Whitepaper:

Description of Inverter Penetration SCR (IPSCR) Metric for Quantifying System Strength in Large Networks

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1 Background

A new collective short circuit strength metric is proposed which attempts to provide relative system strength quantification for large power grids with many Inverter Based Resources (IBRs) connecting. The key concept of this new metric, termed Inverter Penetration Short Circuit Ratio, or IPSCR, is that the short circuit strength which is available within a certain region may come from a combination of conventional sources and IBRs. As the proportion of the generation mix moves towards IBRs, the IPSCR calculated will fall, indicating an overall weakened system. This metric has been tested in the ATC system with some success.

2 Introduction to SCR Based Metrics

The NERC guideline on integrating IBR is a valuable source of information regarding emerging issues related to increasing penetration of IBR. The following sections, taken from the Executive Summary of this guideline, provide introduction to weak systems and SCR based metrics[1]:

Grid strength is a commonly used term to describe how "stiff" the grid is in response to small perturbations such as changes in load or switching of equipment. While strong grids provide a stable reference source for resources, weak grids can pose challenges for connecting new resources and particularly for connecting inverter-based resources. These resources rely on an adequate grid strength (relative to the size of the resource) for synchronizing the power electronics. In addition, inverter-based resources do not provide significant levels of fault current. While these issues alone do not pose a reliability risk, existing control, and protection paradigms need to be adapted to accommodate these changing characteristics from the generation fleet.

The SCR metric is most appropriate when considering a single inverter-based resource interconnecting to the BPS. It does not account for the presence of other inverter based resources or power electronic-based equipment. Additional SCR-based metrics have been developed by industry to address the presence of multiple inverter-based resources, and should be considered accordingly for each system being studied. Each SCR-based metric has potential benefits and drawbacks in its application …. In general, SCR-based metrics should be used by planners, manufacturers, and developers to obtain a high level understanding of area system strength. The relative impact the inverter-based resource (s) will have on the larger power system is assessed with more detailed studies using specific knowledge of the equipment (from the manufacturers and developers) and the network (from the planners) to confirm whether the plant will work correctly.

The following is a short description of two popular metrics:

Short Circuit Ratio (SCR)

[1] NERC Guideline, "Integrating Inverter-Based Resources into Weak Power Systems," June 2017

The traditional SCR metric is most appropriate when considering a single IBR resource connecting to the grid. It does not take into account other nearby IBR. It is calculated according to this formula:

$$SCR = \frac{SCMVA_{POI}}{MW_{IBR}}$$

Where $SCMVA_{POI}$ is defined as the Short Circuit MVA at the Point of Interconnection (POI), and MW_{IBR} is defined as the MW rating of the Inverter Based Generator (IBR) being considered.

Weighted Short Circuit Ratio (WSCR)

WSCR takes into account multiple IBR resources connecting at various SCMVAs, but assumes that all resources are interconnecting at the same location. For this reason WSCR will provide overly conservative results when there is significant electrical distance between the plants. Another potential drawback to WSCR is that a firm border must be drawn regarding which IBR resources will be included in the calculation and which ones will be left out, and the precise location of this border can have dramatic influence on the resulting WSCR value. The WSCR calculation for 'N' IBR resources is calculated according to this formula:

$$WSCR = \frac{\sum_i^N SCMVA_{IBR\ i} * MW_{IBR\ i}}{(\sum_i^N MW_{IBR\ i})^2}$$

3 Inverter Penetration SCR (IPSCR)

3.2 Background and Calculation of IPSCR

The IPSCR metric can be thought of as way to evaluate how much of the local system SCMVA comes from inverter based resources[2]. IPSCR has potential as a screening tool to provide planning and operating engineers with information about which areas of the system may be at risk of "weak grid" issues. IPSCR has two key properties which improve its usefulness over existing metrics such as WSCR in large networked systems:

1. IBR resources are naturally grouped together according to the electrical distance between them without requiring a defined boundary, making IPSCR a convenient metric for analyzing meshed networks of IBR.
2. An IPSCR value can be assigned to any bus in the transmission network and calculated based on local electrical properties. This property enables the creation of contour (or heat) maps of the analyzed system, where regions of concern can be visually identified.

The following methodology is used to calculate IPSCR at every bus of interest:

1. Starting from a base case with all conventional generation and IBR in service (Case A), create new case where all IBR is turned off (Case B).
2. From Case A, create another case in which all conventional generation is turned off (Case C).

[2] Note that the actual short circuit contribution from each IBR resource is approximated as 1 pu for the sake of consistent application of the metric.

3. In Case C, tune Xsource of IBR until all IBR contributes about 1 p.u. SCMVA at their POI's (p.u. SCMVA based on the IBRs rated MW capacity)[3].
4. In Case B and Case C, find the SCMVA at all buses of interest.
5. Calculate IPSCR as $\frac{SCMVA_{Case\ B}}{SCMVA_{Case\ C}}$ at all buses of interest.

The IPSCR algorithm was implemented in PSS/E Version 33.12. In the case of this analysis, IPSCR was calculated at all transmission level buses connecting IBR to the bulk power system. Using the 'Diagram Contour' feature in PSS/E, the resultant IPSCRs were then displayed on an SLD containing only these buses.

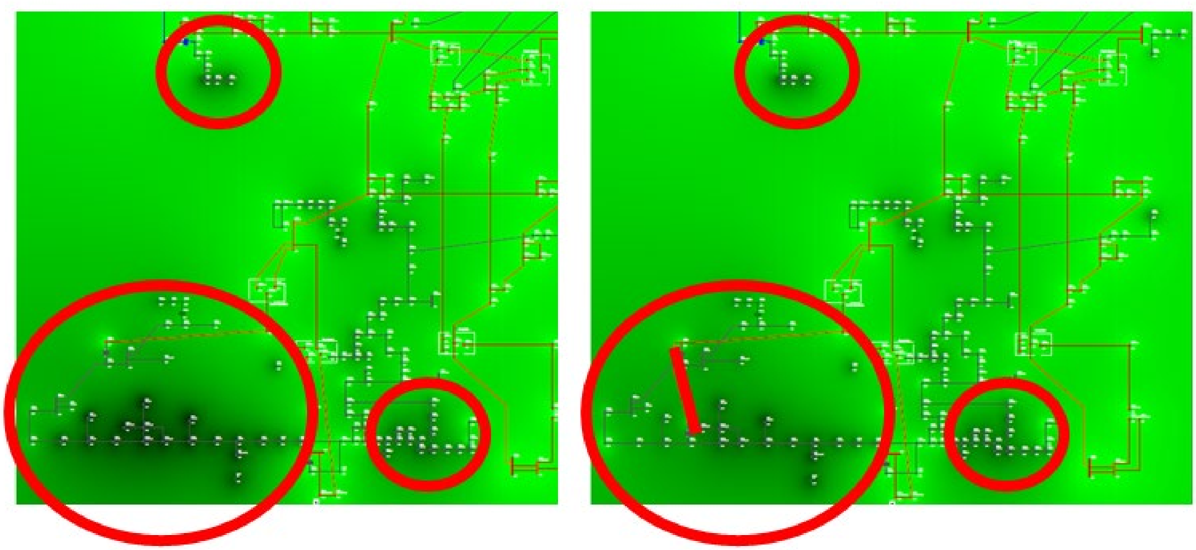

Figure 1: IPSRC Contour Diagram showing lower IPSCR values as darker green. The second map shows the impact of a new transmission line on IPSCR values.

3.3 Limitations of IPSCR

Like other SCR based screening metrics, IPSCR should be used only as a screening tool, and any thresholds used for screening should be tuned according to the specific system requirements and the current state of the art in IBR technology. SCR based metrics, including IPSCR, do not account for the effect of local load in offsetting heavy power flows. Heavily loaded lines can exacerbate weak grid issues because conventional voltage stability limits of the lines can make voltage control more difficult, and compound with the weak-system stability of IBR. Conversely, reducing line flows by offsetting generation with local load can in some cases allow IBR to operate at very low SCRs.

[3] Each IBR should contribute fault current proportional to its rated MW capacity in order for large IBR plants to have a greater effect on IPSCR than small IBR plants. Assuming that IBR contributes approximately 1 p.u. fault current based on their rating has the additional benefit of IPSCR approximately being equal to SCR at the IBR POI when IBRs are separated by large electrical distances. Note that this fault current assumption is a relatively arbitrary assumption which provides a baseline and allows the metric to work. In actual fact, IBR fault current depends on many factors, including converter topology, fault location, and other things.

Additionally, SCR based metrics are not currently reliable in predicting behavior of extremely high renewable penetrations (eg. approaching 100%), nor do they account for the potential ability of controls to be specially designed to operate better in these types of systems. The IPSCR metric is an extension of existing system strength based metrics which assumes increasing penetration of conventionally controlled IBRs.