Considerations for Generator Set Selection

PowerHour webinar series for consulting engineers

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July 29, 2021
2:00 Eastern Time / 11:00 Pacific Time
(1 PDH issued by Cummins Inc.)

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- Earn Professional Development Hours (PDH)

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- Attendees are in “listen only” mode throughout the event.
- If the audio connection experiences issues, please check your audio connection through the "Join Audio" or "Audio Connectivity" button at the bottom left of the Zoom application.

Asking a Question and Interactions:

Q&A Button:

- For technical questions on today's topic
- Ask at anytime

Chat Button:

- For engaging the presenter if an open question is asked!

Meet your panelists

Cummins Instructor & Panelists:

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Technical Marketing Advisor
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Senior Sales Application Engineer
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Cummins facilitator:

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Disclaimer

The views and opinions expressed in this course shall not be considered the official position of any regulatory organization and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Participants are encouraged to refer to the entire text of all referenced documents. In addition, when it doubt, reach out to the Authority Having Jurisdiction.

Course Objectives

Considerations for Generator Set Selection

Sizing and selecting the right-sized generator set for a customer's loads can be a challenging endeavor; we're here to help! While most sizing exercises are best done with sizing programs or with the help of a manufacturer's representative, it is still important to understand the fundamental factors that affect the sizing of generator sets so you can be confident you have the right equipment for your application.

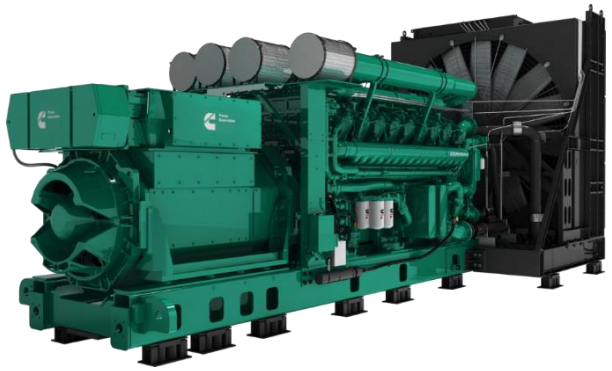
After completing this course, participants will be able to:

- Recognize the importance of key early decisions and where to get more information even before sizing for customer loads.
- Identify the impact of site conditions and overall loads on generator set performance.
- Describe how transient performance impacts generator set sizing: including load application techniques to optimize generator set performance while minimizing generator set size requirements for motor type applications
- Recognize the fundamentals at work behind generator set sizing software.

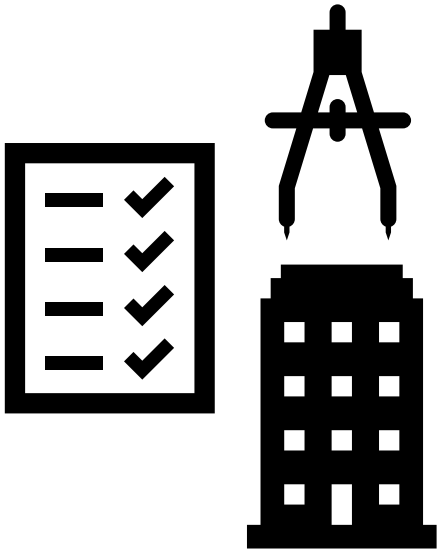
Setting the Stage

Communication is Important!

Product Selection
and Capabilities



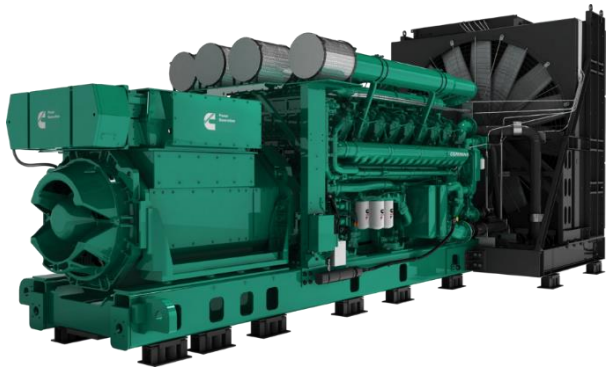
Customer
Requirements



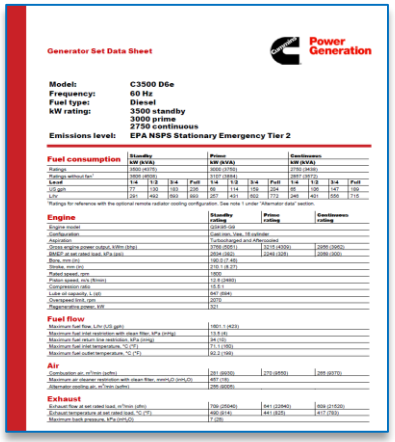
Setting the Stage

Communication is Important!

Product Selection and Capabilities



Product Data and Submittal Details



Generator Set Data Sheet

Power Generation

Model: C3500 D6e
Frequency: 60 Hz
Fuel type: Diesel
kW rating: 3500 standby
3000 prime
2750 continuous
Emissions level: EPA NSPS Stationary Emergency Tier 2

Fuel consumption

	Standby kW (kVA)				Prime kW (kVA)				Continuous kW (kVA)			
Ratings	3500 (4375)				3000 (3750)				2750 (3438)			
Ratings without fan*	3450 (4313)				3107 (3884)				2847 (3559)			
Load	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full	1/4	1/2	3/4	Full
US gph	77	130	183	236	86	114	159	204	95	106	147	189
L/hr	291	492	693	893	327	431	602	773	361	401	556	716

*Ratings for reference with the optional remote radiator cooling configuration. See note 1 under "Alternator data" section.

Engine

	Standby rating	Prime rating	Continuous rating
Engine model	QSK95-G9		
Configuration	Cast iron, Vee, 18 cylinder		
Aspiration	Turbocharged and Aftercooled		
Gross engine power output, kWm (bhp)	3766 (5051)	3215 (4309)	2966 (3952)
BMEP at set rated load, kPa (psi)	2834 (411)	2248 (326)	2080 (302)
Bore, mm (in)	190.0 (7.48)		
Stroke, mm (in)	210.1 (8.27)		
Rated speed, rpm	1800		
Piston speed, m/s (ft/min)	12.6 (2480)		
Compression ratio	16.5:1		
Lube oil capacity, L (gal)	647 (684)		
Overspeed limit, rpm	2070		
Regenerative power, kW	321		

Fuel flow

Maximum fuel flow, L/hr (US gph)	1601.1 (423)		
Maximum fuel inlet restriction with clean filter, kPa (inHg)	13.5 (4)		
Maximum fuel return line restriction, kPa (inHg)	34 (10)		
Maximum fuel inlet temperature, °C (°F)	71.1 (160)		
Maximum fuel outlet temperature, °C (°F)	82.2 (180)		

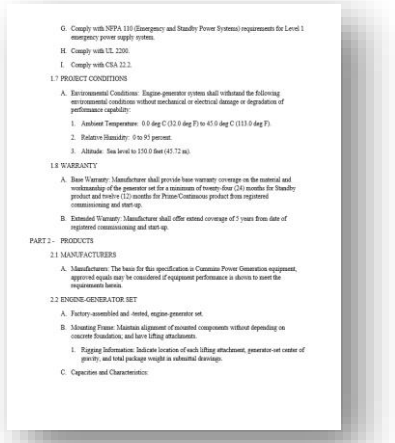
Air

Combustion air, m³/min (scfm)	281 (9930)	270 (9550)	295 (9370)
Maximum air cleaner restriction with clean filter, mmH2O (inH2O)	687 (18)		
Alternator cooling air, m³/min (scfm)	286 (9998)		

Exhaust

Exhaust flow at set rated load, m³/min (cfm)	709 (25040)	641 (22640)	609 (21520)
Exhaust temperature at set rated load, °C (°F)	490 (914)	441 (825)	417 (783)
Maximum back pressure, kPa (inH2O)	7 (28)		

Specification Language



G. Comply with NFPA 110 (Emergency and Standby Power Systems) requirements for Level 1 emergency power supply system.

H. Comply with UL 2200.

I. Comply with CSA 22.2.

1.7 PROJECT CONDITIONS

A. Environmental Conditions: Engine-generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:

1. Ambient Temperature: 0.0 deg C (32.0 deg F) to 45.0 deg C (113.0 deg F).
2. Relative Humidity: 0 to 95 percent.
3. Altitude: Sea level to 150.0 feet (45.72 m).

1.8 WARRANTY

A. Base Warranty: Manufacturer shall provide base warranty coverage on the material and workmanship of the generator set for a minimum of twenty-four (24) months for Standby product and twelve (12) months for Prime/Continuous product from registered commissioning and start-up.

B. Extended Warranty: Manufacturer shall offer extend coverage of 5 years from date of registered commissioning and start-up.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: The basis for this specification is Cummins Power Generation equipment, approved equals may be considered if equipment performance is shown to meet the requirements herein.

2.2 ENGINE-GENERATOR SET

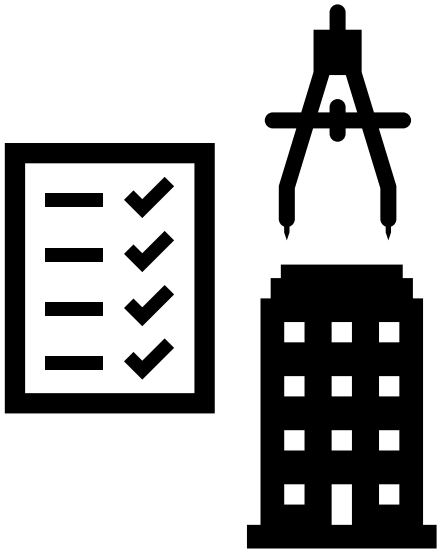
A. Factory-assembled and -tested, engine-generator set.

B. Mounting Frame: Maintain alignment of mounted components without depending on concrete foundation, and have lifting attachments.

1. Rigging Information: Indicate location of each lifting attachment, generator-set center of gravity, and total package weight in submittal drawings.

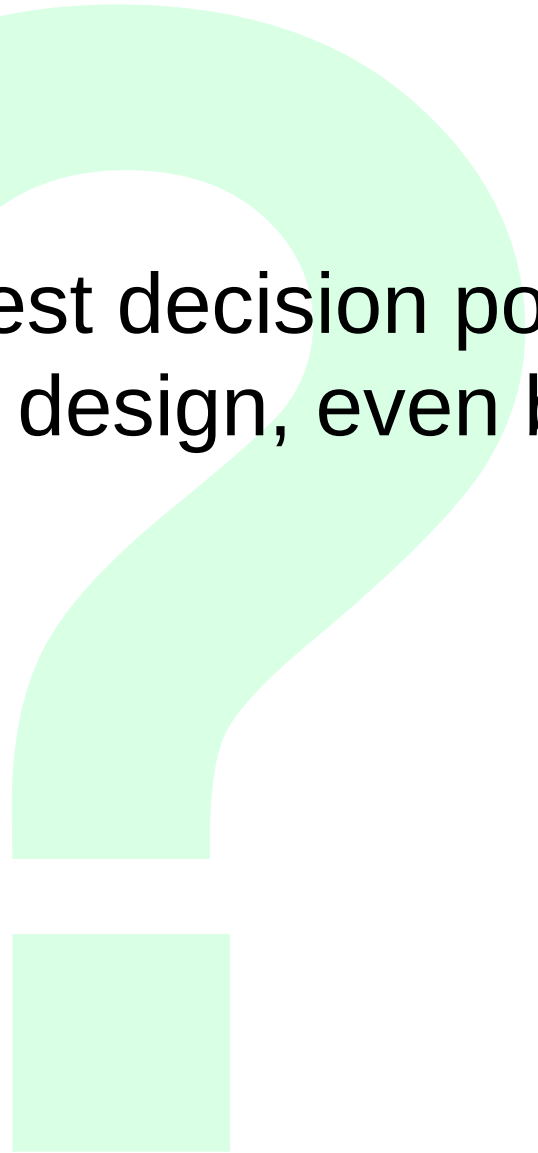
C. Capacities and Characteristics:

Customer Requirements



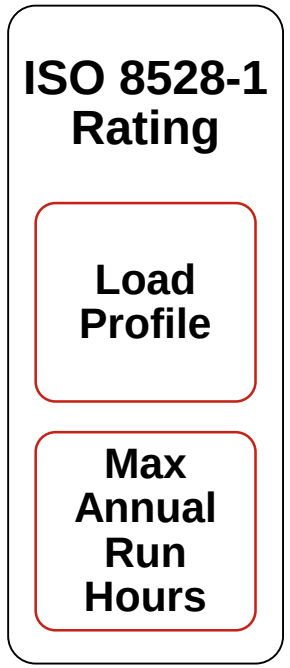
Concept Check

What are some of the earliest decision points when approaching a new system design, even before reaching for your trusty sample spec?



Key Early Decisions

Generator Set Ratings



Key Early Decisions

Generator Set Ratings

ISO 8528-1 Rating	Emergency Standby Power	Prime Rated Power	Limited Time Prime	Continuous Operating Power	Data Centre Power
Load Profile	Variable	Variable	Constant	Constant	Variable OR Constant
Max Annual Run Hours	200	Unlimited	500	Unlimited	Unlimited

Spec Note

Power Rating: Standby *<or applicable rating, but pick only one!>*

Definition: Engine Generator Assembly Power Rating to meet, at minimum, ISO 8528-1 for load profile and duty cycle.

Key Early Decisions

Indoor or Outdoor Install Considerations

Related Content

Generator Set Installation Guidance

T-030 Application Manual

Sound Attenuation Strategies PowerHour

Key Early Decisions

Choosing a Fuel Type

	Diesel	Gaseous
Small Footprint	✓	✓
Transient Capability	✓	✓
Rapid Start Time	✓	✓
Easiest Fuel Maintenance		✓
Lower Initial Cost	✓	**(more parity at low range)**

***** Broad generalizations here! Of course, there are exceptions.

Key Early Decisions

Choosing a Fuel Type – Fuel Storage Requirements

NFPA 70 – NEC Article:	Diesel	Gaseous (utility & on-site fuel source)	Gaseous (utility source only)
708 "COPS"	✓	✓	X**
700 "Life Safety"	✓	✓	✓*
701 "Legally Req'd"	✓	✓	✓
702 "Optional"	✓	✓	✓

* Follow exemption process w/ AHJ per NFPA 110 Level 1 Systems

** **NEC Article 708:** *Prime movers shall not be solely dependent on a public utility gas system for their fuel supply… Where internal combustion engines are used as the prime mover, an on-site fuel supply shall be provided…*

Related Content

Selecting Generator Set Fuel Sources
PowerHour Recording

Key Early Decisions

Emissions

US EPA New Source Performance Standards (NSPS)

Fuel Type

- Compression Ignition (Diesel) and Spark-Ignited (Gaseous)

Usage

- Stationary Emergency – operation when utility power is not available
- Stationary Non-Emergency – operation when utility power is available
- Non-road – mobile, non-propulsion without operational limitation (trailerized)

Local Air Quality Management Board

May mandate stringent emissions limits requiring exhaust aftertreatment

Related Content

Emissions and Air Permitting
PowerHour Recording

Concept Check

Your customer wants your quick gut-check to the size of generator needed for about 350 kWe of loads for their standby application. What size generator set would you suggest as a starting point? (assume “standard” ambient temperature and low altitude)

A) 300 kWe

B) 400 kWe

C) 500 kWe

D) 600 kWe or greater

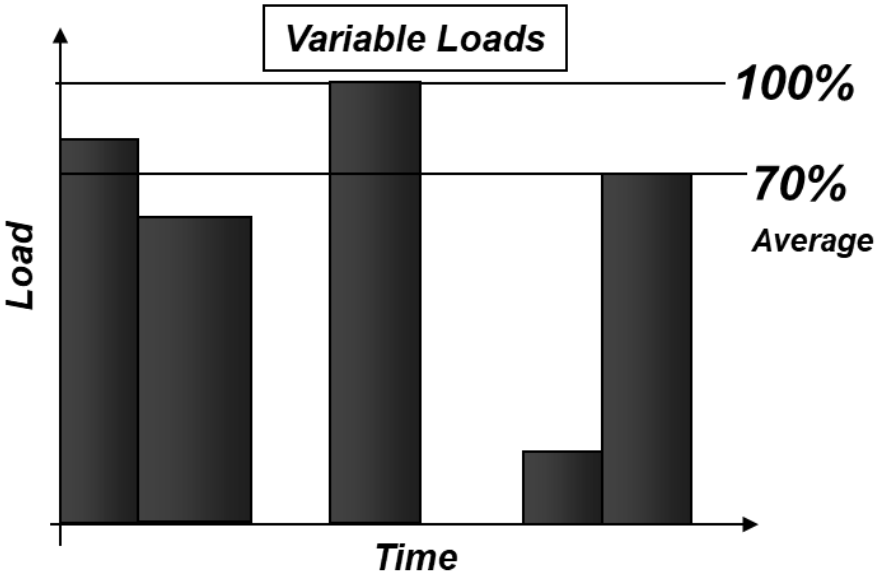
E) I would not dare offer a number at this point!

General Sizing to Overall Load

Considering “Average Duty Factor”

ISO 8528-1:

The permissible average power output, over 24 h of operation shall not exceed 70% of the Emergency Standby Power rating unless otherwise agreed by the manufacturer.

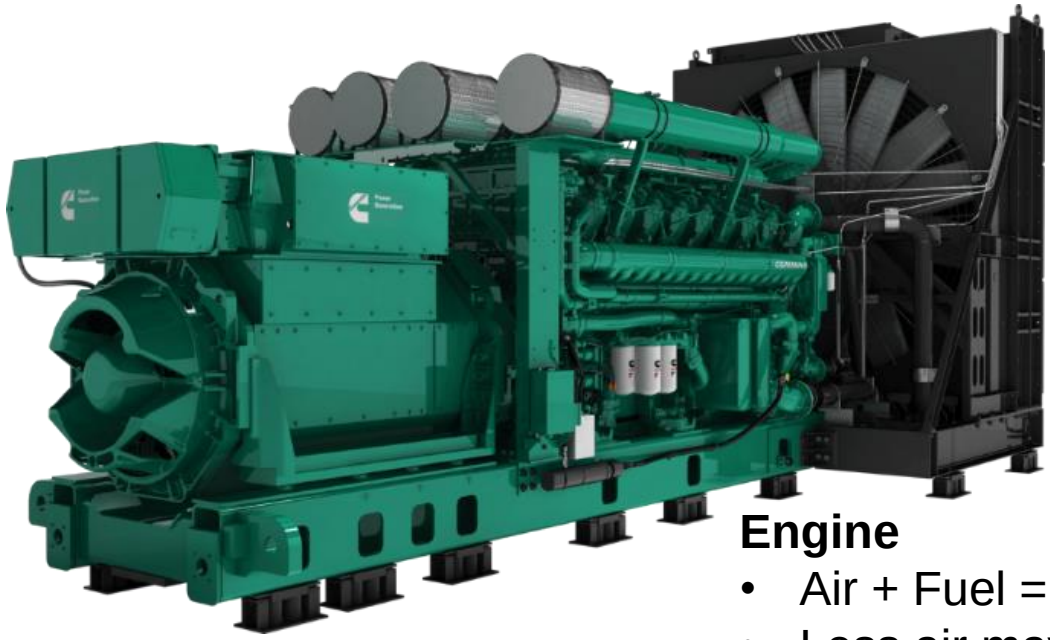


Spec Note
Power Rating: Standby *<or applicable rating, but pick only one!>*
Definition: Engine Generator Assembly Power Rating to meet, at minimum, ISO 8528-1 for load profile and duty cycle.

General Sizing to Overall Load

Potential Impact of Altitude and Temperature

Alternator
- Needs to cool effectively
- Higher voltages may run risk of corona discharge



Cooling System
- May see diminished cooling at higher altitudes or temperatures

Engine
- Air + Fuel = Power
- Less air may result in decreased power

Generator Set = Alternator + Cooling System + Engine
Specify load requirements and site conditions in the specification, and allow the submittal to respond with the “right” configuration for the job!

General Sizing to Overall Load

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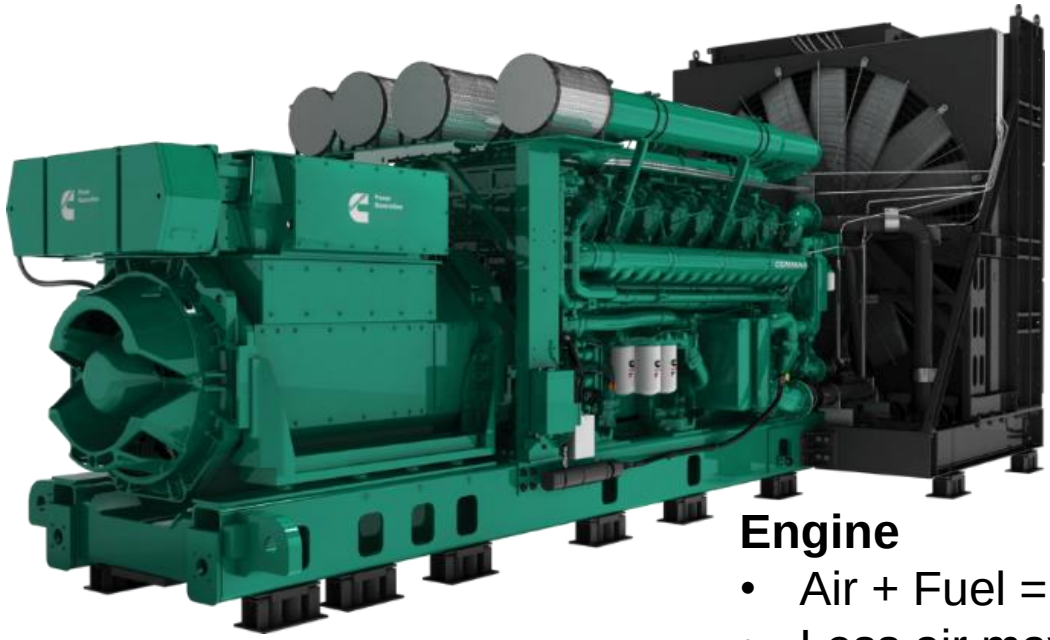

Cooling System
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Engine
- Air + Fuel = Power
- Less air may result in decreased power

Spec Note

Environmental Conditions: Engine-generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:
Ambient Temperature: X °C (Y ° F)
Altitude: X feet (Y m).

Concept Check

Your customer wants your quick gut-check to the size of generator needed for about 350 kWe of loads for their standby application. What size generator set would you suggest as a starting point? (assume “standard” ambient temperature and low altitude)

A) 300 kWe

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Concept Check

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A) 300 kWe

B) 400 kWe

C) 500 kWe

Notwithstanding any other information, this would be my first answer.

D) 600 kWe or greater

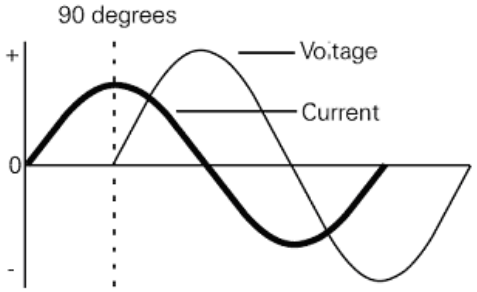
E) I would not dare offer a number at this point!

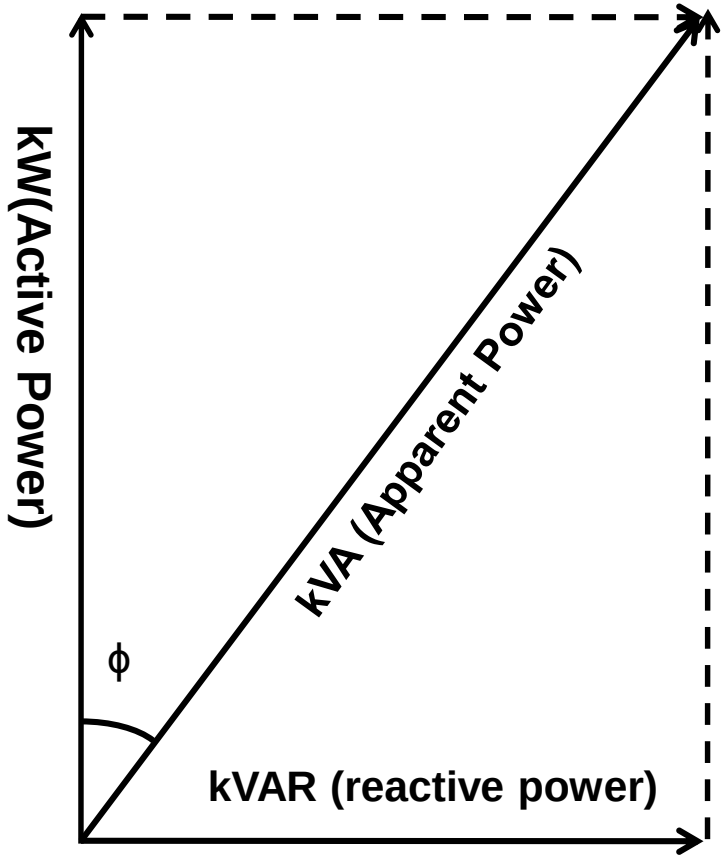
Understanding Individual Loads

Importance of Power Factor

Capacitive Loads

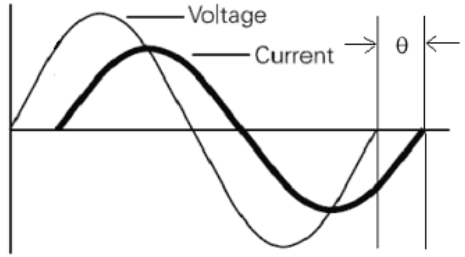
- Charge/release energy
- Current leads voltage
- E.g. Power factor correction (Capacitor) banks





Inductive Loads

- Resists change to current
- Current lags voltage
- E.g. Motors



Understanding Individual Loads

Importance of Power Factor

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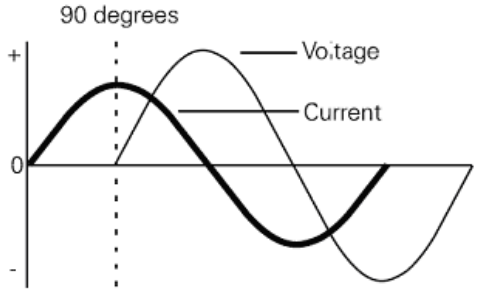

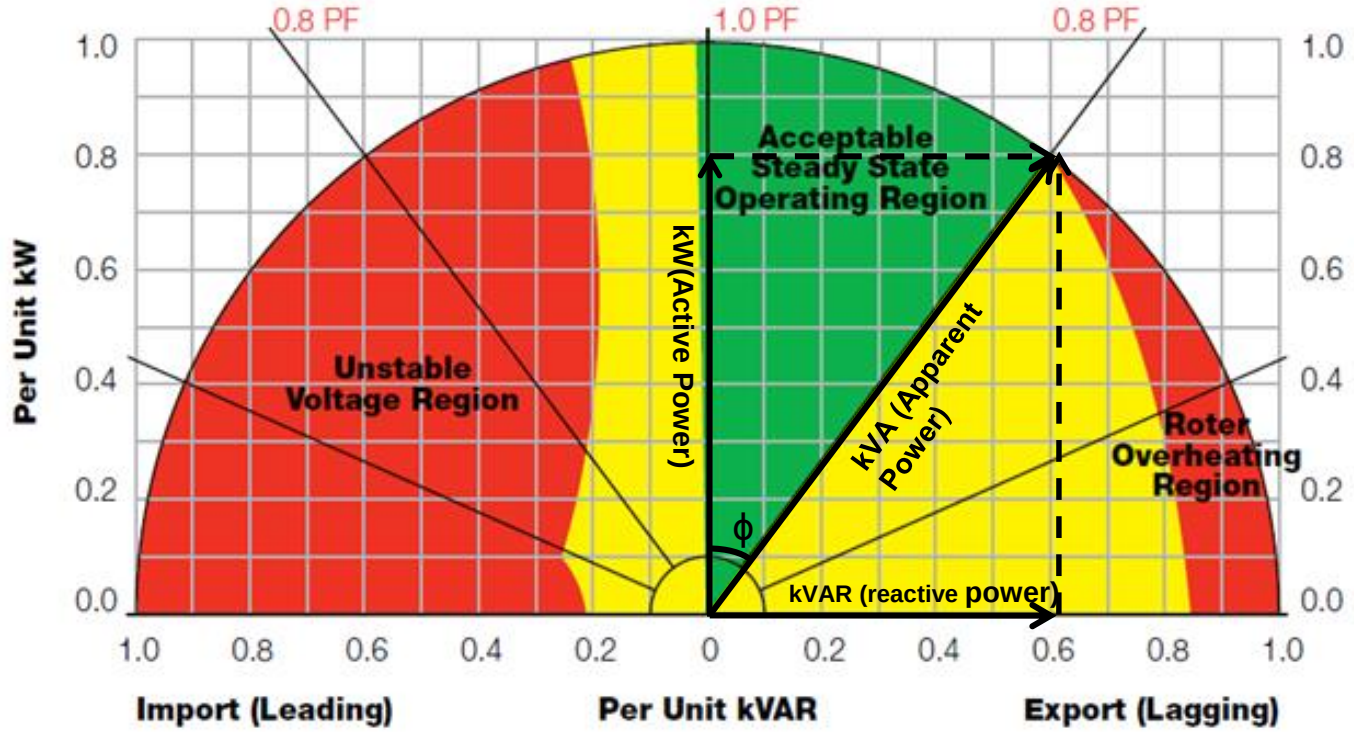

Inductive Loads

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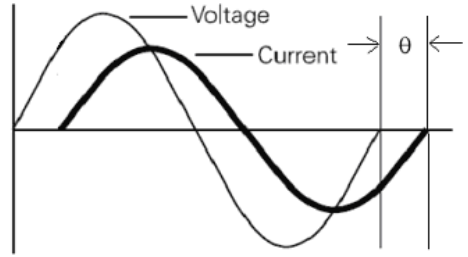


Recommendation: If your loads are operating at low-leading or lagging power factors, request a capability curve to ensure your alternator is operating within its safe limits.

Understanding Individual Loads

Walkthrough of a Transient Response

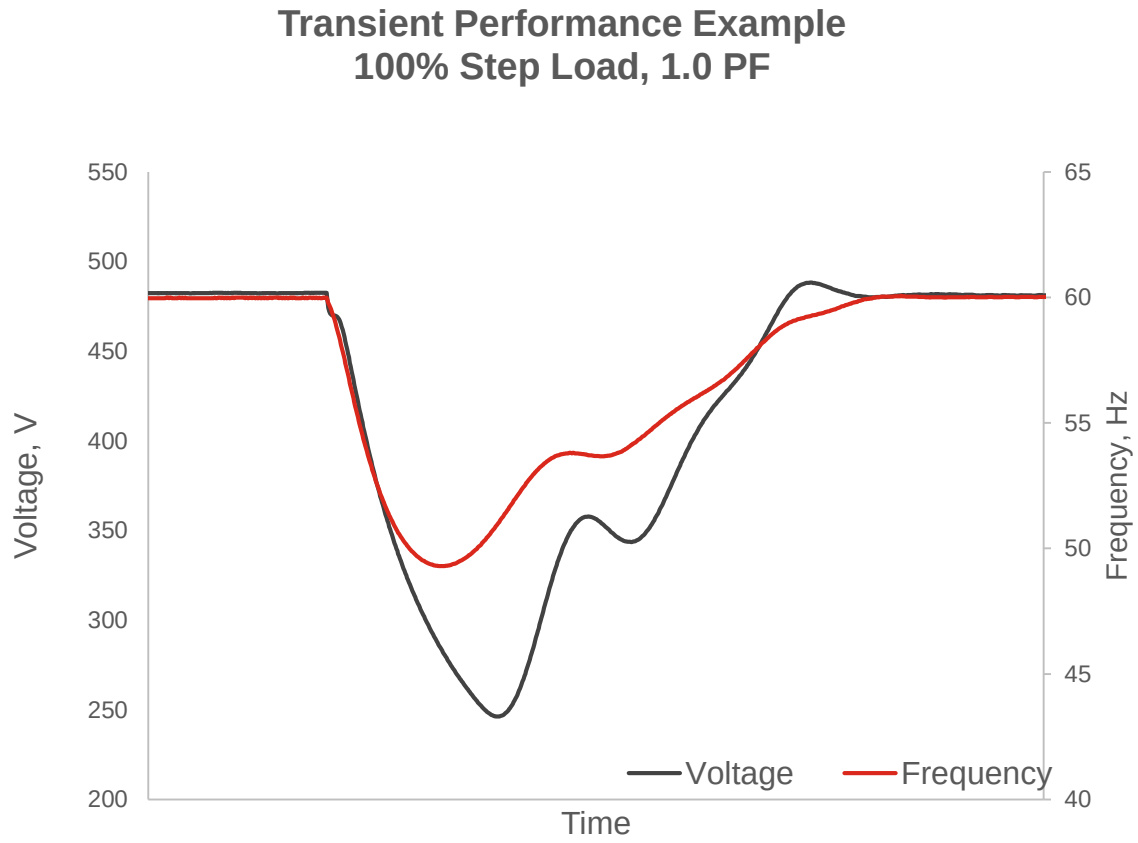
Alternator must support **kVAR**

Can be evidenced by voltage response

Engine must support **kW**

Can be evidence by frequency (i.e. engine speed)

Dynamic response is a combination of frequency and voltage

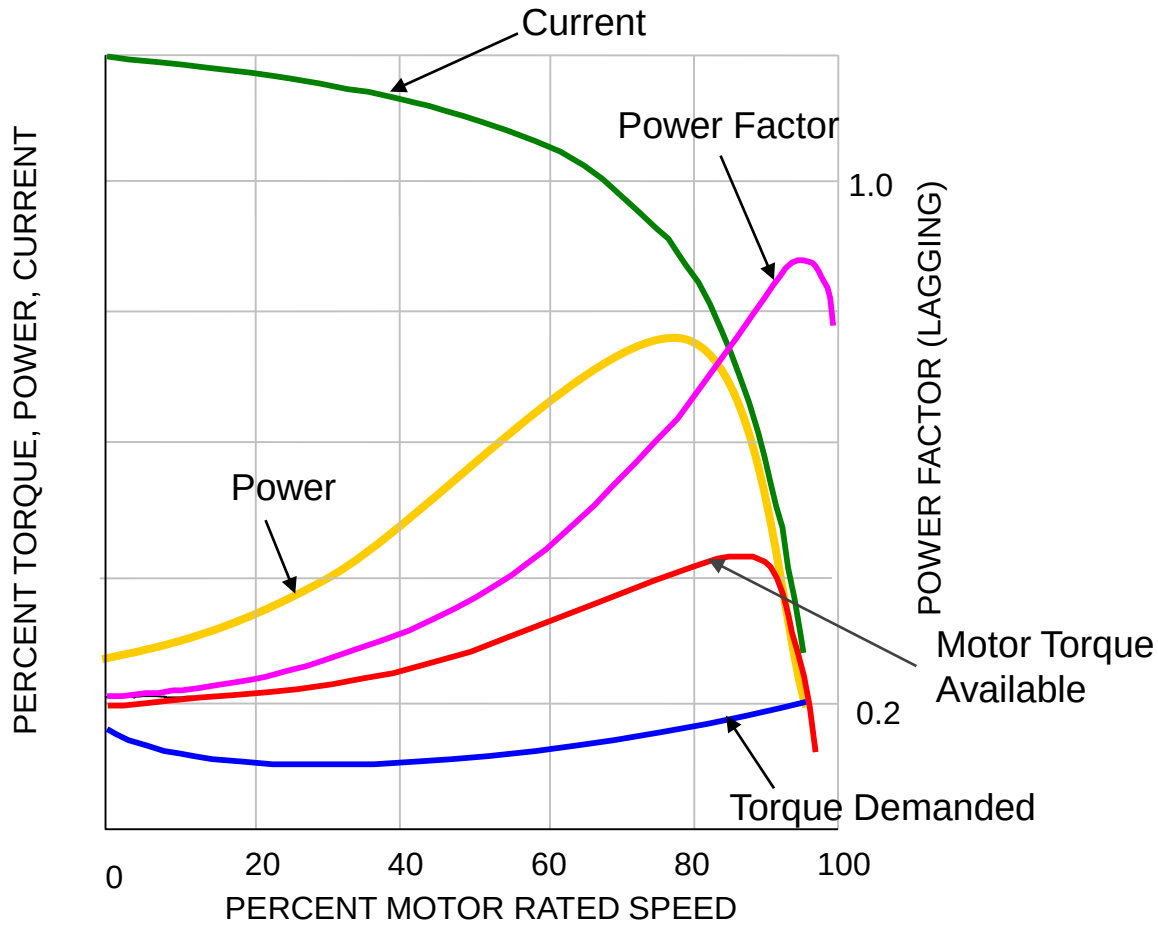


Understanding Individual Loads

Example of Un-Aided Motor Load Response

Initial Motor Starting

- High current
- Low Power Factor
- High VAR
- Ensure Motor Torque > Load Torque



Understanding Individual Loads

Specify Motor Starting Performance for the Alternator

Specify Maximum Allowable Voltage Dip to Meet Your Load Profile's Needs

Spec Note

The alternator shall accept the largest load step with a maximum voltage dip of XX percent based on the transient reactance of the alternator proposed. Provide documentation (with calculations if necessary) demonstrating compliance to this requirement.

Specify Motor Starting kVA Recovery to a Known Industry Standard

Spec Note

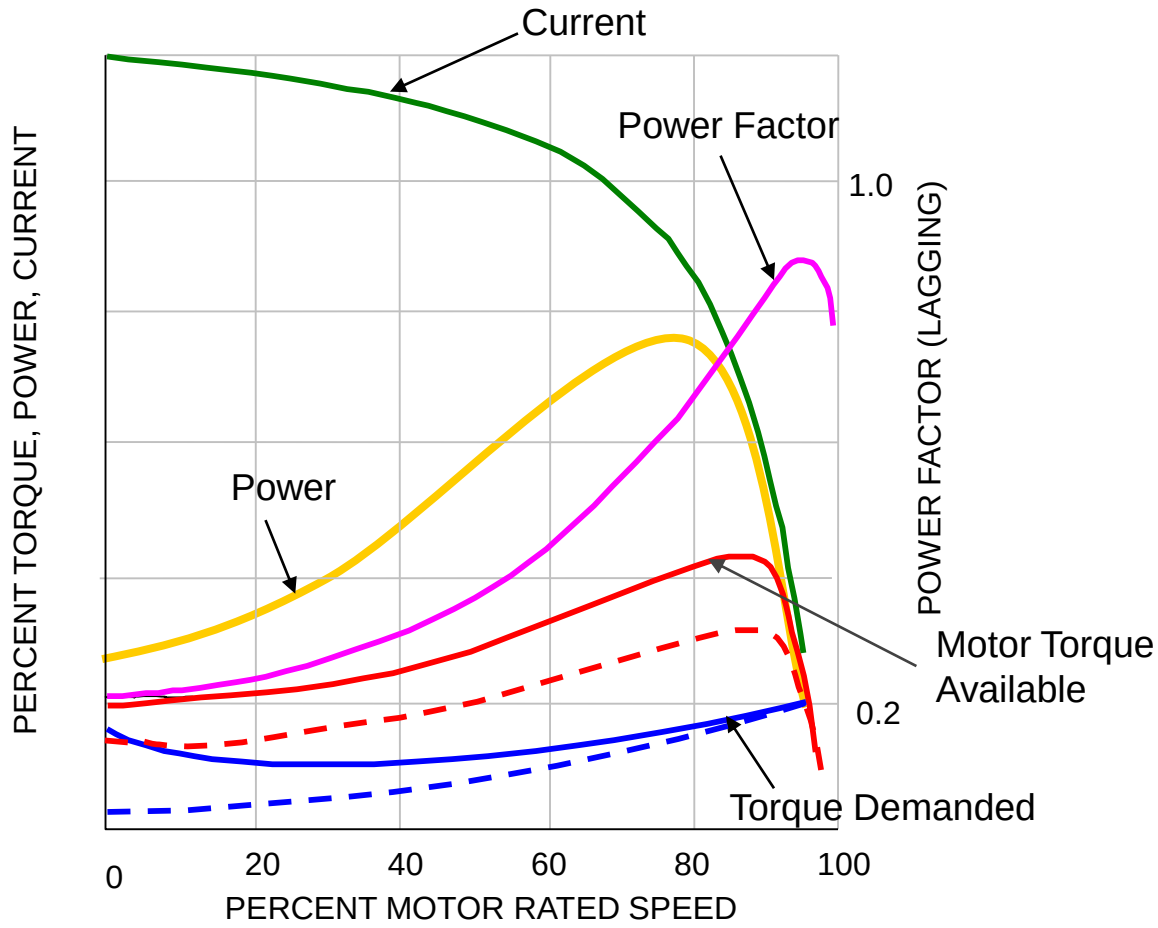
Alternator provided shall provide recovery voltage kVA of XX kVA per the requirements of NEMA MG1, Part 32, section 18.2.2. "Motor starting kVA" based on any other practice is not acceptable and will result in rejection of the proposed alternator. Provide published documentation of performance or a test procedure, compliant to the requirements of NEMA MG1 part 32, for a factory test that will be performed documenting required performance.

Understanding Individual Loads

Example of Un-Aided Motor Load Response

Initial Motor Starting

- High current
- Low Power Factor
- High VAR
- Ensure Motor Torque > Load Torque



Motor Torque @ reduced voltage

Torque demanded of low inertial motor load

Recommendation: Validate performance against motor loads with Generator Set Sizing Software for a complete picture of capability and response.

Understanding Individual Loads

Specify Motor Starting Performance for the Generator Set

Specify Confidence in the Complete Generator Set System, Not Just the Alternator:

Spec Note
The generator set shall be capable of accepting a block load equal to the specified kW at 0.8 power factor at rated site conditions and recover to rated voltage and frequency.

Recommendation: Validate performance against motor loads with Generator Set Sizing Software for a complete picture of capability and response.

Related Content

More on Transients and Motor Sizing

Specifying & Validating Motor Starting Capability White Paper
Understanding Cummins Power Generation's Suggested Specifications for Motor Starting White Paper
How to Size a Genset: Proper Generator Set Sizing Requires Analysis of Parameters and Loads White Paper

Concept Check

Which would you rather see in a specification?

“The alternator shall accept the **<insert here>** with a maximum voltage dip of XX percent based on the transient reactance of the alternator proposed.”

A) full generator set nameplate

B) full alternator nameplate

C) the largest load step for this design

D) the average overall loads for this design

E) whatever I specify

Concept Check

Which would you rather see in a specification?

“The alternator shall accept the **<insert here>** with a maximum voltage dip of XX percent based on the transient reactance of the alternator proposed.”

A) full generator set nameplate

B) full alternator nameplate

C) the largest load step for this design — The most practical answer

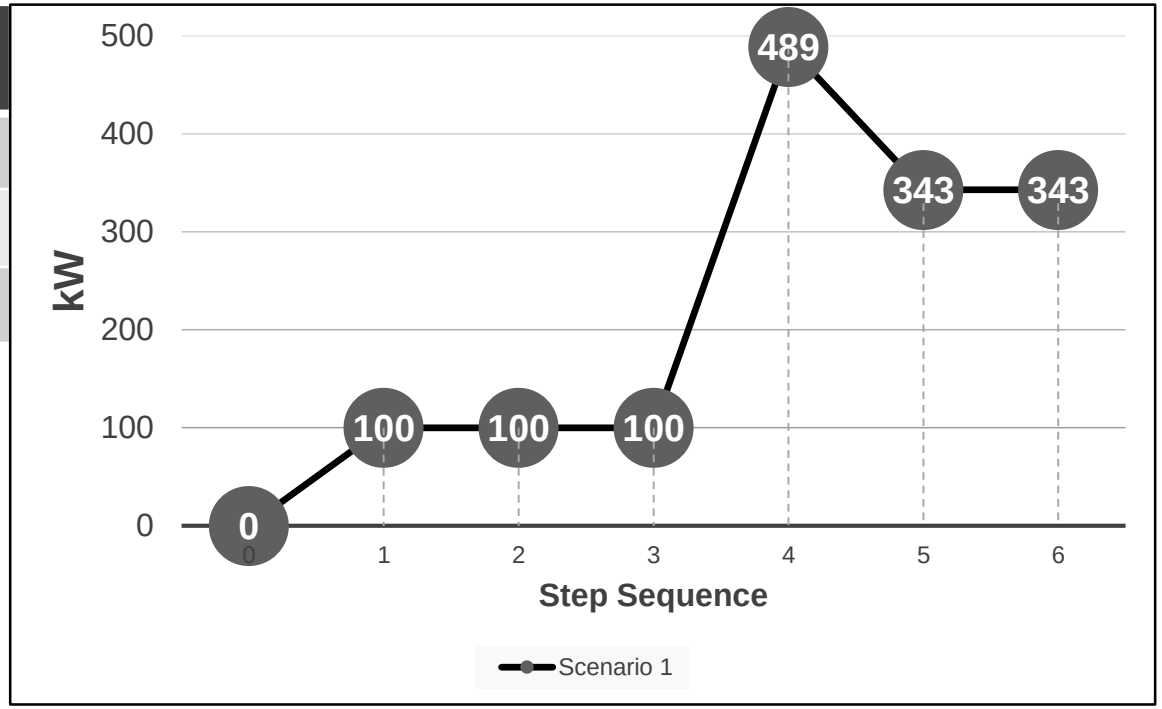
D) the average overall loading for this design

E) whatever I specify

Optimizing Load Profiles & Strategies

Motor Starting Sequencing and Cumulative Loads

Scenario 1	Load	Running kW	Starting kW	Cumulative Step kW
Step 1	Base Load	100	100	0 + 100 = 100
Step 2	300 HP Motor	243	389	100 + 389 = 489
		343		**489**



Optimizing Load Profiles & Strategies

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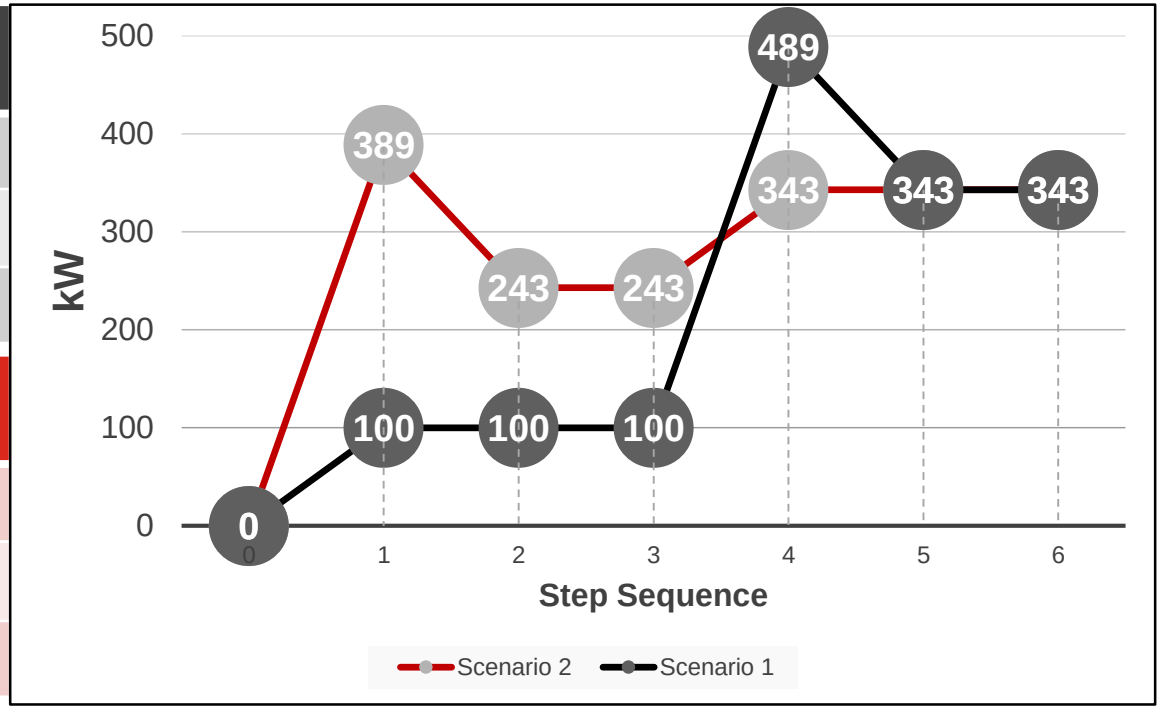
Step 1	Base Load	100	100	0 + 100 = 100
Step 2	300 HP Motor	243	389	100 + 389 = 489
		343		**489**

Scenario 2	Load	Running kW	Starting kW	Cumulative Step kW
Step 1	300 HP Motor	243	389	0 + 389 = 389
Step 2	Base Load	100	100	243 + 100 = 343
		343		**389**



Recommendation: The order of the loads can have a major impact on the recommendation from generator set sizing software. When appropriate, work to arrange challenging loads (such as large motors) to be as early as possible.

Optimizing Load Profiles & Strategies

NEC's Requirements Impact on Sizing

NFPA 70 – NEC Article:	Quick Definition	Examples	Capacity

Optimizing Load Profiles & Strategies

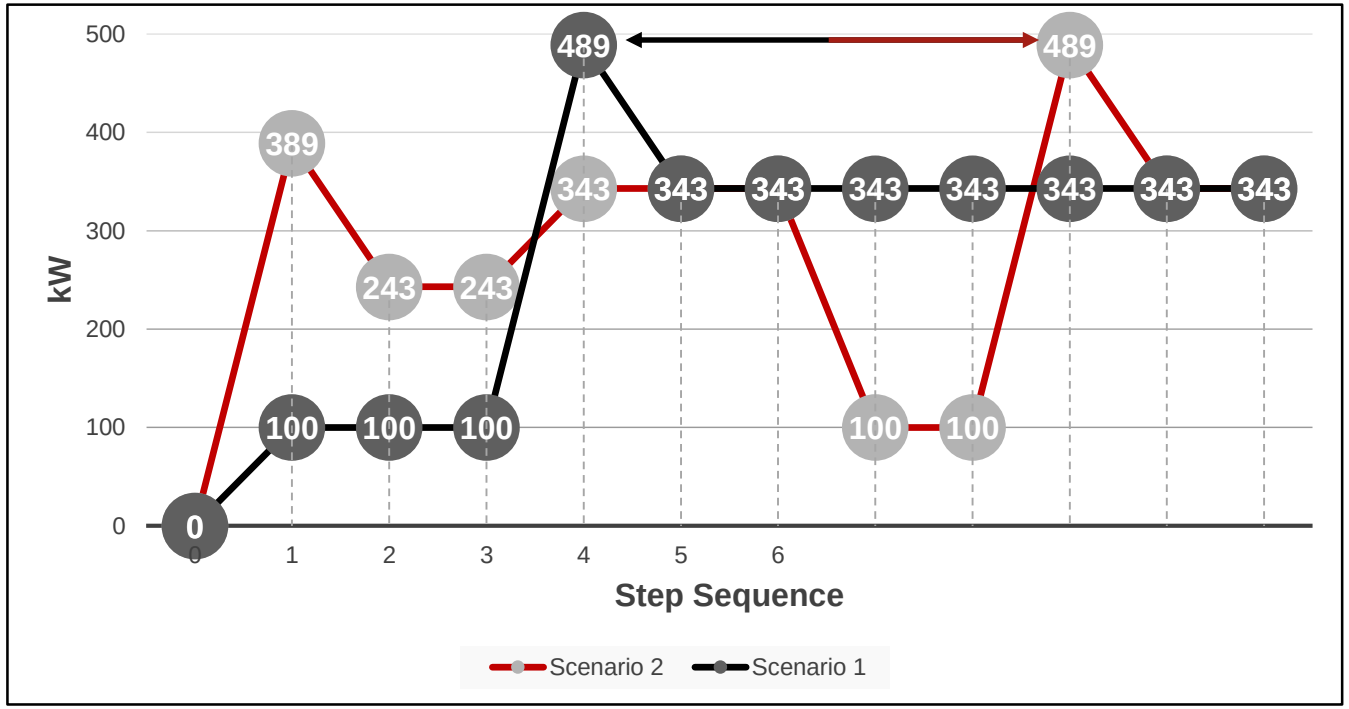
NEC's Requirements Impact on Sizing

NFPA 70 – NEC Article:	Quick Definition	Examples	Capacity
708 "COPs"	Facilities and loads essential to national security, public health, etc.	Police Stations, Fire Stations, Emergency Call Centers, etc.	Rated for all loads to be operated simultaneously
700 "Life Safety"	Loads used to directly protect life in blackout	Means of egress, emergency lighting, etc.	Rated for all loads to be operated simultaneously
701 "Legally Req'd"	Required, but not directly impactful to human life directly	Support of rescue workers	Adequate to supply all equipment intended to operated at one time
702 "Optional"	Customer needs, not legally required	Assets important to customer	To meet customer requirements

Optimizing Load Profiles & Strategies

Motor Starting Sequencing and Cumulative Loads

- Watchout! A cyclical motor should be assumed to start on top of the base load.
- Provide a complete load schedule, both confirmed and potential, in order to confirm performance at worst case scenarios.



Related Content

Generator Set Sizing with Fire Pumps
White Paper

Optimizing Load Profiles & Strategies

Quick Tips

Max. Allowable Project Voltage Dip:

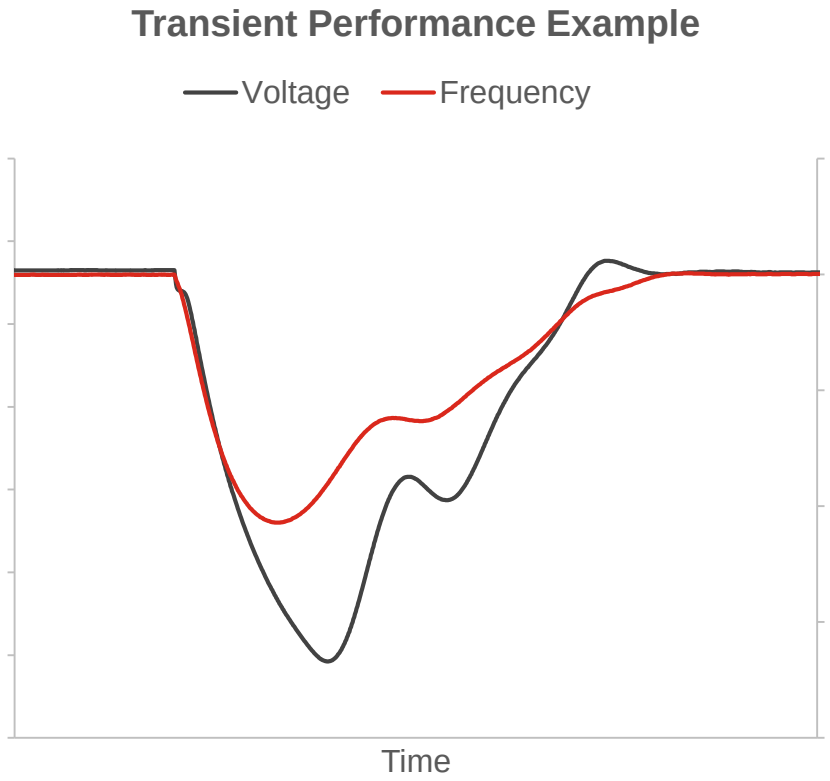
- 25-35% is a reasonable starting point
- 25% may be more appropriate for VFD powered loads.
- 15% for fire pump (GenSize will automatically default subsequent steps to a 15% voltage dip)

Max. Allowable Project Frequency Dip:

- 10-20% is a reasonable starting point

Fuel:

- Select “No Preference” as an option to allow results for for diesel, natural gas and propane to explore all options!



Optimizing Load Profiles & Strategies

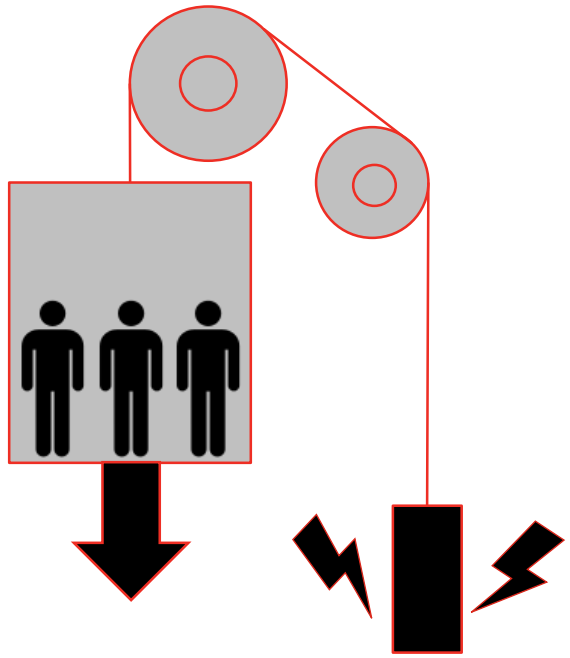
Quick Tips

Reverse Loading Watch-outs

- The generator set has very limited capability to absorb reverse kW ~ 10% engine rating max
- Consider load banks for accommodating these loads

No good results?

- Check high-level “Project Parameters” – Did you over-constrain yourself?



Electric Power Regenerated from Potential Energy

Related Content

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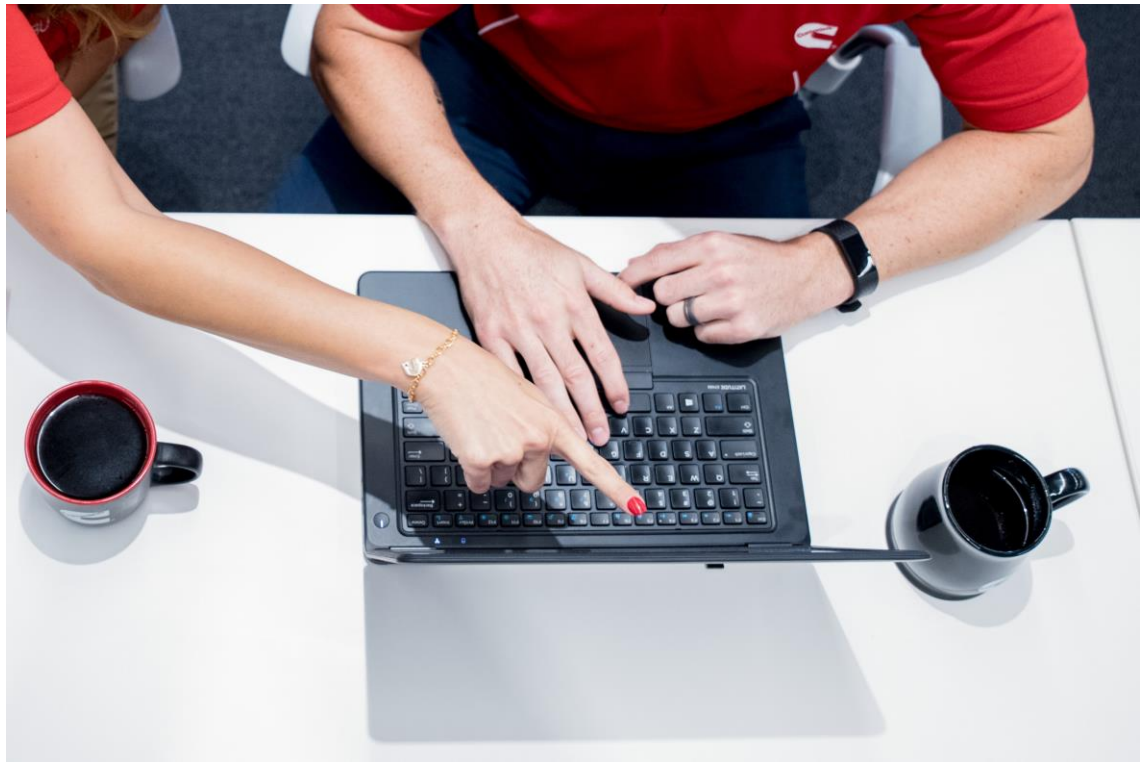


Course Summary

- Recognize the importance of key early decisions and where to get more information even before sizing for customer loads.
- Identify the impact of site conditions and overall loads on generator set performance.
- Describe how transient performance impacts generator set sizing: including load application techniques to optimize generator set performance while minimizing generator set size requirements for motor type applications
- Recognize the fundamentals at work behind generator set sizing software.

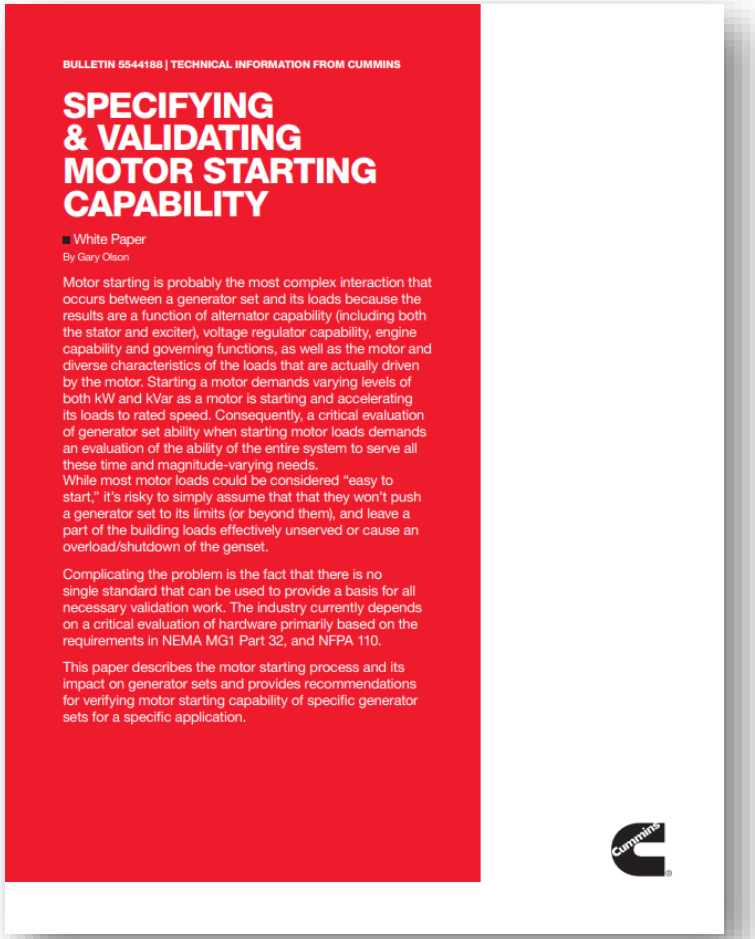
Additional Resources Recap

Cummins White Papers

- Specifying & Validating Motor Starting Capability
- Understanding Cummins Power Generation's Suggested Specifications for Motor Starting
- How to Size a Genset: Proper Generator Set Sizing Requires Analysis of Parameters and Loads
- Generator Set Sizing with Fire Pumps

Cummins PowerHour On-Demand Webinars

- Considerations for Specifying Generator Set Fuel Sources
- Sound Attenuation Strategies
- Emissions and Air Permitting
- Introduction to GenSize
- Advanced Sizing: Transient Performance and Motor Loads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SPECIFYING & VALIDATING MOTOR STARTING CAPABILITY

White Paper

By Gary Olson

Motor starting is probably the most complex interaction that occurs between a generator set and its loads because the results are a function of alternator capability (including both the stator and exciter), voltage regulator capability, engine capability and governing functions, as well as the motor and diverse characteristics of the loads that are actually driven by the motor. Starting a motor demands varying levels of both kW and kVar as a motor is starting and accelerating its loads to rated speed. Consequently, a critical evaluation of generator set ability when starting motor loads demands an evaluation of the ability of the entire system to serve all these time and magnitude-varying needs.
While most motor loads could be considered "easy to start," it's risky to simply assume that that they won't push a generator set to its limits (or beyond them), and leave a part of the building loads effectively unserved or cause an overload/shutdown of the genset.

Complicating the problem is the fact that there is no single standard that can be used to provide a basis for all necessary validation work. The industry currently depends on a critical evaluation of hardware primarily based on the requirements in NEMA MG1 Part 32, and NFPA 110.

This paper describes the motor starting process and its impact on generator sets and provides recommendations for verifying motor starting capability of specific generator sets for a specific application.

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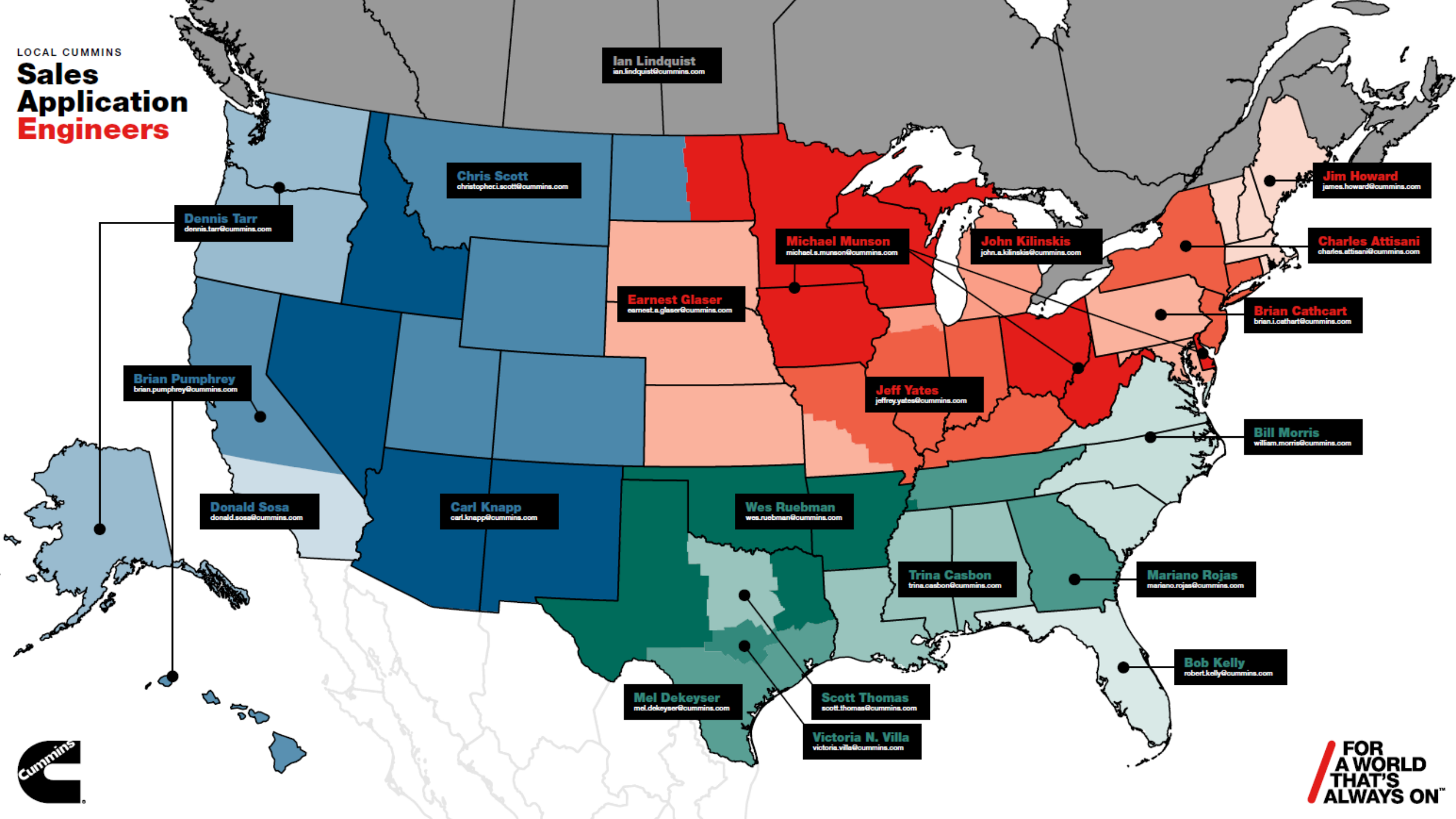

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