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Date 30/07/2020

Short time negative/positive power transients when inverter enters or exits Fault Ride Through mode

Background information

As in other inverter technologies filters are used extensively in signal processing within the SMA inverter, for example to remove high frequency transients that may result in IGBT gate misfiring. One consequence of these filters is introduction of phase delays which may result in absorption/increase of energy by the physical inverter for very short time periods when the inverter enters or exits its Fault Ride Through (FRT) mode in reaction to network faults.

Phase Lock Loop (PLL) mechanism used by the SMA inverter (and many other inverter technologies) is an example of a measuring algorithm that utilises signal filtering as described above. PLL follows the network's voltage establishing network parameters (voltage phase angle) that allow the inverter to synchronise with the network. This is necessary for the inverter to provide active and reactive power output.

During the transients (e.g. at fault entry and exit) inverter's PLL requires time to adjust to new conditions when phase changes occur in network's voltage. While the PLL is re-establishing the correct network parameters inverter's active and reactive power output follow the changes in network's voltage – inverter's output is forced by external changes rather than inverter's control algorithms. This can result in temporary active/reactive power changes (increase or absorption) depending on direction of voltage magnitude change.

The bigger the phase shift during transients the more pronounced the power changes may be. Phase changes during transients are expected to be more drastic in weak networks (low SCR scenarios).

The change in energy output occurs for very short period of time typically 20ms and always during the voltage recovery phase when voltage is outside of normal operational boundary (usually 0.9 – 1.1pu). This has no impact on plant's ability to recover active power to pre-fault levels within very short timeframes (e.g. 100ms).

When network voltage is still in lower ranges shortly after fault clearance, which is most commonly observed post-fault condition, the ability of any generating system (including inverter technologies) to effectively export active power is impaired as the resulting power is a product of current and voltage.

PLL tunning to remove power transients

It has been suggested that the PLL mechanism can be tuned to remove the delay and avoid temporary changes in inverter's power output during transients on the network. Regardless of parameters selected for the PLL mechanism signal filtering will always be required and therefore some time delays in obtaining the phase angle of the network during fast transients will always be present.

In general, SMA advises against tunning of the PLL mechanism. Operation of the PLL is fundamental to the correct operation of the entire inverter. All inverter testing undertaken during product development phases rely on specific parameters selected for the PLL mechanism.

Negative active power & potential impact on inverter operation

SMA does not consider temporary (20ms) absorption of active power (negative active power at inverter terminals) an issue from inverter's operational perspective. Inverter's hardware is designed to be bidirectional and the flow of energy into the PV plant is not expected to cause any damage to the inverter.

PV inverter unlike a wind turbine has no moving parts therefore absorption of active power has no impact on normal operation of the inverter and the power does not have to be dissipated by the use of a chopper as it's done in some wind turbines to prevent impact on the dynamics of the machine.

Inverter tripping or issues with inverter's ability to withstand multiple consecutive faults under conditions described in this document are not expected.

Each plant can undertake similar assessment considering their specific network conditions and scenarios. Please note that negative power should be assessed at inverter's terminals as some of the power flowing back into the PV plant will be absorbed by other elements of the plant such as cabling and transformers.

Modelling in PSS/e and PSCAD

SMA develops their Sunny Central series of inverters using the Model based Design methodology. Therefore, users of the PSCAD model of the SC inverter can be confident that the model represents the physical inverter at a level of detail that provides insight into the inverter characteristics that may not visible in the PSS/E model.

Consequently, responses observed in PSCAD studies are indicative of those expected in the physical inverter and users must understand that very short time transient behaviour that may occur in the physical inverter will be visible in PSCAD.

Temporary energy changes during transients are usually correctly modelled by PSCAD and are observed as a negative/positive "spike" in power (active or reactive) at the inverter terminals.

Such very short time transients may not be visible in responses from the PSS/E model, and users must be careful not to misinterpret the more familiar PSS/E responses as being representative of the physical inverter behaviour.