

STATKRAFT / ELECNOR / ANDRITZ
Feedback to Eirgrid SCU Grid Code Modification
(particularly related to clause SCU 1.4.6.3)

1. Background

On behalf of Statkraft, Elecnor and ANDRITZ, Statkraft submitted feedback to the System Operator on the proposed SCU Grid Code modification on May 17th, 2024. Within that feedback we raised concerns in relation to SCU1.4.6.2 (now SCU 1.4.6.3) that in our view there was little benefit to the System Operator in requiring SCUs to inject reactive power during extreme high voltage transmission system conditions nor to absorb reactive power during extreme low voltage transmission conditions, when it is precisely in the interest of the transmission system to do the opposite (i.e. absorb reactive power during high transmission system voltage and inject reactive power during low transmission system voltage).

We acknowledge the TSO's response to industry feedback related to this clause that was subsequently published on 26th July 2024:

"The TSO may take proactive actions to drive up or down voltage based on upcoming actions on the transmission system, for example, increasing voltage before disconnecting another device."

We further acknowledge subsequent feedback received from the System Operator via Melissa Dunne on 1st December 2024:

"With regards to the feedback from Andritz/Elecnor re SCU Reactive Power Capability, the TSOs expect all technologies connected to the transmission system to have the rectangular capability in order to assist in managing the extreme cases, i.e. in times of severe system stress where you may need to push voltage in one area extremely high or low to mitigate the opposite problem in another area. We may also take proactive actions to drive up or down voltage based on upcoming actions on the transmission system, for example, increasing voltage before disconnecting certain plant/apparatus. And the ACER requirements allow for same."

We still have reservations with this rationale and will provide techno-economic reasons in Section 2 and Section 3 of this report as to why this position should be reconsidered by the System Operator and the Regulatory Authority. However, we also want to raise a related but previously unraised concern that the proposed clause as currently as written is ambiguous when it comes to the expected capability for SCUs beyond this minimum Grid Code requirement.

For example, an SCU contracted under the LCIS Arrangements is incentivized to provide reactive power capability ≥ 0.9 p.u (lagging) and ≤ -0.6 p.u. (leading) in order to achieve the maximum possible Reactive Power Product Scalar. In the absence of any explicit clarification, a likely default interpretation of the Grid Code for such an SCU could be that the reactive power capability at ≥ 0.9 p.u (lagging) and ≤ -0.6 p.u. (leading) must be provided along the entire voltage range (i.e. from 0.9 p.u. to 1.114 p.u. for a 220kV connection). This is represented by an extension (red dashed line) of the proposed rectangular grid code requirement as shown below.

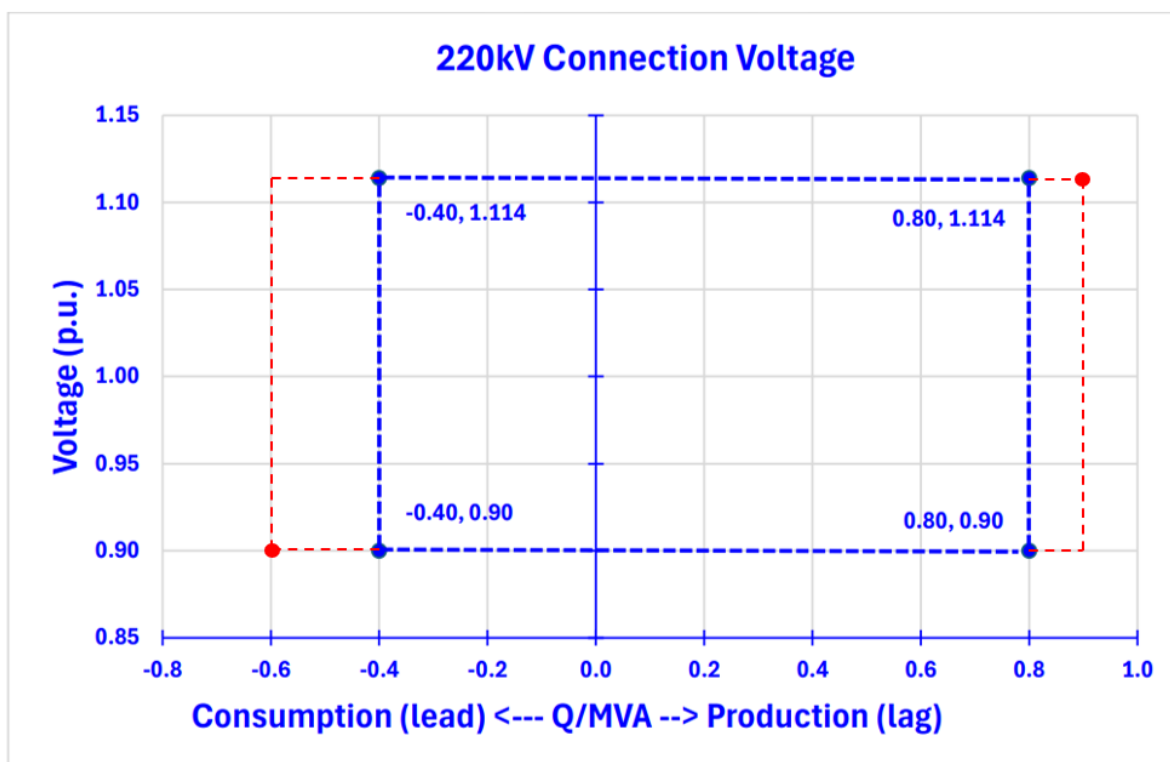


Figure 1 – Possible default interpretation for SCUs that can provide a greater reactive power capability than the minimum Grid Code requirement

2. Techno-Economic Considerations

In addition to the limited benefit that we see to the System Operator in retaining this requirement for this extended region, there are well founded techno-economic reasons as to why a simple linear extension of the proposed rectangular Grid Code requirement should not be implemented. In particular:

- The natural behaviour of rotating machines more closely follows the transmission system's needs (i.e. higher capability to inject reactive power into the system during undervoltage conditions and so increasing the voltage level; and absorbing reactive power during overvoltage conditions and so decreasing the voltage level)
- The operational points shown in red at the top right (max voltage, max var) and bottom left (min voltage, min var) of the extended rectangular box in Figure 1 are challenging for thermal and stable operation of a synchronous condenser machine.
For example, to meet the top right corner in the over-excited range, an SCU would need to operate with an overvoltage (e.g. >1.05 p.u.) on the SCU machine terminals. Similarly, to meet the bottom left operating point in the under-excited range, the SCU would need to regulate to a higher than nominal target voltage on the SCU machine terminals (e.g. >1 p.u.). These are not ideal operating conditions from either an SCU or System Operator perspective.

Therefore, the only option to comply with the requirement at these extremes indicated in Figure 1 would be to either oversize the synchronous machine and/or oversize the power transformer neither of which is economical to do. It is also important in this context to recognise the difference that exists between units that produce Active Power and units that do not produce Active Power (e.g. SCUs).

A report on the *Design Aspects of Synchronous Condensers* [1] submitted by ANDRITZ to CIGRE in the 2024 Paris Session makes this very case that it is neither the optimal technical or economic solution to design and operate a synchronous condenser at these extreme points **[emphasis added]**:

"As those areas are determining the synchronous condenser design, restricting operation in those areas or even clipping these two extreme corners **will yield a more economic condenser solution**. Furthermore, it was recognized that the **lower left and upper right operating corners are not good engineering practice in terms of voltage control** ([8])."

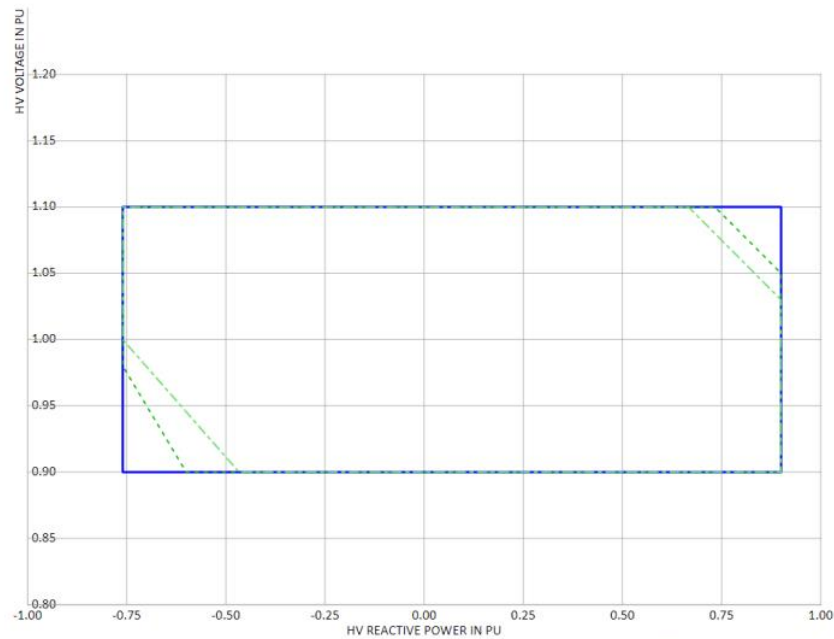


Figure 7 : Exemplary specified operation range of a synchronous condenser plant at PCC – rectangular shape (blue) vs. different extent of clipped corners (green).

Figure 2 – Figure 7 extracted from CIGRE report [1]

3. Other System Operator Examples

Furthermore, there are several examples from other System Operators where the requirement at these extreme operating points have been clipped. In fact, many of the examples included below show a required reactive power capability that is even clipped with respect to the proposed minimum rectangular Grid Code requirement indicated in blue in Figure 1 (i.e. ≤ 0.8 p.u. and ≥ -0.4 p.u), and not only with respect to the extended rectangular box indicated in red in Figure 1 (i.e. ≤ 0.9 p.u. and ≥ -0.6 p.u).

a) Austria

The System Operator can request one of three options for the reactive power requirement (Bereich I, Bereich II or Bereich III), all of which have a clipped reactive power requirement at the respective extreme corners of the U-Q/P graph.

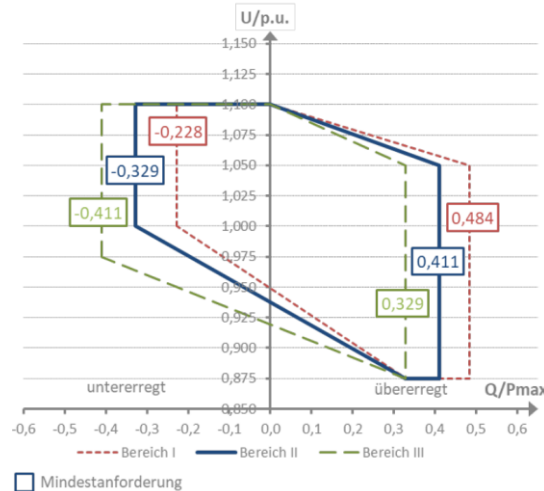


Figure 3 – Austrian requirement [2]

b) Finland

The System Operator has no requirement for reactive power over-excited operation for over-voltages nor under-excited operation requirements at under-voltage.

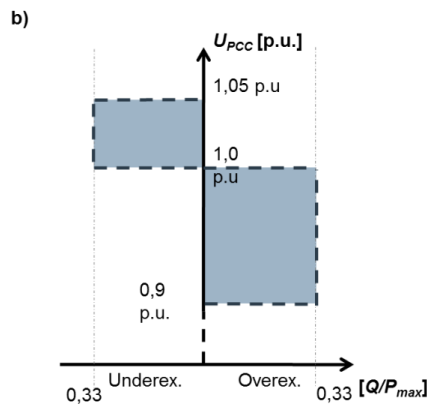


Figure 4 – Finnish requirement [3]

c) **Norway**

The System Operator has clipped the reactive power requirement in the top-right and bottom-left of the U-Q/P graph.

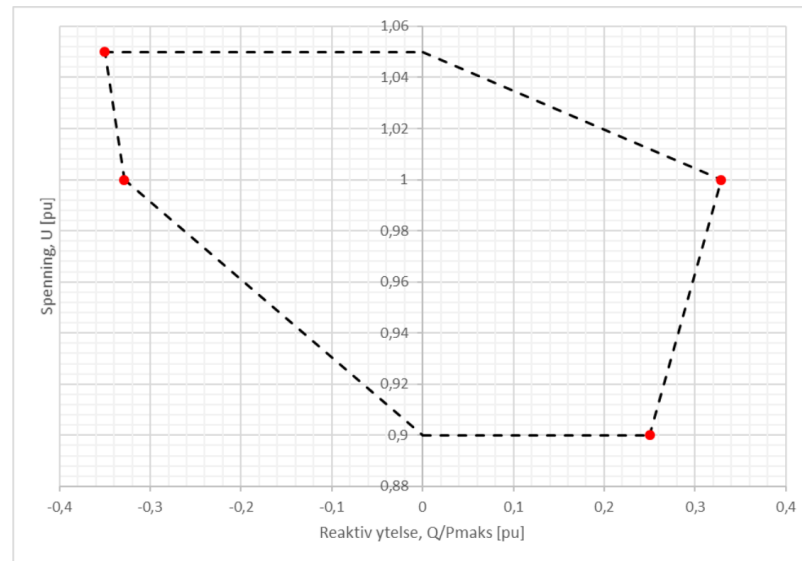


Figure 5 – Norwegian requirement [4]

d) **Portugal**

The System Operator has clipped the reactive power requirement in the top-right and bottom-left of the U-Q/P graph.



Figure 6 – Portuguese requirement for Type D (synchronous) generation plants [5]

e) Italy

The System Operator has clipped the reactive power requirement in the top-right and bottom-left of the U-Q/P graph.

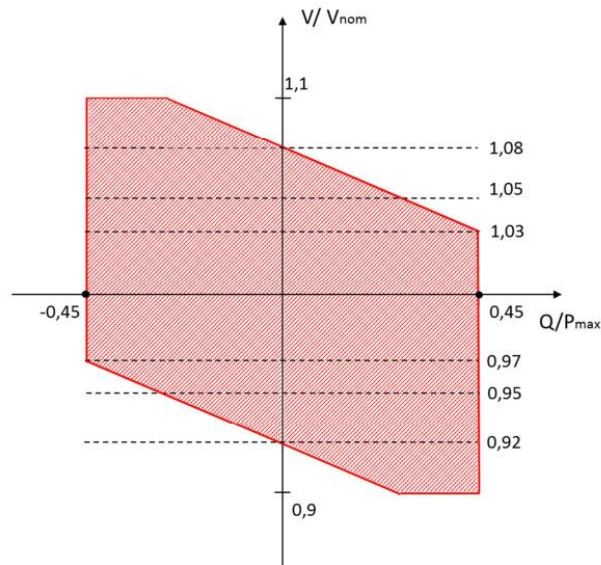


Figure 7 – Italian requirement for Type D (synchronous) generation plants [6]

f) Australia

The System Operator's (AEMO) proposed reactive power-voltage profile in Australia for generating plants (defined via $\tan\phi$).

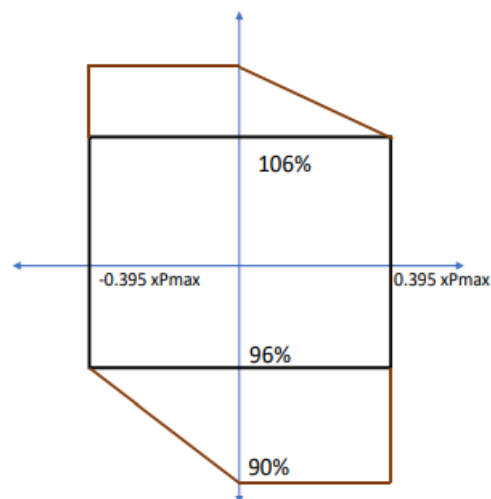


Figure 8 – Australian proposed profile (with a midpoint at 101%) [7]

4. Solution

In order to avoid any ambiguity in the Grid Code, we propose that the following text (shown in the black box below) is added to clause SCU1.4.6.3. This point is further represented by the red lines in Figure 9 below (which are shown for illustrative purposes only and not intended for inclusion in the Grid Code).

SCU1.4.6.3 Synchronous Condenser Units connecting to the Transmission System shall comply with the following Reactive Power requirements at the Connection Point. The Synchronous Condenser Unit shall be capable of moving to any operating point within its U-Q/MVA profile in appropriate timescale to target values. The appropriate timescale shall be identified during the TSO's Connection Offer process.

Where Synchronous Condenser Units can provide reactive power capability beyond the envelopes shown, the additional capability may not have to be provided across the full voltage range and the slope for the additional capability shall be agreed between the TSO and the Synchronous Condenser Operator.

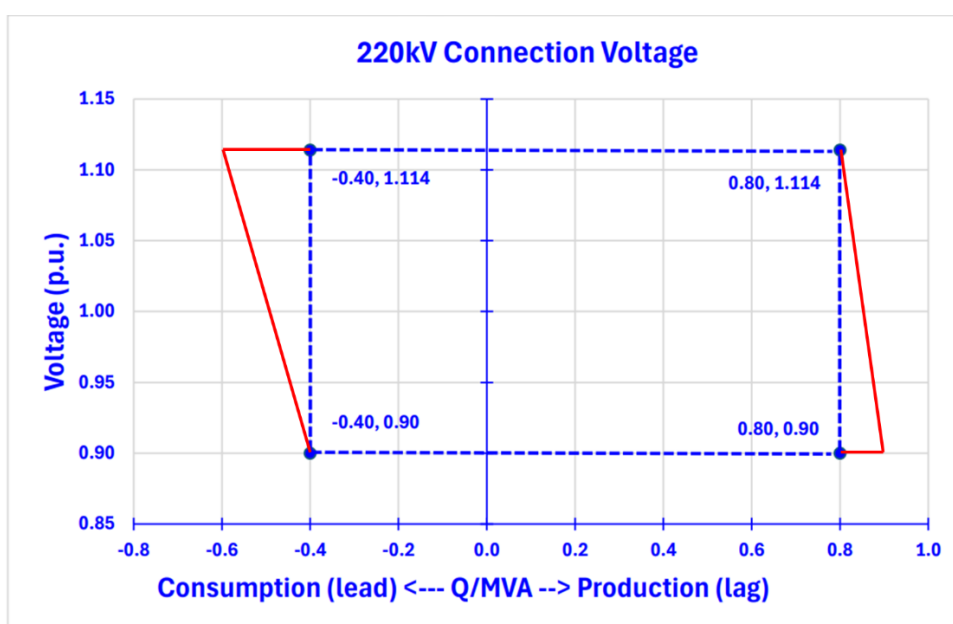


Figure 9 - (Solution A)

Furthermore, for the reasons outlined in Section 2 and Section 3 and the limited benefit to the System Operator outlined in our original feedback referenced in Section 1, we believe there is a strong case that the region within the proposed rectangular reactive power requirement (i.e. ≤ 0.8 p.u and ≥ -0.4 p.u) should also be clipped as shown in Figure 10 below. This is represented by the green dashed lines which is proposed to be included in the Grid Code if Solution B is accepted. The continuation of the lines outside the minimum Grid Code requirement equivalent are shown again in red for illustrative purposes only and not intended for inclusion in the Grid Code, as this would be already addressed by inclusion of the text proposed in Solution A.

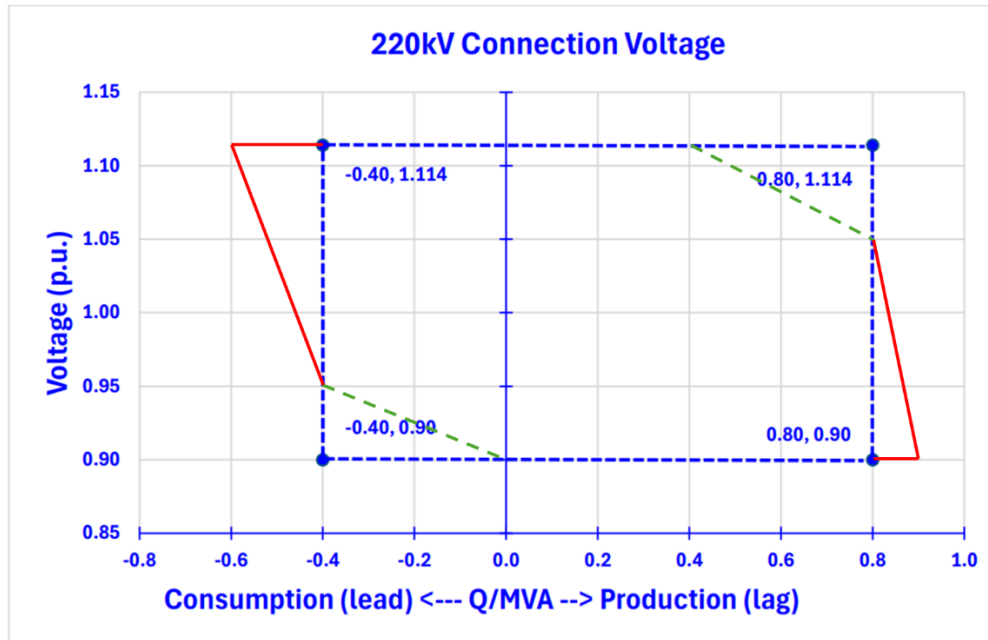


Figure 10 - (Solution B)

5. Conclusion

In relation to the region beyond the proposed minimum Grid Code requirement (i.e. ≥ 0.8 p.u and ≤ -0.4 p.u), there is clear ambiguity associated with clause SCU 1.4.6.3 as currently written which cannot be left open to interpretation. It is our opinion for the reasons outlined in this report that without any clarity, compliance with the likely default interpretation at the extreme corners as indicated in **Figure 1** would be neither economically efficient or good engineering practice. Therefore, we see no reason why Solution A should not be incorporated into the proposed SCU Grid Code Mod. It is essential that there is clarity for this region in the Grid Code from the outset.

In relation to the region within the proposed minimum Grid Code requirement (i.e. ≤ 0.8 p.u and ≥ -0.4 p.u), we understand the System Operators preference is to retain the status quo and have similar requirements across all technologies while also reserving the right to take actions at the extreme corners of the U-Q/P chart. However, it is the responsibility of the Regulatory Authority to ensure consumers in Ireland are not overspending for services in the energy sector. As such, any benefit to the System Operator must be critically assessed against the fundamental technical constraints and cost for SCUs and ultimately consumers in complying with this requirement. For that reason, it is our opinion that the justification provided by the System Operator to date is not sufficiently robust to rule out an option such as Solution B, particularly when the likelihood of ever needing to operate SCUs at the extreme corners is very low in reality and when there are numerous examples where other System Operators have incorporated a clipped requirement. Therefore, we encourage the System Operator to give due consideration to Solution B (in addition to the text proposed in Solution A) so that its inclusion or exclusion from the Grid Code can be meaningfully assessed by industry and the Regulatory Authority.

6. References

- [1] [A1_PS2_11171_2024_Design aspects of SC.pdf](#)
- [2] <https://www.e-control.at/documents/1785851/0/TOR+Stromerzeugungsanlagen+Typ+D+Version+1.3.pdf/a1d4dee4-95e4-b4e0-6c13-61997a9e5cd5?t=1718018866869>
- [3] <https://www.fingrid.fi/globalassets/dokumentit/en/customers/grid-connection/grid-code-specifications-for-power-generating-facilities-vjv2018-.pdf>
- [4] <https://www.statnett.no/globalassets/for-aktorer-i-kraftsystemet/systemansvaret/retningslinjer-fos/nvf-2023---nasjonal-veileder-for-funksionskrav-i-kraftsystemet.pdf>
- [5] <https://www.dgeg.gov.pt/media/di2bctqf/i015736.pdf>
- [6] <https://download.terna.it/terna/0000/1151/51.PDF>
- [7] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/aemo-review-of-technical-requirements-for-connection-ner-clause-526a/final-report_access-standards-review_final_.pdf?la=en
- [8] https://www.acer.europa.eu/sites/default/files/documents/Recommendations_annex/ACER_Recommendation_03-2023_Annex_1_NC_RfG_clean.pdf

Reference 8, excerpt from Page 79:

Figure (17)7

U-Q/P_{max}-profile of a synchronous power-generating module

