Improved low-voltage ride-through capabilities for large generators

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Agenda

- Introduction Static Excitation
- Grid Faults / Grid Code requirements
- Possible solutions
- Simulations & Test Bank
- Conclusion

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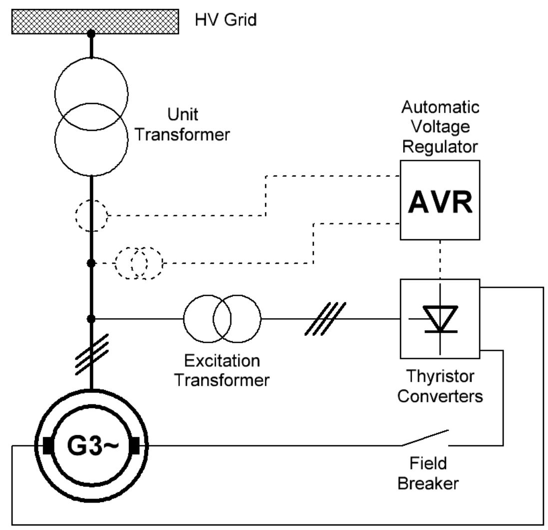
Provides DC field current for supply of synchronous generator rotor by use of semiconductor (thyristor) converters

Regulates generator terminal voltage through variation of field current

Regulation of terminal voltage allows control of reactive power output of generator (cosφ / tanφ ➔ power factor)



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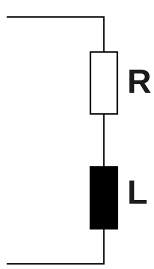
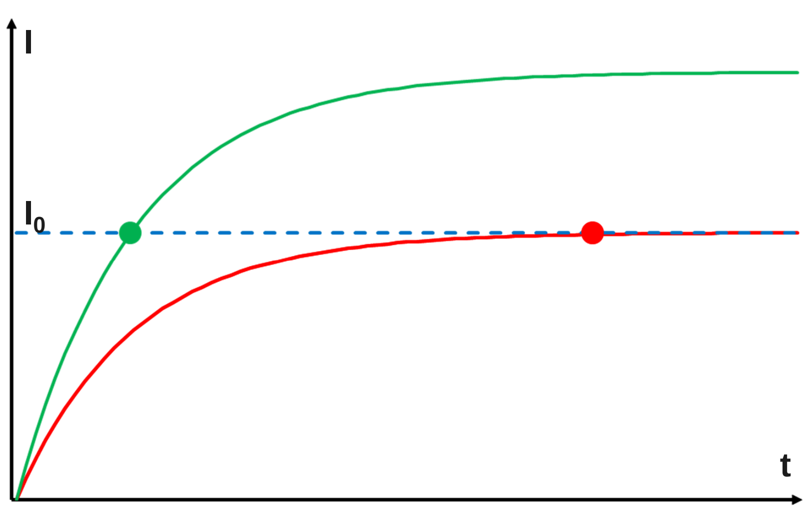
For fast **transient changes** (grid voltage drops, load changes), the field current has to be changed fast to maintain torque and **avoid loss of stability**



$$I = U \cdot \left(1 - e^{-\frac{t}{\tau}}\right)$$

$$\tau = \frac{L}{R}$$



Static Excitation & Grid Faults

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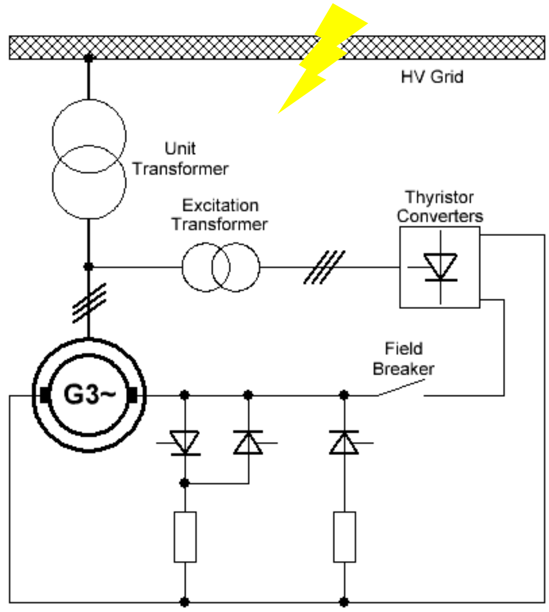
Main Problem:

Static excitation system usually directly fed by the generator terminals

- Voltage breakdown in grid leads to decrease of available excitation voltage
- Torque cannot be maintained, possible loss of synchronism
- Stringent requirements in Grid Codes

➔ Solution to be found to be independent of the generator terminal voltage



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Grid Code Requirements (1/2)

Grid Codes...

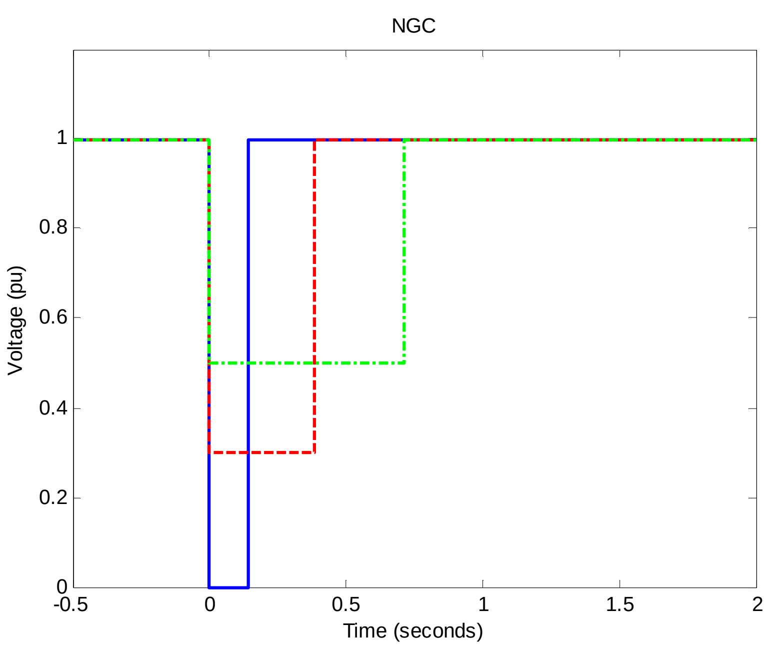
- … are issued by the Transmission System Operating Companies (TSOs)
- … define the conditions to be fulfilled by systems that are connected to the grid
- … define scenarios that may occur during grid operation, and that may not lead to a trip / loss of synchronism of a connected system (plant), in order to maintain grid operation / stability (avoidance of fault propagation / expansion ➔ Blackout)

Low-Voltage Ride-Through requirements...

- … are part of the grid codes
- ... define scenarios of voltage dips in the grid that may not lead to a trip
- ... were initially mainly aimed on renewables (primarily wind), but have been extended to cover also conventional plants

Grid Code Requirements (2/2)

Low-Voltage Ride-Through (LVRT) requirements



Example: National Grid (England)

(Voltage drops in the High Voltage grid)

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Possible solutions

Some solutions available to increase the **Low-Voltage Ride-Through (LVRT) capability**, e.g.

- Compound excitation system
- Switchable loads for diverting the surplus generator output power
- Energy storage (electrical or inertia) on the terminal side
- ➔ usually only feasible for low output power, mainly renewables (e.g. wind), industrial range

Most available solutions involve major modifications in the existing system

- Additional weak points
- ➔ Reduced reliability / availability of the equipment, maybe even adverse effects

Possible solutions

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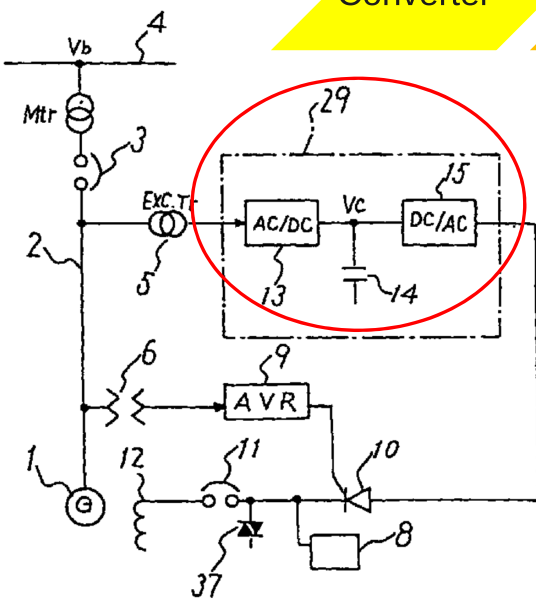
Converter → Energy Storage → Inverter



Patent Excitation Booster by Mitsubishi

Additional components / systems in main current path

- May affect reliability / availability
- Increases losses (entire excitation power has to be rectified and inverted)
- Possible additional EMC issues by using inverter

Static Excitation System with DEM

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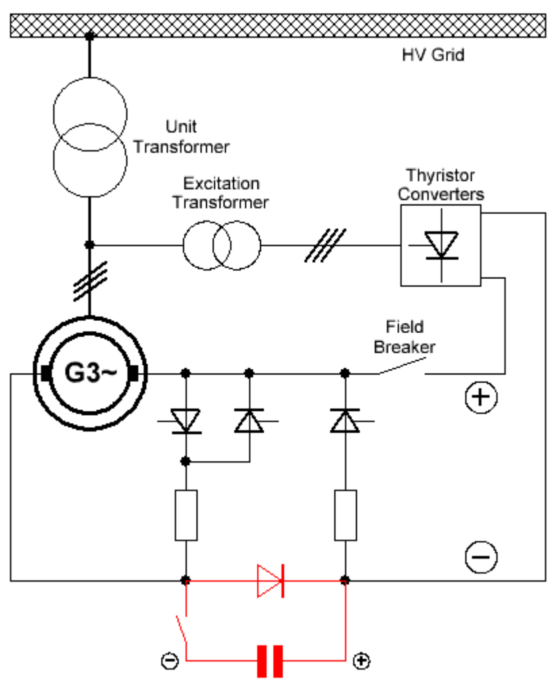
Solution: Adding an energy storage device to the excitation system as additional voltage supply independent from the terminal voltage

- Avoid trips in case of grid faults
- Only diode in main current path, diode failure does not affect normal operation of the excitation system
- Increase reliability and availability of power plant



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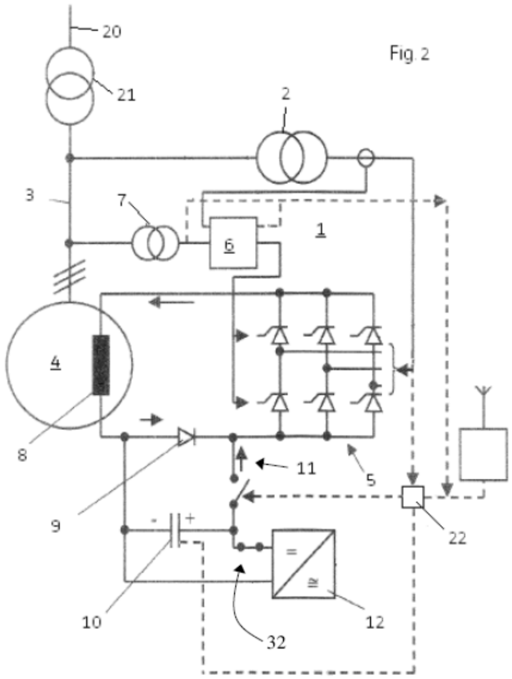
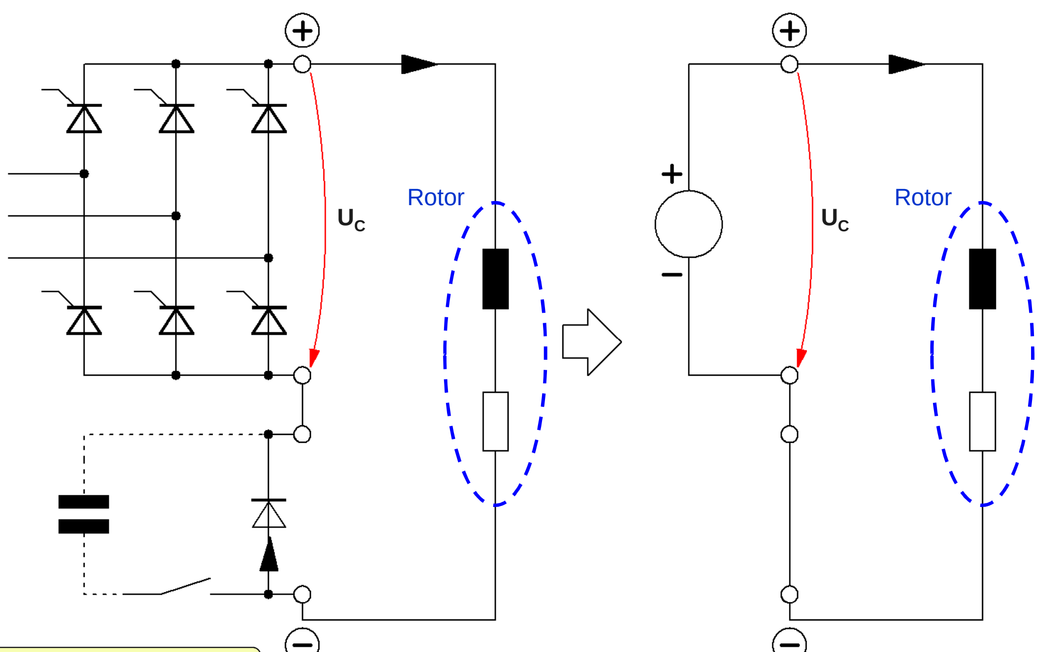


Alstom Patent:

“Static Energising System for a Generator and Method for Operation of such an Energising System”

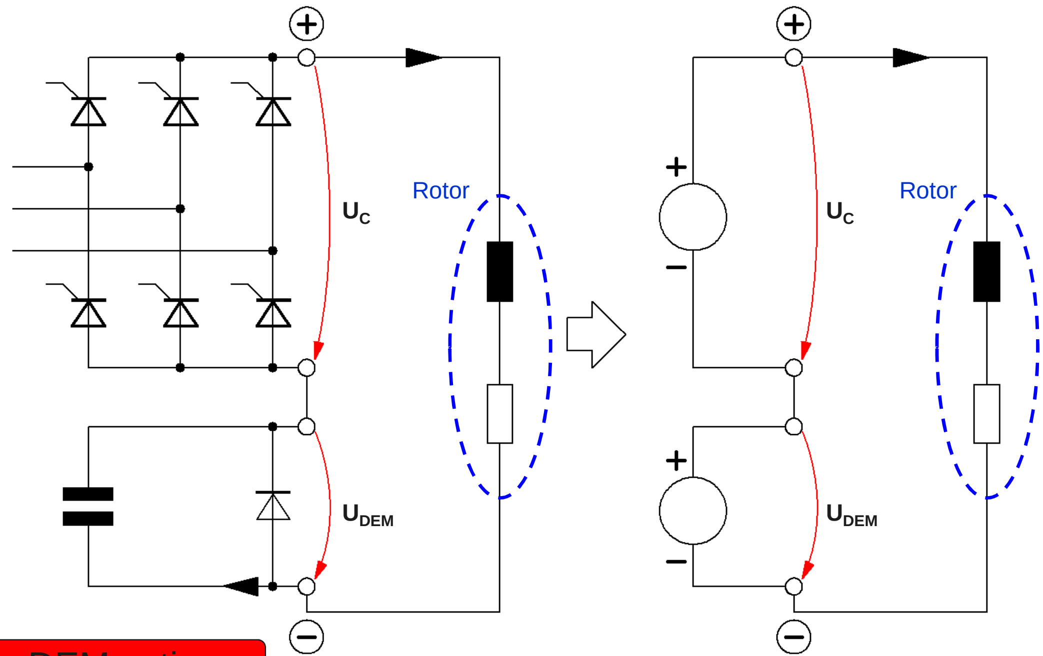
EP1805887

Simplified schematic



DEM inactive

Simplified schematic



DEM active

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Simulations

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System simulated with different tools depending on focus

- Behaviour of the system itself (machine, DEM, power electronics)
- Behaviour of the system in the grid, neglecting internal details (considering only fundamental for steady-state)
  ➔ Simplified model for Grid studies

Results show that Critical Clearing Time can be significantly increased

- Generator remains synchronous in case of grid faults
- Target Grid Code requirements met

Test Bank

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Cooperation with Universidad Pontificia Comillas, Madrid, Spain

Build-up of a small-scale Test Bank with full power plant functionality

Machine rating 15 kVA

Custom-made «Voltage Sag Generator»

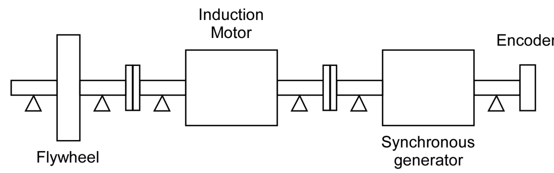
- Impedance matrix with semiconductor switches
- Flexible generation of various grid voltage dips (symmetric, non-symmetric, selectable depth)

DEM with Supercapacitors (EDLC)

Complete Test Bank controlled via DSpace DSP system with MATLAB frontend

Test Bank

DEM, Voltage Sag Generator, Excitation / Control, Inverter racks



Machine set

Test Bank

Voltage Sag Generator

Capacitor Bank

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Dynamic Excitation Module Technology

- Promising approach to increase Critical Fault Clearing Time / Low-Voltage Ride-Through capability of large Turbogenerators with Static Excitation
- Increasing demand by Grid operators due to increasing amount of renewable energy production

Validation in Soft- and Hardware

- Simulations of component, system and grid behaviour
- Test Bank to validate the simulation results in hardware (testing ongoing)

Outlook

- Increasing demand for solutions to improve Grid Stability expected in the near future
- Components needed for solution will become more affordable in the next years

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