TECHNICAL BRIEF

# Roadmap for Adoption of Future Inverter Technology

## BACKGROUND

As the power system continues to evolve and there is an increase in inverter-based resources (IBRs), there could be a need to adopt future inverter technology and capability that could allow for operating a 100% inverter-based resource network in a safe, secure, and reliable manner. Such inverter technology has been labeled as grid-forming in certain industrial discussions.

However, power system operation can be considered to be a team sport where the responsibility can be expected to be spread around multiple participants. An improvement in stability, security, and reliability can manifest when each player contributes a little, in a beneficial manner and the entire burden cannot (and should not) fall on a most valuable player (MVP). Only under certain conditions, such as blackstart, there can be a need for an MVP.

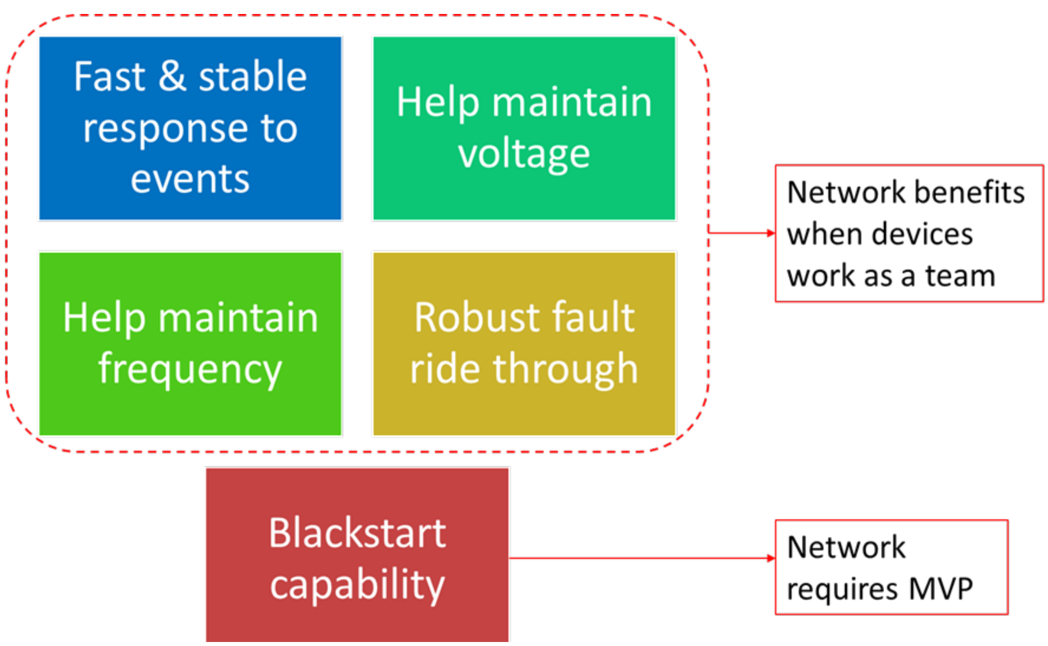



***Figure 1:*** *Devices working together to improve system stability, security, and reliability.*

Now, there are hundreds of GWs of IBRs presently in the interconnection queue for whom, utilization/delivery of full capability is either not required, or is optional (market product) and hence, it can result in a bit of underutilization of inverter capability. This underutilization of capability today can lead to an increased burden of capability provision on future IBR. Thus, the burden of maintaining stability, security, and reliability of power supply may fall only on few resources, which can subsequently require these few sources to be of higher rating and exceptionally robust. As a result, it can take longer for manufacturers to offer products in the marketplace.

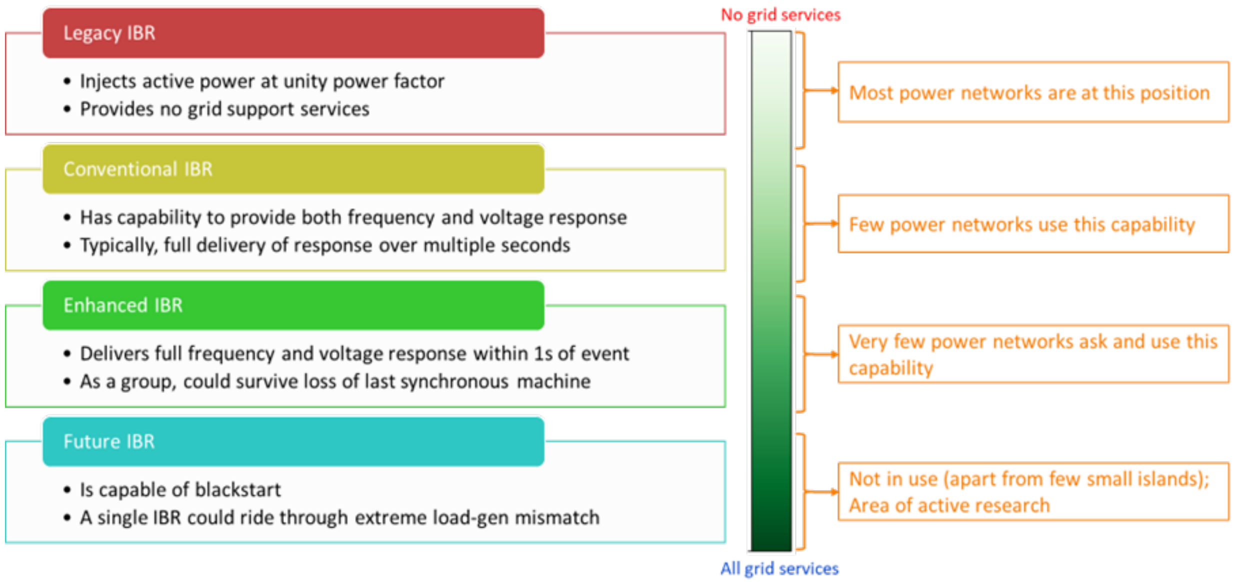


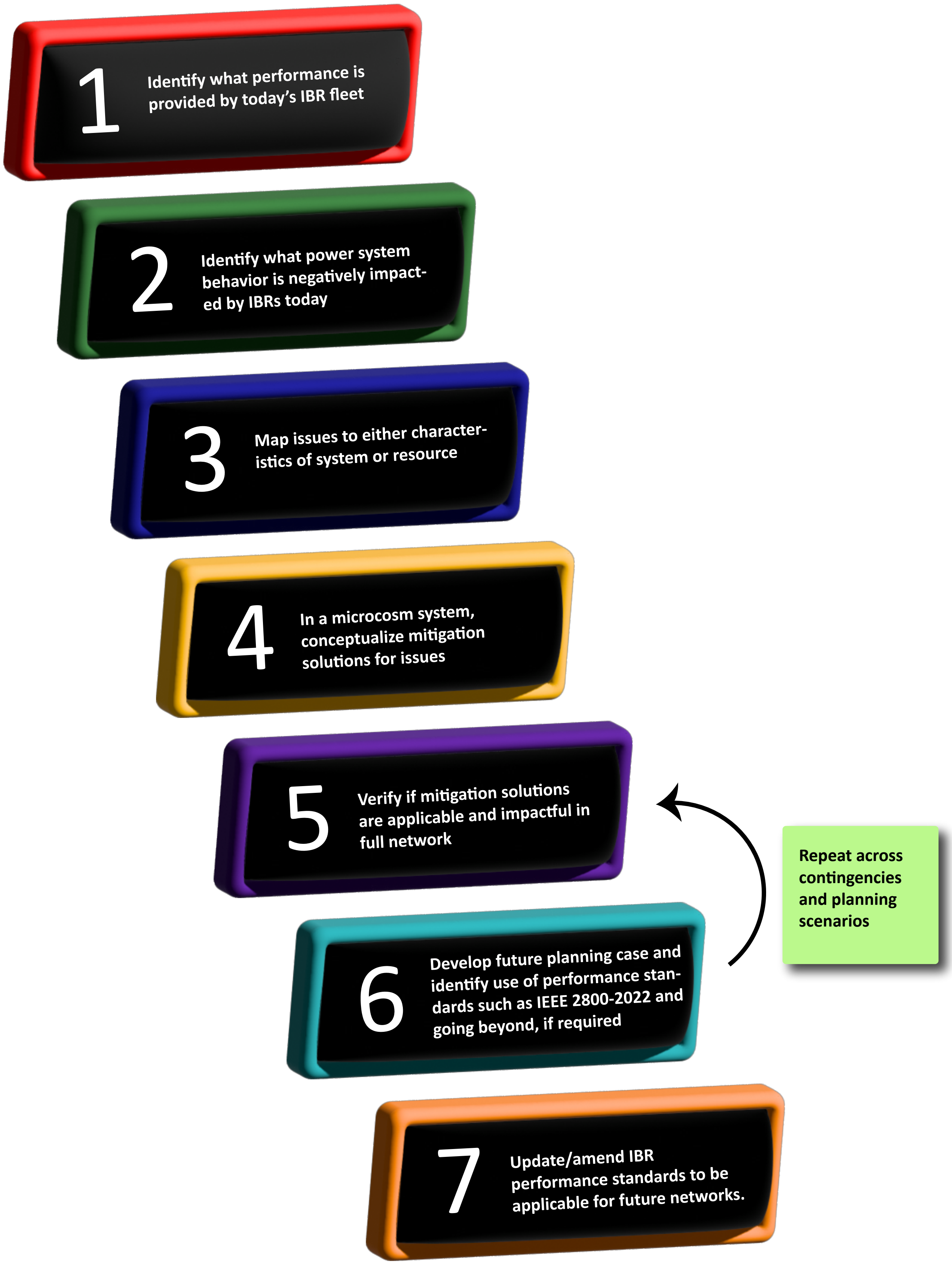

***Figure 2:*** *Underutilization of present inverter capability across power networks*

This scenario/condition where a few sources are expected to be of a higher rating and robustness to take upon the burden of ensuring stability, security, and reliability of the network can result in a challenging scenario requiring identification of location and size of these future IBRs. However, under this scenario wherein only a few sources are expected to shoulder the burden of the network, identification of location and size of these future IBRs can be extremely challenging and varied as it will depend on the characteristics of other resources within the network. Thus, it may be pragmatic to first identify the capability that can be enabled and utilized on the existing IBR fleet.

To aid in the need for identifying and adoption of such future IBRs, a step-wise approach is defined in this document.

## STEP-WISE APPROACH

At a high level, the various steps in this approach can be shown as in the figure.



Each step can be expanded upon more as follows:

**Step 1:** Document capability and expected performance to be delivered by IBR fleet that is presently connected to the network. This capability and performance can be broadly categorized as response to:

- Small signal voltage changes
- Small signal frequency changes
- Large signal voltage changes
- Large signal frequency changes

Here, it is important to make a distinction between capability that is presently enabled and is being utilized versus capability that is available, but is not presently being utilized. Based on utilization of capability, the IBR can be classified either as legacy, conventional, or enhanced.

**Step 2:** Identify and document all issues observed presently with IBRs in the system under study. These issues can be related to stability and/or fault ride through capability. It is possible that some issues may have only been observed in planning simulation studies while some issues may have also been observed in operations.

**Step 3:** Prepare an initial evaluation of potential causes for these issues to identify if the potential causes are:

- because of characteristics of the system
- because of characteristics of the resources
- both

It is acknowledged that identification of these causes may not always be straightforward and multiple causes could be applicable.

**Step 4:** For each cause/scenario identified in the step above, conceptualize a mitigation solution that could be first tested in a microcosm system. Such an exercise can result in identification of a common mitigation solution that could be applied for multiple causes. The mitigation solution is expected to be based on delivery of specific performance and provision of services to the network rather than use of industry terminology/buzzwords.

**Step 5:** Verify that the conceptualized mitigation solution is relevant and applicable to the network under study through carrying out dynamic studies. Here, few options are possible:

- assume that performance capability and characteristics of existing IBR fleet remains unchanged and any mitigation solution is only through additional transmission asset(s) being deployed. Here, transmission asset(s) include FACTs devices and/or synchronous condensers. In this option, mitigation solutions from generation/load asset(s) are not considered.
- for existing IBR fleet, if information is available regarding unused capability that can be enabled (ignoring economic component at the moment), and if such unused capability aligns with the mitigation solution, then activate such capability in existing IBR fleet. Such an option can be interpreted as an IBR transitioning from the legacy/conventional category to the enhanced category.
- pick asset(s) from existing generator interconnection queue for adoption of mitigation solution, while keeping performance and capability of other IBR resources unchanged. Here, load asset(s) could also be considered. Further, asset(s) that have already been approved to be built, but have not yet been built/commissioned, could also be considered.

It is assumed that at least one from the above provided options would be successful in providing a solution to the issues identified. If any one solution by itself is helpful in improving performance but not sufficient as a complete solution, a combination of the above solutions can and should be considered.

**Step 6:** Through the use of load and generation projection trends, renewable targets, and other such information, extrapolate "type" of source in the network for a future case (X-year planning horizon).

- For such a future case, first ensure development of a viable power flow solution.

- If a relevant industry performance standard exists (such as IEEE 2800-2022 or similar), then identify if performance requirements from such a standard are expected to be adopted by these future resources.
  - Also identify which performance requirements are expected to be mandatory and which are expected to be optional, while attempting to align with the response categories in Step 1.

  It should be noted that the existence of a standard does not automatically imply its applicability in a region. Many standards related to performance requirements of resources are voluntary in nature. Hence, ensuring applicability of adoption is critical.
- Repeat scenarios/contingencies in Step 5 to ascertain stable and reliable performance of the network. Here, a comparison can be made between utilization of only mandatory performance requirements versus utilization of both mandatory and optional performance requirements.
- Identify any additional scenarios/contingencies that can stress this future case (such as islanding and system separation). These additional scenarios/contingencies could be unique to the future planning horizon case as criticality of contingencies can change with change in resource mix.
  - With performance defined for IBR fleet based on relevant and applicable industry performance standards, evaluate capability of the network to withstand these additional scenarios/contingencies.
  - Here again a comparison between utilization of only mandatory performance requirements versus utilization of both mandatory and optional performance requirements can be carried out.
- If successful, repeat with either a higher renewable target or additional stressed conditions/scenarios.
- If not-successful, repeat with more advanced features and capability from IBR resources. This capability could imply that the IBR is now classified as a future IBR.

**Step 7:** If it is identified from the previous steps that existing relevant and applicable performance standards are not sufficient, then the performance obtained from the successful mitigation solution (through advanced future IBR technology) could be used as a reference to bring about updates in the standards for performance expectations from IBRs in a future grid.

At the end of this approach, it is expected that a more informed picture would be obtained with respect to the required ability of IBRs in a future network, and the expected services that can be required from these devices to further improve the stability, security, and reliability of the network.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