TECHNICAL NOTE

Support for generator customers in complying with grid code requirements

Introduction

The purpose of grid codes is to maintain stable, safe and economic operation of the electricity network at all times. They consist of rules that must be complied with in order to connect a power plant to the network. These rules relate not only to power plant overall performance, but also to the performance of individual plant components.

As a generator manufacturer, ABB can work together with customers to interpret the grid code and determine which requirements apply to generators. ABB can then assist in selecting the correct generator to comply with the requirements and therefore to achieve certification. The actual process of ensuring compliance with the grid code remains the responsibility of the customer.

The information in this Technical note is provided for the high voltage 1-15 kV AMG series of generators for diesel and gas engines, but it also applies to most of ABB's turbine driven DOL (direct-on-line connected) synchronous generators.

Interpreting the grid code

Grid codes are chiefly concerned with transmission system voltage and frequency variations, and fault events, as well as power plant reactive power capabilities and safe operation. The requirements usually relate to the power plant connection voltage and nominal power, rather than the nominal voltage and power of generator units.

Generator performance plays an essential part in network voltage stability. However, many of the requirements should be seen from both the withstand and support perspective – i.e. they should be seen as relating to:

- how the generator equipment – as components of the power plant – should withstand different network events
- how the generator should support network stability when such events occur

If the generator requirements are already known, ABB can directly recommend the most suitable design. Otherwise ABB can support the customer in analyzing the grid code requirements to produce a mutually agreed list of key generator requirements. The main generator requirements typically fall into the following performance categories:

- steady state operation range (voltage / frequency / power)
- dynamic stability and network support (fault ride-through)
- voltage control and excitation performance (reaction time and reliability)
- generator and excitation modelling (standard models and factory acceptance testing)

ABB's engineering team will check the generator design and if needed carry out modifications to ensure it meets the agreed requirements. This process involves a number of trade-offs between different parameters to secure key performance areas like efficiency, stability, loadability, voltage performance, etc.

This Technical note aims to provide a general introduction to the subject, and the modifications described below are examples of the techniques that are most commonly used. In this brief article it is not possible to provide comprehensive coverage of all the techniques and methods available.

Meeting the generator requirements

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01 Distribution of magnetic flux density – the generator's magnetic flux density will be limited to ensure that highly non-linear behavior is avoided.
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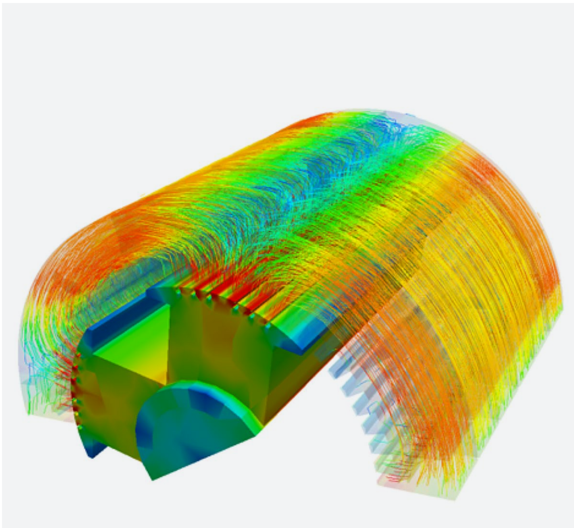
02 Generator power diagram – generator stability at all required reactive power levels is ensured, with the necessary margins.

Steady state operation range
The generator's reactance level will be adjusted to a low value in order to ensure steady state stability at all required reactive power levels, with the necessary margins. This is mainly done by varying the number of stator turns and length of the magnetic core, but other dimension changes are considered on a case-by-case basis to ensure the best overall performance. Depending on the voltage range, the insulation system will be adjusted to achieve the expected design lifetime. The magnetic flux density will be restricted to ensure that highly non-linear behavior is avoided and total excitation remains feasible at different operation points. Additional consideration is given to ensuring that the voltage and current waveform harmonics do not exceed acceptable levels.

In addition to basic design changes, electromagnetic losses and their distribution can be further optimized for wider voltage / frequency / power operation zones and specialized uses like temporary condenser operation.

The generator's basic mechanical structures, like winding support, frame and bearings always meet the mechanical demands imposed by the design modifications described above.



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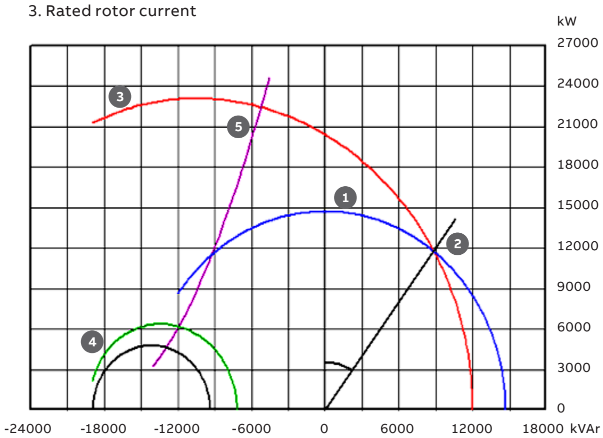
P/Q DIAGRAM

1. Stator current at rated load
2. Nominal working point
3. Rated rotor current
4. Minimum excitation limit
5. Stability limit



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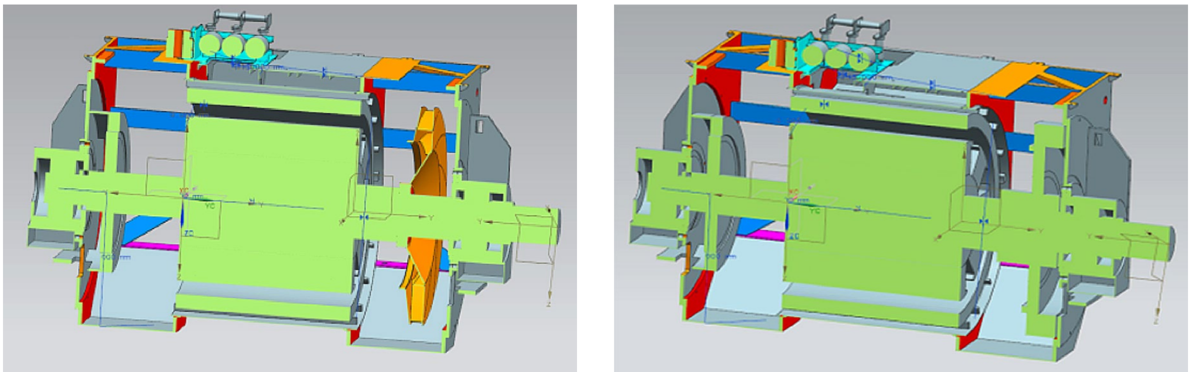

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03 Modular structures allow the addition of an inertia wheel (in this case with integrated fan) and/or other mechanical design modifications.

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04 Example of fault ride-through defined by grid code. Voltage recovery is the most demanding aspect of a fault ride-through event.

Dynamic stability and network support

To ensure optimal transient performance, the transient and sub-transient reactance levels are adjusted. Designers can adjust all the generator's reactances by modifying the stator windings and the magnetic core, and they can change the relationship between reactances by – for example – changing the pole shoe design (transient reactance) and damper winding design (sub-transient reactance). The required low voltage ride-through time margins are achieved – in addition to reactance modification – by adjusting the system inertia, which is usually done by the addition of a flywheel. In this case, the generator's mechanical structures, frame and bearings are upgraded to meet the mechanical demands imposed by the design changes. Special attention is paid to material strengths and structural durability in demanding transient operation.

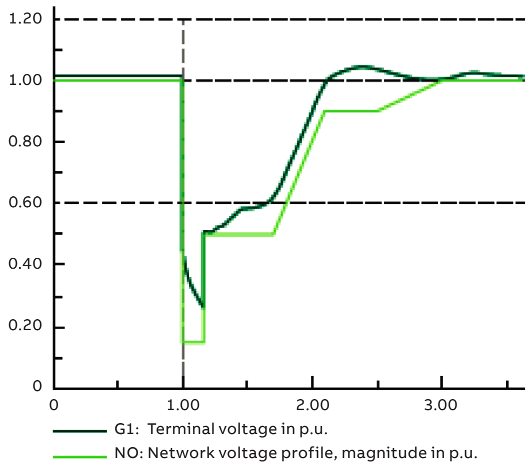
ABB's modular generator design provides great flexibility, allowing mechanical design modifications, such as the addition of a flywheel, to be realized.

The automatic voltage regulator (AVR), which is described in the next section, also plays an important role with regard to low voltage ride-through.

Voltage control and excitation performance

ABB supplies the UNITROL® series of automatic voltage regulators, which means that customers can source their generator and AVR from the same vendor for optimal compatibility and assured performance. The compact, powerful UNITROL® 1000 range of AVRs provides stable and reliable control with full support for grid codes. They include an optional built-in Power System Stabilizer (PSS) and feature fast detection of voltage dips. ABB supplies detailed computer representations of the internal control algorithm and IEEE models for system simulations.

Additional services available from ABB include calculation of the PSS parameters, simulations of reference step responses and stability simulations for different network conditions.



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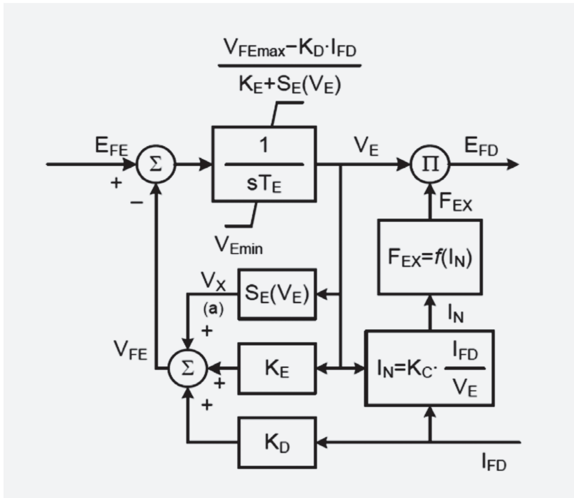
05 AC exciter system with non-controlled rectifier according to IEEE 421.5-2016

Generator and excitation modelling

ABB can supply all the data relating to the generator, exciter and AVR that customers need. The widely used standard two-axis model parameters are provided as part of the generator's technical specifications. Additionally, IEEE 421.5-2016 excitation system model parameters are available.

The accuracy of the parameters is continuously monitored. As a common practice, selected IEC 60034-4 parameter measurements are carried out as part of the factory acceptance testing (FAT) process. Additional testing can be performed according to the customer's needs: for example, generator transient parameters can be tested using the sudden short-circuit method.

ABB can perform preliminary transient simulations to verify the generator's dynamic performance. Larger power plant simulations are the responsibility of the customer, but ABB can provide support in the form of insight and guidance with regard to the generator and voltage control.



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Links for further information:

Synchronous generators for diesel and gas engines
http://new.abb.com/motors-generators/generators/generators-for-diesel-and-gas-engines

ABB Indirect excitation systems
http://new.abb.com/power-electronics/excitation-systems/indirect-excitation-systems

European Commission on grid code regulation
http://ec.europa.eu/energy/en/topics/wholesale-market/electricity-network-codes

421.5-2016 – IEEE Recommended Practice for Excitation System Models for Power System Stability Studies
https://standards.ieee.org/findstds/standard/421.5-2016.html

For more information please visit:
www.abb.com/motors&generators

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