Update report Stakeholder feedback template:

AEMO Review of technical requirements for connection

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Stakeholder: Bo Yin

Schedule 5.2 Conditions for Connection of Generators

NER Schedule 5.2 issue	Schedule 5.2 (Generators) – feedback on revised recommendations and relevant draft NER amendments
NER S5.2.1 – Outline of requirements	
Application of Schedule 5.2 based on plant type instead of registration category and extension to synchronous condensers	
NER S5.2.5.1 – Reactive power capability	
Voltage range for full reactive power requirement	The following reply is intended to clarify the coordination between 5.2.5.1 and 5.2.5.13. **Firstly,** 5.2.5.1 specifies the reactive power capability obtained through the use of the OLTC (On-Load Tap Changer control) of a tap-changing transformer. However, the control system mentioned in 5.2.5.13 does not rely on a tap-changing transformer for set point adjustment. It is important to note that the dynamic reactive power capability used for voltage regulation in 5.2.5.13 might be significantly lower than the reactive power capability defined in 5.2.5.1. Consequently, it may not be possible for the plant to achieve the reactive power range specified in the performance standard under S5.2.5.1 (5.2.5.13 2B). **Secondly,** voltage control refers to the ability to manage reactive power in an AC power system, ensuring that network voltage levels remain within a target voltage range set by NSPs (Network Service Providers) while enabling effective active power transfer from generation to load. According to this definition, the reactive power capability serves two purposes: active power transfer and voltage regulation. However, the amount of reactive power required for voltage regulation depends on the SCR (Short Circuit Ratio) and X/R (Reactance-to-Resistance) values. To illustrate the amount of reactive power needed for different SCR and X/R values, let's consider the following example: the upstream system voltage range is limited to 0.9 pu to 1.1 pu. Figure 1 depicts the Point of Connection (PoC) connected to a system with a known impedance defined by SCR and X/R.

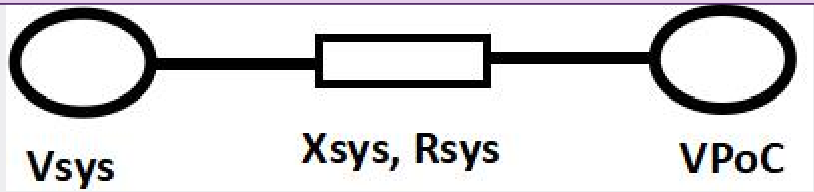


Figure. 1 two terminal system with known system impedance

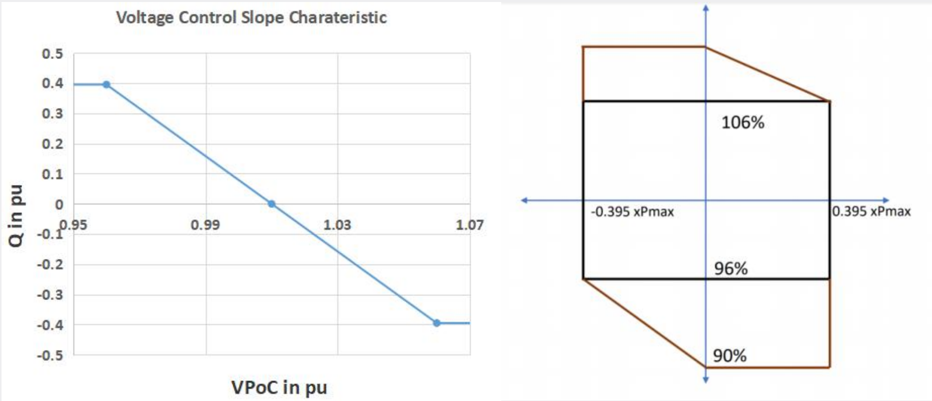


Figure.2 voltage slope control characteristic

Let's assume voltage slope control is applied at the PoC using the equation VPoC = Vref - (Droop * QPoC / Qbase), as shown in Figure 2. Here, Vref is set as 1.01pu and Droop is set as 0.05, with the intention of operating within a voltage range of 0.96pu to 1.06pu.

Based on the given values of SCR, X/R, VPoC, PPoC, and QPoC, the voltage value (Vsys) can be solely determined. In order to further analyze and address the points mentioned, let's delve into the specifics of the operating points for voltage regulation.

To begin, let's consider the operating points correspond to different conditions:

VsysM represents the operating point when the active power reactive power at the PoC is set to [0 1].

VsysL corresponds to the operating point when the active power reactive power at the PoC is set to [Qmax 1].

VsysH corresponds to the operating point when the active power reactive power at the PoC is set to [Qmin 1].

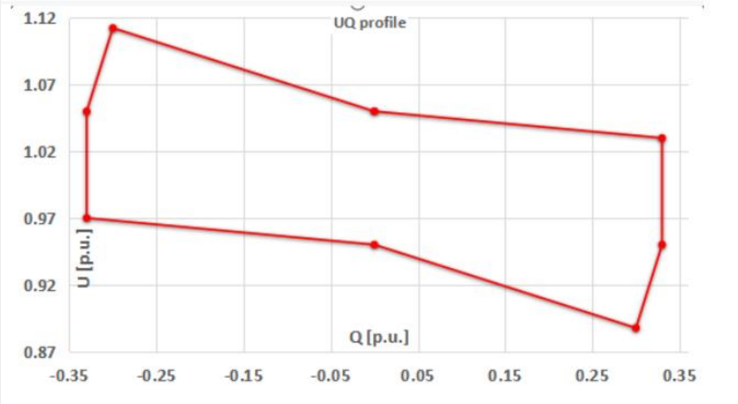
By restricting Vsys to the range of 0.9 to 1.1 pu, we can determine the corresponding Qbase, which represents the maximum allowable reactive power to maintain Vsys within the specified limit. This information is presented in the table below, highlighted in red:

	SCR	X/R	Vref (pu)	Droop (pu)	Qbase (pu)	VsysM (pu)	VsysL (pu)	VsysH (pu)
case 1	10	5	1.01	0.05	0.395	1.00	0.90	1.08
case 2	5	5	1.01	0.05	0.2	0.99	0.90	1.08
case 3	3	3	1.01	0.05	0.04	0.96	0.90	1.02
case 4	1.5	2	1.01	0.05	0.005	0.93	0.90	0.96

By examining the table, it can be observed that for an SCR of 10, the upstream voltage reaches its lowest limit of 0.9 pu when Qmax is at 0.395 pu. However, for an SCR of 3, the same voltage limit is reached with Qmax at 0.04 pu. From this analysis, it can be concluded that only a small amount of reactive power is required for voltage regulation in a weakened grid scenario.

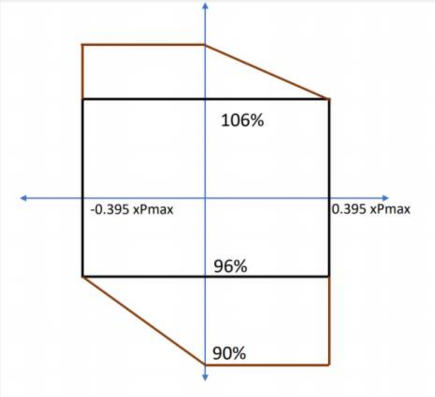
Taking this perspective into account, it is highly valuable for AEMO to undertake an investigation aimed at determining the precise amount of reactive power being utilized by power plants. Such an investigation would not only shed light on the actual utilization of reactive power in real-world scenarios but also offer valuable insights for optimizing system designs and making informed investments.

Thirdly, when it comes to specifying the voltage range for the full reactive power requirement, it is important to consider the system's needs and make efficient investments. For effective voltage regulation, a high inductive reactive power (Q) is needed at high voltage levels, particularly when there is low active power production. Conversely, a high capacitive reactive power (Q) is needed at low voltage levels, especially when there is high active power production. However, it is worth noting that providing a large amount of reactive power at low voltage levels requires a higher RMS current rating for the inverter, which translates to increased costs. Achieving a balance between the system's requirements and cost-effectiveness can be achieved through a voltage profile that accommodates both aspects.



In conclusion, understanding the actual reactive power requirements in real-world scenarios, in combination with considering the system's needs and optimizing cost-efficiency, will contribute to specifying an appropriate reactive power capability requirement at the point of connection.

Finally, it is essential for NSPs to coordinate and specify the mid-point voltage and voltage range for both 5.2.5.1 and 5.2.5.13 in a coordinate way if the reactive power capability is defined with a mid-point voltage as shown in below . This coordination ensures accurate and consistent in reactive power capability and voltage control in the plant.



NER Schedule 5.2 issue	Schedule 5.2 (Generators) – feedback on revised recommendations and relevant draft NER amendments
Treatment of reactive power capability considering temperature derating	
Compensation of reactive power when units are out of service	
S5.2.5.7, S5.2.5.8, S5.2.5.13	
Simplifying small connections	•
NER S5.2.5.2 – Quality of electricity generated	
Reference to plant standard	
NER S5.2.5.4 – Generating system response to voltage disturbances	
Overvoltage requirements for medium voltage and lower connections	•
Requirements for overvoltages above 130%	•
Clarification of continuous uninterrupted operation (CUO) in the range 90% to 110% of normal voltage	For connection point voltage variations less than 10%, within the range of 90% to 110% of nominal voltage, within the range of 90% to 110% of nominal voltage, must not result in: (1) any reduction in active power output at the connection point, other than reductions reasonably attributed to transient response, losses, energy source availability and any other factors that the Network Service Provider and AEMO agree are reasonable in the circumstances; or (2) a reduction of reactive power capability of the operating production units below the minimum amounts to be absorbed or supplied (as applicable, considering the voltage change) under the performance standard established under clause S5.2.5.1. The CUO requirement assumes the dynamic reactive power which is obtained without reliance on OLTC action. This is inconsistent with S5.2.5.1.
NER S5.2.5.5 – Generating system response to disturbances following contingency events	
Definition of end of a disturbance for multiple fault ride through	
Form of multiple fault ride through clause	•
Number of faults with 200 ms between them	
Reduction of fault level below minimum level for	

NER Schedule 5.2 issue	Schedule 5.2 (Generators) – feedback on revised recommendations and relevant draft NER amendments
which the plant has been tuned	
Active power recovery after a fault	•
Rise time and settling time for reactive current injection	•
Commencement of reactive current injection	
Clarity on reactive current injection volume and location and consideration of unbalanced voltages	–
Metallic conducting path	
Reclassified contingency events	
NER S5.2.5.7 – Partial load rejection	
Application of minimum generation to energy storage systems	
Clarification of meaning of CUO for NER S5.2.5.7	
NER S5.2.5.8 – Protection of generating systems from power system disturbances	
Emergency over-frequency response	•
NER S5.2.5.10 – Protection to trip plant for unstable operation	
Requirements for stability protection on asynchronous generating systems	
NER S5.2.5.13 – Voltage and reactive power control	
Voltage control at unit level and slow setpoint change	
Realignment of performance requirements to optimise power system performance over expected fault level (system impedance) range – Voltage control	
Materiality threshold on settling time error band and voltage settling time for reactive power and power factor setpoints	•
Clarification of when multiple modes of operation are required	–
Impact of a generating system on power system oscillation modes	

NER Schedule 5.2 issue	Schedule 5.2 (Generators) – feedback on revised recommendations and relevant draft NER amendments
Definition – continuous uninterrupted operation	
Recognition of frequency response mode, inertial response and active power response to an angle jump	•

Schedule 5.3a Conditions for connection of MNSPs

Issue	Schedule 5.3a (HVDC links) – feedback on revised recommendations and relevant draft NER amendments
NER S5.3a.1a Introduction to the schedule	
Alignment of schedule with plant-type rather than registration category	
NER S5.3a.8 – Reactive power capability	
Reactive power	
NER S5.3a.13 – Market network service response to disturbances in the power system	
Voltage disturbances	
Frequency disturbances	
Fault ride through requirements	
NER S5.3a.4 – Monitoring and control requirements	
Remote monitoring and protection against instability	
New standards	
Voltage control	
Active power dispatch	

Multiple Schedules

Issue	Multiple schedules – feedback on revised recommendations and relevant draft NER amendments
NER Multiple clauses	
References to superseded standards	

NER structural amendments

Issue	NER structural amendments – feedback on revised recommendations and relevant draft NER amendments
NER structural amendments	
Drafting principles	
Proposed approach	

Consequential amendments

Issue	Consequential amendments – feedback on revised recommendations and relevant draft NER amendments
Definitions	
Definitions changes	
Technical changes	
Incorporating synchronous condensers	
Additions to information provision	
Relevant system – in relation to small plants exempt from some requirements	
S5.2.5.8 Over-frequency emergency generation reduction requirements	
S5.2.5.8 Protection settings and relationship to ride through clauses	
S5.2.5.8 Conditions for which the plant may trip and recording of conditions	

Issue	Consequential amendments – feedback on revised recommendations and relevant draft NER amendments
S5.2.5.8 Network Service Provider liability	
S5.2.5.11 Minimum operating level	
S5.2.5.11 Response direction for bidirectional units taking power from the system	
Drafting changes	
Drafting changes	

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