Are there methodologies and approaches to analyse the possible harmonic interactions and predict the scenarios with harmonic interactions?

Impedance based methods are used for many diagnosis purposes in power systems. This includes evaluation of SSR issues (network impedance calculations), torsional interactions (UIF calculations) and control interactions (impedance based evaluation). The impedance based method can be extended to evaluate the harmonic interactions as well.

The multi infeed interaction factor (MIIF) is a screening method that can be used to determine the possibility of fundamental frequency interaction between two HVDC systems. The possibility of interaction is determined based on the resultant voltage step chance at one HVDC terminal when a small voltage step change is induced at the other HVDC terminal by switching in a shunt reactive element. The voltage step change is applied at fundamental frequency. The formula for MIIF is given in Equation (1). When the HVDC terminals are electrically far apart the MIIF value approaches zero and values near one indicate the terminals are very close.

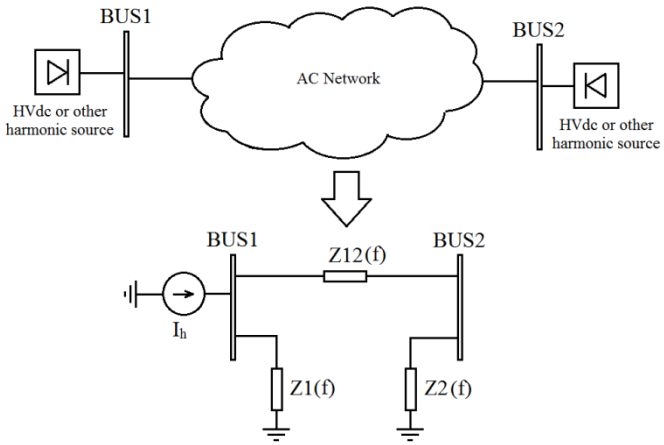
$$MIIF_{e,n} = \frac{\Delta V_e}{\Delta V_n} \qquad (1)$$

where

ΔV_e observed voltage change at bus e

ΔV_n observed voltage change at bus n

The impedance of any power system can be reduced to a two port network as shown in the following figure.



The MIIF which gives the voltage ratio can be rewritten using impedances as follows:

$$MIIF(f) = \left|\frac{Z_2(f)}{Z_{12}(f)+Z_2(f)}\right|. \qquad (2)$$

The MIIF can be calculated at any frequencies to evaluate possibility of harmonic interactions between two devices. However, MIIF only consider the voltage ratio and the current distribution is not considered (i.e. Z1 is missing in the equation). In order to account for variations in the impedance $Z_1(f)$, the MIIF equation can be modified by introducing an additional term. This additional term represents the ratio of current flowing towards $Z_2(f)$ to

the current supplied by the harmonic source. With this additional term the modified MIIF becomes a ratio of energy between the two buses:

$$\text{MIEIF(f)} = \left|\frac{V_2(f)}{V_1(f)}\right| * \left|\frac{I_2(f)}{I_1(f)}\right|. \quad (4)$$

This modified MIIF is designated as multi-infeed energy interaction factor (MIEIF). Based on the equivalent network shown in Figure 3, Equation (4) can be represented using impedances as:

$$\text{MIEIF(f)} = \left|\frac{Z_2(f)}{Z_{12}(f)+Z_2(f)}\right| * \left|\frac{Z_1(f)}{Z_1(f)+Z_2(f)+Z_{12}(f)}\right|. \quad (5)$$

The method is well explained in [1] and the process of harmonic impedance calculation which is typically done for any power electronic device at the planning stage can be easily extended for the calculation of the frequency dependent MIEIF.

[1] *N Denboer, C Karawita, M Mohaddes, Frequency scan based screening technique for harmonic interactions of HVDC systems, ACDC Conference,2017.*