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DER Report

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Duke Energy Progress Distributed Energy Resources Case Study – EPRI Paper-December 2019 J. Boemer, A. Gaikwad, E.Farantatos

Overview: This paper provides an analysis of the impact of widespread distribution connected inverter based resources on a large utilities transmission footprint. This focuses on transient performance and employs the DER_A model. Below is my attempt to provide an interpretation of the results.

IEEE 1547 defines "ride through" as the ability to withstand voltage or frequency disturbances inside defined limits and continue operating as specified.

However, the EPRI report states that "Further ,presently, the utility requires any DER to interconnect conforming with IEEE Std. 1547a-2014 and does not require voltage or frequency ride-through capability from DERs". This gives the impression to me that the DER will go off-line and not come back the instant that the voltage goes below 0.88 pu. The key here, I believe, is that as long as the trip settings are not violated, the DER will remain connected but will not provide either frequency or voltage support until the voltage recovers to > 0.88 pu.

Therefore, the general assumption in this analysis - DER will remain connected and recover as long as UV trip settings not violated. This relates to assumption that the DER is per IEEE 1547a-2014. The key points are v not < 0.45 for >0.16 sec OR < 0.6 for >1.0 sec OR <0.88 for 2.0 sec. If any of these are violated, the DER will trip and go off line and not recover.

- None of the DER units are exposed to <= 0.6 v so the 2 second trip time applies
- Upon voltage recovery, the DER wil ramp up at a rate depending on the voltage recovery rate and the ramp rate of the DER. The voltage recovery rate in turn depends on the resource mix between DER and synchronous machines plus other network parameters.
    - For the Duke system, with lower amounts of DER, the rate is on the order of 300 MW per second
    - Note – this is **not compliant** with recent NERC recommendation that momentary cessation respond to full output in 1 to 3 cycles

Analysis assumptions:

- The area modeled has **12700 MW** of load and is interconnected with neighboring systems

- The DER is modeled as UDER (connected to distribution transmission) and ranges from **490** to **3650 MVA**. This corresponds to levels approaching 2023 forecast. As DER increased corresponding amounts of synchronous generation is reduced.
- The analysis results are for what is believed to be a worst case transmission bus fault of **5 cycle** duration but with no lines disconnected.
- For a given DER dispatch, the cumulative MVA of load exposure to a given voltage is a surrogate for how much of the DER is exposed to that voltage-no details are given regarding actual voltages experienced by particular DERs.
- Even with the largest DER dispatch of 3650 MVA, apparently none is exposed to v<0.6 pu.
- For all dispatches, all load is exposed to v<0.88 pu as a result of the so called worst case fault. Not shown in the report are voltage profiles during and subsequent to the fault. It would be helpful to see some plots of voltage recovery at different points in the system.

Concerns:

- The analysis does not include plots of voltage vs time at various key locations in the system. The results provided are in terms of cumulative load MVA exposed to a given voltage level during the fault, as a way to show the impact of different levels of DER penetration. For example, where voltage dips to o.7 pu:
    - With 490 MW of DER, approximately 2500 MVA of load is exposed
    - With 3650 MVA of DER, approximately 9000 MVA of load is exposed

  It appears that the assumption is that a proportionate amount of the DER for each case is exposed to this voltage. Without the voltage vs time plots, it is impossible to see how close the DER comes to tripping at various locations and at various penetration levels.

- One example is provided where DER trip time is reduced from 2 sec to 0.1 sec and of course, the DER is unable to recover. It would be interesting to see the margins of recovery for the different penetration scenarios.
- The most severe fault as modeled with high speed clearing and **no transmission is disconnected**- in the real world, faults may be of longer duration and will result in disconnection of transmission.
- All DER is able ride thru the fault and remain connected as well as provide support to the transmission system. It appears that voltage droop is just on the edge of causing DER tripping. If the system goes over the edge for larger DER penetration, a cascading effect may occur and that voltage recovery may be extended causing more tripping. This needs further investigation.
- All DER is modeled as UDER vs RDER – this may provide optimistic results as RDER may suffer reduced voltages at locations lower down from the transmission system.

Pros:

- Provides further verification of DER_A model.
- Provides impact of using different voltage control modes and their impact.

- Includes analysis of islanding situations.
- Generally, it appears to be a very good analysis. It could be expanded to show additional fault cases and provide more detailed voltage results at various locations and provide plots of voltage recovery after fault clearing.