Provision of Short Circuit Level Data

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A System Operability Framework Document

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Purpose

This paper explores options for how to define and reference short circuit level (SCL) for new and existing connections to the GB electricity system. This is required as more non-synchronous generation connects to the electricity system, alongside a reduction in traditional synchronous generators, impacting system stability.

In this short paper we describe why short circuit level is important and explore several options as to how short circuit requirements could be defined for new and existing generation. We are seeking feedback from industry as to which of these options provides the optimum solution for defining short circuit level. This will allow both the ESO and Transmission Owners (TOs) to design an optimum network and for the developers connecting to the network to understand the full range of short circuit conditions that their generation needs to remain stable.

We are seeking feedback on this paper by 31st March 2022 and we plan to discuss further via industry forums and webinars. We plan to publish conclusions and approach by the end of May 2022.

Background

Short Circuit Level (SCL) is the amount of current that flows on the system during a fault. These faults can be caused by a lightning strike, weather conditions or equipment failure. During the fault, the system can see a direct connection to the earth and current flows from all sources into it. When SCL is low, any voltage change causes a bigger disturbance which travels further throughout the system. If left unmanaged, these disturbances could trip generation or make the whole system unstable, which could damage equipment. Similarly, if SCL is too low the network protection, which opens circuit breakers to protect the system, could miss that a fault is happening and leave the network in an unsafe and unstable condition. Therefore, the lower these levels are, the more likely that the system is to experience significant voltage excursions, stability problems, power oscillations, or fault ride through issues following a disturbance.

Large coal and gas generators typically create five times more fault current compared to wind and solar. A 100MW generator would provide in the region of 500-700 MVA of SCL. Wind farms are limited by the rating of their electronic components so the same level of generation may provide only around 100MVA of SCL. As synchronous generation continues to be displaced by non-synchronous generation, and with much of the new generation capacity located offshore, system strength, and subsequently short circuit levels, will drop. It is therefore necessary that Transmission Licensees have sufficient reinforcement plans and ancillary service contracts in place so that they meet their obligations under the Grid Code and the Security and Quality of Supply Standard (SQSS). It is also essential that the ESO and TOs provide enough information for transmission system users to allow them to identify any risks and any necessary mitigation measures so that they can continue to meet their technical obligations in general and their fault ride through requirements in particular.

A description of the data that is already being provided by the ESO, emerging issues regarding declining SCL and the potential options for further data provision are summarised in the following sections. This paper should highlight the issue to the industry, and we wish to seek further feedback from industry participants on the potential options available.

Data currently provided by the ESO

National Grid ESO currently provides SCL data through several distinct routes; the Electricity Ten Year Statement (ETYS), the Connections process, and under clause PC.A.8 of the Grid Code[1].

[1] https://www.nationalgrideso.com/document/162271/download

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Electricity Ten Year Statement (ETYS)

Since its inception, the ETYS has included maximum SCL data at all system nodes. These are estimates of the maximum fault levels that could be seen at each node. Maximum SCL is used when assessing the ratings of circuit breakers and when performing protection studies. It is estimated with conditions on the transmission system set to maximise the fault infeed including:

- National demand set to its peak value,
- An intact transmission system,
- All generation plant is assumed in service, and
- The system voltage profile is set according to G74.

Since 2019, ETYS has also included an estimate of SCL for the current year (year 1) at all system nodes at the time of the minimum system demand[2]. This provides a general indication of system strength at minimum demand compared to that at peak demand. This approach does not consider specific nodes in detail, rather it is estimated with conditions on the transmission system set to reflect a typical operating minimum demand arrangement including:

- National demand set to its minimum value,
- An intact network is applied,
- Only generation that is required to meet the minimum demand is synchronised.
- A typical system voltage profile is applied.

Connection process

During the connection process, and to enable Users to carry out necessary design studies including fault ride through assessment, TO will provide each User with minimum pre and post-fault level information. This provides data about a credible minimum system strength that the User's plant is expected to experience calculated at the time of the connection agreement. Similar to ETYS, this fault level information considers load and generator patterns for a summer minimum scenario. Further assumptions are made to calculate this value, including:

For the area close to the User's plant:

- Local generation adjacent to the User's connection, is assumed unavailable/not providing short circuit contribution,
- An onerous, credible local maintenance outage pattern, and
- An additional onerous fault outage that is required to be secured by the National Electricity Transmission System (NETS) SQSS.

For the wider system:

- National demand is set to its minimum value,
- A typical system wide outage pattern is applied to the network,
- Regular operational outages (e.g. voltage control circuits) are taken into account,
- Only generation that is required to meet the minimum demand is synchronised.
- A typical system voltage profile is assumed.

Emerging issues and proposed options

SCL has been traditionally used as a proxy to system strength. The displacement of synchronous generation by inverter-based generation means we have to investigate whether the SCL is still the right measure for system strength. In particular, the impact of inverter-based generation on calculating SCL is an area of uncertainty with various methods to assume their contributions as explained later in this paper.

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[2] https://www.nationalgrideso.com/document/181476/download

If unmanaged, a continual decline in system strength could result in an eventual decline of SCL below the minimum levels that were used to design some of the plants connected to the network. This will eventually necessitate that some action is taken by Transmission Owners and by the ESO to ensure that obligations in relation to system stability are met. Additionally, Offshore Transmission Owners and Transmission System Users will need to ensure they continue to meet their obligations on system stability and fault ride through. Traditional SCL calculations may not provide sufficient information to users to assess their compliance with requirements. It is therefore necessary to look at other indices that may be used instead of, or in conjunction with, the SCL to allow such assessment to take place.

The short circuit ratio (SCR) is traditionally used as the primary index for assessment of the system strength of the connection point when considering a single inverter-based resource connecting to the power system. It is defined as the ratio of the short-circuit MVA capacity at the busbar in the existing network before the connection of the new generation source to the rated megawatt value of the new connected source.

If SCR is low, the system is weak and very sensitive to active/reactive power injections (or absorptions). It is therefore difficult to stabilise the system voltage on a weak system. When SCR is high, the system voltage is less sensitive to active and reactive power injections (and absorptions).

Traditional SCR does not account sufficiently for the presence of nearby 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. For example, CIGRE gives a general equivalent circuit-based approach, termed as equivalent circuit-based short circuit ratio (ESCR). This is presented for calculation of the short circuit ratio for any given wind power plant (WPP). When more than one WPP is connected to a power system, electrically close to each other, the short circuit level of the network in the region is shared between these WPPs. Hence the network strength, seen from one WPP is significantly less than the network short circuit level calculated at the bus. CIGRE gives the definition of ESCR:

$$ESCR_i = \frac{S_i}{P_{WFi} + \sum_j (WPIF_{ji} \times P_{WFj})}$$

Where S_i is the ratio of the short-circuit MVA capacity at the busbar in the existing network before the connection of the new generation source,

P_{WFi} is the rated megawatt value of the new connected WPP.

$WPIF_{ji}$ is the wind plant Interaction factor and defined as:

$$WPIF_{ji} = \frac{\Delta V_i}{\Delta V_j}$$

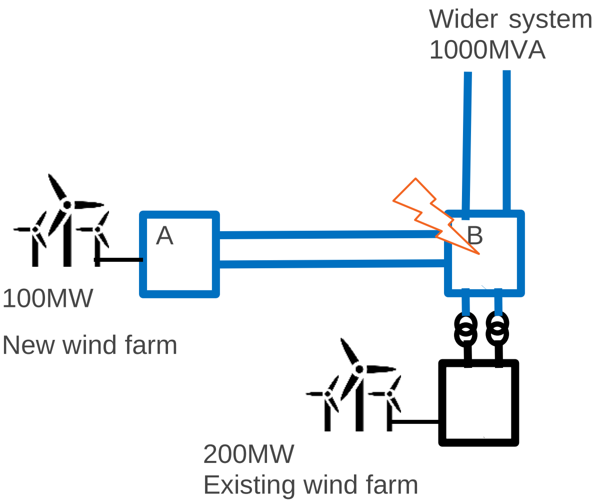
Where ΔVi is the voltage changed observed on bus “i” for a small voltage change at bus “j”. Bus “i” and bus “j” are the buses where the WPPs connect to the transmission system.

Two other approaches referred to as composite short circuit ratio (CSCR), and weighted short circuit ratio (WSCR) are presented and compared against ESCR. Each SCR-based metric has potential benefits and drawbacks. Further detail can be found in CIGRE technical brochure 671[3].

Below, we present four potential SCR-based options to calculate system strength for connection design and compliance. An example network (Figure 1) is used to demonstrate the options. In this example, a new 100MW wind farm is connecting to the network. At the same connection point, an existing wind farm with a rating of 200MW is already connected.

[3] https://e-cigre.org/publication/671-connection-of-wind-farms-to-weak-ac-networks

Figure 1: *An example network*



Option 1: Existing windfarm contribution based on inverter rating

For this option, the contribution of the SCL from existing windfarms is considered to be their inverter rating.

The short-circuit MVA capacity at the bus in the existing network before the connection of the new generation source = SCL for wider system + contribution from existing wind farm = 1000+200=1200MVA

SCR = SCL/the rated megawatt value of the new connected source = 1200/100=12

Option 2: No SCL contribution from grid following inverter

For this option, the contribution of the SCL from existing windfarms are ignored.

SCL=1000MVA; SCR=1000/100=10

Option 3: Considering negative contribution from existing inverter based on its minimum short-circuit ratio (MSCR) requirements (available short circuit level)

This option assumes that a Grid Following inverter will consume short circuit level which is only provided by synchronous machine and Grid Forming inverter. The total consumption will depend on the rating and the minimum short-circuit ratio of the inverter, which is the lowest short circuit ratio that the inverter requires at its connection point to maintain code compliant performance.

In this example if MSCR 3 is assumed for the existing windfarm, the available SCL=

1000-200*3=400MVA

SCR= 400/100=4

Option 4: Considering equivalent circuit-based short circuit ratio (ESCR)

Assuming wind plant interaction factor $WPIF_{ji}$ is 1, ESCR=

SCL/ [MW of new wind farm+(WPIF * MW of the existing)] = 1000/[100+(1x200)] = 3.3

Table 1 compares the results of these 4 options, where Option 4 presents the lowest resulting value

Table 1: Comparison of results calculated via different options

Option	SCL(MVA)	SCR
1	1200	12
2	1000	10
3	400	4
4	1000 or 333	3.3 (ESCR)

Discussions and ongoing work

As a higher proportion of our generation is coming from renewable generation, we are beginning to see lower SCL on the system, creating potential operability challenges. Grid stability is underpinned by obligations in both the Grid Code and the NETS SQSS and these obligations are shared between Network Users, Transmission Owners, and the ESO. Due to the changing, dynamic nature of the NETS, all parties will be required to review whether their ability to meet the requirements are affected, whilst continuing to satisfy the Grid Code and SQSS requirements.

Traditionally we have had the required level of SCL from all the generation that is running to meet the energy needs of the country. As we're now seeing a shortfall in SCL in some areas we need to look to top up our SCL from other sources.

We are currently working to manage low SCL issues through our NOA Stability Pathfinder projects. We have identified areas of the network where additional support is needed and we're reaching out to Transmission Owners and commercial parties to provide us with additional short circuit current support. There could also be some scope for additional strategic investment by TOs or the deployment of balancing services by the ESO on a long-term basis to increase the short circuit level within a specific area to provide additional support for multiple generation connections where it is economic to do so. Any incremental contributions to SCL from these projects will be taken into account when providing system strength data to Users.

The actions TO and ESO take to meet the requirements on voltage control, frequency control, stability, and protection are likely to affect the SCL and the system strength. As a minimum, the effect of these actions will be reflected in any data published or provided to a User. However, there could be additional merit in

- Identifying if there is a minimum level of system strength that will be required to be maintained at all Grid Entry Points on the system.
- Assessing if the use of this minimum value by all Users to specify their equipment provides sufficient certainty for the plant design without being too onerous for some Users who may not experience such a weak system by virtue of their location.
- Evaluating whether this minimum value could be specified in Grid Code to give certainty and clarity on what SCL level would be maintained at Grid Entry Points.

We will continue working with industry to explore whether there is a merit to define minimum short circuit level in Grid Code and how it is best specified.

We are also introducing a non-mandatory grid forming technical specification to the Grid Code[4], as well as working to design a future stability market to make sure these needs are met. Part of these solutions are likely to include Synchronous Condensers. These are similar to a traditional coal or gas generator, but can provide stability services such as SCL, without the active power injection and need to burn CO2 emitting fuels. We are

[4] https://www.nationalgrideso.com/industry-information/codes/grid-code-old/modifications/gc0137-minimum-specification-required

also exploring SCL and stability support from wind, solar and batteries with grid forming capability as defined in the ongoing Grid Code specification. These activities should allow all technologies and providers to compete to drive innovation and get the right level of SCL at the lowest cost.

Feedback required

In this paper we have discussed the current provision of SCL data, and the operability challenges caused by reducing SCL. Current SCL data may not be adequate to qualify the strength of the network, especially where new inverter-based generators are connected. Transmission system users such as wind farms may expect a more specific indicator to show how strong the network is to take the new generation.

The aim of this paper is to share with industry the options we are considering for calculating the strength of the network, the work ongoing to manage this issue and the potential need for specifying the minimum short circuit level in Grid Code for user connection.

We welcome feedback from industry on the topics discussed in this paper, specifically regarding SCL data provision options and whether an absolute minimum short circuit level should be established. Any feedback received will help us to better quantify and share system strength information in future.

Please send any feedback to SOF@nationalgrideso.com.

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