Needs and Challenges for Energy Storage in Smart Grids

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Challenges for electric grids in the future

- The use of electricity increases globally.
- Free electricity markets can increase the risk for severe congestions.
- Renewable energy sources are usually time-varying and not controllable if no energy should be wasted.
- When industrial processes are modified for energy savings, usually more electric power is necessary.

The grids must be upgraded.
Complicated task to upgrade the transmission system

- Limited space close to cities, and in many parts of central Europe
- High costs for new lines and the cost for the required space
- Legal problems for getting right of way
- Environmental issues (consequence investigations) are time consuming and sometimes problematic.

It is not likely that a slight upgrading of the HVAC grid is sufficient.
What can be done?

- HVDC SuperGrids interconnecting hubs of renewable energy sources with large consumption centres and large storage facilities (hydro power).
- Grids covering several thousands of kilometres can aggregate the power from wind farms in different weather systems such that the need for energy storage is reduced.
- Electric energy storages close to consumption centres and close to renewable generation facilities.
- Corrective control instead of N-1 in the HVAC grid.
- Electric energy storages to assist the HVAC grid when faults occur in the HVDC SuperGrid.

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Several types of energy storages will be necessary in the Smart Grid

- Capacitor (or flywheel) storages for durations up to 10 s.
- Supercapacitor storage for durations up to 10 min.
- Battery storages for durations up to one hour.
- Longer durations might have to be covered by means of hydro power storages in combination with a strong grid.
Converter topologies for energy storages

- Single-unit energy storages with two- or three-level voltage source converters. Require high switching frequencies and AC-side filters to get good AC waveforms.

- Multiple-unit energy storages with modular multilevel or chain-link converters. Produce excellent AC waveforms using low switching frequencies thanks to multilevel output voltage.
Two-level implementation

Energy storages may be hard to motivate. One solution: add-on.
Experimental results for a two-level VSC with a capacitive energy storage

Fig. 10. Measured bus voltage magnitude under load disturbance.

Fig. 11. Measured bus voltage phase angle under load disturbance.

Hailian Xie running the real-time simulator

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Modular multilevel converter M2C

Connection to HVDC transm.

If no common dc connection is required, a full-bridge implementation with one arm per phase is chosen.

Some SMs may have Energy storages

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M2C - Today

- M2C-a major step forwards for high-power converters, thanks to Marquardt
- Very high efficiency
- Excellent waveforms without filters
- 3 manufacturers and 3 concepts
- M2C or chain-link implementations of energy storages seem to be very promising.

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Driving force:
High efficiency and excellent waveform

Only 5 sub-modules per arm in this case

Very low switching frequency

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Sub-module design

- 3 concepts: Siemens, ABB, Alstom Grid
- Half-bridges with standard IGBTs
- Multiple half-bridges with presspack IGBTs
- Full-bridges
- The double sub-module by Marquardt

Source: Siemens

Source: ABB

Source: Alstom Grid

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SiC JFET from SiCed

(Source SiCed)
The SiC JFET may be interesting in the future

The simplest SiC switch.

Very low Ron for voltage ratings below 4 kV

No need for anti-parallel diodes.

Initial small-scale tests already performed.

(ECCE 2010)
Final remarks about battery energy storages

- The state-of-charge is a very important quantity for the coming cycles, but also for the lifetime of the battery.
- This may be a challenge for multiple-unit implementations because different sub-modules may have different operation cycles.
- Challenge to find control methods for maximum battery lifetime
- Distributed intelligence may be necessary in each submodule for monitoring of the remaining lifetime.