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ISO 8528-5 and *Generator Transient Performance*

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INTRODUCTION

Generator sets powering critical facilities like data centers and hospitals must deliver reliable, high-quality power with stable voltage and frequency, even under changing load conditions.

The ISO 8528-5 standard defines transient performance classes for generator sets and specifies frequency/voltage limits for different load steps. However, simply specifying an ISO 8528-5 class does not guarantee that a generator set will meet the actual needs of a critical application.

This paper explains key concepts related to generator set ratings, transient performance, and application considerations to optimally specify equipment for a given use.

GENERATOR RATINGS

Generator set ratings are generally defined in terms of maximum power available at a given load factor (ratio of average load to rated output), based on intended application per ISO 8528-1 [2].

STANDBY

The standby rating is applicable to variable loads with an average load factor of x% of the standby rating, with 100% of rating available for the duration of the outage. Refer to the manufacturer's Engine Specification data sheet for the Standby Rating Load Factor for each generator set model. Typical standby operating time is 200 hours per year or less, with certain models capable of up to 500 hours.

PRIME

The prime power rating is applicable for variable loads with an unlimited number of operating hours per year.

CONTINUOUS

The continuous power rating is defined as the maximum power the generator set is capable of supplying with a constant or non-varying load for an unlimited number of hours. No overload capability is available at this rating; therefore, use above the continuous rating is prohibited.

Ratings are based on a design constraint for durability, thermal, and wear life factors of key engine-generator components under various ambient and loading scenarios. User value is maximized by selecting optimal ratings for a given application. Generator performance is key for selecting ratings as it will affect the transient responses.

ISO 8528-5

ISO 8528-5 categorizes generator sets into four transient performance classes, G1 through G4, with G4 being a user specific category [1]. When comparing G1, G2 and G3 categories, G3 defines the most stringent requirements. Most industrial generator sets meet G3.

The standard defines allowable steady-state frequency/voltage deviations and transient response criteria for each class. Transient response is tested using different load steps for acceptance (per ISO 8528-5 BMEP method) vs rejection (100% load). This typical transient response is shown in `Figure 1`.

ISO 8528-5 CONT:

Key steady-state parameters include:

- Frequency droop (δf_{st}): No load to full load frequency regulation, more typical in older engines with mechanical governors.
- Steady-state frequency band (β_f): Allowable frequency variation.
- Voltage deviation (δU_{st}): Allowable voltage variation.
- Rated no-load frequency ($\delta f_{i,r}$): Frequency generator is designed to operate without load.
- Declared frequency (f_r): Frequency at which the generator is designed to operate.
- Maximum steady-state voltage ($U_{st,max}$): Maximum voltage under steady-state conditions.
- Minimum steady-state voltage ($U_{st,min}$): Minimum voltage under steady-state conditions.
- Rated voltage (U_r): Voltage of which generator is set to at rated frequency.

These are calculated as:

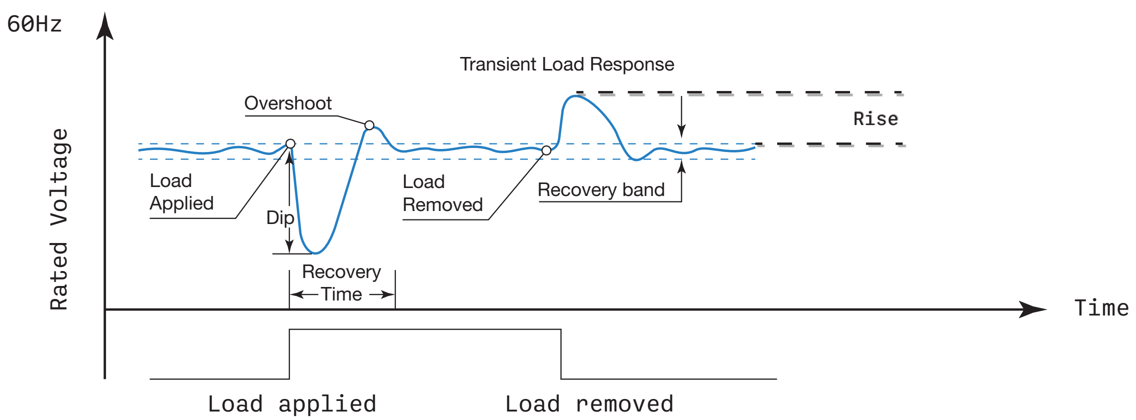
$$\delta f_{st} = (\delta f_{i.r} - f_r) / f_r \times 100$$

$$\beta_f = \Delta f / f_r \times 100$$

$$\delta U_{st} = \pm(U_{st,max} - U_{st,min}) / 2 \times U_f \times 100$$

Figure 1

Typical transient characteristics when applying or removing load on a generator set as per ISO 8528-5:2022 [1]



BMEP AND ITS ROLE

Brake Mean Effective Pressure (BMEP) indicates an engine’s ability to do work and the effectiveness of utilizing the injected fuel.

BMEP is defined per the equation below using the max engine power, crank revolutions, displacement, and speed. BMEP is used to define load step sizes for ISO 8528-5 transient testing. See Figure 2.

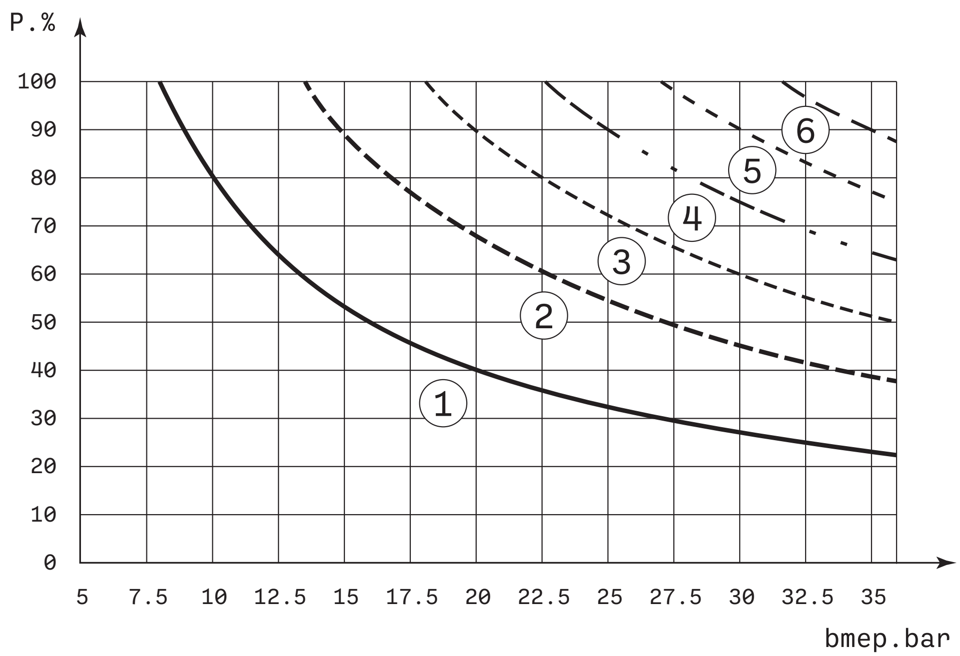
BMEP = (P x N_r x 1000) / (V_d x N)

Where:

P = Max power, N_r = crank revolutions, V_d = displacement, N = speed

Figure 2

Directly from ISO 8528-5:2022, labeled as Figure 6 on page 20



Key

bmep brake mean effective pressure of declared power in bar

P power increase refers to declared power at site conditions

1 first power stage

2 second power stage

3 third power stage

4 fourth power stage

5 fifth power stage

6 sixth power stage

Reference values for maximum possible sudden power increase as a function of brake mean effective pressure, bmep, at declared power (four-stroke engine)

TRANSIENT RESPONSE CONSIDERATIONS

Applying or removing a load impacts generator voltage and frequency. See `Figure 1` The magnitude and duration of the dip/rise, and recovery time depend on:

- Alternator size and motor starting (NEMA/IEC) method - oversizing helps limit voltage dips
- Voltage regulator response - ability to reduce excitation during over-frequency
- Engine-alternator inertia and speed governor response
- Turbocharger response and engine BMEP (ability to handle sudden load with minimal frequency dip)
- Application load types - high inrush current, low power factor loads require oversizing

The interplay of such electrical-mechanical factors makes it challenging to predict transient response for different load steps and configurations without detailed analysis or testing. ISO 8528-5 provides a simplified framework to specify and compare performance.

ISO 8528-5 CLASSES

Transient criteria include frequency, voltage limits, and recovery times as defined in `Figure 3` and shown in `Figure 1`. A few main points below:

Frequency low/high limit: ±7% / ±10% for diesel, ±15% / ±10% for gas (G3)

Voltage low/ high limit: -15% / +20% (G3)

Freq recovery: ≤3s, Voltage recovery: ≤4s (G3)

Important: Performance is evaluated using different load steps for acceptance vs rejection:

Load Acceptance: Increasing alternating load steps up to 100% based on number of “BMEP steps” see `Figure 2`. Higher BMEP engines take smaller steps.

Load Rejection: 100% rated load rejection in a single step. Must meet G3 criteria to be classed as G3.

ISO 8528-5 CLASSES CONT.

ISO 8528-5 defines transient classes G1 through G4, specifying progressively tighter limits for frequency/voltage deviation and recovery times for load acceptance and rejection. See `Figure 3.`

`Figure 3`

`Derived from Table 4 on pages 38-40 of ISO 8528-5:2022`

Table - Performance class operating limit values

Parameter		Symbol	Unit	Operating Limit Values – Performance Class G1	G2	G3	G4
Frequency droop		δf_{st}	%	≤-8	≤-5	≤-3[r]	AMC
Steady state frequency band		β_f	%	≤±2.5	≤±1.5	≤±0.5	AMC
Related range of downward frequency setting		$\delta f_{s.do}$	%	>(2.5+δf_{st})			AMC
Related range of upward frequency setting		$\delta f_{s.up}$	%	>+2.5			AMC
Rate of change of frequency setting		v_f	%/S	0.2 to 1			AMC
Transient frequency difference from initial frequency	100% Sudden power decrease P	δf_d	%	≤+18	≤+12	≤+10	AMC
	Sudden power increase			≤-(+ δf_{st})	≤-(10 + δf_{st})	≤-(7 + δf_{st})	
Transient frequency deviation from rated frequency	100% Sudden power decrease P	δf_{dya}	%	≤+18	≤+12	≤+10	AMC
	Sudden power increase [d,e,q]			≤-15	≤-10	≤-7	
				≤-25	≤-20	≤-15	
Frequency recovery time		$t_{f.in}$	S	≤+10	≤+5	≤+3	AMC
		$t_{f.de}$		≤+10	≤+5	≤+3	
Related frequency tolerance band		α_f	%	3.5	2	2	AMC
Steady state voltage deviation		δU_{st}	%	≤+5	≤+2.5	≤+1	AMC
				≤+10	≤+10		
Voltage unbalance			%	1	1	1	1
Related range of voltage setting		δU_s	%	≤±5			AMC
Related change of voltage setting		v_U	% s^{-1}	0.2 to 1			AMC
Transient voltage deviation	100% Sudden power decrease	δU^{+}_{dyn}	%	≤+35	≤+25	≤+20	AMC
	Sudden power increase	δU^{-}_{dyn}		≤-25	≤-20	≤-15	
Voltage recovery time[1]		$t_{U.in}$	s	≤+10	≤+6	≤+4	AMC
		$t_{U.de}$		≤+10	≤+6	≤+4	
Voltage modulation [kl]		$\hat{U}_{mod.s}$		AMC	0.3	0.3	AMC
Active power sharing [o]	Between 80% and 100% of the nominal rating	ΔP	%	--	≤+5	≤+5	AMC
	Between 20% and 80% of the nominal rating			--	≤+10	≤+10	AMC
Reactive power sharing	Between 20% and 100% of the nominal rating	ΔQ	%	--	≤+10	≤+10	AMC

MANUFACTURER LOAD ACCEPTANCE TESTING

ISO 8528-5 defines testing methods for evaluating generator transient response and voltage flicker. The standard specifies frequency and voltage deviation limits and recovery times for each class. See `Figure 3`. Manufacturers must test performance at each BMEP-based load step for load acceptance. It is common for manufacturers to run load step tests at 25%, 50%, 75%, and 100%. As a result, any step exceeding the `Figure 3` limits would prevent G3 classification.

While the ISO 8528-5 standard provides guidelines for assessing the transient performance of generator sets, it is crucial to understand the customer's actual requirements thoroughly. Customers often pose questions like "Is this genset capable of handling a 0-100% load step?" which, although conceptually flawed, reflect their underlying concerns. Such a drastic load step is an unrealistic scenario and does not align with the standard's approach of evaluating performance based on brake mean effective pressure (BMEP) and defined load acceptance steps.

The standard's focus is on ensuring that a generating set can withstand a specific load step without exceeding predetermined voltage, frequency deviations, and recovery time limits. Therefore, instead of entertaining hypothetical scenarios, it is essential to comprehend the customer's operational constraints and load profiles accurately. By doing so, the appropriate performance class can be determined, and the generating set's capabilities can be evaluated against the customer's actual requirements, ensuring a satisfactory solution.

APPLICATION AND SIZING

Given the impact of connected load types/sizes and step timing on generator set response, the following must be carefully evaluated:

- Maximum individual load steps and total load
- Load types and characteristics (inductive, capacitive, non-linear, regenerative, soft-start, etc.)
- Critical and non-critical loads, priority, and step sequence
- Maximum voltage/frequency dips acceptable for sensitive loads
- Site conditions (altitude, ambient temperature, fuel type etc.)

Gaseous engines respond slower than diesel due to fuel delivery differences. Excessive exhaust backpressure, intake restriction, or high temperatures can derate generator output. Fuel type (natural gas vs propane) affects rating. Accurately defining such criteria and performing proper transient analysis is crucial to selecting optimal generator set rating and configuration.

Practical considerations like alternator sizing and selective coordination of loads into prioritized steps can have a bigger impact on transient response than a higher ISO 8528-5 class.

For example, a G3 generator set with a large alternator powering gradually applied loads could perform better than a lightly loaded G2 generator set with an undersized alternator connected to large motors.

SUMMARY

While ISO 8528-5 provides a useful framework to specify generator set performance, a holistic application engineering approach - evaluating engine-alternator capabilities and ratings against detailed load types/profiles - is necessary to optimize equipment selection, ensure power quality and reliability.

REFERENCES

[1] ISO 8528-5:2022, Reciprocating internal combustion engine driven alternating current generator sets - Part 5: Generating sets.

[2] ISO 8528-1:2018, Reciprocating internal combustion engine driven alternating current generator sets - Part 1: Application, ratings and performance.

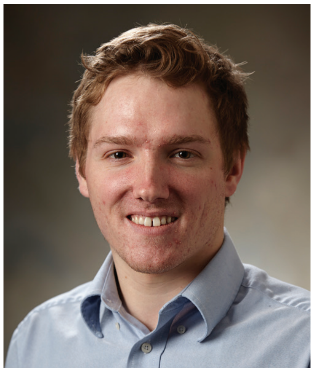
KOHLER ADVANTAGES

Kohler's Power Quality testing validates stringent application demands beyond just ISO requirements. Advanced modeling ensures Kohler generator sets are designed to handle real-world transient conditions.

KD Series engines are designed for high power density and BMEP, delivering exceptional transient performance and motor starting in a compact package. Turbocharging and combustion optimization enable the KD series to accept ISO G3 load steps with ease.

The APM603 controller/ voltage regulator provides class-leading alternator control with best-in-class transient response, advanced proportional integral derivative (PID) control, and 3-phase sensing to enable rapid response to load changes while maintaining G3 compliance.

Kohler has decades of experience engineering complete power systems for the most demanding critical facilities worldwide. Kohler generator sets, transfer switches, switchgear, and controls are designed and tested as an integrated system, ensuring optimal performance.



ABOUT THE AUTHOR

Brock Wudtke, with over 11 years of experience has demonstrated a diverse skill set and made significant contributions across engineering design, project management, and process improvement roles.

As a Project Design Engineer, he has excelled in leading the development of innovative products, such as diesel generators for data center applications. His expertise spans various engineering domains, including comprehensive product testing, computational analysis, CAD modeling, ERP, and PLM best practices and proficiency in industry codes and standards.

ABOUT KOHLER ENERGY

Kohler Energy, a global leader in energy resilience solutions, brings bold design and powerful impact to the energy systems that sustain people and communities everywhere around the world. The organization provides solutions across Home Energy, Industrial Power Systems, and Powertrain Technologies. Leveraging the strength of its portfolio of brands – Power Systems, Home Generators, Kohler Uninterruptible Power, Clarke Energy, Heila Technologies, Curtis Instruments, and Engines.

With more than a century of industry leadership, Kohler Energy builds resilience and goes beyond functional, individual recovery to create better lives and communities.

For more details, please visit kohler.com/energy.

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