Manual

Frequency Inverter Operation on Emergency Generators

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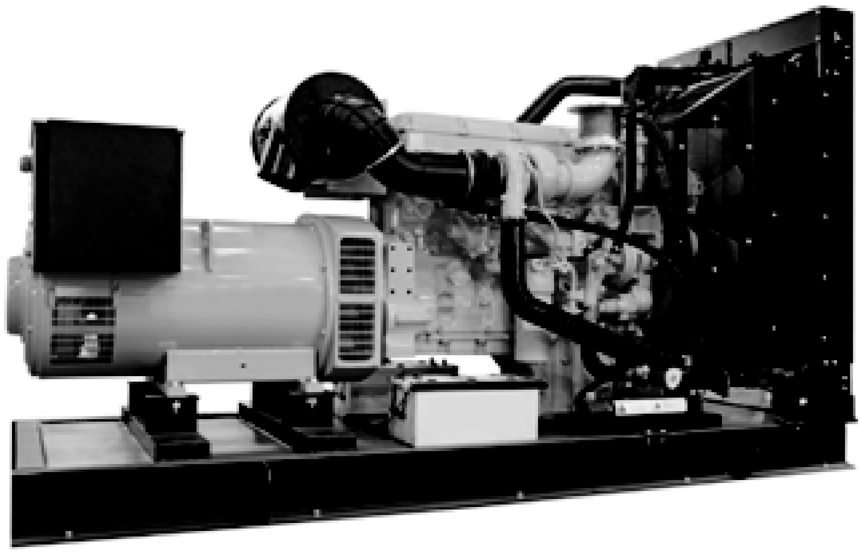
1 Introduction

Plant operators, especially in the logistics sector, are more and more often considering to install an emergency power supply that will allow them to operate their plants even in case of a power failure. Usually, synchronous generators with a diesel engine are used for this purpose; for smaller power ratings, gasoline engines can be used as well. These generators have a power range from a few kVA up to 1500 – 2500 kVA.

Plant operation with reduced power is already taken into account for this, since a generator often only covers part of the installed grid supply power.



The generator requirements have changed over time: Earlier, the loads were mainly ohmic-inductive with sinusoidal currents; today, many non-linear consumers such as frequency inverters, lamps, and UPS must be powered. The characteristics of these loads must be taken into account when dimensioning the generator.

2 Characteristics of Isolated Networks

Operation on a generator without connection to the grid is called isolated operation. In contrast to the public grid, which has a high voltage and frequency stability, isolated networks can have much higher voltage and frequency fluctuations when the load changes. The reason for this is that the demanded power of a plant is much closer to the nominal power of the generator. In the public grid, even large power jumps are distributed over a large number of generators, which means they have only a small effect.

A load jump can lead to a voltage dip and a frequency dip on the consumer side. This effect is balanced by the voltage control of the generator and the speed control of the combustion engine. Balancing is subject to a transient response of the controller.

Large, dynamic load jumps can trigger the overcurrent monitoring function of the generator.

Load shedding can lead to an increase in frequency and voltage as the fuel supply must first be reduced while the exciting current in the generator needs a few time constants to decrease.

The voltage and frequency quality of the interconnected power system cannot always be ensured in case of generator operation. The operator must be aware that the permitted limits for voltage and frequency deviations can be exceeded or that the protective equipment of the generator can shut the generator down.

On the inverter end, this can cause supply system or DC link error messages.

Star point connection:

The star point of the generator should be connected in such a way that the supply system has the same properties as for grid operation.

If the existing supply system has been operated as IT network, the star point can remain free. If the supply system has been operated as TT/TN network, the generator star point must also be connected to PE.

Power-on sequence:

The emergency generator should always be started up with no load. The consumers are then successively connected.

2.1 Generator properties in comparison to a transformer

In comparison with a transformer, a generator has a higher internal resistance. This means that the inner voltage drop is much higher and the generator exhibits a less rigid behavior than a transformer supply.

In transformers, the line impedance is calculated on the basis of the nominal power, nominal voltage, and the short-circuit voltage. With this, the short-circuit impedance of the transformer can be calculated.

The difference between a generator and a transformer is shown below with a comparison calculation:

S_{Tr} = 630 kVA; V_N = 400V; u_k = 6%

$$Z_{Tr} = U_N^2 \times \frac{u_k}{S_{Tr}}$$
$$Z_{Tr} = (400V)^2 \times \frac{0.06}{630000VA}$$
$$Z_{Tr} = 15.2\,m\Omega$$

At 400 V secondary voltage, this transformer has a short-circuit impedance of 15 mΩ.

In synchronous generators, the saturated direct-axis subtransient reactance xd'' is the comparative value. This value is usually between 8% and 16%. It is listed in the data sheet of the generator.

$$Z_G = U^2 \times \frac{xd''}{S_N}$$
$$Z_G = (400V)^2 \; \frac{0.115}{630000VA}$$
$$Z_G = 29\,m\Omega$$

A generator with a nominal power of 630 kVA and xd'' of 11.5% has an impedance of 29 mΩ at 400 V, which is twice the value of a transformer with the same power rating.

If, in addition to this, a generator is used that is smaller than the transformer, e.g. 400 kVA, the line impedance increases to 46 mΩ. This is about 3 times the transformer impedance.

INFORMATION

A generator has a higher inner voltage drop than a transformer of the same power rating. This is why you should always use generators with as low an xd'' value as possible to reduce this effect.

2.2 Short circuit protection for generator operation

Some special conditions must be considered in case of a short circuit:

Short circuits in generator operation are smaller than in transformer operation due to the high internal impedance and the magnetic flux linkage, and they strongly decrease over time. The reason for this is that the short circuit current forms an opposing field to the exciter field. As a result, the initial peak short circuit current decreases within a few 100 ms to a relatively small steady-state short circuit current compared with a transformer.

A steady-state short circuit current of about 2–5 times the nominal generator current can flow due to the voltage control of the generator. This means that the effectiveness of conventional protection devices, such as fuses or power circuit breakers, is limited as these elements need a much higher short circuit current to trip immediately. Power circuit breakers that are tripped by an overcurrent relay are better suited.

2.3 Power factor correction for generator operation

For generator operation, the voltage ripple is usually higher than for grid operation. This places additional strain on the capacitors.

The use of a power factor corrector for the generator must be considered. Unchoked power factor correction systems should be switched off during generator operation.

2.4 Parallel operation of generators

If several generators are operated in parallel for increased power, both the generators (winding) and the control system must be suitable for parallel operation.

If this is not the case, you must expect increased compensation currents between the generators.

3 Non-Linear Loads on the Generator During FI Operation

3.1 Grid characteristics of non-linear consumers

Frequency inverters place increased demands on generators due to the line harmonic they cause. The total harmonic distortion (THD) for 3-phase SEW inverters with B6 bridge is typically between 35 and 45 %, depending on their power rating and DC link capacity.

- Three-phase units cause harmonics of the 5. / 7. / 11. / 13. / 17. / 19. ... order.
- Single-phase units additionally cause harmonics of the 3. / 9. / 15. / 21. ... order (divisible by 3).

Single-phase consumers with non-sinusoidal currents have a negative effect on the neutral conductor load. Distributing the consumers as symmetrically as possible to the line phases is beneficial for the winding load of the generator. However, the harmonics (especially the third harmonic) add up in the neutral conductor and can overload the star point of the generator.

Due to the increased internal resistance of the generator and the non-sinusoidal currents, a higher voltage ripple must also be expected. This effect is amplified if the generator power is smaller than the usually supplied transformer power. This means that the specified grid quality cannot always be ensured.

Experts recommend to use emergency generators only to about 20% of their capacity in case of inverters without choke, or to about 35 – 40% in case of inverters with choke.

This recommendation refers to inverters with a large DC link capacity. The unchoked SEW inverters with a small DC link capacity have a similar harmonic behavior as chocked inverters with a large DC link capacity.

It is also recommended for a non-linear load proportion > ≈ 15 % of the nominal generator power to project the generator to the harmonic load.

The system planner must contact the generator manufacturer for this purpose.

3.2 Project planning variant for non-linear loads or for heavy load fluctuations

For cost-effective operation of non-linear loads, you can use the following project planning variant:

The internal combustion engine is projected to the expected effective power. The generator is over-dimensioned.

System example:

	System nameplate	Generator nameplate
Apparent power	1050 kVA	2150 kVA
Effective power	840 kW	–
Output current	1517 A	3103 A
Voltage	400 V	400 V
Frequency	–	50 Hz

In this example, the generator uses 40% of its total effective power.

INFORMATION

The system nameplate is not sufficient to evaluate a system. The generator nameplate must be consulted as well.

4 Regenerative Power Supply Units on a Generator

SEW-EURODRIVE has received an increasing number of inquiries recently about the connection of a regenerative power supply unit to an emergency generator. Many storage/retrieval systems are equipped with regenerative power supplies. In case of an emergency, these systems must also be able to work with a generator.

If regenerated power is supplied to a generator, the following aspects must be taken into account in addition to the already mentioned points, which strongly limits the operational safety of regenerative power supplies connected to a generator:

1. The regenerated energy must be absorbed by other consumers in the system at all times. The generator itself cannot absorb any regenerated power; it is usually protected by a reverse current monitor.
2. The regenerated power must not exceed 20 – 30% of the generator power. Above that, the generator control can no longer handle the occurring sudden load variations.

   In generator operation, a rigid frequency of 50 Hz or 60 Hz cannot be expected because the frequency strongly fluctuates in case of sudden load variations.

   In block-commutated regenerative power supply units, this is less of a problem as these units simply switch their power semiconductors to the highest line phase. In sinusoidal commutation regenerative power supply units, the change in frequency per time must not exceed a certain limit; otherwise, the synchronization will not work.
3. Harmonics must be managed completely by the generator if there is no harmonic filter installed in the system. This heats up the generator in addition.
4. Regenerative power supply units need a stiffer grid than inverters; the generator must be dimensioned for this. As its internal resistance is higher than that of a transformer of the same power rating, the generator must be overdimensioned accordingly.
5. Due to their operating principle, block-commutated regenerative power supply units cause grid disturbances that also affect the grid voltage (commutation notches). If the voltage control of the generator is sampling at the moment of commutation, it does not work properly.
6. The behavior of other grid participants with damping or exciting effect in the grid is usually not known to SEW-EURODRIVE.

INFORMATION

Due to these aspects, we strongly advice against operating regenerative power supply units on a generator. If a customer wants to implement this nonetheless, it must be pointed out to him (before submitting the quotation, if possible) that he can only operate the regenerative power supply unit at his own risk.

Exception: Disabling the block-commutated MDR/MXR regenerative power supply units.

In MDR60A and the new block-commutated MXR081 regenerative power supply unit, you can disable the regenerative branch through a binary input, so that the regenerated energy is dissipated via brake chopper and braking resistor. In motor operation, the unit works like an inverter.

The following units are affected:

MDR0150	Binary input X3/3
MDR0370	Binary input X3/3
MDR0750	Binary input X3/3
MDR1320 as of serial number DCV200	Terminals A1/A2
MXR81A	Binary input DI03

In this way, MDR/MXR works like an inverter connected to the grid. The notes on generator dimensioning apply.

INFORMATION

Sine-commutated regenerative power supply units do not have these options:

- MXR80A 50/75 kW
- MDR61B 160/250 kW

The energy flow of these units cannot be limited to one direction only because their output stages are always active to control the DC link.

The direction of energy flow is only determined by the load: If energy is taken out of the DC link, the unit works as a supply unit; if energy is fed into the DC link, the regenerative function is active.

Conclusion:

The operation of non-sinusoidal consumers on an emergency generator is generally possible; there are, however, limits for utilization and dynamics.

If an operator is planning a system with non-sinusoidal consumers, the generator must be dimensioned in cooperation with the generator manufacturer.

If this is not possible, a rule of thumb for the generator is to overdimension it by factor 2.5 – 3 for the proportion of non-linear load.

The operation of regenerative power supply units in an isolated network is technically possible, but subject to many restrictions due to the incalculabilities of the system.

This is SEW-EURODRIVE advises against operating regenerative power supply units in isolated systems.

5 Overview of Possible System Constellations

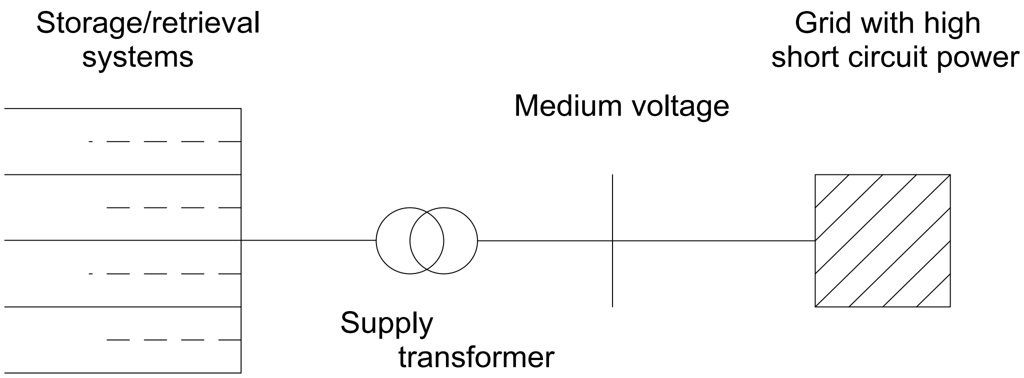
Example: High-bay warehouse.

There are two options for operating an emergency generator:

- Supporting function for the present grid in case of weak supply; the generator runs in parallel with the grid
- Isolated operation with one or several generators

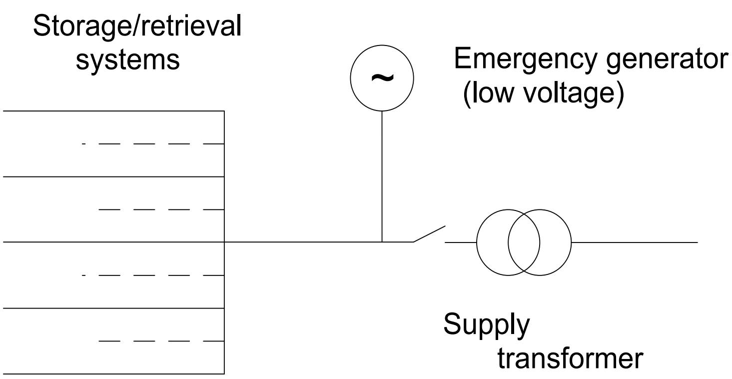
5.1 Connection via medium-voltage system and transformer

The transformer acts as an impedance, the medium-voltage system can be neglected due to the high short circuit power. Project planning is according to SEW guidelines.



5.2 Emergency generator on low-voltage end

The direct-axis subtransient reactance xd" acts as impedance.



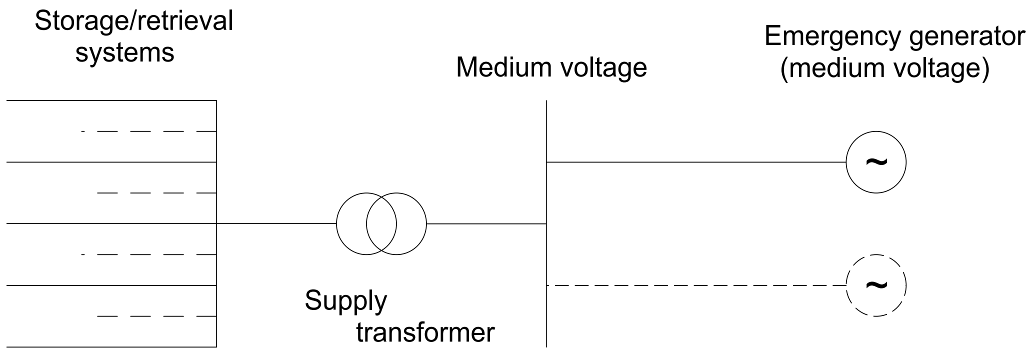
The line impedance is higher than during operation with a transformer.

5.3 *Supply via medium-voltage system*

If a customer wants to operate an extensive system with several transformers via emergency generators, this can be realized via the medium-voltage system of the customer. The following options are available:

5.3.1 Direct supply to medium-voltage system

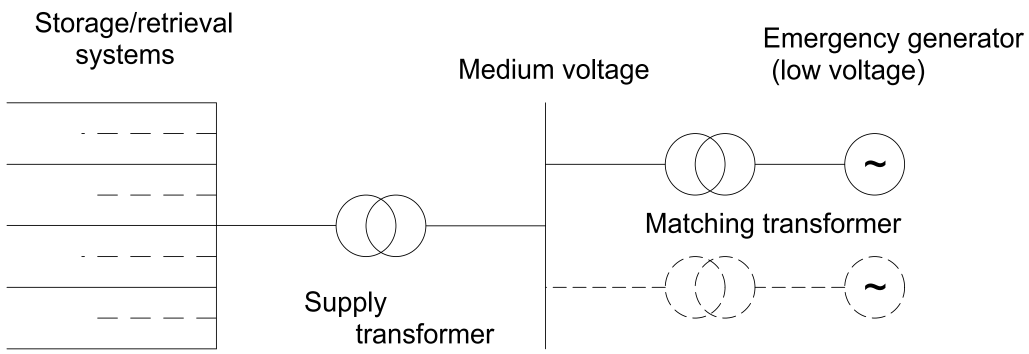
In larger systems with emergency backup of several MVA, several generators can supply power in parallel via the medium-voltage system. An operator can supply a larger network with several distributor substations in case of a grid failure in this way. Up to 15 kV, generators can supply power directly.



The impedance arises from the transformer impedance and the resulting impedance of the generators.

5.3.2 Supply to medium-voltage system via matching transformer

If the generators cannot supply power directly, you must install a matching transformer that steps up the low voltage (e.g. 400 V / 500 V / 690 V) to the medium-voltage level (10 kV – 20 kV).



This is the least favorable case for operating storage/retrieval systems, as the impedance of the matching transformer acts in addition to those of the generator and the supply transformer.

6 References

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