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Stability of Electrical Supply Grids with ongoing Increase of Power Electronic Devices in Generation and Transmission of Electrical Energy

Motivation

The massive expansion of renewable energy and the energy transition affects the network structures and network elements in the electrical transmission and distribution networks across all voltage levels. Due to this reason technical grid improvements are required. Dynamically integrated HVDC (high voltage direct current) systems in the high voltage level, offshore wind farms in the medium, high and extra high voltage level as well as massively growing decentralized energy supply due to local PV roof installations in the low voltage level is are only a few of the leading changes taking place in the grid.

Fig. 1: Transmission and distribution grid

Unlike conventional network structure and network participants, the new network structure and participants generally differ in properties. Among other things, there is rapid increase in the installed capacity of power converter systems, as well as reversal of typical energy flow directions (decentralized power e.g. PV plants in conventional distribution structures generate more power than locally consumed).

Fig. 2: Typical PV roof installation in local distribution grids

The interaction of the existing conventional network components with the relatively new inverter applications in the network raises many questions:

- protection concept with conventional high short-circuit power opposed to nominal current limited power converters
- stability, especially when high converter power in the network are available
- optimized load flows for increasing the transmission power of the networks.

The behavior of the networks in these topologies and the use of converter in ever wider applications in high and very high power range will be investigated.

These changed conditions give rise to new technical challenges. Analysis and evaluation of network with these new conditions in the area of protection, but also stability of electrical grids, is not possible with conventional load flow methods. There could be an inherent danger for the supply stability (black out) of electrical grids, as the behavior of power converters in these grids was not investigated in all details.

Planned research approach

The integration of power converter in grids will be investigated and proved with a new holistic approach for modern grid calculation and simulation, as the actual deployed methods are based on simplified models of the converters. The simulation of highly dynamic operational situations (like short circuit at any point, load shedding, highly dynamic change of generation by renewable sources), and also the unwanted interaction of power converters with mutual, unfavorable influence (up to power oscillations in between those) will be strongly improved. The prediction, what really happens in these situations in the grids will be improved as well and respective counter measures can be developed, which can be investigated in the simulation and their effectivity can be proven.

In order to prove the simulation results we will build a laboratory grid and purchase components accordingly in the size of 200 kW at 690 V each, which allows on the one hand side to transfer the results to high and very high grid powers, on the other hand side fits into the given infrastructure at BTU Cottbus with machine beds and feed in power.

The power rating of the laboratory grid is higher than comparable existing labs, as smaller power ratings have the disadvantage of higher resistive behavior and therefore higher damping compared to high power components. In order to achieve results which can be transferred to grid applications the lab power ratings have to be designed such, that the damping effects through parasitic resistances have practically no influence.

Possible Master and PhD projects:

Improved forecast and estimation of the behavior of power converters in the grids

- Protection concepts: can todays protections concepts based on short circuit currents even protect the grids while the share of power electronics is increasing, or do we need alternative protection concepts, e.g.
    - Change in the short circuit power in the 380 kV grid of 50 Hz transmission with increasing replacement of conventional coal fired power plant by wind power and investigation of the dynamic effects.
- Impact on the stability of grids due to the structural change from conventional synchronous generators, which are either voltage sources (in island operation) or power sources (at the stiff grid) to power converters, which are generally programmed to be current sources, which deliver their respective power (sun/wind) into the grid. Is a change into voltage source behavior needed?
- Primary droop control: should power converters (and all renewables) need to participate on primary control? From which share of total generation onwards?
- Behavior of the 110 kV distribution grids in the countryside of the state Brandenburg, in case of very high infeed by wind and/or PV and highly dynamic grid disturbances (Short circuit, load shedding …)

- Challenges to the low voltage distribution grid with high share of PV roof top installations and their power converters accordingly:
    - Investigation of the grid of a village in Brandenburg and comparison of the short circuit power and behavior with high PV infeed or without PV feed-in (during the night).

Fig. 3: railway converter, like it is placed near to the railway station Cottbus

Local relations

The ongoing changes in the supply of electrical energy in the area of Cottbus, increased share of renewables, the new converter station with 2x15 MW for railway supply and the future temporarily shut down of the coal fired main power stations near to Cottbus will lead to the same structural changes in the grids comparable to the rest of Germany. Therefore, it is also in the interest of this region and the state of Brandenburg to investigate deeper in order to prevent unwanted surprises or even black-outs.