Quick Insight Brief:
Harmonic Considerations for Inverter-Based Resource Installations

There is a growing number of installations of inverter-based resources (IBR), particularly transmission-connected wind and photovoltaic power plants. These resources are connected to the power system through a power electronics interface. One of the operational challenges of IBR is the increase in harmonic distortion. Based on emerging experience, voltage harmonic distortion has been trending upwards when there is a general increase in IBR and reduction in synchronous generators [1].

Other contributors escalating the trend include increasing nonlinear loads, loss of system dampening, and changes in system configurations. Recent research has also shown that a large increase in distortion is unlikely correlated to the IBR output [2]. Figure 1 below illustrates an IBR installation used for harmonic testing as part of the PV-MOD Project [3]. With this said, IBRs are often accompanied by long cables and large collector capacitance, which can increase the existing background harmonic distortion caused by transformers, load, and other harmonic sources.

IBR installations are typically required to provide reactive power support. However, because the IBR plant's reactive power capacity is limited, the reactive power must be provided externally—that is, by capacitor banks. These are often large capacitors connected to the substation medium-voltage collector bus. This configuration provides very little damping to any system resonances caused by this configuration. An example configuration from recent EPRI research (shown in Figure 2) illustrates this fact [4]. Each 34.5-kV collector circuit hosts a generation capacity of 75 MW. Each circuit terminates at a 34.5-kV collector bus where a 34.5-/161-kV, 80-Mvar interconnection transformer is present.

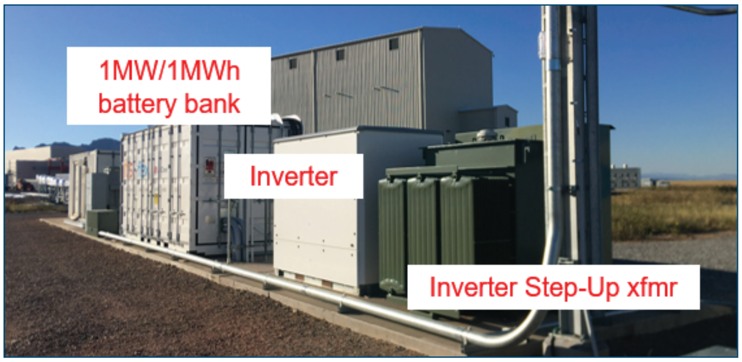

FIGURE 1. INVERTER HARMONIC TESTING AS PART OF THE PV-MOD PROJECT [3]

Impedance scans performed at the collector bus with one and two 9-Mvar capacitor banks in service are shown in Figure 3. With one and two 9-Mvar banks/buses in service, the impedance peaks (that is, the resonance points) occur near or at the 5th and 7th order harmonics (see Figure 3). As a result, the 5th and 7th order harmonic currents on the system are amplified—increasing both the background distortion and the harmonics produced by the IBR plant.

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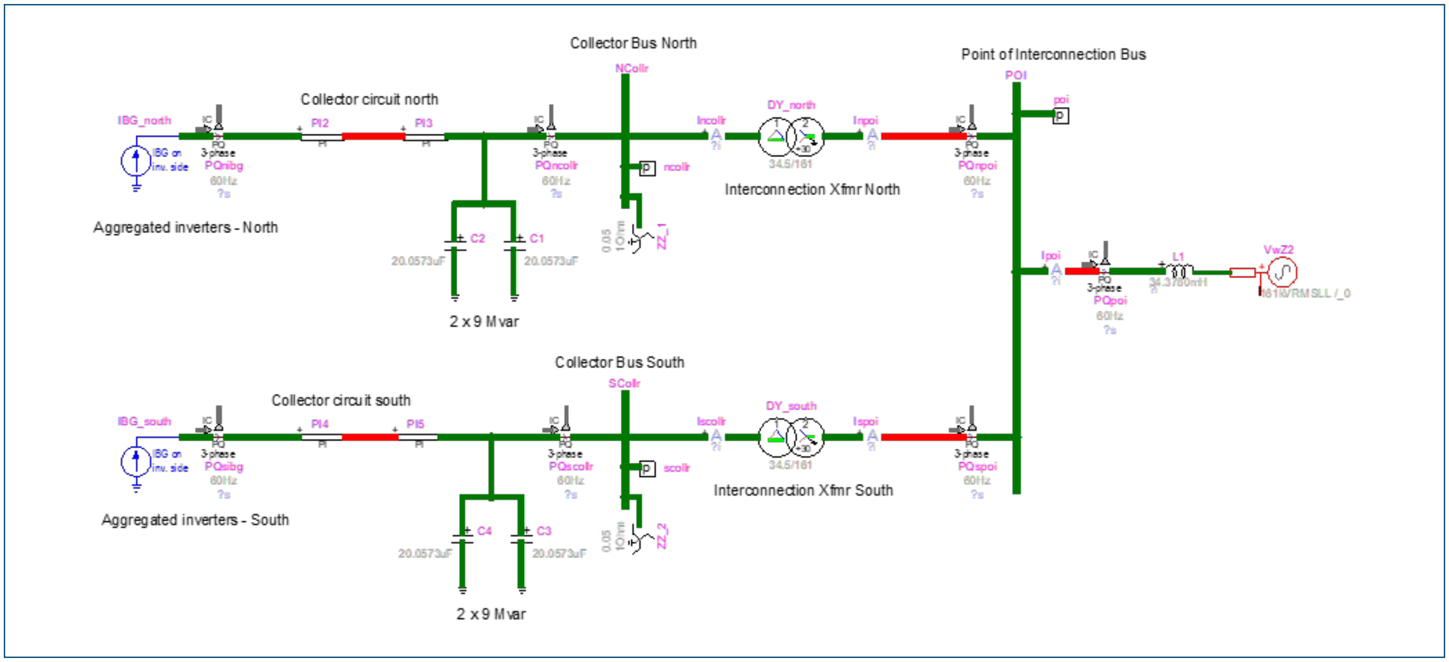

FIGURE 1. A ONELINE DIAGRAM OF A 150-MW IBR PLANT CONNECTED TO A 161-KV BUS

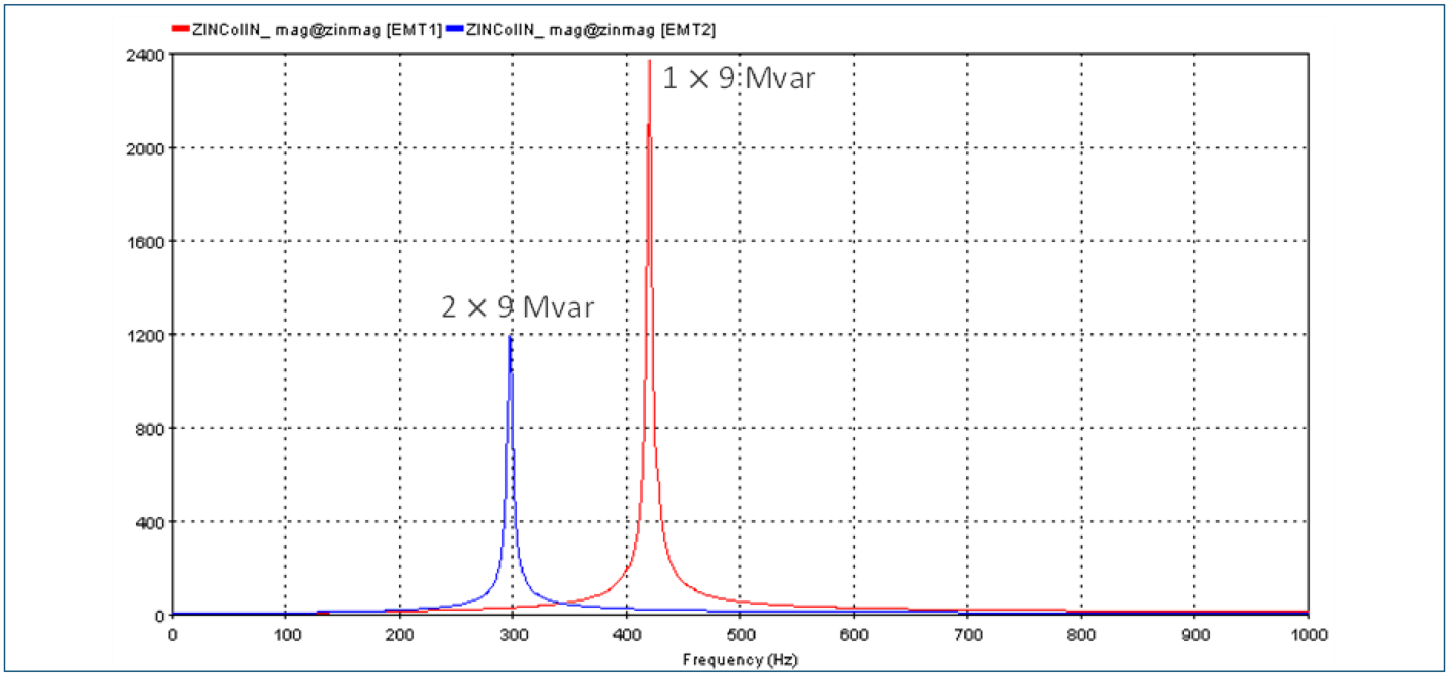

FIGURE 2. IMPEDANCE SCANS SEEN FROM A COLLECTOR BUS LOOKING INTO THE SYSTEM WHEN ONE AND TWO 9-MVAR CAPACITOR BANKS ARE IN SERVICE

The EPRI report [4] provides a way to address the abovementioned concerns through a methodology to design a harmonic filter that presents a stable and low impedance at high-order harmonic frequencies.

However, this issue is often discovered late, and then it becomes a question of who pays for the filters and where they should be located. Even if planning studies are conducted, the utility and the developer may determine that the plant meets the harmonic standards for today's grid and no filters are needed; however, Reference [4] demonstrates that replacing synchronous generation with IBR generation can alter the frequency response of the system—which may require a future filter or a change to an existing filter. In this case, the problem is not the fault of the IBR plant owner or the utility. Therefore, studies need to be considered that account for all possible dispatches of both the present and future systems.

Dealing with system voltage distortion is a shared responsibility between the utility provider and customer. Therefore, it is expected that both parties resolve harmonic voltages as efficiently and economically as possible. Provisions and studies conducted early in the process are both cost-effective and less time-consuming. EPRI's transmission harmonic planning research (P40D.B) provides tools and methods that can be easily implemented to deal with this growing concern. In addition, EPRI's participation in the PV-MOD project has been leveraging lab/field measurements to advance IBR harmonic modeling [4].

These new learnings could potentially be used to implement IBR plant conformity procedures that are being developed in IEEE P2800.2, Recommended Practice for Test and Verification Procedures for Inverter-based Resources (IBRs) Interconnecting with Bulk Power Systems [5].

In addition to the system voltage distortion issues, IBRs have shown a susceptality to capacitor switching. This is often referred to as transient immunity (or surge immunity in Reference [6]) Capacitor bank switching is one of the operations that IBRs should be immunized against and where spurious tripping has been observed in the field [1]. EPRI's transmission transient planning research (P40D.C) has developed guidance in applying EMT models in addressing this concern [7].

REFERENCES

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Transmission Planning

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