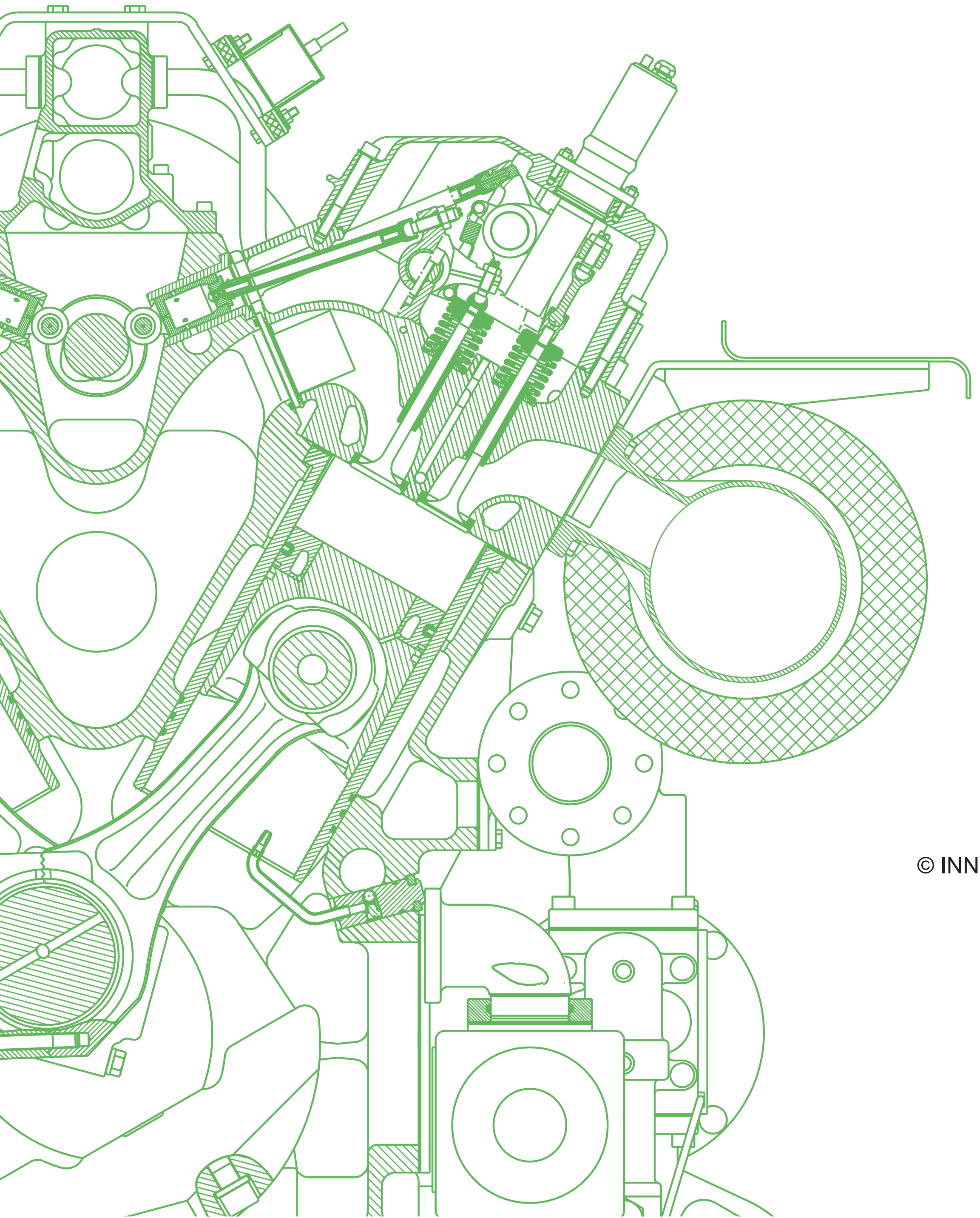
TA 2108-0031

Technical Instruction

Isolated operation - general



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1 Scope

This Technical Instruction (TA) applies to the following Jenbacher Gas Engines:

- Type 2 engines
- Type 3 engines
- Type 4 engines
- Type 6 engines

provided with the "Isolated operation" option.

2 Purpose

3 Additional information

Relevant standards and directives:

Unless otherwise indicated, this document refers to the most recent versions of the standards and guidelines referenced (e.g. ISO 8528-5). Previous versions mentioned in this document for clarification purposes are designated with the respective year of publication (e.g. ISO 8528-5:2018).

Relevant documents:

TA 1000-0001 – Fuel quality - diesel fuel

TA 1000-0300 – Fuel gas and combustion air requirements

TA 1503-0057 – Engine operation in isolated network with GEN2 controller

TA 1530-0182 – Generator power reduction and reactive power management

TA 2108-0025 – Isolated operation of spark-ignition gas engines with DIA.NE (engine type 3)

TA 2108-0026 – Isolated operation of spark-ignition gas engines with DIA.NE (Type 6 engines)

TA 2108-0029 – Isolated operation of spark ignition gas engines with DIA.NE (type 4 engines)

TA 2108-0030 – J208 in isolated operation with DIA.NE XT

TA 2108-0032 – J920 with DIA.NE XT in isolated operation

TA 2108-0033 – Isolated operation of high-speed diesel engines with DIA.NE (type 6 engines)

ISO 8528-2

ISO 8528-5

ISO 8528-12

DIN VDE 0100

4 Definition

4.1 General definition of isolated operation

Isolated/emergency power/standby operation is used when the plant is required to maintain the power supply to the consumers in the absence of the public power grid (see Figure 1). As soon as this occurs, the bus bar frequency and voltage must be maintained within defined limits.

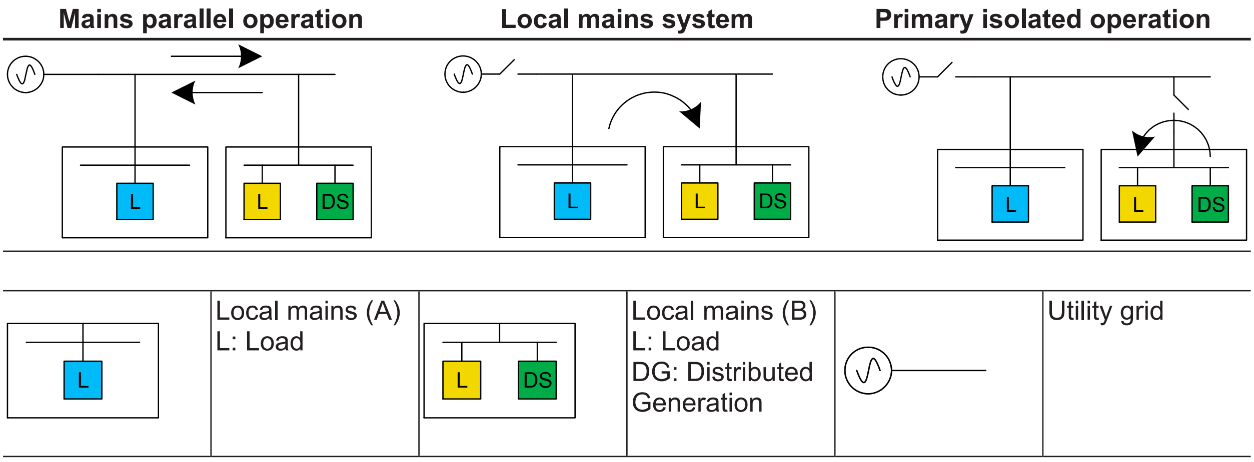

Figure 1: Mains configurations

If the consumers are powered by a generator driven by a reciprocating internal combustion engine (hereinafter referred to as a module), the frequency is controlled by the engine speed. Voltage is controlled by the automatic voltage regulator (AVR) integrated in the generator. For type 3 engines with TecJet gas metering and type 4 engines, a new model-based frequency control system will be available from June 2019. This control system is described in **TA 1503-0057**.

TA 1503-0057 – Engine operation in isolated network with GEN2 controller

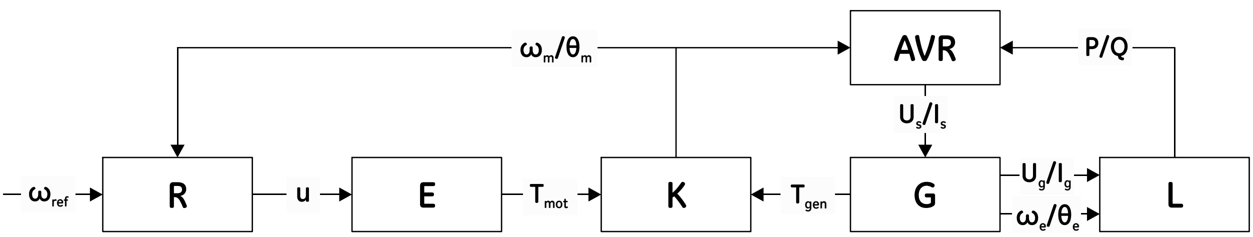

Figure 2: isolated operation

E	Jenbacher Engines	L	Load
K	Coupling	AVR	Automatic Voltage Regulator
R	Regulator	G	Generator
u	Controlled variable	U_s/I_s	Excitation voltage/current
ω_e/θ_e	Generator electrical speed/angle position	U_g/I_g	Generator voltage/current
ω_m/θ_m	Generator mechanical speed/angle position	T_{gen}	Generator torque
ω_{ref}	Speed set point	T_{mot}	Engine torque
P/Q	Active power/reactive power		

For systems that have several engines in a local mains system, the frequency and voltage are controlled by one or all modules. The active and reactive power must then be controlled by the load management system. A small proportion in terms of power can also be power-controlled exclusively in this local system. To this end, the dynamics of the power control must be sufficient for the respective engines so that very rapid setpoint adjustments can be reliably followed.

4.2 Relevant standards and directives

Unless otherwise indicated, this document refers to the most recent versions of the standards and guidelines referenced (e.g. ISO 8528-5). Previous versions mentioned in this document for clarification purposes are designated with the respective year of publication (e.g. ISO 8528-5:2018).

5 Categories of isolated operation

Mains emergency operation	Isolated operation of the engine is only required as a stand-by solution for the mains supply, and is not designed for continuous operation.
Primary operation (100% isolated)	Isolated operation of the engine is used as the primary energy source for the consumers. Additional modules or the mains can be available as stand-by energy sources.
emergency power supply mode	This is the same as stand-by operation, but with far higher demands on the start-up time (e.g. 15 seconds start-up time, black start) and maximum availability.
Feeding into local mains systems	The engine operates as part of a local mains system which is not connected to the public mains system. This operation presents particular requirements regarding short interruptions, loading and load shedding, and redundant operation (n-1).
Greenhouse applications[1)]	Very gentle power shifts due to relatively small loads combined with an extensive load management for power shifts, transition from mains to isolated operation. The engine is generally operated at 100% of its rated load, since suitable small load stages are available.
Emergency extinguishing systems[1)] **(sprinkler operation/ emergency fire operation)**	The engine is designed to supply fire pumps. Special requirements apply with regard to the time until the first load can be connected. The engine must have the maximum possible availability (even if suffering from faults) and must not be shut down without valid reasons during operation in support of firefighting operations.

[1)] If present

6 Factors influencing isolated operation

The dynamics of a module are affected by a large number of factors. The mechanical and electrical properties determine the starting and voltage behaviour in the event of sudden load changes. In order to state the frequency and voltage behaviour of a module under load changes, the maximum load application and load-shedding capability must be ascertained. Attention must be paid to the following, among other things:

- Coincidence factor of the consumers
- intermittent output in the course of operation

The required module rated power can only be laid down if the electrical consumers to be supplied are known. This entails above all taking note of the occurring load surges when consumers are switched on, e.g. lifts, pumps, fans, lighting and non-linear consumers. If the associated load profile is known, the following must be factored into the later design configuration:

6.1 Load application

The load consumption capability of the module depends not only on the engine type-specific setting of the speed controller, but also on the mean effective pressure (BMEP) at nominal frequency and rated output, the dynamics of the turbocharger, the dynamics of the gas metering and the characteristics and settings of the generator regulator (AVR). The mass moments of inertia of the engine and generator also have a large impact, whereby higher mass moments of inertia (particularly of generators) generally facilitate higher power shifts or result in smaller frequency deviations.

Since the function of all the influences cannot be quantified, recommended mean values for load application should be given, taking a maximum permissible frequency dip and a maximum voltage dip as criteria.

Due to the high mean effective pressure of Jenbacher Gas Engines, the load must be applied in limited stages (see ISO 8528-2). As the permissible times between the individual power stages relate to the aforementioned influencing factors, an appropriate time-based load profile may need to be coordinated with the system operator. If the load must be applied in a number of stages, the appropriate circuitry for this in the consumer equipment via a load management system must be taken into account. The permissible values for the dynamic frequency and voltage fluctuations at load changes can be taken as a criterion.

Depending on its size, the module takes a few seconds to a few minutes between load connections largely so that it can thermally stabilise. This must be taken into account, especially when engines that have not reached their operating temperature are started. The exact figures for diesel and gas engines are different.

In order to prevent overloads and the consequential failure of the module, it must be ensured that at the moment when the load is applied, the existing power requirements of the consumer equipment do not exceed the recommended power output for the particular generating set and engine type.

6.2 Load shedding

The response of a gas-driven module after load shedding also depends on the aforementioned influencing factors. On some gas engines with pressure-charging, a load-shedding limit is defined to minimise the risk of turbocharger surge or deflagrations.

The limits for load shedding are specified separately for each engine type (see the specific TA for each engine type). Further information can be found in Section ⇨ Load shedding.

7 Factors influencing locals mains systems (multi-engine plants)

The following can impact frequency and voltage behaviour in multiple-engine local mains system operation:

- Load distribution
- External or internal specification of a variable speed droop for the speed controller
- Dynamic behaviour of the individual engines as described above
- Droop setting of the voltage regulators (voltage droop and voltage knee)
- dynamic behaviour of the generator taking into account the damping characteristics of the mains system in question .

More detailed information about the factors influencing the distribution of active and reactive power in accordance with ISO 8528-5 can be found in **TA 1530-0182**.

TA 1530-0182 – Generator power reduction and reactive power management

Where different energy generators are being used in combination (modules from different manufacturers or different types of energy generators), other options in addition to a load distribution line or speed-drop control are provided by a higher-order load management system, but these options should be checked first for each specific project. Further information can be found in Section ⇨ Black start.

8 Assessment of isolated operation performance

The operational behaviour of a module powered by a reciprocating internal combustion engine is assessed in compliance with ISO 8528-5.

Depending on the specific application, a distinction is made between different design classes for isolated performance (G1 to G4) in accordance with ISO 8528-5. The numerical values referenced represent permissible limit values which ─ unless otherwise stated ─ may not be exceeded (see also table 1 below). These values refer to pressure-charged internal combustion engines as defined in ISO 8528-5.

The respective design class always applies to a power generation plant if all the limits laid down for this design class have been met. If customers request deviations from the limit values in terms of higher quality, these must be agreed in writing. For such special arrangements, class G4 is envisaged pursuant to 8528-5.

Class G4 is therefore freely definable in accordance with customer-specific requirements (CSR) and is specifically displayed for Jenbacher Gas Engines at ± 7 % for the dynamic frequency and voltage difference, disregarding the control stabilisation time, in the island diagrams of the various engine types. Other limit levels can be defined and displayed to take account of application-specific issues.

If an emergency power supply is provided for hospitals or communal facilities (in compliance with DIN VDE 0100, Part 710 and Part 718, respectively), operational behaviour is assessed in accordance with ISO 8528-12. In both cases, special attention must be paid to the required interruption/transition times. The assessment criteria laid down in ISO 8528-12 are equivalent to those laid down in ISO 8528-5.

Table 1: Excerpt of selected operating limits for the design classes in accordance with ISO 8528-5:2018. Table 4 in Section 15.2 of the standard is used for the overall analysis.

Parameter	Symbol	Unit	Limit values			
			G1	G2	G3	G4
Bandwidth of frequency deviation for evaluating stabilisation time after load jumps	α_f	%	3.5	2	2	CSR
Steady-state frequency bandwidth	β_f	%	≤±2.5	≤±1.5	≤±0.5	CSR
Transient frequency deviation after load application for:						
• Spark-ignition gas engines	δ^-_{dyn}	%	≤-25	≤-20	≤-15	CSR
• Diesel engines	δ^-_{dyn}	%	≤-15	≤-10	≤-7	CSR
Transient frequency deviation after load shedding	δ^+_{dyn}	%	≤+18	≤+12	≤+10	CSR
Frequency control settling time after load application	$t_{f,zu}$	s	≤10	≤5	≤3	CSR
Frequency control settling time after load shedding	$t_{f,ab}$	s	≤10	≤5	≤3	CSR

Parameter	Symbol	Unit	Limit values			
			G1	G2	G3	G4
Static voltage difference	δU_{st}	%	≤±5	≤±2.5	≤±1	CSR
Dynamic voltage deviation after load application	δU^{-}_{dyn}	%	≤-25	≤-20	≤-15	CSR
Dynamic voltage deviation after load shedding	δU^{+}_{dyn}	%	≤+35	≤+25	≤+20	CSR
Voltage control settling time after load application	$t_{U,zu}$	s	≤10	≤6	≤4	CSR
Voltage control settling time after load shedding	$t_{U,ab}$	s	≤10	≤6	≤4	CSR

9 Power shift diagrams for isolated operation

The power shift diagrams of the respective engine types are available in the following Technical Instructions:

- Type 2 - J208 spark-ignition gas engines with DIA.NE XT TA 2108-0030
- Type 3 spark-ignition gas engines with DIA.NE XT TA 2108-0025
- Type 4 spark-ignition gas engines with DIA.NE XT TA 2108-0029
- Type 6 spark-ignition gas engines with DIA.NE XT TA 2108-0026
- Type 9 spark-ignition gas engines with DIA.NE XT TA 2108-0032
- Type 6 diesel engines with DIA.NE XT TA 2108-0033

The diagrams listed above provide information on the permissible, switchable effective electrical power (*block load*, both positive and negative, plotted on the y axis) as a function of the current effective power (base load, plotted on the x axis) for each individual class as specified in ISO 8528-5.

The specified power outputs are shown as a percentage of the rated power (taking given reductions into account), rated frequency and cosφ = 1 of the engine version concerned, in accordance with the product range.

9.1 Power shift diagrams

The power shift diagrams in the Technical Instructions for each of the engine types apply to the engine at operating temperature.

These diagrams show design classes G1 to G4 and the limit outputs (see example diagrams for load acceptance capability in Figure 3 and load shedding capability in Figure 4). The limit output is the output that can still be applied in consideration of the limit values for minimum and maximum frequency and minimum and maximum voltage without the engine shutting off. The lines show the maximum load that can be applied or shed, which corresponds to the respective limit values for the design classes. Where special requirements have been specified for loads to be added or shed, additional technical concepts (choice of shedding stages, mains interconnection control, load management system) must be taken into account.

The series-specific Technical Instructions for isolated operation include the (2) diagrams for loading and load shedding with and without consideration of the stabilisation time for frequency and voltage. For diesel engines, the stabilisation time for the voltage is always taken into account. The second form takes the criterion of maximum frequency dip into account (see Appendix A). The x axis describes the starting load (base load) and the y axis the switching load (block load), each as a percentage [%] of the rated power.

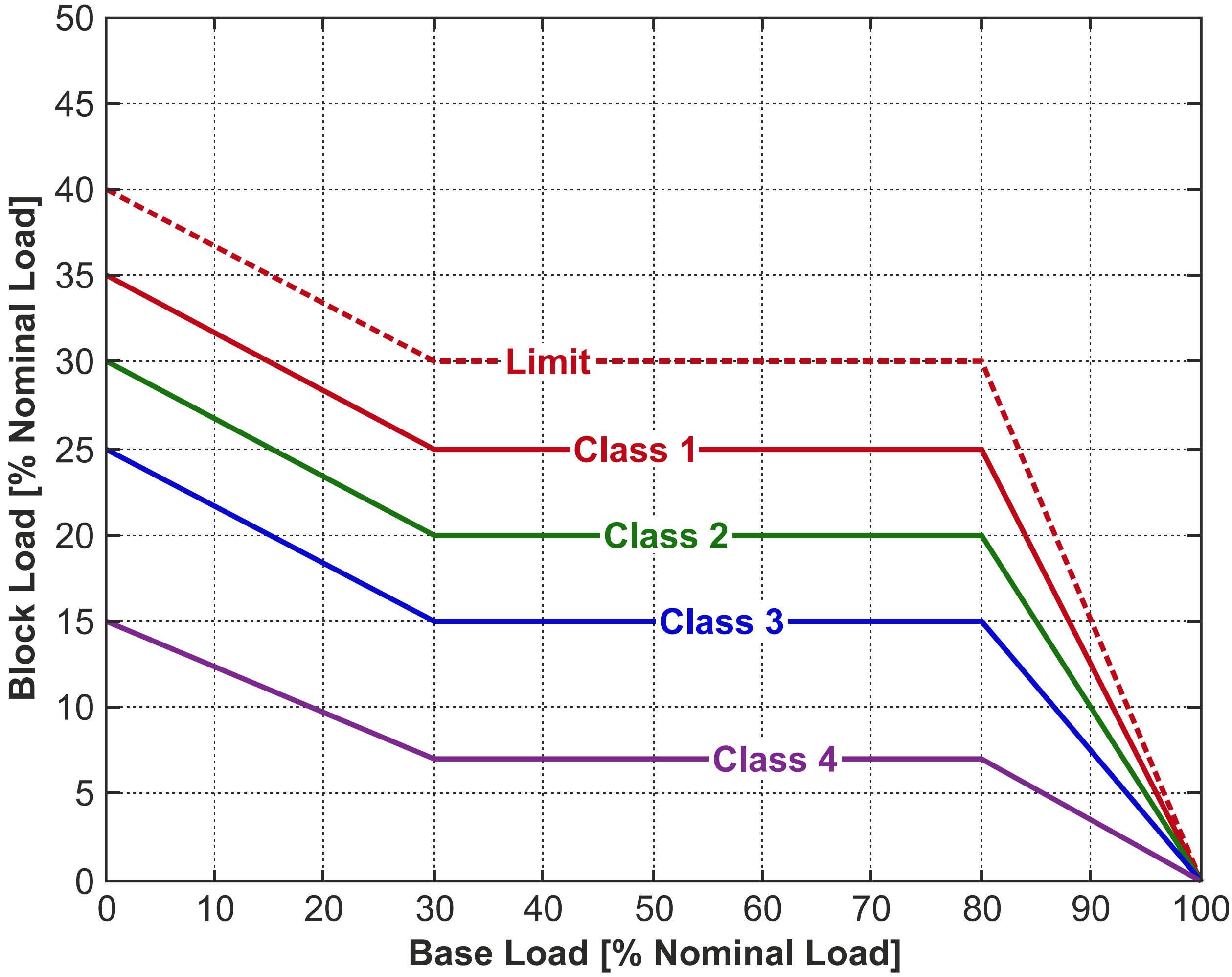

Figure 3. Load application diagram

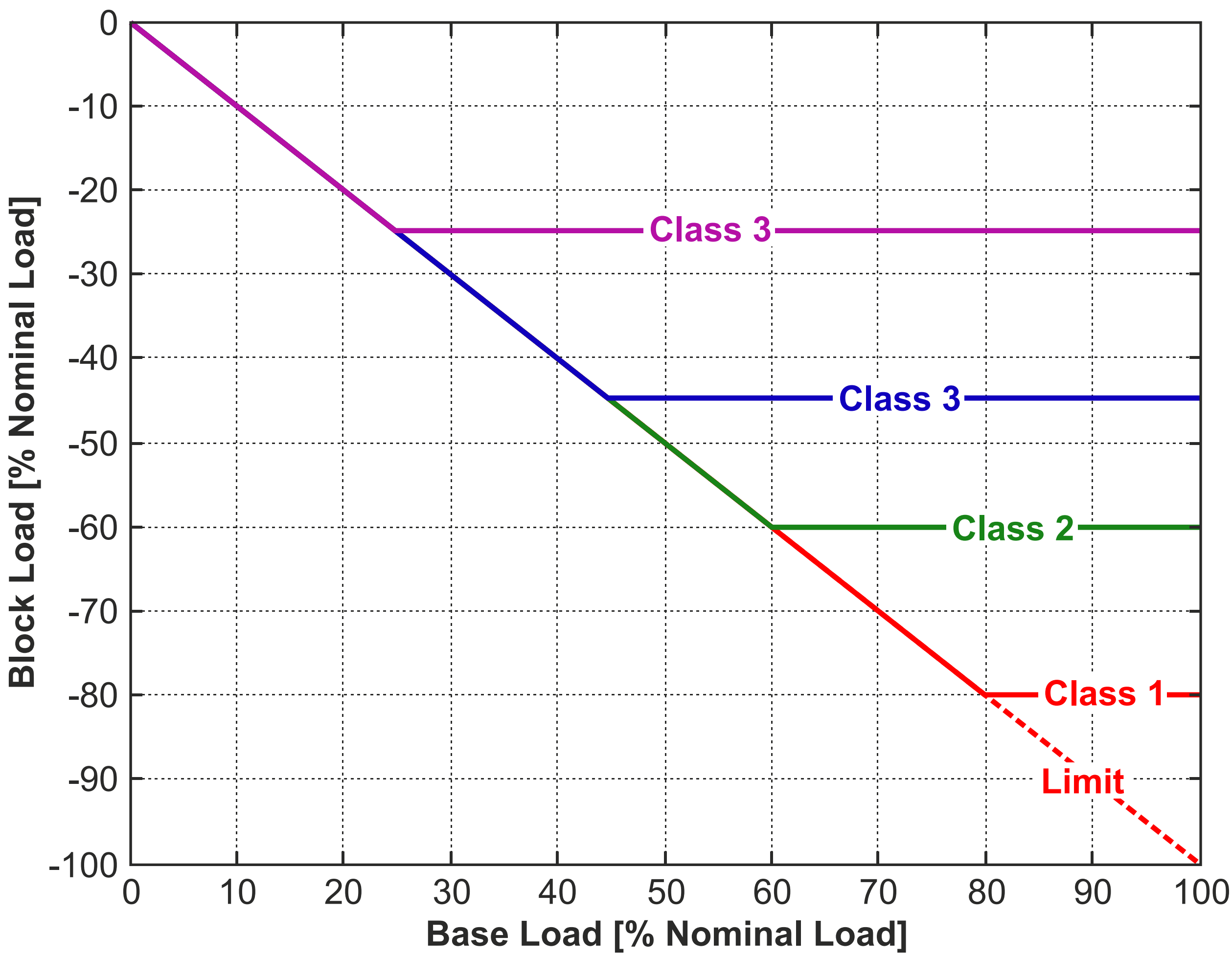

Figure 4. Load-shedding diagram

9.2 Load shedding

Gas engines:

Normally, the transition from mains parallel operation to isolated operation or during isolated operation results in sudden, unexpected load reductions as experienced by the module. Due to the efficiency-optimized design of the turbocharger, a “turbocharger surge” can occur. Currently, type 6 engines are subject to separate limit levels for load-shedding capability (see **TA 2108-0026**, load-shedding capability).

TA 2108-0026 – Isolated operation of spark-ignition gas engines with DIA.NE (Type 6 engines)

Diesel engines:

Diesel engines with common-rail injection load reduction do not need any limitations by load shedding during the transition from mains parallel operation to isolated operation or during isolated operation. (100 % load shedding without overspeeding is possible)

10 Planning and technical features

The classification into one of the design classes (Section ⇨ Assessment of isolated operation performance) depends on the consumers to be supplied during isolated operation and is therefore determined by the customer. This results in the maximum possible power shifts with respect to the specified design class. Careful coordination with the customer during the tender and planning stage is therefore essential. The size and type of the electrical consumers and their starting and operational characteristics must be known by this stage. In the case of electric motors, the magnitude of the effective starting power is relevant as this determines the effective torque at the motor shaft. The torque depends on the type of electric motor and the starting conditions (star-delta starting, soft start, thyristor-controlled drives, heavy starting, etc.).

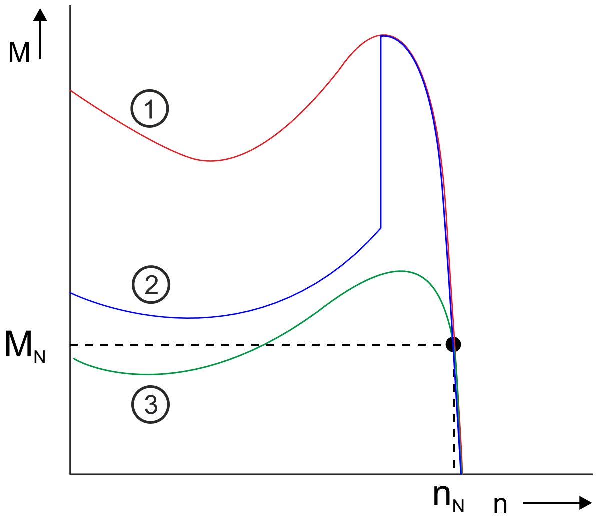

Figure 5. Torque profile for an electric motor start

1	Direct start
2	Star-delta starting
3	Soft start

Gas modules

You must take into account that during isolated operation, the power consumption by single "rotating" consumers with comparatively high moments of inertia J (large fans, pumps, etc.) must not exceed approx. 40% of the rated power of the module. In addition, remember that the starting reactive current of electric motors is several multiples of the nominal value. This percentage is based on empirical data and indicates the point from which dynamic interactions between the module and the consumer can occur. Cases like this require special measures, which can be determined by means of simulations. To this end, power flow analyses are used, which can be created on special approval and with corresponding data on the consumer equipment provided by INNIO Jenbacher GmbH & Co OG.

In isolated operation with several engines, a situation often arises in which the first module must already supply consumers, while the other sets are synchronised with the busbar. In such cases, you must ensure that only very limited load fluctuations (max. 2 % of the rated module load) occur during the synchronisation process. The more frequent such load fluctuations are, the longer the synchronising procedure will take.

Since the current and cos(ϕ) curve of consumers have an effect on the engine dynamics, these must be obtained by the customer and communicated to INNIO Jenbacher GmbH & Co OG in the case of special requests.

Diesel modules

On diesel modules, the engine speed is stabilised by the fuel injection and can therefore be controlled within a small speed range. (Absolute error < 5 rpm). Full synchronisation can therefore be reached after a few seconds.

10.1 Supplying power to installations with an uninterruptible power supply (UPS installations)

When supplying power to UPS installations, it is essential to use their interaction features (e.g. staggered switching in, ramp-shaped loads). This will reduce the effect of added loads and result in a generally more efficient use of the module. Normally, strict tolerances apply to the maximum admissible voltage and frequency differences on the input side of UPS systems. This must be taken into account.

10.2 Parallel operation with UPS systems

Because of the differing voltage forms and dynamic characteristics (frequency control of a module is based on "rotating masses", while in UPS systems the frequency control is inertia-free using power electronics), parallel operation with standard software is not possible. In such cases, clarification for the specific project in question and corresponding adaptations are necessary.

10.3 Automatic backup time of 15 s in conformity with DIN VDE 0100, Part 710 and/or 718

Engine types 2, 3 and 4 Jenbacher Gas Engines are able to supply power to emergency power consumers within a 15 second time frame in conformity with the above standard but must be clarified in detail for each project (special approval). Due to the design of the auxiliary equipment on type 6 engines, emergency power can only be supplied to emergency consumers after clarification for the specific project.

10.4 Soft magnetisation of transformers

Where transformers have to be accelerated in self-contained start mode, the acceleration power must be monitored to ensure that the module is not overloaded. By way of guidance, transformers with a **nominal power of 2 or more times nominal generator power** can be accelerated. However, the method described below should be used as standard.

In the case of very large isolated operation loads, e.g. large transformers, which cannot be added directly because of excessive starting currents, it is possible to soft-magnetise them. The module is started, the generator de-energised, the generator switch activated and the generator energised again. During this procedure, transformer outputs (= sum total of all transformers connected) in the order of ten times the generator apparent power can also be ramped up.

10.5 Black start

In a black start, the plant is completely disconnected from the public power grid. The gas engine from INNIO Jenbacher then acts as the prime mover and must safeguard engine starting with only 24 V DC auxiliary power from the starter batteries as well as close the generator breaker at rated speed to power the customer’s consumer equipment.

A black start can take place on an engine at a standstill (preheated start) or on an engine that has just been shut down (hot start).

10.6 Several generating sets operating in parallel

With regard to the generators used, please bear in mind that a specific reactive-load distribution using voltage statics takes place as well as an identical voltage reduction using a voltage knee. You should also take into account the pitch factor of the winding in case the generator star points are connected. If this is not identical, star-point throttles must be used. An external voltage correction value (90 to 110 percent of the nominal voltage) via a higher-level reactive load management system can also be used.

During parallel operation of Jenbacher modules, the so-called active load distribution line is normally used. This makes it possible to set a required load distribution between the individual modules. The use of transducers should be tested if the load distribution line is subject to different loads. There is also the option of controlled load distribution via speed droop control or specifying an external speed setpoint offset by a higher-level system control or station control.

10.6.1 Speed or frequency droop

In this case, the engine speed is changed by means of a preset power gradient (speed drop) in order to produce a desired percentage (ramp-limited specification via bus or analogue input) of the nominal load as the isolated load. By varying the gradient, it is possible to increase the load on more heavy-duty engines (e.g. diesel modules). You can also vary the intersection between the speed droop and nominal speed using an external signal (ramp-limited specification via bus or analogue input). This will ensure that the local mains system operates at the rated speed and nominal load. Make sure here that the speed drop setting does not adversely affect the plant dynamics (frequency and voltage) in any way. Note that reductions in engine power will limit the external default signals.

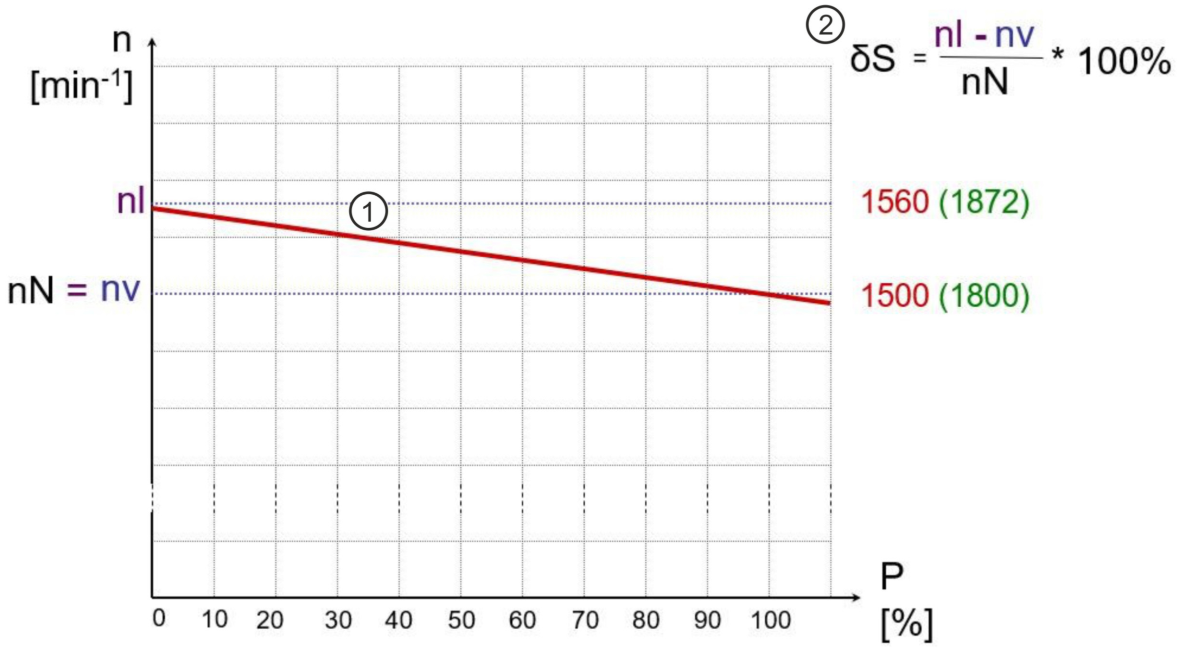

Figure 6. Speed droop

①	Speed droop with 4 % gradient (δS)
②	Speed droop function nl → Speed setpoint for engine operation without load nv → Speed setpoint for full-load operation nN → Engine speed

10.6.2 Active load distribution line (isochronous mode)

For the standard INNIO Jenbacher load distribution line, the power generated from each module is transmitted by an mA output signal and the average output of all engines is loaded by an mA input. By default, both signals scale the 4 to 16 mA to the 0 to 100 % range of the nominal power for the module concerned. The distribution percentages between engines can be adjusted (the standard distribution is equal percentages). When switching individual engines in and out, load application and shedding are effected using a time-based ramp.

When implementing this version of the load distribution line in systems with engines from different manufacturers, the various scales and input resistances of the inputs and outputs must be factored into the engine control systems. Here, it should be noted that any reduction in engine power will have an impact on the load distribution.

10.6.3 Reactive load distribution (voltage droop)

The reactive load required by the consumers is shown in the case of multi-engine systems by means of an equal distribution to the generators running in combination. The distribution is achieved by adjusting the voltage droop. The essential point in this regard is that all the generators must have the same settings for rated voltage, voltage statics (typically 3%), voltage knee point (trip point, gradient, dwell) and AVR reaction times. Different settings may result in pole slip and therefore damage to the generator. An external voltage correction factor can also be defined by a reactive load management system. This value is limited in the maximum permissible range of 90 to 110 percent. The maximum possible change over time in the external default value is also limited

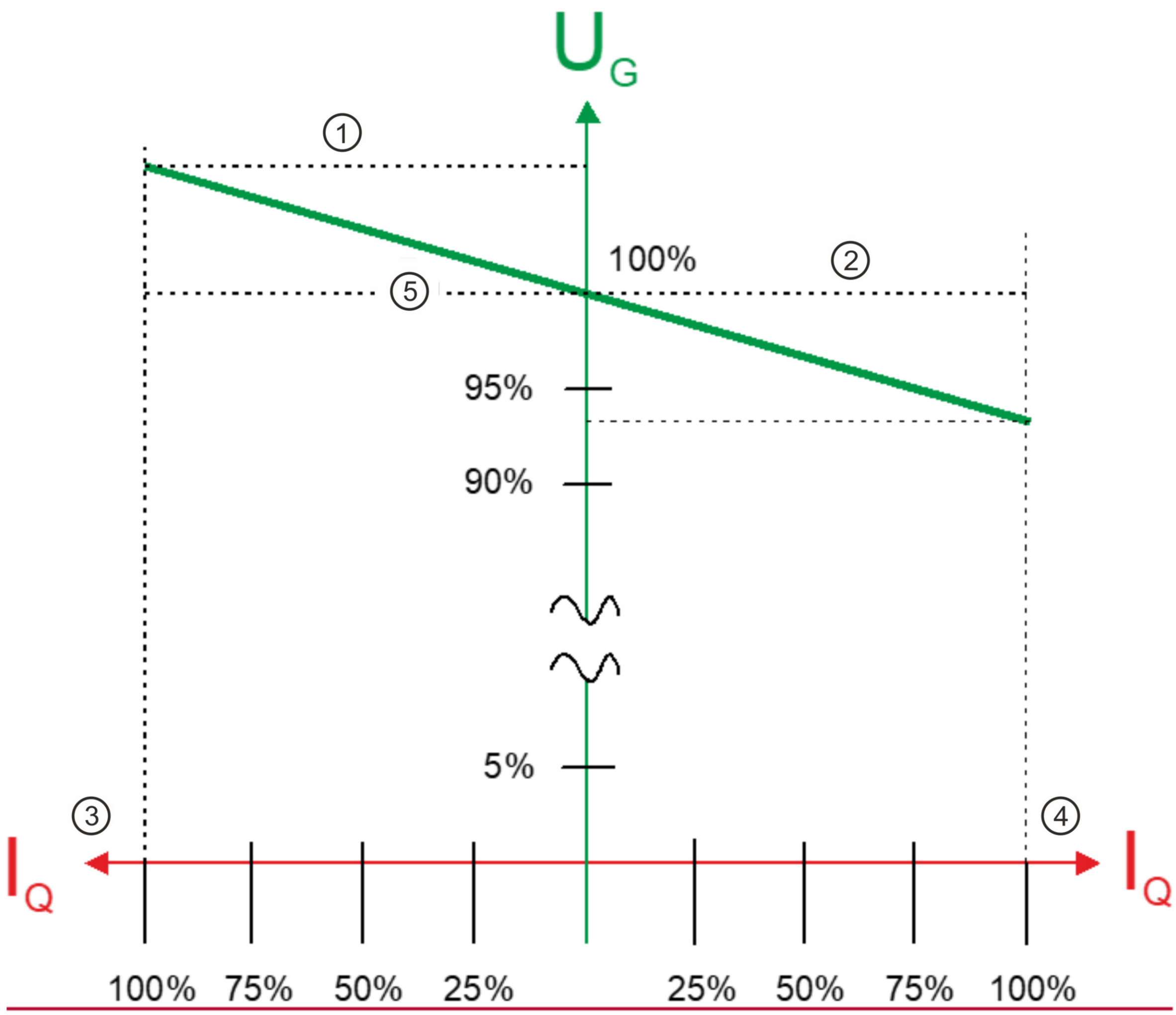

Figure 7. Reactive-load distribution

①	Underexcited generator operation	③	Overexcited generator operation
②	Mounting	④	Load discharge
⑤	Voltage droop with 6 percent gradient (default 3 percent)		
U_G	Generator voltage	I_Q	Generator reactive current (reactive power)

10.6.4 Load management

If a mains system is operated using different types of energy generators (gas engine, diesel engine, gas turbine, solar power, wind turbine, water power or battery backup) or at least several energy generators of the same type, this is described as a micro or mini-grid. In such cases, grid simulations are essential and energy storage estimates helpful. Where specific projects are in the analysis phase, the inertia of the subsystems and the transfer functions for engines, controllers and generators must be regarded as essential system input values. On this basis it is possible to select and simulate the above or other combined load estimates. On particularly stable and powerful basic energy generators operated in speed-controlled mode, lower-capacity modules can be connected in power-controlled operation mode.

The rule of thumb for this eventuality is to apply a **ratio of module inertias of about 2:1**. If the system has to meet high technical demands, the dimensioning must be tested and validated by simulations.

If a higher-level load control system is employed, an input can be used to connect an external speed offset default value. Note that reductions in engine power will limit the external default signals. The current maximum permissible load increase for the individual engine is provided as an engine control system output. All pending power reductions are taken into consideration.

10.7 Points requiring special attention

10.7.1 Information on operational condition from switch conditions – delay times

The operational condition of the engine is assigned on the basis of responses from the generator switch and the mains switch. There are essential transition points in operating conditions at which a rapid response from the switch is required in order to activate the corresponding controller functions.

In some field systems, it is precisely this immediate response that is causing difficulties. Ensure that only low-voltage and medium-voltage switches with inherent delays of under 60 ms are used. If these responses are also channelled by relays or higher-level control systems (software), additional, undesired delay times are added. For example, even a doubling of the switch response time can result in engine shutdowns due to “overspeed” on the transition from mains parallel operation to isolated operation at low load. Switch responses must therefore always be provided directly to the module controller.

10.7.2 Unknown customer load ratios – capacitive loads

If the ratio of capacitive to inductive loads (e.g. in the lower load range, when all the compensators have been added) is very large, this can result in unexpectedly large generator loads, pole slip and generator damage. It is therefore essential to ensure that the generator is always operated in the inductive range. *Worst-case* scenarios can be assessed using grid stability analysis.

10.7.3 Mains power consumption control system

If the currently required power for the plant to be supplied is recorded at the point of supply, mains interconnection control may be sensible from a financial and technical point of view. The recorded power is produced by the internal combustion engine up to a certain necessary difference, and because of this, the transition from network to isolated operation results in a particularly gentle transition behaviour.

10.7.4 Auxiliaries

The exhaust gas system is not purged for emergency power operation on type 6 and 9 engines.

Here, the maximum time from emergency power activation to engine start (when the engine turns) is largely determined by the engine-specific duration of the prelubrication.

11 Boundary conditions

11.1 Rated engine load

The relevant nominal load for each engine version can be found in the product range and adjusted in accordance with the appropriate reduction diagrams. These produce the actual 100% nominal load which is used as a reference value in the load diagrams.

Increased-load versions are operated in isolated operation at their original nominal load.

Furthermore, only the rated loads corresponding to the gas type used are permissible for generating sets with multiple or mixed gas operation.

11.2 Gas engine emissions

Isolated operation is subject to active emission control at a defined exhaust gas emission level of 500 mg/ Nm^3 @ 5% O2 NOx irrespective of the emissions required in mains-parallel operation. Parameters in the engine control system make it possible to ensure that during transition to isolated operation, the control automatically switches to higher emission values. To a certain extent, this will improve the control quality in the overall control range as well as increasing the load-adding capabilities and availability. The switch can be parameterised but this is not obligatory.

If the emissions are kept below the value stated above, e.g. 250 mg/Nm^3 @5%O2 NOx, special approval will be needed.

11.3 Diesel engine emissions

Diesel engines have the same emissions targets in mains parallel operation as in isolated operation. These correspond to the World Bank exhaust gas emission values for steady-state generating sets, i.e. a maximum of 1460 mg/m^3 NO_x. The control tables are adjusted off-line in order to achieve the set emissions targets.

11.4 Mixture cooling water temperature, mixture temperature

The power shift diagrams apply to a mixture temperature corresponding to the product range. The reduction in the mixture temperature results in an increased load-adding capability and therefore an increase in availability.

11.5 Ignition point/injection timing

Gas engines

The ignition point in isolated operation is chosen 2 degrees below that of mains parallel operation. The power shift diagrams apply when the ignition point matches the default parameter values.

Diesel engines

On diesel engines the ignition point can be compared with the injection timing.

11.6 Intake temperature

The power shift diagrams apply to intake temperatures corresponding to the product range. Any reduction in the intake temperature will improve the load-adding capability.

11.7 exhaust-gas back pressure

The power shift diagrams apply up to a maximum exhaust-gas back pressure of 60 mbar. Reducing the exhaust-gas back pressure improves load-adding behaviour.

11.8 Isolated operation with biogas, landfill gas and sewage gas

The use of biogas, landfill gas and sewage gas does not require special approval for the isolated operation of type 2, 3 and 4 engines. Modules in dual-gas operation require project-specific clarification due to the energy content of the gas. Mixed-gas operation and switching gas types during isolated operation both need special approval.

When changing over from mains-parallel operation to isolated operation, particular care must be taken to ensure that the requirements for constant gas pressure and quality are met (TA 1000-0300).

In the event of a black start, an external feed must be used to power the gas compressor.

The use of gas engines in isolated operation with non-natural gas in life-preserving systems is not permitted due to the uncertainty of the gas supply!

11.9 Gas supply

To ensure appropriate operational behaviour of the modules, the fuel gas must be of consistent quality and at constant supply pressure (TA 1000-0300).

The module's black-start capabilities can only be ensured with suitable gas quality and sufficient gas pressure. To this end, steps must also be taken to safeguard an uninterruptible power supply to the upstream main gas valves. Type 6 engines with prechambers are approved for black starts in the product range (as from 2012), as they require prelubrication and a drive for the prelubrication pump.

In the case of multi-gas operation, this gas should therefore have the best possible availability for island operation.

11.10 Diesel supply

A supply of suitable diesel fuel within the set limit values (TA 1000-0001) must be ensured in order to obtain the appropriate operational behaviour of the modules.

Black start capabilities of the module can only be ensured subject to the proviso of suitable diesel fuel quality.

11.11 Generator

To keep the speed drop within the limit levels permitted for the control class in the event of added loads, the generator voltage is reduced selectively and dynamically by the "generator voltage knee point". In the case of multi-engine systems, special care must be taken to ensure that these settings are identical on all modules.

The setting of the generator voltage knee (starting point and gradient) is specified in accordance with the ISO 8528-5 standard. The following setting points are used for INNIO Jenbacher GmbH & Co OG.

Standard settings based on two modules with different rated speeds.

1,500 rpm generator set	**1,800 rpm generator set**	
1,500 – 1,470 rpm	1,800 – 1,764 rpm	Nominal voltage
1,370 rpm	1,644 rpm	0.9 x nominal voltage

The diagram below shows the voltage knee point.

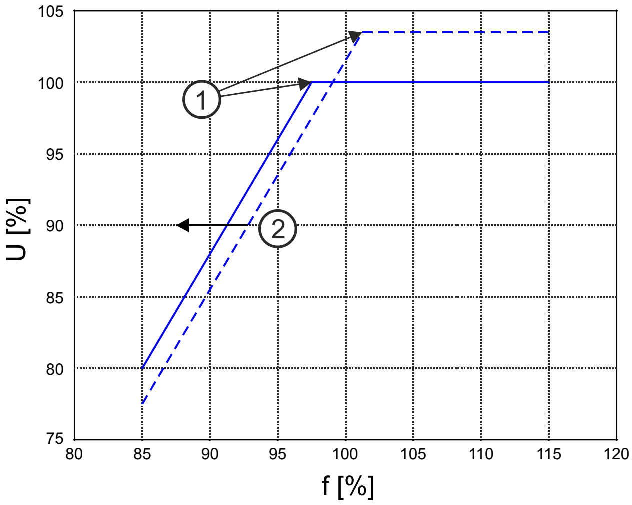

Figure 8. Frequency/voltage characteristic

U [%]	Voltage (% rated value)	①	Voltage knee
f [%]	Frequency (% rated value)	②	Gradient

In order to increase engine stability, it is possible to set the voltage knee point to more than 100% of the nominal speed (broken line) by coordinating the consumers.

12 Appendix A. Isolated Operation Performance Assessment Characteristics

A.1. Generator frequency

The static and the dynamic frequency characteristics are impacted by the complete control system (engine control, AVR, engine behaviour, mass moment of inertia, etc.).

Figure 9 shows the relevant parameters for assessing the steady-state and transient frequency behaviour of a module in accordance with ISO 8528-5. In this context, the frequency behaviour is depicted following a positive and negative jump in the frequency setpoint (speed droop). Characteristic values can be found in table 2.

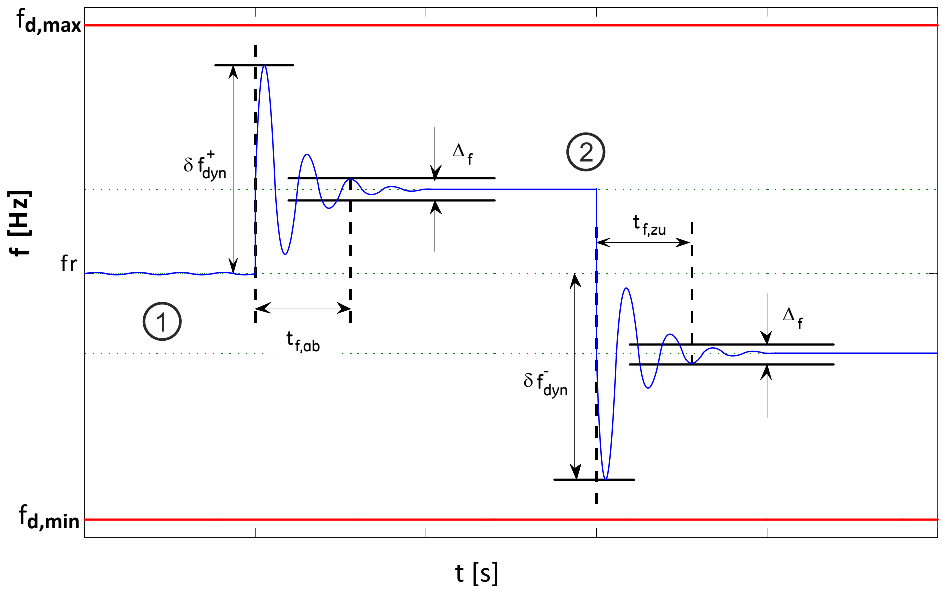

Figure 9. Frequency stabilisation behaviour

f	Frequency	t	Time
①	Load shedding	②	Load application

Parameter	Symbol	Unit	Description
Frequency deviation bandwidth for determining the stabilisation time	α_f	%	Frequency band around the equilibrium frequency where the frequency settles permanently within a specified stabilisation time after switching power on or off , expressed as a percentage of the rated frequency. $\alpha_f = \frac{\Delta_f}{f_r} \times 100$
Steady-state frequency bandwidths	β_f	%	Zone of a frequency fluctuation occurring around a stationary mean value at constant power output, expressed as a percentage of rated frequency.
Undershoot frequency	$f_{d,min}$	Hz	Minimum permissible frequency deviation after a sudden load application.
Overshoot frequency	$f_{d,max}$	Hz	Maximum permissible frequency deviation after a sudden load rejection.
Dynamic (temporary) frequency deviation (from the mains frequency) after a load application	δf^{-}_{dyn}	%	Temporary frequency difference between the undershoot frequency and the rated frequency, occurring during the stabilisation process after a sudden load application and expressed as a percentage of the rated frequency. The dynamic frequency deviation must not exceed the permissible frequency tolerance.

Dynamic (temporary) frequency deviation (from the mains frequency) after a load rejection.	δf^{+}_{dyn}	%	Temporary frequency difference between the overshoot frequency and the rated frequency, occurring during the stabilisation process after a sudden load rejection and expressed as a percentage of the rated frequency The dynamic frequency deviation must not exceed the permissible frequency tolerance.
Frequency control settling time after load application	$t_{f,zu}$	s	Time between the sudden load application and the frequency permanently settling in the stationary tolerance band.
Frequency control settling time after load shedding	$t_{f,ab}$	s	Time between the sudden load rejection and the frequency permanently settling in the stationary tolerance band.

A.2. Generator voltage

The voltage behaviour of the module is influenced mainly the voltage behaviour of the generator and possibly the voltage controller. The static and dynamic frequency behaviour of the module also influences the static and especially the dynamic behaviour in the rated zone. This also depends on the individual design of the module. Figure 9 shows the voltage limits following a positive and negative jump in the voltage setpoint (voltage droop).

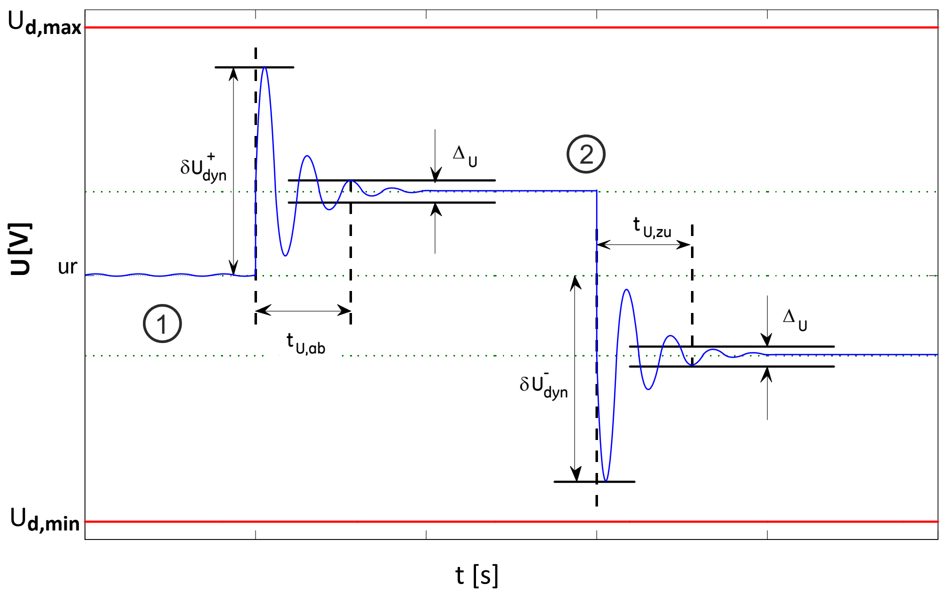

Figure 9. Voltage stabilisation behaviour

U	Voltage	t	Time
①	Load shedding	②	Load application

Voltage deviation bandwidth for determining the stabilisation time	ΔU	V	Frequency band around the equilibrium voltage, where the terminal voltage settles permanently within a specified stabilisation time after switching power on or off , expressed in volts.

			$\Delta U = 2\delta U_{st} \times \frac{U_r}{100}$
Static voltage difference	δU_{st}	%	Maximum deviation by the voltage from rated voltage after the decay of dynamic processes in the zone between no-load and rated power output, taking into account the heating effect and the frequency behaviour of the module. The static voltage deviation is expressed as a percentage of the rated voltage: $\delta U_{st} = \pm \frac{U_{st,max} - U_{st,min}}{2U_r} \times 100$
Undershoot voltage	$U_{d,min}$	V	Minimum permissible voltage deviation after a sudden load application.
Overshoot voltage	$U_{d,max}$	V	Maximum permissible voltage deviation after a sudden load rejection.
Dynamic (temporary) voltage deviation (after a load application)	δU^-_{dyn}	%	Difference between the minimum peak value of the terminal voltage after a sudden load application and the rated voltage peak value, referred to the rated voltage peak value and expressed as a percentage of rated voltage.
Dynamic (temporary) voltage deviation (after a load rejection)	δU^+_{dyn}	%	Difference between the minimum peak value of the terminal voltage after a sudden load rejection and the rated voltage peak value, referred to the rated voltage peak value and expressed as a percentage of rated voltage.
Voltage control settling time after load application	$t_{U,zu}$	s	Time between a sudden load application and the terminal voltage returning permanently to the within the static voltage deviation, taking the frequency stabilisation time into account. Note: The magnitude and change over the time of the dynamic speed variation of the engine are the influencing factors.
Voltage control settling time after load shedding	$t_{U,ab}$	s	Time between a sudden load rejection and the terminal voltage returning permanently to the within the static voltage deviation, taking the frequency stabilisation time into account. Note: The magnitude and change over the time of the dynamic speed variation of the engine are the influencing factors.

13 Revision code

Revision history

Index	Date	Description / Revision summary	**Expert** *Auditor*
6	31.07.2019	Generelle Überarbeitung aufgrund der Einführung der Gen2 Inselregelung / General adoption due to the introduction of Gen2 island operation	**Mayer R.** *Kopecek H.*
5	15.04.2019	GE durch INNIO ersetzt / GE replaced by INNIO	**Opoku**

Revision history

			Pichler R.
4	19.12.2014	Anpassung an Diesel / Adaption to Diesel	**Bacher/Attia** *Hirzinger-Unterrainer*
3	05.03.2012	Überarbeitung / revision	**Bilek** *Graus*
2	16.02.2011	Komplette Überarbeitung / complete revision	**Provin** *Samiento*