EPRI Proposed Update to SIR Screen H, Voltage Flicker Test

For NY Interconnection Technical Working Group
May 12, 2021

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Screen H Background

1. Power quality requirements in IEEE 1547-2018
2. 10/18, NY SIR created Screen H
3. 10/19, Screen H updated to consider x/r ratio and grid ΔV characteristics with power variations at PCC
4. 4/20, Plant variability (shape factor) data considered but not adopted
5. 5/21, EPRI proposal with additional plant variability data including NY 2 MW plant
IEEE 1547 2018, Section 7 on Power Quality

<table>
<thead>
<tr>
<th>PQ Section</th>
<th>1547 2003</th>
<th>1547 2018 PQ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC injection Limit</td>
<td>.5% current</td>
<td>Same</td>
</tr>
<tr>
<td>Synchronization</td>
<td>±5% ΔV at PCC</td>
<td>Table Δf, ΔV, ΔΦ</td>
</tr>
<tr>
<td>Rapid Voltage Change</td>
<td>None</td>
<td>ΔV≤ 3%</td>
</tr>
<tr>
<td>Flicker</td>
<td>Shall not create</td>
<td>Pst &lt; .35, Plt &lt; .25</td>
</tr>
<tr>
<td>Harmonic Current</td>
<td>&lt;5% TDD</td>
<td>&lt;5% TRD, ~4% evens²</td>
</tr>
<tr>
<td>Harmonic Voltage</td>
<td>None</td>
<td>Same</td>
</tr>
<tr>
<td>OV Temporary</td>
<td>No disturbing GFO</td>
<td>138% Vl-g³</td>
</tr>
<tr>
<td>OV “Cumulative Instantaneous”</td>
<td>None</td>
<td><a href="mailto:2pu@1.5ms">2pu@1.5ms</a> and 1.4@16ms</td>
</tr>
</tbody>
</table>

1. IEEE 1547 addresses limits at interconnection (PCC)
2. There are small differences to IEEE 519-2014, including TRD instead of TDD and no voltage distortion limits
3. From ANSI C62.92 and considering new C62.92-6 for inverters
Can it be determined that the voltage fluctuation is within acceptable limits as defined by IEEE 1453

1. Voltage flicker emission generated by each fluctuating installation (Pst) should be limited to its emission limit (E_{pst}). Calculate Pst using the following formula:

\[ P_{st} = d \times \frac{F}{d_{pst=1}} = \frac{\Delta S}{S_{SC}} \times 0.2 \times 2.56\% \]

- \( d \sim \left( \frac{\Delta S}{S_{SC}} \right) \) is the relative voltage change caused by the project
- \( \Delta S \) is the power variation from the project
- \( S_{SC} \) is the available short-circuit capacity of area EPS at the PCC
- \( F \) is the shape factor related to the shape of expected voltage fluctuation (\( F \) can be considered equal to 0.2 if detailed information is not available)
- \( d_{pst=1} \) is the relative voltage change that yield \( P_{st} \) value of unity assuming rectangular voltage fluctuation (2.56% assuming 1 dip per minute)

2. Can it be determined within the Supplemental Review that aggregate DER does not cause voltage excursion outside of ANSI C84.1 Range A?

3. Can it be determined that an aggregate DER voltage fluctuation of 75% does not result in a voltage change of greater than half the bandwidth of any voltage regulating device on the associated feeder.

A Pst greater than 0.35 as calculated in Step 1 or no to the determination in Steps 2 and 3 constitutes failure of this screen.
Screen H: Voltage Flicker Test

Can it be determined that the voltage fluctuation is within acceptable limits as defined by IEEE 1453

1. Voltage flicker emission generated by each fluctuating installation (Pst) should be calculated using the following formula:

\[
\left( \frac{d}{d} \right) \times F \leq 0.35 \quad \text{and} \quad d = \left( \frac{R_L \times \Delta P + X_L \times \Delta Q}{V^2} \right)
\]

When: \( \frac{X_L}{R_L} \leq 5 \)

OR

\[
\left( \frac{d}{d} \right) \times F \leq 0.35 \quad \text{and} \quad d = \left( \frac{\Delta V}{V} \right) \approx \frac{\Delta S}{S}
\]

When: \( \frac{X_L}{R_L} \geq 5 \)
Reference Tier 1 Failed CESIR's from Industry Members

Ver. 13 April 2021

Included are 11 total CESIR, 8 that were submitted and in the last 2 years, plus the 3 in the excel summary file.
July 24, 2019, 2 MW PV Plant

Worst 10 min variability
2MW NY, 63 changes at 25%

Power (kW)

Ramp (% of rating/sec)

12.42% 12.93% 12.72%

14.05% 14.32% 14.99%
2MW TN, 69 changes at 12%
180 kW AZ, 65 changes and 23%

Minute with most number of changes

Highest slope up: 19%/sec

Highest slope down: 17%/sec
10 MW TN, 25 changes at 25%
Plant Variability Screen using Worst-Case 10-minute $P_{st}$

- IEEE 1547 Flicker Allocation is $P_{st} = .35$
- These data are from 2MW plants in NY and TN
- This Short Circuit Ratio Test is NYSIR Screen F

Graph showing $P_{st}$ vs. Plant Size (kW) with different SCR values (5, 10, 15, 25, 40)
Flicker Estimate Using PV Plant Date (EPRI 3002014488)

1. The voltage impact of a fluctuating load can be estimated in terms of $P_{st}$ at a connection point, see the formula below. This calculation assumes that $d (\Delta V)$ is proportional to the load kVA change ($\Delta S$) to the short circuit power ($S_{SC}$). Included are fluctuation shape factor (triangle, step, etc.) and duty cycle from the flicker curve to yield a $P_{st}$ estimate, see Grid-IQ*.

$$P_{st} = d \times \frac{F}{d_{pst=1}} = \frac{\Delta S}{S_{SC}} \times \frac{\text{Shapefactor}}{\text{CurvePstValue}}$$

2. $S_{SC}$ is determined by $V^2/z$ at the PCC. The accuracy of the $\Delta V$ estimate depends on the nature of the power change (real or reactive) relative to the $x/r$ ratio at the PCC. In case of typical fluctuating loads power may be mostly reactive and in case of it is DER mostly real. Since $x/r$ is usually greater than 1, the above likely overestimates voltage change for real power changes. A better estimate of $\Delta V$ may be obtained using the short circuit power ($V^2/r$) at PCC or the following formula.

$$\frac{\Delta V}{V} \sim \frac{R_{SOURCE} \times \Delta P - X_{SOURCE} \times \Delta Q}{V^2}$$

3. Using a reasonable estimate of $\Delta V$ along with worst case PV plant 10-minute variability data the following calculations may be useful for screening PV plant size relative to the PCC.

For PV ≤ 250kW use

$$P_{st} = \frac{\Delta V}{V} \times \frac{F}{d_{pst=1}} = \Delta V\% \times 3.6$$

For PV > 250kW use

$$P_{st} = \frac{\Delta V}{V} \times \frac{F}{d_{pst=1}} = \Delta V\% \times 1.2$$

*Grid-IQ Flicker Evaluation Module (FEM), [https://github.com/epri-dev/OS-FEM/releases](https://github.com/epri-dev/OS-FEM/releases)
Together...Shaping the Future of Electricity