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AMENDMENTS TO AEMO INSTRUMENTS FOR EFFICIENT MANAGEMENT OF SYSTEM STRENGTH RULE ISSUES PAPER – CONSULTATION RESPONSE

APD Engineering welcomes the opportunity to provide feedback on AEMO's Issues Paper on amendments to the System Strength Requirements Methodology (SSRM), System Strength Impact Assessment Guidelines (SSIAG) and Power System Stability Guidelines (PSSG). APD strongly supports this consultation on system strength instruments which will develop an 'Efficient Management of System Strength' Rule with the overarching objective of establishing a manageable framework for the supply of System Strength Services.

APD has provided comments on a selected set of consultation questions raised by AEMO.

ABOUT APD

APD Engineering is an electrical engineering consultancy highly skilled and experienced in the delivery of power system studies, network modelling, engineering design services and project commissioning for a broad range of clients. APD hosts one of the largest Power Systems teams in the world and provides power system modelling and technical advisory services to clients across Australia and New Zealand.

Our engineers have detailed knowledge and understanding of different types of technologies in the market including photovoltaic inverters, wind turbine generators, storage technologies etc. APD is at the forefront of challenges, deriving strategic and pragmatic solutions for successful connection of complex renewable energy projects.

APD has a broad range of experience gained from working with AEMO and NSP's (NEM, NT, WA, New Zealand), renewable energy developers, EPCs, partnering consultancies and OEMs. Our detailed knowledge of Australia's and New Zealand's energy markets, Rules, regulatory requirements, and stakeholders provide immense value in delivering positive outcomes for renewable energy developments across Australia and New Zealand.

Our detailed response is attached as Appendix A.

Please do not hesitate to contact Dr Lasantha Perera on Lasantha.perera@apdeng.com.au if you would like to discuss this submission in further detail. APD looks forward to working with AEMO's System Strength team on the subject matter discussed in the Issues Paper.

Yours sincerely,

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APD ENGINEERING

APPENDIX A – RESPONSE TO ISSUES PAPER CONSULTATION

Q29. Should a material threshold be defined for the purpose of general system strength impact assessment? If so, what should those thresholds be and why (for IBL, load types, individual or cumulative, as well as generators including LIBR, connected into transmission and distribution networks)?

A material threshold should be defined to minimise project impacts to developments that pose a negligible impact on system strength.

Consideration should be given to define the AFL threshold as either a portion of the total synchronous generation fault level at the connection point, or an absolute reduction in AFL. This should be applicable to both IBR and LIBR. For inverter-based load, this should also apply to a single IBL, Large IBR (LIBL) or an accumulated IBL within a localised area, such as a distribution zone.

The purpose of such a threshold would be to ensure a well-tuned plant of commercially small size (<5MW) can connect to the network and not be required to acquire SSR for a negligible reduction in AFL.

Q30. Are there any other issues relevant to the general system strength impact that AEMO ought to take into account?

General system strength impact is now defined by the reduction in AFL and any adverse system strength impact. APD recommends that AEMO consider providing practical examples in the SSIAG to demonstrate the intended meaning of adverse system strength impact. APD believe there would be significant benefit to the industry as a whole for further tangible examples, case studies, and measures published in the SSIAG to help the industry understand AEMO's position on what constitutes adverse system strength impacts.

Q31. Should there be an engineering safety margin applied to the SCR withstand capability calculation considering limitations associated with SMIB based evaluation?

As per the new clause 4.6.6(b)(1A), the 'System Strength Impact Assessment Guidelines' must require a 'Preliminary Assessment' to be carried out using a simple isolated model, such as a SMIB model, in PSCAD. The purpose of this Preliminary Assessment is to determine whether there is a general system strength impact. This is specifically intended to confirm the following:

- Stability of the plant at the proposed minimum SCR
- The plant SCR withstand capability for use in calculating the general system strength impact (or SSQ) and the SSLF.

The above analysis will be used to determine the amount of system strength charge for fee paying applicants, or whether an applicant requires remediation equipment to meet the minimum SCR standard.

In APD's experience, there are a few factors that could affect the outcome of the above-described analysis. It is understood that the plant SCR withstand capability largely depends on each 'generating unit' (e.g. inverter) minimum SCR withstand capability as well as all the impedances between the 'generating units' and the point of connection (PoC) of the generating system.

It has become standard practice in the industry that at the early design stages, many assumptions are made in determining the cable lengths, cable impedances, the transformer impedances, etc. Moreover, soil resistivity and the actual site conditions which could affect the impedances are usually ignored throughout the connection studies. Hence it is fair to assume that no tolerances are considered in the early design stages and in the creation of the SMIB model of the generating system.

It is noteworthy that for each electrical equipment, the OEM can design and build the equipment within a certain tolerance (e.g. +/-10% for transformer impedances as per the IEC standard). These tolerances can be adjusted depending on the commercial procurement contracts; however, they cannot be eliminated. Hence, for instance, in a transformer, a difference in impedances is expected between the final product and the specifications used in the early design stages/studies.

As already mentioned, the plant SCR withstand capability is largely dependant on the reticulation system impedance and the minimum SCR withstand capability of each individual inverter. As an example, if the inverter minimum SCR withstand capability is 3, depending on the reticulation system/eBoP, this could result in a plant withstand capability of 4. Hence, a tolerance on all electrical equipment that connect the individual generating units to the PoC should be considered to account for the worst-case scenario. For instance, if a park transformer with a 12% impedance is assumed in the connection studies, an impedance of 12% + 1.2% = 13.2% should be used for the purpose of the Preliminary Assessment. The same goes for all other electrical equipment between the inverter and the PoC.

In addition to the tolerance in impedances, the method of aggregating the plant for creating the SMIB model could also affect the outcome of the Preliminary Assessment. This is especially more profound in generating systems with large reticulation systems such as wind farms. In these plants, aggregating the plant into a SMIB, or a simple representation with a few aggregated generators would not be able to account for the minimum SCR an inverter would see at the end of the longest feeder in the plant. Hence, The plant minimum SCR withstand capability should be determined by accounting for the weakest System Strength point in the reticulation system. Hence, an appropriate methodology/tolerance should be employed in making the simple isolated model of the plant for the purposes of the Preliminary Assessment.

Q33. What criteria should be applied to determine whether a project is classified as a committed project for Full Assessment purposes? Why?

AEMOs proposed Definition of committed projects for Full Assessment dot point 1:

AEMO has proposed to require a Full Assessment (FA) to be conducted prior to the demonstration and acceptance of negotiated access standards (NAS) under NER 5.3.4A. In doing so, AEMO are removing the requirement for an FA to commence only after AEMO issue a letter of satisfaction with the NAS under NER 5.3.4A. This will also make 5.3.4A dependant on conclusion of an FA and any remediation requirements of 5.3.4B.

APD concur with AEMO that, in some circumstance, an FA may be required to demonstrate compliance with proposed access standards or to provide evidence of required amendments to a proposed standard. APD also agree with the approach to guarantee a stable baseline of the network model (however, a stable baseline should also be clearly defined) for a new connection applicant's plant by only including committed projects. It is currently considered that committed projects would be defined as those that have offers to connect issued (5.3.4A and 5.3.4B accepted). This is deemed a necessary approach as it is required to not put undue financial risk onto a connection applicant due to potential issues of any other connection applicant's plant.

APD consider it important to clearly define the exact milestones in the connection application process that would allow a plant to commence an FA. With AEMO's proposed changes, APD consider the timing and pre-requisites for commencement of an FA become relatively undefined if the milestone of achieving a NER 5.3.4A letter is removed. In the Issues Paper, AEMO have proposed this change without defining a new clear milestone, which poses increases risk to project timeframes. Furthermore, this may introduce financial implications if contractual obligations are dependent on achieving the 5.3.4A milestone only.

It is expected that all existing requirements leading up to an FA should be met prior to an FA commencing. That is, under the proposed change AEMO would need to decide the Proponent has used all available information to them in development of the performance standards. AEMO would be agreeing the proposed standards would be acceptable should they pass an FA. The FA would then be the last step in confirming these standards. A new public set of formal acceptance criteria should be made available to Proponents to formalise a new milestone in the connection application process for FA commencement. This is then considered the same as the exiting process being undertaken for FAs but with an additional milestone to avoid iterations of 5.3.4A letters. It is currently unclear if there would be any benefit from the proposed re-definition of the SSIAG Section 3.3 (a).

In order to gain efficiencies from the proposed change the formal acceptance criteria for FA commencement may include due diligence completion of all NER clauses except for schedule S5.2.5.5. This would allow FA works to commence earlier than currently possible and in parallel with completion of the current due diligence processes. I

AEMOs proposed Definition of committed projects for Full Assessment dot point 2:

The revised definition of a committed project states that any equipment design of a previously committed project, such that the model becomes unrepresentative, would revert the status of the project to be uncommitted. This would lead to significant financial consequences for proponents, for example:

- At the R1 submission stage if there is a change in reactive power contribution from the harmonic filter, the project would become uncommitted.
- A reduction to the maximum MVA for a generating system would also lead to the project becoming uncommitted

This may lead to a financial disincentive for projects to make changes to a generating system that benefit the connecting network. It would also significantly increase the risk of developing a new project.

Given the significant financial risks, the technical trade-off for uncommitting a project should be appropriately justifiable. The criteria for uncommitting a project could be refined to more clearly understood material changes such as:

- A fundamental change in generating technology
- Increase in active power export capacity in MW
- Increase to the proposed minimum SCR

In terms of an FA, should projects other than the generating system under assessment become uncommitted a consistent approach for management of this eventuality must be defined. It must be considered if a project has been included in an FA that later becomes uncommitted, do the results of the FA remain an accurate representation of the network performance such that they are still granted weight and merit. AEMO would need to determine a set of technical criteria to determine all FA studies run with the now uncommitted generating system in service be required to be repeated without it.

Q34. How and when is it appropriate to include future network augmentations (new transmission upgrades, configuration changes, considered projects, system strength remediation upgrades etc.) into the Full Assessment? Why?

APD believe the main consideration should be the time at which the connection applicants will be fully operational. It may not be practical for a project to complete FA with future network augmentations significant timeframes in advance given the likelihood of other significant changes to the network that may occur in the interim which may impact the outcomes. It is considered the proponent must be informed prior to augmentations if there is risk they may not be allowed to operate should the plant not meet performance standards after the augmentations.

The connection applicant should be made aware of these future network augmentations and associated risks, and a risks-based approach be considered. Should it be considered feasible, a connection applicant may be able to complete online commissioning and post-commissioning activities prior to the future network augmentations, there should be no barrier to the plant connecting and commencing commercial operation.

It is understood that the NSP would be required to conduct an FA inclusive of the future network augmentations and the connection applicant's plant, and if issues are identified the applicant's plant would not be able to operate until these are resolved.

This approach would allow online commissioning and post-commissioning activities to proceed in parallel with any required settings or design modifications to be implemented for operation after the network augmentations are completed.

Q35. Are there any other issues relevant to the Full Assessment methodology that AEMO ought to take into account?

1. Multiple concurrent connection applications in proximate locations

AEMO raises concerns in Section 4.4.2 Issue 2 dot point 1 in relation to address issues arising from multiple concurrent connection applications in proximate locations. In Section 4.4.3 Issue 2 AEMO identify committed projects included in an FA should have reached the stage at which performance standards have been approved. However, in Issue 1, it is indicated that these projects themselves must have passed an FA themselves prior to acceptance of their access standards under NER 5.3.4A. This is not considered to address AEMO's concern, on the contrary it is considered to likely further exacerbate the issue by resulting in the requirement to potentially conduct more FAs if exact criteria for FA commencement are not adequality defined.

In the interests of efficiency and alleviating the burden increases in FAs would produce on industry, it may be considered that all plants that have reached an 'FA ready' stage but not currently completed an FA, be concurrently integrated into a single model for a Stability Assessment (SA). Unlike the proposed SA in the Issues Paper, all new plants connection point quantities should be recorded not only specific network node voltages, but the data would not be assessed unless the SA acceptance criteria was not met. This would allow early determination of specific plant that may breach SA and FA acceptance criteria, as if an issue was identified it may be determined which plant/s are responsible. This could occur at set intervals throughout a year if there are multiple concurrent connection applications in proximate locations (proximate locations should be explicitly defined). This approach could only be considered should the network have sufficient hosting capacity to facilitate connection of all nearby plants and Proponents agree to this approach.

If issues are identified with a currently non-committed but 'FA ready' plant (reactive power in phase with voltage oscillation, etc) the plant deemed to cause the issue would be removed from service and FA can continue on all other 'FA ready' plant. If no issues are observed, the existing data collected can be used for more detailed analysis and FA on all applicable plant without the need to re-produce simulation results.

2. Inter-trip schemes and dispatch constraints cannot be applied to address a reduction in AFL.

APD consider use of these schemes should be assessed on merit, cost and risk basis. An intertrip may be acceptable for some projects where an alternate may not be feasible due to technical or financial constraints. A rule against these options may not benefit the overall power system or its customers, as it may result in the network receiving less benefits from smaller generating systems that may not be viable if other options are required.

3. Definition of NER Clauses related to 5.3.4A to be assessed in the FA

AEMO has proposed 5.3.4A cannot be finalised until completion of an FA where applicable. APD consider the applicable GPS schedules and clauses that the FA outcomes will have bearing over should be explicitly defined. APD consider that the full scope of the FA remains undefined in this regard in the issues paper.

Q36. Is the proposed scope of a Stability Assessment appropriate?

While APD consider the proposed scope of a Stability Assessment is appropriate in a general sense as described in Section 4.5.3 of the Issue Paper (Issue 1 Scope of Stability Assessment: Potential Stability Assessment Scope (example only)), there is still room for additional details to remove any ambiguities on the extent of the scope. It is stated that a Stability Assessment is a subset of power system analysis focused on the efficacy of system strength services in ensuring stable voltage waveform. The subsequent discussion in the section implies that this subset will be limited to studying the power system response for a range of disturbances including credible contingencies and protected events using an EMT model of the grid. APD consider that it is important to provide explicit details in SSIAG on the acceptance criteria of a Stability Assessment as the Figures 3 and 4 indicate that the focus is only limited to post-disturbance RMS voltage magnitude at key system nodes. However, Section 3.2.2 (Description of stable voltage waveforms) indicates that definition of stable voltage waveform has other elements than the RMS voltage magnitude. Therefore, it is suggested that AEMO further clarify the assessment criteria (in other words, what does AEMO mean by satisfactory voltage waveform stability) of a Stability Assessment.

There is also ambiguity around the starting point of a Stability Assessment. The general indication throughout the issue paper is that SSSP should provide adequate SSS in order to maintain the minimum levels of system strength for the stable operation of the power system with the existing plant at the time of assessment. As such, a stability assessment at first should ensure that the existing power system meets all the criteria for stable voltage waveform. This should equally apply to any committed plants considered for a Stability Assessment for a newly connecting plant, i.e. the power system with all the committed plants prior to the connection of the plant under study should meet all the criteria for a stable voltage waveform. It is generally assumed that all committed plants considered, should have undergone a Full Assessment or a Stability Assessment prior to them being considered for a Stability Assessment of another plant.

It is also suggested to include a section providing the 'Definition of committed projects for Stability Assessment' similar to 'Definition of committed projects for Full Assessment' in Section 4.4.2 of the Issue Paper.

Q37. Are there any studies, contingencies, and evaluations that should, or should not, be part of a Stability Assessment? Why?

AEMO's expressed intention of the Stability Assessment is to identify steady state voltage stability using wide-area EMT studies. APD suggests that these studies should be undertaken at a variety of network voltage conditions. Minor changes (<3%) in voltage of nearby network buses can reveal control system interactions that are not observed during operation at the given condition. Changes to voltage occur in the network during normal operation due to loading, transformer tapping and reactor shunts. This is why it is important to conduct the stability assessment at a defined variety of network voltages. The number of these voltage conditions to be assess should be determined by AEMO following consideration of the effort intended for the SA, noting that currently, the SA has the potential to be only marginally less effort than an FA.

Q38. What study assumptions could be recommended to ensure there is no "free rider" situation for (system strength services) non-paying Applicants?

To ensure that there are no circumstances that may allow "free rider" Applicants with respect to system strength services, additional EMT studies can be completed with any nearby SS remediation measures out-of-service. By doing so, this would ensure that the Applicant is not reliant on the system strength contributions from any other applicant or SSRS. If the Applicant can demonstrate a positive outcome for SA in these scenarios, then it can be determined that they are not receiving a "free ride".

Q39. Are there any other issues relevant to the Stability Assessment methodology that AEMO ought to take into account?

APD believe that AEMO is required to specify the approach that they are planning to use to determine the cause of a voltage waveform instability: i.e. whether it is caused by the insufficient provision of SSS by SSSP or by the plant itself. Figure 5 of the issue paper indicates, when the criteria for satisfactory voltage waveform stability is not met by a plant, the SSSP adjusts its plans to stabilize the voltage in the first instance. However, it is not entirely clear how to establish whether an SSSP has done what is required to remedy the issue in case the issue remained following the adjustments by SSSP. For instance, a similar size plant with the same BoP with another OEM may be able to meet the stable voltage waveform criteria following the SSSP adjustments while the plant under study may still fail the criteria. Thus, a collaborative approach is required between the SSSP and the connecting applicant to work out the SSS adjustments and SSRS to meet the stable voltage waveform criteria in such circumstances. It would help connecting applicants who have paid a SSS Fee if AEMO is able to specify the level of expectation on SSRS as a result of a Stability Assessment, in order to make the connecting parties aware the level of further work required in such circumstances.

A minor omission is also observed in Figure 5 that it is not stated that an FA is undertaken for Non SSS Fee paying applicants. This needs to be corrected to accommodate an FA prior to the proposed SSR and GPS. It is also observed that the acronym 'SSR' in Figure 5 is not listed under the Glossary of the Issue Paper. APD presume that 'SSR' is System Strength Remediation and therefore propose AEMO to correct the acronym to 'SSRS' to align with the Glossary.

Q40. Are there any other issues relevant to the calculation of SSLF that AEMO ought to take into account?

In the Issue Paper, the SSLF is defined as the ratio of the additional fault level at SSN required to restore the available fault level at the Applicant's point of connection. A ratio is between two quantities and one quantity is 'the additional fault level at SSN required to restore the available fault level at the Applicant's point of connection'. For clarity, it is proposed that AEMO provide this ratio as an equation clearly identifying the two quantities. Based on our understanding we presume SSLF is defined by the following equation.

$$\text{SSLF} = \frac{\text{The additional fault level at SSN required to restore the AFL at the Applicant's POC}}{\text{The difference between pre and post connection AFL at the Applicant's POC}}$$

It is also not clear what AEMO mean by 'to restore the available fault level'. Does it mean to achieve the same AFL at the POC pre and post connection of the plant under study? For example, if the AFL at a certain POC pre connection is 100MVA, is the same level expected post connection? Is it fair to assume that the AFL at any potential POC for a new IBR prior to its connection will be positive if the minimum fault level requirement at SSNs is met by the SSSP given AEMO only consider the existing IBR for the evaluation of the minimum fault level requirement (page 20 of Issue Paper)? An AFL at a given POC (prior to the connection of the plant under study) may already be negative if all the nearby committed IBR plants are also considered. Therefore, AEMO is required to specify how the committed IBR plants should be treated in SSLF calculation methodology similar to specifying the inclusion of committed or anticipated network augmentations in the model.

Q42. Are there any other issues relevant to the calculation of AFL that AEMO ought to take into account?

For the AFL equation in Section 4.7.3, APD believe that it is reasonable to assign k = 0 for grid forming IBR when not used for SSS given that it does not require a certain synchronous fault level to operate stably. However, assigning k = -1 when grid forming IBR are used for SSS is not entirely accurate in APD's opinion due to the fact that grid forming inverters may not necessarily be required to specify a 'SCR_withstand', as they do not require a withstanding synchronous fault level to operate stably. Therefore, grid forming IBR when used for SSS should be considered under SSG and should be excluded from the RHS of the equation. AEMO has also introduced a scaling factor 'alpha'. There are no details on the rationale for this scaling factor or how it will be determined. AEMO is required to include further details in SSIAG on how this factor is determined.

In the current SSIAG published on 29 June 2018, Section A.2.2 provides details of how an AFL calculation is practically performed using standard fault level calculations in PSS/E. It is not clear from the Issue Paper whether AEMO is planning to retain the same approach for AFL calculation in the new SSIAG. It is suggested that AEMO provide details of practical implementation of the AFL equation in PSS/E using a wide area network similar to the current SSIAG.

As highlighted in our response to Question (40), it is ambiguous how AEMO is planning to treat the committed IBR plants in the AFL calculations. APD are of the view that committed IBR plants should be considered in AFL calculations together with the SSS adjustments by SSSP to accommodate them. Therefore, AEMO is required to specify how the committed IBR plants should be treated in AFL calculation methodology.

Q43. For (high SCR) connections where SCR may change over time, what would be a sensible process to trigger the need for GPS assessment or confirmation of compliance at SCR of 3.0?

It is importance to always maintain an acceptable level of system strength at different nodes of the grid such that the network is always operating securely and reliably. When a plant is proposed to connect to a node of the network, it is tuned to comply with the NER requirements assuming the minimum SCR at the POC at that point of time. A GPS is then proposed and after going through a rigorous process is accepted by the NSP/AEMO and becomes the performance standard of the generator.

Tuning of the plant is usually a time-consuming and effort-intensive task. Once a GPS is approved and a generating system is constructed, any process which would invalidate the existing GPS, or would trigger the need for another GPS assessment, should not result in ceasing of the plant generation or any loss of revenue. Accordingly, a sensible process for GPS assessment would provide the generator with a gap period in which it would have the opportunity to re-assess its GPS and potentially re-adjust its parameters such that it can comply with the NER under the minimum SCR of 3.0. In order to provide the generator with such gap period, proper planning practices should be adopted to predict the system strength level ahead of it actually reaching critical levels. Under such scenario It would make sense to trigger the change process once the SCR at a certain point reaches levels or is predicted to reach levels below 6.

Q44. Are there any other issues AEMO should take into account when considering compliance of affected plant?

A change in the system strength over time is inevitable at different network nodes. At the early stages of the connection application, a generating system is being tuned to meet a certain access standard at the POC and this access standard is reflected in the GPS. Usually, it is much easier to achieve a higher access standard when the generator is connecting to a node with a high SCR. This Access standard/GPS usually becomes the baseline for any changes that might occur in the plant parameters/eBoP and any access standard which demonstrate a lower performance would not be accepted by AEMO/NSP. An example of this is the 5.3.9 process, where the existing GPS is usually taken as the baseline and an access standard lower than the existing GPS usually won't be acceptable.

If a change process is to trigger and the generating system is to be re-tuned/re-adjusted to comply with the NER under new SCR conditions, it would be fair to provide the generator with the opportunity to go below the levels that are already proposed in their existing GPS. This is because some certain high-performance standards that can be achieved in high SCR conditions might not be achievable or could result in poor performance of the plant/grid under low SCR conditions. An example for this is the Iq injection requirement where a k-factor of 4 could result in an acceptable performance under high SCR conditions, however, the same k-factor could result in oscillations, re-triggering of the inverters and potentially voltage overloads under a low SCR condition.

Another aspect which seems important is to make sure that a gap period is provided to the affected generators, as going through the change process could be time-consuming and effort-intensive.