Review of Voltage Flicker for SIR Screen H

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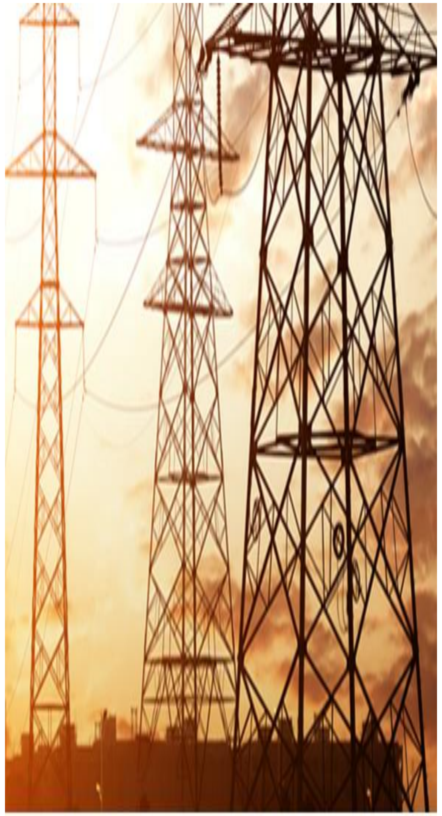

Background and Objective

- NYSERDA/DPS requested Pterra to review voltage flicker screening method
  - Some projects failed the voltage flicker screening but passed the detailed time series simulations
  - Refine the voltage flicker screening method, if necessary
- Discuss a consideration to include the resistive and inductive part of the system impedance
  - More precise way for calculating the relative voltage change if the X/R ratio of the system is less than 5
  - Need one additional data (system X/R ratio) and additional steps in the calculation process
- Additional ideas / consideration will be provided after the data from time series simulations are provided to Pterra

Background

PROPOSED

IMPLEMENTED - SIR

$$P_{st} = \left(\frac{d}{d_{pst=1}} \right) \times F$$

$$d = \left(\frac{\Delta V}{V} \right) \approx \left(\frac{\Delta S}{S_{SC}} \right)$$

X/R < 5

$$d = \left(\frac{R_L \times \Delta P + X_L \Delta Q}{V_r^2} \right)$$

- *d is the relative voltage change caused by project*
- *dpst=1 is the relative voltage change that yield Pst value of unity assuming rectangular voltage fluctuation (2.56% assuming 1 dip per second)*
- *F is the shape factor related to the shape of expected voltage fluctuation (conservatively, F can be considered equal to .2 if detailed information is not available)*
- *ΔS is the power variation from the project*
- *S_{SC} is the available short-circuit capacity of area EPS at the PCC.*

All parameters can be calculated by requesting 1 additional data (SC X/R ratio at the POI)

Excerpt from IEEE Std 1453 -2015

The flicker severity can be computed using the following equation:

$$P_{ST} = \left(\frac{d}{d_{Pst=1}}\right) \times F \qquad (14)$$

where

F is a shape factor (see Annex C). For motor-starting without inrush mitigation, a value of unity may be used for F.

Relative voltage change (d) can be evaluated as the ratio of load power change (ΔS_i) to the short-circuit power (S_{SC}). The following equation may be used for balanced three-phase loads:

$$d = \frac{\Delta V}{V_r} \approx \frac{\Delta S_i}{S_{SC}} \qquad (15)$$

For motor starting evaluation, ΔS_i is the maximum apparent power during the start.

For a two phase load (e.g., welding load), the following equation may be used:

$$d = \frac{\sqrt{3} \times \Delta S_i}{S_{SC}} \qquad (16)$$

For systems with low X/R (less than 5), use Equation (17) as follows:

$$d = \frac{R_L \times \Delta P + X_L \times \Delta Q}{V_r^2} \qquad (17)$$

The variable $d_{Pst=1}$ in Equation (14) represents the relative voltage change that will yield P_{st} value of 1.0 corresponding to the number of voltage changes per minute due to the load operation. This value can be obtained using the plot in Figure 5.

IEEE Std 1453 considers this formula to estimate voltage change "d" when X/R < 5

Also in IEC/TR 61000-3-7 : if the system X/R ratio of the system is low (e.g. less than 5), the relative voltage change should be calculated in a more precise way using the resistive and inductive part of the system impedance

Pst Limit & Voltage Change Limit

$$P_{st} = \left(\frac{d}{d_{pst=1}} \right) \times F$$

Pst limit = 0.35 based on IEEE Std. 1547 - 2018

$$0.35 = \left(\frac{d}{2.56\%} \right) \times 0.2$$

$$d < 4.48\%$$

Voltage change should be less than 4.48%

Example

5 MVA PV Project with unity power factor (PF=1) is connected to 13.2 kV circuit where short circuit at POI is 30 MVA and additional data (X/R) ratio is known (X/R=3.75)

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==========================================================================================================
 2. Bus Fault on:           0 Project1     13.2 kV 3LG
                                                      FAULT CURRENT (A @ DEG)
               + SEQ               - SEQ              0 SEQ             A PHASE            B PHASE            C PHASE
            1312.1@ -75.1       0.0@    0.0        0.0@    0.0      1312.1@ -75.1      1312.1@ 164.9      1312.1@  44.9
                                                      THEVENIN IMPEDANCE (OHM)
         1.50003+j5.61789   1.50003+j5.61789   1.50003+j5.61789

                SHORT CIRCUIT MVA= 30.0           X/R RATIO= 3.74519      R0/X1= 0.26701     X0/X1= 1.
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$$d = \left(\frac{\Delta V}{V}\right) \approx \left(\frac{\Delta S}{S_{SC}}\right)$$

Voltage change d = 75%*5/30 = 0.125 (12.5%)

Pst = 0.125 * 0.2/2.56% = 0.98 (FAIL – beyond 0.35 limit)

X/R < 5

$$d = \left(\frac{R_L \times \Delta P + X_L \Delta Q}{V_r^2}\right)$$

Voltage change d = (75%*5*1.5)/13.2^2 = 0.032 (3.2%)

Pst = 0.032 * 0.2/2.56% = 0.25 (PASS– less than 0.35 limit)

Is it difficult to obtain X/R Ratio Info ?

- Sample from ASPEN Oneliner's Short Circuit Output

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==============================================================================================
  2. Bus Fault on:           0 Project1     13.2 kV 3LG
                                                              FAULT CURRENT (A @ DEG)
          + SEQ                - SEQ                0 SEQ             A PHASE           B PHASE           C PHASE
        1312.1@ -75.1        0.0@    0.0         0.0@    0.0      1312.1@ -75.1     1312.1@ 164.9     1312.1@  44.9
                                                              THEVENIN IMPEDANCE (OHM)
       1.50003+j5.61789   1.50003+j5.61789   1.50003+j5.61789

          SHORT CIRCUIT MVA= 30.0          X/R RATIO= 3.74519     R0/X1= 0.26701     X0/X1= 1.
----------------------------------------------------------------------------------------------
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$$d = \left(\frac{R_L \times \Delta P + X_L \Delta Q}{V_r^2} \right)$$

With MVAsc and X/R ratio known, RL and XL can be calculated (1.5 + J5.6 Ohm)

- CYME and Milsoft Output

Proposed Action Items

Refine the calculation for relative voltage change:

1. For distribution system with X/R < 5 , use the formula recommended in the standard which consider the resistive and the inductive part of the system

2. If the above is not sufficient, another option for discussion:
   - Use special feature in a power-flow tool. For example: a commercial software has a feature to calculate sudden voltage drop/rise using power flow database; all the voltage regulation control should be disabled
   - Use the data and results from detailed time series study to test the idea