WHITE PAPER

by Pedro Ponte, Project Applications Engineer

Transient Performance of Generating Sets

Providing a stable and undisturbed source of power is a critical aspect of power generation. The sensitivity of loads to the power quality is often of extreme importance and will play a major role on customer decision. While the Utility represents a virtually infinite source of power and the impact of site loads is practically negligible, the same is not applicable when the supply is made from a finite source of power such as a Diesel or Gas genset.

Understanding site loads and transient performance is essential when sizing and selecting generating sets. Considerations such as starting requirements or load stepping will perform a critical role on the generating set response.

On one hand the characteristics of customer loads, usually referred to as load profile, will have a determining impact on the required generating set size. On the other hand, the way those same loads are applied will have a direct result on the behaviour of the generating set and its capacity to provide a stable and responsive power supply.

Both aspects will undoubtedly impact the final result. Neglecting either one of them will often lead to oversized machines. Some extreme examples show sizing’s almost 4 times bigger than actually required. Or even more concerning, to equipment not meeting customer requirements.

An overview on ISO 8528-5 performance class vs. customer requirements for transient performance

ISO 8528, the standard for “Reciprocating internal combustion engine driven alternating current generating sets” and therefore applicable to both diesel and gas, defines amongst other things the transient performance classes and its acceptable limits.

While this standard offers a common ground and a reference when comparing different generating sets and at the same time an assurance that certain parameters are met, it does not necessarily ensure that the customer requirements are satisfied.

Specifications often determine the required transient performance and in many cases without actual consideration on the most critical factors. It should be noted that each load is different, therefore also is its impact on the power supply and its reaction to the quality of the power supply. The availability of simulation tools today makes it easier to study the role loads have on the overall system and on the generator set sizing performance. Taking into consideration both the supply and the demand side of an installation is the most effective way of achieving the best equipment sizing and optimum performance.

The next few pages provide an overview on the performance classes and transient behaviour parameters as defined in ISO 8528 while at the same time discusses its applicability to actual customer requirements.

1. Generator set behaviour under variable load

Applying or removing a load to a generating set has an impact on the quality of the power being delivered. The extent of this impact will depend on several factors but significantly on the size of the load in question.

Consider a generating set running in stabilized conditions with or without any loads changes. At this time, voltage and frequency are being provided at nominal conditions and only small variations will be seen. This variation under stabilized conditions is called steady state band and its acceptable limits are defined in the ISO 8528.

Let’s now imagine that a load is applied to the genset. At this moment there will be a sudden need to provide more current that will be drawn from the generator set. This will lead consequently to a drop both in the voltage and in frequency. Faced with this scenario the generating set, which is designed to work at constant speed and to provide power at a specific voltage, will respond, as quickly as possible, to normalize both voltage and frequency back to rated values.

A similar behaviour will be observed if we remove that same load from the genset. The difference being this time, instead of a drop, we will now see an increase in both rated voltage and frequency due to the removal of that same load.

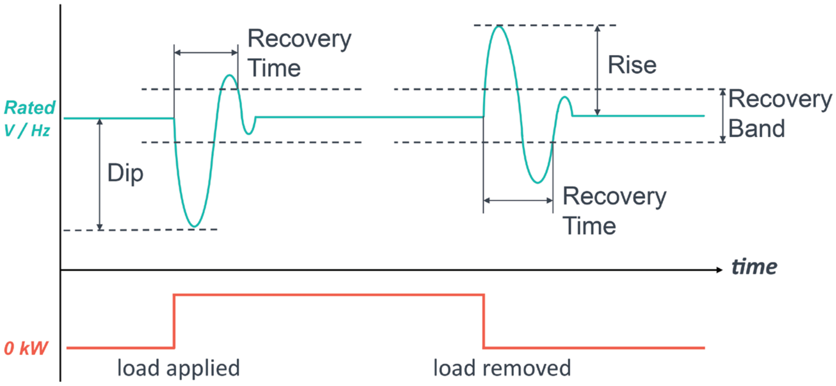


Figure 1. Typical transient characteristics when applying or removing loads on a generating set

During the period for all of this to happen, there are several parameters that can be monitored. Amongst those are the variation (in percentage from nominal and running values) in both voltage and frequency, usually known as dip or rise. And the time it takes (in seconds) for both the voltage and the frequency to recover within a specific recovery band. These parameters define what is usually called as load acceptance and load rejection. Figure 1 shows a representation of the behaviour described above.

2. ISO 8528

2.1 PERFORMANCE CLASSES

Performance classes are defined in part one of the ISO 8528:

- Class G1 applies to generating set applications where the connected loads are such that only basic parameters of voltage and frequency need to be specified (e.g. general-purpose applications, lighting and other simple electrical loads).
- Class G2 applies to generating set applications where its voltage characteristics are very similar to those for the commercial public utility electrical power system with which it operates. When load changes occur, there may be temporary but acceptable deviations of voltage and frequency (e.g. Lighting systems, pumps, fans and hoists).
- Class G3 applies to applications where the connected equipment makes severe demands on the stability and level of the frequency, voltage and waveform characteristics of the electrical power supplied by the generating set. e.g. Telecommunications and thyristor-controlled loads. It should be remembered that both rectifier and thyristor-controlled loads may need special consideration with respect to their effect on generator set voltage waveform.
- Class G4 applies to all the cases where the frequency, voltage or waveform characteristics of the electrical power supply are specifically adapted for the application. This performance is usually defined as an agreement between manufacturer and customer (AMC).

2.2 PERFORMANCE CLASS OPERATING LIMIT VALUES

The table below provides an overview on the transient operating limits as per the ISO 8528-5:2018.

Table 1. Performance class operating limit values as per ISO 8528-5:2018. See next page for additional details.

#	Parameter		Symbol	Unit	Operating limit values				Notes
					Performance class				
					G1	G2	G3	G4	
1	Frequency droop	Isochronous	δf_{st}	%	0	0	0	AMC	(1)
		Droop mode			(≤ -8)	(≤ -5)	(≤ -3)	AMC	
2	Steady-state frequency band		ß_f	%	≤ ± 2.5	≤ ± 1.5	≤ ± 0.5	AMC	
3	Related range of downward frequency setting		$\delta_{fs,do}$	%	> 2.5			AMC	(1)
					(> 10.5)	(> 7.5)	(> 5.5)	AMC	
4	Related range of upward freq. setting		$\delta_{fs,up}$	%	> + 2.5			AMC	
5	Rate of change of frequency setting		ν_f	%/s	0.2 to 1			AMC	
6	Transient frequency difference from initial frequency	100% load decrease	δf_d	%	≤ + 18	≤ + 12	≤ + 10	AMC	
		BMEP load increase			≤ - 15	≤ - 10	≤ - 7	AMC	(1)
					(≤ - 23)	(≤ - 15)	(≤ - 10)	AMC	
7	Transient frequency deviation from rated frequency	100% load decrease	δf_{dyn}	%	≤ + 18	≤ + 12	≤ + 10	AMC	
		BMEP load increase			≤ - 15	≤ - 10	≤ - 7	AMC	
					≤ - 25	≤ - 20	≤ - 15	AMC	(2)
8	Frequency recovery time		$t_{f,in}$	s	≤ + 10	≤ + 5	≤ + 3	AMC	
			$t_{f,de}$					AMC	
9	Related frequency recovery band		α_f	%	3.5	2	2	AMC	
10	Steady-state voltage deviation		δU_{st}	%	≤ ± 5	≤ ± 2.5	≤ ± 1	AMC	
					≤ ± 10	≤ ± 10	≤ ± 1	AMC	(3)
11	Voltage unbalance		$\delta U_{2,0}$	%	1	1	1	1	
					0.5	0.5	0.5	0.5	(4)
12	Related range of voltage setting		δU_s	%	≤ ± 5	≤ ± 5	≤ ± 5	AMC	
13	Rate of change of voltage setting		ν_U	%/s	0.2 to 1			AMC	
14	Transient voltage deviation	100% load decrease	δU_{dyn}	%	≤ + 35	≤ + 25	≤ + 10	AMC	
		BMEP load increase			≤ - 25	≤ - 20	≤ - 10	AMC	
15	Voltage recovery time		$t_{u,in}$	s	≤ + 10	≤ + 6	≤ + 4	AMC	
			$t_{u,de}$	s	≤ + 10	≤ + 4	≤ + 4	AMC	
16	Voltage modulation		$\hat{U}_{mod,s}$	%	AMC	0.3	0.3	AMC	
17	Active power sharing	between 80% and 100% of the nominal rating	ΔP	%	–	≤ + 5	≤ + 5	AMC	
		between 20% and 80% of the nominal rating			–	≤ + 10	≤ + 10	AMC	
18	Reactive power sharing	between 20% and 100% of the nominal rating	ΔQ	%	–	≤ + 10	≤ + 10	AMC	

(1) Values between brackets are applicable to droop mode only. For more information on this subject the reader's is advised to consult Cummins White Paper #5410679 – Considerations when Paralleling Generating Sets.

(2) For spark ignition engines

(3) G1 – For small units up to 10 kVA
G2 – Minimum requirements for generating sets with synchronous generators in parallel operation when reactive current characteristics shall be taken into consideration, the frequency swing range shall be less than or equal to 0.5%.

(4) For parallel operations

PARAMETER DEFINITIONS

1 Frequency droop, δf_{st} (%)
Frequency difference between rated no-load frequency and rated frequency expressed as a percentage of the rated frequency.

2 Steady-state frequency band, ß$_{f}$ (%)
Acceptable window of variation in rated frequency under stabilized conditions

3 Related range of downward frequency setting, $\delta_{fs,do}$ (%)
Lower range of frequency setting expressed as a percentage of the rated frequency. This is usually an adjustable parameter on the controller.

4 Related range of upward frequency setting, $\delta_{fs,up}$ (%)
Higher range of frequency setting expressed as a percentage of the rated frequency. This is usually an adjustable parameter on the controller.

5 Rate of change of frequency setting, ν_f (%/s)
Rate of change of the downward and upward frequency setting.

6 Transient frequency difference from initial frequency, δf_d (%) On load increase (-) or on load decrease (+)
Temporary frequency deviation from initial frequency during a sudden load increase or decrease related to initial frequency.

7 Transient frequency deviation from rated frequency, δf_{dyn} (%) On load increase (-) or on load decrease (+)
Temporary frequency deviation from initial frequency during a sudden load increase or decrease related to rated frequency.

8 Frequency recovery time, $t_{f,in}$, $t_{f,de}$ (s)
The time it takes for frequency, after a sudden load increase or decrease, from leaving the steady state frequency band until it stabilizes within the frequency recovery band.

9 Related frequency recovery band, α_f (%)
Tolerance frequency recovery band expressed as a percentage of the rated frequency. Should not be mistaken for the steady state frequency band.

10 Steady-state voltage deviation, δU_{st} (%)
Acceptable window of variation in rated voltage under stabilized conditions.

11 Voltage unbalance, $\delta U_{2,0}$ (%)
Unbalance between phases at no-load conditions.

12 Related range of voltage setting, δU_s (%)
Range of voltage setting expressed as a percentage of the rated voltage. This is usually an adjustable parameter on the controller.

13 Rate of change of voltage setting, ν_U (%/s)
Rate of change of voltage setting expressed as a percentage of the related range of voltage setting per second.

14 Transient voltage deviation, δU_{dyn} (%) On load increase (-) on load decrease (+)
Temporary voltage deviation from rated voltage during a sudden load increase or decrease.

15 Voltage recovery time, $t_{u,in}$, $t_{u,de}$ (s)
The time it takes for voltage to return and remain within its specified voltage tolerance band, after a sudden load increase or decrease.

16 Voltage modulation, $\hat{U}_{mod,s}$ (%)
Quasi-periodic voltage variation (peak-to-peak) about a steady-state voltage having typical frequencies below the fundamental generation frequency, expressed as a percentage of average peak voltage at rated frequency and constant speed. This is a cyclic or random disturbance which can be caused by regulators, cyclic irregularity or intermittent loads. Flickering lights are a special case of voltage modulation.

17 Active power sharing, ΔP (%) (parallel operation)
Deviation of shared active power (kW), expressed as a percentage between the proportion of power supplied by an individual genset and the proportion of the total active power supplied by all gensets.

18 Reactive power sharing, ΔQ (%) (parallel operation)
Deviation of shared reactive power (kVAr), expressed as a percentage between the proportion of reactive power supplied by an individual genset and the proportion of the total reactive power supplied by all gensets.

2.3 POWER STAGES FOR LOAD ACCEPTANCE AND LOAD REJECTION

Another important aspect when defining transient performance classes relies on the way the load stages are applied. The parameters defined previously are tested at specific conditions and the first thing to keep in mind is that the ISO defines load acceptance and load rejection differently:

- Load acceptance is based on BMEP step loading
- Load rejection always refers to 100% load removal in one step

With regards to load rejection, the above is self-explanatory. When ensuring if the operating limits defined by the ISO are met, this is based on a complete removal of 100% of the rated load. Some considerations on load rejection are discussed in part 3 of this paper.

However, for load acceptance the scenario is different. This based on a defined number of load steps that vary with the engine's break mean effective power, commonly known as BMEP.

The BMEP is a theoretical calculated value that represents the average pressure inside the engine cylinder and provides a useful way of comparing relative engine performance. Cummins Power Systems Generator set datasheets and engine performance datasheets will always provide the BMEP value at rated load. This value can however be calculated the following way:

$$BMEP\ [kPa] = \frac{P \times n_r \times 1000}{V_d \times N}$$

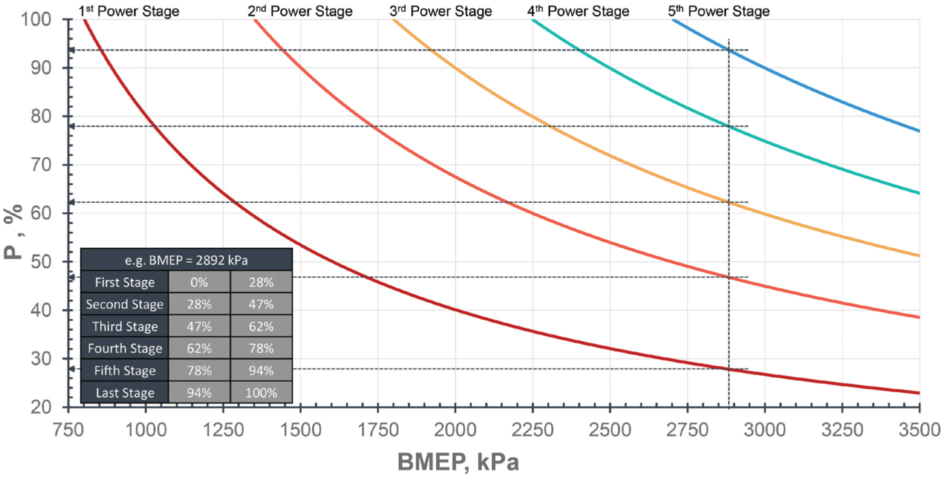
Where P is the mechanical Power (kW), nr the number of crank revolutions (2 for a 4-stroke), Vd the cylinder volume (dm3) and N the number of revolutions per second.

e.g. The BMEP of a four stroke QSZ13 G5 (13 L engine) with a gross power output of 470 kW at 1500 RPM (25 rev/s), the BMEP is:

$$BMEP\ [kPa] = \frac{470 \times 2 \times 1000}{13 \times 25} = 2892\ kPa$$

More could be discussed about BMEP that is out of the scope of this paper. For now we will stay with this definition and look on how it impacts the actual steps for load acceptance.

Figure 2 shows the reference values for the maximum sudden power increases as defined in ISO 8528-5:2018. A total of five power stages are represented in the standard which will lead to a maximum of six load steps for determining the transient performance classes.



e.g. BMEP = 2892 kPa		
First Stage	0%	28%
Second Stage	28%	47%
Third Stage	47%	62%
Fourth Stage	62%	78%
Fifth Stage	78%	94%
Last Stage	94%	100%

Figure 2. Reference values for maximum possible sudden power increases as a function of brake mean effective pressure (BMEP) at declared power (4-stroke engines)

Let's take as an example the above mentioned engine with a BMEP of 2892 kPa. From the graph we can identify the required load acceptance steps, for testing purposes, according to the ISO 8528-5:2018. Those same steps are represented on the table shown.

For the generating set from this example to meet either G1, G2 or G3 performance classes, every parameter must therefore be met on each load stage.

In most situations, if the performance class requirements are met for the largest load step, the other power stages are likely to meet the same performance class. Either way, all of the stages must be tested and recorded. Some considerations on load acceptance are discussed in part 3 of this paper.

The Figure 3 shows an example of a transient test performed on the field as per ISO 8528-5:2018 requirements. The graph shows the different load steps for an engine with a BMEP of 1951 kPa. It should be noted that transient parameters have been recorded directly from the controller. For the necessary accuracy in a transient test an adequate power quality analyser must be used.

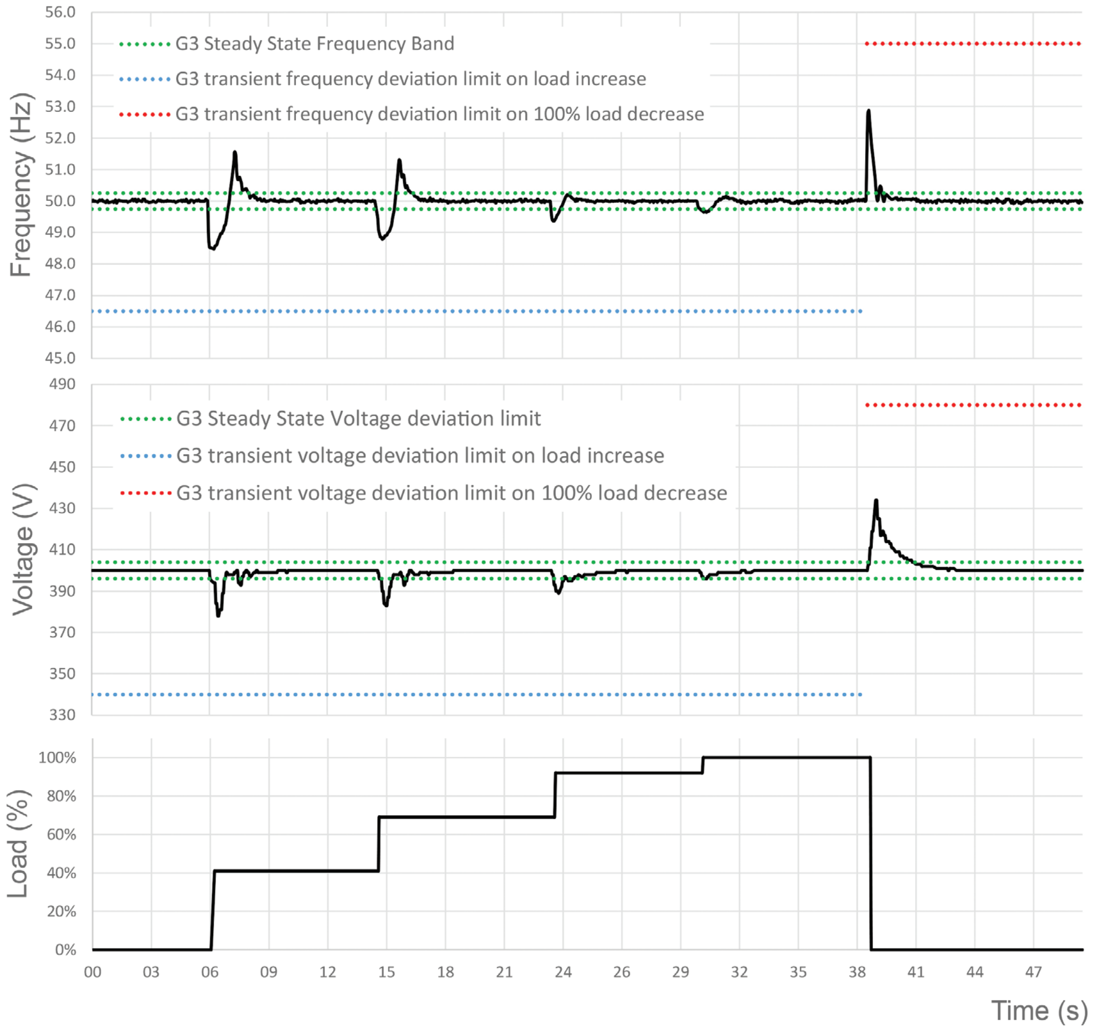


Figure 3. Extract of a transient test performed in the field on an engine with a BMEP of 1951 kPa using a purely resistive load bank (power factor = 1)

3. Beyond ISO 8528-5

3.1 UNDERSTANDING CUSTOMER REQUIREMENTS & DEFINING ACCEPTABLE TRANSIENT PERFORMANCE

ISO 8528-5 provides a reference for transient performance and is a useful way of comparing generating sets. It will also provide some sort of assurance that the equipment meets specific requirements. However, it does not ensure necessarily that the same will meet customer expectations.

As we have seen before there will be well defined load acceptance steps based on the BMEP that will be used to assess the generating performance class. Nevertheless questions are frequently asked such as: Is this genset G3 performance class with 60% load step? While questions like this are in concept incorrect, the content of the question itself is extremely valid and much more important.

The first thing to do is to fully understand what the actual requirements are. In most cases, like the example provided, customer is in fact looking for G3 operational limits on voltage and frequency dips for a specific load step. In this particular case it would be all about ensuring the specified generating set, when suddenly loaded at 60% of its rated power (or the site rated power), would not deviate more than 7% on frequency and 15% on voltage (in case of diesel) and should be able to recover to the respective recovery band within 3 and 4 second for frequency and voltage respectively.

The table below provides a resume, as referenced, on the typical customer requested/acceptable operating limit values for the most significant parameters as defined in chapter 16 of ISO 8528-5:2018.

Table 2. Typical customer operating limit values

Equivalent class		Steady state	Frequency droop	Load rejection	Load acceptance	Recovery band	Recovery time
G1	Hz	±2.5%	8%	18%	15% (25%)(1)	3.5%	10 s
	V	±5%	–	35%	25%	10.0%	10 s
G2	Hz	±1.5%	5%	12%	10% (20%)(1)	2.0%	5 s
	V	±2.5%	–	25%	20%	5.0%	6 s
G3	Hz	±0.5%	3%	10%	7% (15%)(1)	2.0%	3 s
	V	±1%	–	20%	15%	2.0%	4 s

(1) Specific frequency acceptable operating limits for gas generating sets in brackets.

Another typical example relates to full G3 performance class requirements. Whilst most modern generating sets will achieve G3 performance class, some however will not. This is due in most cases related to the load rejection. As referenced above, ISO requirements call for full load rejection, meaning a full rated load removal in a single step. Meeting G3 performance class for 100% load rejection is often quite challenging and not always possible to achieve.

In these scenarios some measures might be taken, such as oversizing the alternator which might improve the transient performance. Before deciding on this we should first answer a couple questions:

- How likely it is that all the loads will be removed at once and what is the impact of doing it? In the event of a power cut, retransfer will in many situations be made gradually back to the utility. In situations however where that is not the case, with open transition for example, then no impact of voltage or frequency deviation will be felt on the customer side.
- How likely is that the generator set sized for the site will be loaded to its full rating? While a specific generator set might not meet G3 requirements on full load rejection, it will typically be able to meet those limits with 90% load rejection or less. A properly sized generator set will always be oversized when compared to the loads to provide. Even on standby applications, which are often operated closer to the limit rating of the equipment, the load factor will typically be around 70% to 90% of its full rating.

Many specifications nowadays call for G3 performance class, especially in critical applications such as data centres and hospitals. Most commercial applications however will find G2 performance class requirements entirely acceptable. The table below shows typical voltage and frequency tolerances for some loads.

Table 3. Typical voltage and frequency tolerances
(Cummins T030 - Liquid Cooled Generator Set Application Manual)

Equipment	Voltage	Frequency	Comments
Induction Motors	±10%	±5%	Low voltage results in low torque and increased temperature. High voltage results in increased torque and starting amps.
Coils, Motor Starters	±10%	N/A	The holding force of a coil and its time constant of decay are proportional to the ampere-turns of the coil. Smaller coils may drop out within these tolerances for transient dip. A transient voltage dip of 30% to 40% for more than two cycles may cause coil dropout.
Incandescent Lighting	+10% -25%	N/A	Low voltage results in 65% light. High voltage results in 50% life. Low frequency may result in light flicker.
Fluorescent Lighting	±10%	N/A	High voltage results in overheating.
HID Lighting	+10% -25%	N/A	Low voltage results in extinguishment. High voltage results in overheating.
Static UPS	+10% -15%	±5%	No battery discharge down to -20% voltage. UPS are sensitive to a frequency change rate greater than 0.5 Hz/s. Oversizing of the generator set may be necessary to limit harmonic voltage distortion.
Variable Frequency Drives (VFD)	+10% -15%	±5%	VFD are sensitive to a frequency change rate greater than 1 Hz/s. Oversizing of the generator set may be necessary to limit harmonic voltage distortion.

These examples are laid out purely for discussion and there will certainly be many different perspectives. The first point to be made is that understanding customer requirements is essential when defining acceptable transient performance. Secondly, that meeting ISO 8528 performance class does not necessarily align with those same requirements.

3.2 IMPACT OF THE LOADS AND LOAD STEP SEQUENCING ON TRANSIENT PERFORMANCE

In a real-world application, the generator sets will not be under test conditions against a load bank but supplying power to a variety of onsite loads. These same loads will directly impact the equipment overall performance and power quality. The magnitude of impact depends greatly on answering a couple questions. One related to the nature of the loads and the other one to the method of applying them. Answering to these questions will not only allow to determine the equipment performance but also to correctly size the right generator set for each application.

What type of loads are being supplied and how many?

Understanding the loads being supplied by the generating set is of paramount importance. Whilst there are situations where the load properties are not known, efforts should be made to identify the properties of the load. Their nature (capacitive or inductive) and their starting and running characteristics, all play a major role in many aspects of generator set performance. From a transient behaviour perspective this can be narrowed down to two parameters, active power (kW) and reactive power (kVAr), and focused mostly during starting conditions.

The starting method of a specific load will probably have the biggest impact on transient performance. Motors, for example, are available with a variety of different starting such as Direct-on-line (DOL), Wye-Delta, Variable Frequency Drives (VFD), soft-starter and others.

A DOL motor for example, where the motor is started by connecting directly the supply and full line voltage applied, will typically have a very low power factor. This method will demand a high starting current, around 4.5 to 8.5 times the full load current (FLC), and the starting torque required will typically be within 1.2 to 3.5 times of its full load value (FL). Imagining a situation where we could change this, for example, to a Wye-Delta (Y-Δ) then the starting requirements would decrease significantly. The starting current demand would be reduced to perhaps around 2 times the full load current and its torque to within 0.8 to 1.5 times the full load value which could in turn lead to a better transient performance and potentially allow for a smaller equipment sizing.

There are other aspects, outside of the scope of this paper, that should also be considered. These include the feasibility of changing or choosing a load with a specific starting method and the cost associated with it. In the end the decision will be driven by a balance between all these parameters and the benefit of each solution. The table below lists some different starting methods and their characteristics.

Table 4. Comparison on different starting methods

Starting method	% Voltage @ motor terminals	Motor starting current as % of FLC	Motor starting torque as % of FL
Direct-on-Line	100%	450% – 850%	120% – 350%
Wye-Delta	100%	Approx. 200% Can spike to 400% on transition	80% – 150%
Autotransformer			
50% tap	50%	300%	45%
65% tap	65%	390%	76%
80% tap	80%	480%	115%
Solid state soft starter	0% – 100%	0% – 400%	Proportional to applied torque voltage
Variable frequency drive	0% – 100%	0% – 400%	Proportional to applied torque voltage

How are the loads being connected to the generator set?

The ideal scenario in any application would be to have all loads connected together. This would not only reduce downtime but also the cost of additional equipment (e.g. feeder circuit breakers). Doing this however, drastically impacts the size of equipment required, especially when stringent transient behaviour is necessary. Cases like these combined with incorrect sizing might even lead to voltage and frequency dropping to unsustainable levels and equipment shut down.

Within a list of loads for a specific site application typically not all of them have the same level of criticality. While some might be required to become online as quickly as possible on utility failure (e.g. fire pumps, medical equipment), others might be deprioritised during this stage (e.g. general-purpose appliances). At the same time any sensitivity of loads to variation in the power supply quality should be taken into consideration. Equipment such as Fire Pumps and MRI scanners for example, are usually restricted to low variations in frequency and voltage (typically less than 10% dip accepted). Operating outside of these requirements might lead to equipment malfunction.

One approach usually used, considering the above, is to assign the loads to the generator sets in different stages, often called Step loading. This will help to reduce the size of the equipment and at the same time will improve the quality of the power supply and its behaviour under varying load.

Assigning different steps can be achieved either by the use of automatic transfer switches (ATS) or by using feeder circuit breakers (switchgear) that allow the power to be gradually transferred into the generator set. Whilst adding breakers and controls into the system might seem initially an added cost into the project, it often offers more flexibility and is usually a much more cost-effectively solution than oversizing the generator set.

Example

The example described next represents a study performed on the same group of loads on one site. In this analysis, using Cummins online sizing tool Gensize™, the impact of step sequencing and starting methods, in the overall generator set sizing, can be observed. Customer requires for this particular application that the maximum frequency and voltage dips must not exceed 7% and 10% of the rated values respectively. For simplification only the initial and final step sequencing is shown in figure 4.

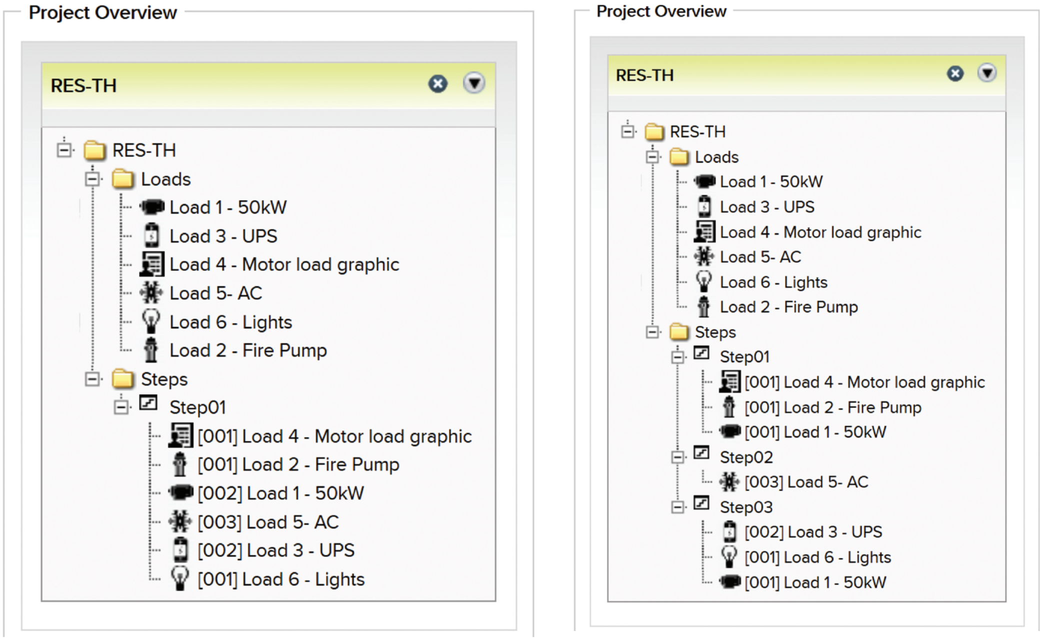
In the first scenario shown in Table 5, all the loads are connected to the Genset in one step as soon as this is ready to load. In the second, the starting methods of some loads have been modified to provide lower starting currents. Finally, the last column shows an optimized load distribution over 3 different steps.

As it would be expected in the first situation, with all the loads being connected at once, this would require an excessively oversized generating set. Results show that a 2000 kVA generator set would be required and in steady state conditions would be running only at 23.6% load factor. This result is mainly influenced due to the high starting requirements and the need to comply with the specified transient performance.

The second example, where all the loads were kept in one step and some starting methods have been changed (for example by using VFD's), resulted in sizing a 1000 kVA generator set with an average load factor of 47.2%. Whilst the load factor in this scenario is still relatively low there are situations when, for example, the criticality of the loads might require for all of these to come immediately on.

In the third sizing shown, the loads have now been optimized over 3 steps taking into consideration not only their size but also their criticality. At this stage no changes were made on the load starting methods. The results show that a 550 kVA generator set would be able to meet customer requirements just by reassigning the loads at different moments in time. This generator set would now be running at approximately a maximum 85.7% load factor in steady state conditions. The decision now would have to be made based upon the likelihood of all loads running together and either if it would be acceptable or not such load factor on the generator set.

Additional considerations could also have been made around the load starting methods for this last scenario. It is unlikely however that changing those would have led to a smaller generator set. Instead it would probably improve only the expected transient behaviour of the generating set.



Project Overview

RES-TH

- RES-TH
  - Loads
    - Load 1 - 50kW
    - Load 3 - UPS
    - Load 4 - Motor load graphic
    - Load 5- AC
    - Load 6 - Lights
    - Load 2 - Fire Pump
  - Steps
    - Step01
      - [001] Load 4 - Motor load graphic
      - [001] Load 2 - Fire Pump
      - [002] Load 1 - 50kW
      - [003] Load 5- AC
      - [002] Load 3 - UPS
      - [001] Load 6 - Lights

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      - [001] Load 1 - 50kW
    - Step02
      - [003] Load 5- AC
    - Step03
      - [002] Load 3 - UPS
      - [001] Load 6 - Lights
      - [001] Load 1 - 50kW

Figure 4. Gensize™ step sequencing. Left: all loads assigned in one step; Right: loads connected in 3 steps

PROJECT DETAILS SUMMARY

Table 5. Gensize™ simulation results

Number of load steps	**1 step**	**1 step**	**3 steps**
Comments	All loads at once	Different starting methods	Different load steps
Running kW	377.2	377.2	377.2
Running kVA	414.6	414.6	414.6
Running PF	0.9	0.9	0.9
Max. step kW	526.5	479.9	237.5 (Step 1)
Max. step kVA	1063.1	556.7	411.2 (Step 1)
Model (Gensize™)	2000 DQKAH	C1000 D5B	C550 D5e
Base kVA rating	2000	1000	550
Genset load factor	23.60%	47.20%	85.70%

4. Conclusions

Power quality is a crucial parameter in most installations. Poor quality can result in loads failing to energise or even in damage to them. ISO 8528-5 defines the performance behaviour requirements commonly accepted in the industry for generating sets. Referencing to this standard ensures, up to a certain extent, that minimum requirements of transient behaviour and proper equipment performance are met. At the same time, when comparing different products, it also offers a common language of reference. Specific load stages and respective acceptable limits are defined within this standard. As discussed in this paper load acceptance testing is based on calculated load stages, based on the engine BMEP, while load rejection always refers to full load removal. Despite this level of standardization, it is important nevertheless to balance the understanding of the ISO with actual onsite requirements.

Sizing a generator set that meets the site rated power requirements, involves choosing the smallest equipment that can meet both the load demand but also the transient performance requirements and supply a reliable and stable power. While a generator set with G3 performance class should be expected to perform better than when compared to another with G2 class, one should not assume that the same will automatically meet all onsite requirements. For this to happen a broader knowledge of the loads to be supplied and the expected mode of operation is recommended.

As discussed earlier, the nature of the loads and its starting requirements play an important part on equipment performance. Loads with low starting power factor, for example, will demand more starting current and might lead to oversized generator sets. Loads with rectifiers on the other hand will have an impact in the harmonic distortion in the power lines.

Connecting all loads simultaneously into a generator set, which might be necessary in some situations, will lead to an oversized equipment. Understanding the criticality of the loads and the method of applying them offers a chance for optimum sizing. Critical loads will be required to become online as soon as possible, other loads however might be deprioritised and connected in different stages. This is done through the use of transfer switches and breakers in which is often called step loading. Splitting into steps allows the generator set to gradually supply the necessary power with lower voltage and frequency dips, and consequently faster recovery times.

Finally, it should be noted that sizing a generator set that meets customer requirements involves more than just considering the transient performance. Other questions should be considered which will have an impact on the equipment choice: How many generator sets are required for the installation? Is there the need for redundancy? Should we make a provision for added loads in the future? Etc. Answering these and other questions will lead to optimum generator set sizing and ensure customer satisfaction.

References & recommended reading

ISO 8528-1:2018 – Reciprocating internal combustion engine driven alternating current generating sets —Part 1: Application, ratings and performance

ISO 8528-5:2018 – Reciprocating internal combustion engine driven alternating current generating sets — Part 5: Generating sets

Cummins White Paper #5410679 – Considerations when Paralleling Generating Sets

Cummins White Paper #7007 – How to size a genset: Proper generator set sizing requires analysis of parameters and loads

Cummins White Paper #6001 – High- or Medium-Speed Generator Sets: Which Is Right for Your Application?

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