Comments on ERC0329 'Reactive current response to disturbances (clause S5.2.5.5)'

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Distribution of Document

This document is submitted to the AEMC and as such is of the public record.

About Renewable Energy Revolution:

Renewable Energy Revolution is an engineering consultancy that has designed and assessed over 2 GW of renewable energy under the Australian NER.

Revision History

Early LinkedIn Release - Version 1.3 - July 1, 2021 - Only S5.2.5.5(o) is discussed.

Description of rule to be changed

In 2018, the technical requirements in Chapter 5 of the NER were updated following a rule change request by AEMO. This update was wide ranging and covered many of the technical requirements in Schedule 5.2.5.

The comments in this document relate to the requirements in S5.2.5.5(o), which requires all asynchronous generators to meet minimum access standard requirements relating to reactive current rise and settling times during faults. The existing requirements are 40 milliseconds and 70 milliseconds respectively (2 and 3.5 cycles of AC power at 50 Hz).

The wording of the rule to be changed has been extracted here for convenience from version 166 of the NER:

(o) For the purpose of paragraph (n):

(1) the *generating system* must commence a response when the *voltage* is in an under-voltage range of 80% to 90% or an over-voltage range of 110% to 120% of *normal voltage*. These ranges may be varied with the agreement of the *Network Service Provider* and *AEMO* (provided the magnitude of the range between the upper and lower bounds remains at Δ10%);

(2) where *AEMO* and the *Network Service Provider* require the *generating system* to sustain a response duration of 2 seconds or less, the reactive current response must have a *rise time* of no greater than 40 milliseconds and a *settling time* of no greater than 70 milliseconds and must be *adequately damped*; and

(3) where *AEMO* and the *Network Service Provider* require the generating system to sustain a response duration of greater than 2 seconds, the reactive current *rise time* and *settling time* must be as soon as practicable and must be *adequately damped*.

A statement of the nature of the issue with the existing wording of the NER in practicality

In weak areas of the Australian power system, increased rise times may even pose a risk to the power system, as noted by the AEMC in the Final Determination [1] of the NER v113 Rule Change[1]:

> *"The Commission recognised that a fast response is a generally desirable property when managing faults, but that the speed of response also needs to be consistent with response stability, which is affected by power system conditions at the connection point."*

Also in the Final Determination [1] the text notes that these rise and settling times were derived from a German Standard. After more than 12 months of searching and asking this standard cannot be found even with the help of German native speakers. To compound this situation, the referenced German grid code specifies that the reactive current injection must be on the LV side of the generator transformer. This is two 'filters' (transformers) away from the POC. Summary: No clear page number reference for 40 / 70 ms in German Grid code and POC interpretation is not in line with LV open loop injection that could indeed be confirmed by type tests.

In the final determination, the commission also stated[2]:

> *"The system security risks associated with oscillatory behaviour can be significant. Under the right set of circumstances, connection point voltage oscillations may lead to power system stability issues and associated system security risks. The* ***trade-off between speed of response (rise time) and response stability (settling time) therefore needs to be carefully considered*** *given the needs of the power system and conditions at the point of connection."*

The rise times are unreasonable as there is no quantitative basis for the rules themselves. There was also clearly a failure of the authors of the NER change in Version 113 to conduct any review of rise and settling times in the commonly installed equipment. For example a straightforward process would have been:

1. Identify common Central Solar Inverters and Large Wind Turbines. This must also include future platforms such as the Haliade X 14MW and V236 15 MW to ensure they could be used in the Star of the South proposal.
2. Tabulate for all technologies the expected connection point: X/R ratios, Connection Voltages (33kV to 500kV) and SCRs of connection points.

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[1] Final determination [1], page 167

[2] Final determination [1], page 134

3. Simulate the expected rise and settling times of technology with the various real world requirements in 3, and then;
4. Write the Australian National Electricity rules such that desired technology can connect at the desired points

There is no literature that shows that slightly slower rise times pose a risk to power system security. Indeed the opposite may be true, as the Final Determination [1] comments highlighted already.

In practicality, the tuning of the plant and the rise time may lead to higher overshoots or dips as the plant responds to faults. In the case of a DFIG tuning is only going to have a moderate effect as it is a partial converter and the induction machines still interact with the power system. In the case of a full converter these fast rise times (with a failure in any money to be spent on research or modelling) are pushing the limits of what is reasonable for the electromechanical system. To think the new 15 MW offshore platform from Vestas or Haliade X will be able to alter massive amounts of power in milliseconds is unreasonable and shows a poor grasp of electromechanics of interconnected systems.

Thus, due to the caused overshoots by unreasonably fast rise times, this rule actually is a risk to the basic historic tenant of power system operation to maintain voltage variation less than 10%. This is described in S5.2.5.4 which has been implemented for a long time.

It is also important to understand the basis of responsibility. In section 4.1.1(b) of the NER it clearly states: ***"By virtue of this Chapter and the National Electricity Law, AEMO has responsibility to maintain and improve power system security."*** <u>As such no generating systems should ever pose a material risk to power system security, regardless of rise and settling times</u>.

Any attempt to use a minimum rise or settling time as a protection mechanism *is trivial* in the fact that it will not alter the base responsibilities of parties defined within the National Electricity Rules.

Conjecture 1:
It is important to understand that mandating minimum rise and settling times also may create a risk from an engineering process and systemic risk standpoint. That is, mandating minimum rise or settling time may indeed create a false sense of security, and does not consider the cumulative effect of nearby generation. The philosophical basis that implementation of such extreme minimum rise times provides any system security is flawed and indeed it may be quite the opposite.

Problems with lack of definitions in the NER

One core problem identified by RER is a failure to define terms. If the term ‘reactive current’ has not been defined, how do we legally interpret the NER? Is it binding? What happens if it is challenged?

Statement: The author is not a lawyer and the dialogue below should not be taken as legal advice.

This failure to define terms existed in the v113 rules change. The recent submission ERC0329 [2] also does not remedy this.

There is a balance to be struck between making sure the technical wording can be correctly interpreted under the law and defining terms such that the general audience is happy with those terms.

The term ‘reactive current’ - what does that mean? For those familiar with the renewable energy systems would say that it is the Q or iq term of the current vector in the Rotating Reference Frame (RRF) of converter control, or in the case of a Doubly Fed Induction Generator (DFIG) it is the Q or iq current vector after the Phase Locked Loop (PLL) has processed the output current of the DFIG.

However, to the everyday renewable energy investor this gets a bit crazy. In terms of the law, I have not seen anyone want to involve a Phase Locked Loop in energy law. *In the opinion of the author we must avoid PLLs being involved in the wording. This means at a maximum we should talk in terms of Clarke transformed quantities (alpha beta Stationary Reference Frame (SRF)) and never venture to Park transformed quantities (dq RRF). This is because due to the complex nature of PPLs the wording would carry a high risk of being difficult to enforce.*

So, we all may have varying ideas as to how to define ‘reactive current’. As a diligent engineer we flip to the Glossary to check out the definition. Alas, the core work has not been done. On performing a search for ‘reactive current’ we find 26 matches in the NER version 166 none of which define the term.

So what to do? We want a legally valid wording - a clear interpretation. Let us see what we can dig up. We find a term for the ‘reactive power’ on page 1335 of version 166. The definition of reactive power is as follows [3]:

reactive power

The rate at which *reactive energy* is transferred.

Reactive power is a necessary component of alternating current electricity which is separate from *active power* and is predominantly consumed in the creation of magnetic fields in motors and *transformers* and produced by *plant* such as:

(a) alternating current generators;

(b) capacitors, including the capacitive effect of parallel *transmission* wires; and

(c) *synchronous condensers*.

For those of us who have studied Electrical Engineering it is evident that this is a traditional definition of reactive power, otherwise known colloquially as average reactive power or by a definition of scientific merit Fryze Power. So now this is perplexing in terms of a legal interpretation. We know that if we were to test this definition that it must be Fryze (or average) power. There would be a number of ways to test it, its age, its words or its historic usage would be a few. In a 50 Hz system this Fryze power would be commonly interpreted as averaged over 20 ms, one line cycle.

This is supported by the definition of 'reactive energy' on page 1334 of version 166, repeated here [3]:

reactive energy

A measure, in varhour (varh), of the alternating exchange of stored energy in inductors and capacitors, which is the time-integral of the product of *voltage* and the out-of-phase component of current flow across a *connection point*.

Thus we reach the end of the road, the only logical conclusion is that, if tested, the 'reactive power' would be defined over an averaged period of 20ms. Thus, given no definition of terms this means the 'reactive current' can only be inferred from the 'reactive power' thus it too must be time averaged on a 20ms basis.

Yes, we could complicate this with multiple phases etc. For now let's just say a 'reasonable Electrical Engineer' would deduce that:

reactive current is reactive power divided by voltage, or there is no definition whatsoever.

We know that we could use instantaneous power theory (which the controls of these generators are based upon) to define the iq. Which leads us to the key thing to understand in Conjecture 1.

Conjecture 2:
The interesting observation here is that the actual rules indeed mandate a rise and settling time that is actually an equivalent of an instantaneous reactive current rise time of 20ms (40ms minus 20ms filtering delay inherent in the Glossary defined term for 'reactive power'). This rise time is far from what is every realistically possible for a large generator.

A solution without using Clarke Transformed quantities

The above section shed light upon the depth of the problem that has been created. On initial inspection it may seem that we need to introduce instantaneous power theory. However, there is a way to avoid using alpha and beta voltages. This is likely desirable as it would require the definition of many more terms. The steps to correct this error in the NER are described below.

Step 1 - Define terms

active current *is active power divided by voltage*
reactive current *is reactive power divided by voltage*

where voltage is defined on page 1366 of version 166 as [3]:

voltage

> The electronic force or electric potential between two points that gives rise to the flow of electricity.

Step 2 - Consider the times submitted by the wind farms consortium and add the inherent filtering delay based on the time-averaged Fryze Power technique to S5.2.5.5(o)

Thus S5.2.5.5(o) becomes:

For the purpose of paragraph (n):
(1) the generating system must commence a response when the voltage is in an under-voltage range of 80% to 90% or an over-voltage range of 110% to 120% of normal voltage. These ranges may be varied with the agreement of the Network Service Provider and AEMO (provided the magnitude of the range between the upper and lower bounds remains at Δ10%);
(2) where AEMO and the Network Service Provider require the generating system to sustain a response duration of 2 seconds or less, the reactive current response must have a rise time of no greater than ***80 milliseconds and a settling time of no greater than 110 milliseconds (including a 20 millisecond time delay inherent in the time domain reactive current calculation)*** *and must be adequately damped; and*

(3) where AEMO and the Network Service Provider require the generating system to sustain a response duration of greater than 2 seconds, the reactive current rise time and settling time must be as soon as practicable and must be adequately damped.

Any reasonable Electrical Engineer can obtain the direct interpretation that this is the equivalent of a iq reactive current rise time under instantaneous power theory of 60 ms (by subtracting the inherent filtering delay). Where a modelling software is used that has a 5ms filtering delay then it is clear that the rise time to be met is 65 ms (60 ms base plus 5 ms filtering delay).

Step 3 - (Optional) Add the inherent filtering delay based on the time-averaged Fryze Power technique to the Automatic Access Standard so it makes more sense S5.2.5.5 (g)(2)

(g) For the purpose of paragraph (f):
(1) the generating system must commence a response when the voltage is in an under-voltage range of 85% to 90% or an over-voltage range of 110% to 115% of normal voltage. These ranges may be varied with the agreement of the Network Service Provider and AEMO (provided the magnitude of the range between the upper and lower bounds remains at Δ5%); and
(2) the reactive current response must have a rise time of no greater than ***60 milliseconds and a settling time of no greater than 90 milliseconds (including a 20 millisecond time delay inherent in the time domain reactive current calculation)*** *and must be adequately damped.*

Any reasonable Electrical Engineer can obtain the direct interpretation that this is the equivalent of a iq reactive current rise time under instantaneous power theory of 40 ms (by subtracting the inherent filtering delay). Where a modelling software is used that has a 5ms filtering delay then it is clear that the rise time to be met is 45 ms (40 ms base plus 5 ms filtering delay).

A solution using Clarke Transformed quantities

RER will provide a review and support the AEMC if there is the desire to utilise Clarke transformed quantities and define instantaneous power theory terms.

There would be two approaches to achieve this. The first approach would be to use SRF alpha beta quantities. There would be the need to define alpha voltage, beta voltage, alpha current, beta current, etc. Alternatively, the other approach is to use the three phase basis for instantaneous power which would require the definition of the A, B, C phase voltages and currents. However, this is not necessary if the previous section guidance is followed.

Conclusions and Directives

The current wording of S5.2.5.5(o)(2) was discussed with regard to ERC0329. This document detailed the failure of the NER to define ‘reactive current’ and how this has led to a NER that is difficult to enforce and interpret.

This document provided direction on wording that can quickly remediate the major technical problem(s) with the Australian National Electricity Rules in 2021.

The changes in this document should be fast-tracked. This document details how a key rule within the Australian NER is broken, and has been for years.

References

[1] Final Determination of National Electricity Amendment (Generator technical performance standards) Rule 2018 No. 10. Website:
https://www.aemc.gov.au/sites/default/files/2018-09/Final%20Determination_0.pdf

[2] ERC0329 main submission, NATIONAL ELECTRICITY RULE CHANGE PROPOSAL Reactive current response to disturbances (clause S5.2.5.5) Proponents: GE International Inc, Goldwind Australia, Siemens Gamesa Renewable Energy and Vestas Australia.
Website:
https://www.aemc.gov.au/sites/default/files/2021-03/ERC0329%20Rule%20change%20request%20pending.pdf

[3] Australian National Electricity Rules version 166. Website:
https://energy-rules.aemc.gov.au/storage/rules/d459671744c0bce886f981401063a331a9945d25/assets/files/NER%20-%20v166%20-%20Full.pdf