LCL Filter Parameter Selection Using Graphical Method For a 13.8 kV ac 1.1 MVA 7-level Flying Capacitor Grid-Connected Converter Utilizing Variable Switching Frequency

Although the design procedure for LCL filters has been extensively discussed, existing methods often focus their consideration on 2-level or 3-level neutral point clamped converters, constant switching frequency, and passive damping. A graphical method to select the filter parameters is proposed and applied to 1.1 MVA 13.8 kV ac 22 kV dc 7-level flying capacitor multilevel (FCML) grid-connected converter based on 10 kV SiC MOSFETs. The new method accounts for any number of levels, any modulation scheme, variable switching frequency, and active damping. This graphical method can help designers gain insight into filter performance and iterate to select the optimal filter parameters.

Fig.1 demonstrates the core of the graphical method: the filter transadmittance $Y_{21[LCL]}$ is compared with the attenuation requirement plot $Y_{21[req]}$. The latter is obtained from the converter voltage spectrum generated by a time-domain simulation subtracted by the standard requirement (i.e. IEEE 519). If the transadmittance ($Y_{21[LCL]}$) has smaller magnitude than the attenuation requirement ($Y_{21[req]}$), the filter attenuation will pass the fulfill the requirements. On the contrary, if the filter transadmittance curve ($Y_{21[LCL]}$) is greater than the attenuation requirement curve in a specific frequency range, the current harmonics will exceed the standard limits at those frequencies. Fig. 1 also shows the grid current spectrum if the LCL parameters of $Y_{21}(LCL)$ are utilized, the dashed line represents the standard limits. It is possible to see at the frequencies the requirements cross the filter curves the harmonics magnitudes are exacerbated and does not fulfill the criteria. Note the attenuation requirement first valley is caused by the flying capacitor ripple while the second is caused by the output switching frequency of the converter. The valley magnitude will change depending on the flying capacitor ripple limit defined on the variable switching frequency scheme.

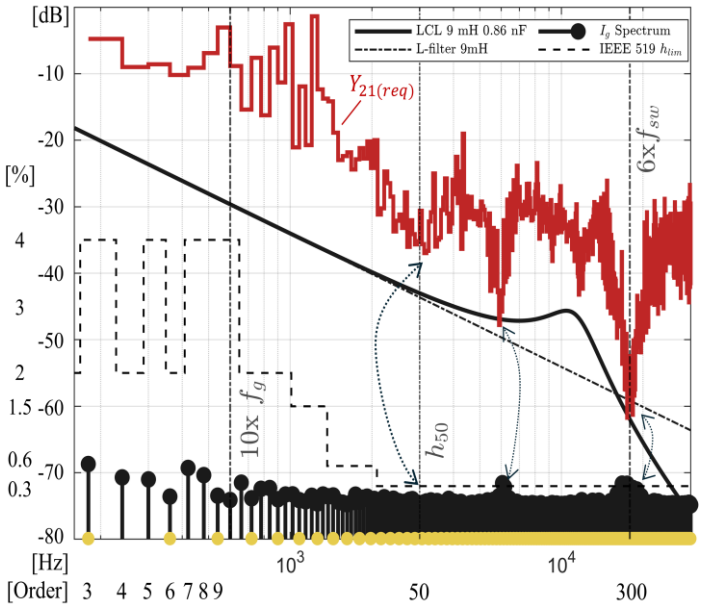

Fig. 2. Graphical Method Example (Red) Attenuation requirement $Y_{21(req)}$ (black line) LCL transadmittance $Y_{21(LCL)}$ (stem curve) current harmonic spectrum (dashed line) individual current harmonics limits as per IEEE Std 519.

To ensure that the filter design accommodates all operating conditions, the attenuation requirement is computed using the converter voltage virtual harmonic spectrum that is generated on the most stringent requirement (minimum magnitude) under various conditions, including different power factors and grid voltage levels. For the reasons described above, the graphical method can help designers gain insight into filter performance and iterate to select the optimal filter parameters.