White Paper: Active power variation criteria framework
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Overview

This document outlines a basic framework for limiting active power variations from large loads in order to protect generator shafts from damage. There are other concerns relating to load variation, including power quality, interarea oscillations, ride-through failure and others. These concerns may require separate criteria, as the framework proposed here is focused on Sub-Synchronous Oscillations (SSO).

Highlighted Yellow: Framework assumptions, to be determined. Example values are proposed here but should be adjusted as needed.
Highlighted Blue: Key defined variables

Basic assumptions for criteria:

1. **EL** (Endurance Limit) for synchronous generator shaft torque is 0.1 pu. (This may be either defined as a "minimum", or as a set of EL values for different frequencies or equipment, but this may introduce significant complexity).
2. Amplification of active power at terminals may result in 1x – 50x amplification depending on the degree of torsional frequency content, and the duration of periods where the torsional frequency content is present. For example, a load profile assuming continuous modal frequency driving may cause the **ratio between active terminal power and shaft torque** to be 50x. This can be a tunable parameter **LSR** (Load Shape Ratio). **Dividing EL by LSR** will yield the maximum amount of continuous steady state active power variation (Maximum Continuous Terminal Variation, or **MCTV**) at the machine terminals. For example, MCTV = 0.01 pu if LSR is 10 and EL is 0.1.
3. Criteria applies to loads in excess of 20 MW in aggregate. (could be defined by load type rather than minimum power, or some combination of both). Could be, for example, "Any training load", or "Any training load with frequency content >0.1 Hz".
4. Criteria considers synchronous generators in excess of 20 MW in aggregate. (could be defined by generator type rather than minimum power, or some combination of both).
5. If there are multiple loads which are synchronized, they can be treated as a single load (remaining geographically independent) to calculate MCTV at each generator.

Active Power Variation framework:

1. Variation shall not cause a flicker problem. Perform powerflow based screening to determine maximum variation for square waves at 8.8 Hz. This is not expected to be the limiting variation constraint.
2. Maximum variation at load location will be the minimum of the following 2 criteria:
    a. Criteria 1: Maximum variable portion of load cannot cause terminal power at each machine to exceed MCTV on that machine's base. If MCTV is not exceeded, no study is required. If MCTV is exceeded, a study is required to determine whether machine damage will occur or mitigation is required at a value lower than Criteria 2.
    b. Criteria 2: Maximum total **variation will not exceed some threshold over a 5 second period** (threshold definex as Maximum Locational Load Variation, or **MLLV**.) Example, 25 MW… this threshold is a backstop for future changes in the system, new large close in generators, unknowns related to active power transients unrelated to torsionals, and unknown risks due to machine mode cycling and interarea oscillations. Note that this number is not well defined by industry and contains the potential for both under-constraint and over-constraint. In particular, it will not protect close-in generators installed after the analysis is complete if the generators are very small, or if a bad torsional mode is continuously excited.

Example process to apply limits:

1. Select EL, LSR, and MLLV. You may select LSR to be very low if there are no torsional frequencies possible, or very high if the torsional content is unknown.
2. Apply MLLV to load (accounting for potential co-located load interconnections).
3. Run impedance based calculation with load at MLLV to select generators with active power change larger than MCTV, considering a reasonable number of outage conditions. This will exclude very remote generators and highlight generators electrically close to the loads. The analysis is performed using the following assumptions:
    a. Hold synchronous machine or GFM internal voltage phasor constant.
    b. Hold GFL IBR machine active and reactive power constant.
    c. Freeze all other slow dynamic devices such as switch shunts, transformer taps, AGC, etc..
4. For selected generators with active power change larger than MCTV, load project may proceed based on one of the following alternatives:
    a. Perform detailed study to evaluate whether physical limits are exceeded when MCTV is exceeded (respecting MLLV always) and mitigate as needed.

b. Reduce the load variation (by implementing mitigation measures or other approaches) until neither the MCTV or MLLV is exceeded, and then a study will not be required.

