry's generator, switchgear and UPS technologies.

Having conducted CEU/PDH seminars around the country, Slavens provides support for Generac's large kW projects for the Central United States and works closely with engineers and end users in the region.

Slavens received his BS EET degree from Texas A&M in 1986.