Vestas

August 29, 2022

To: Australian Energy Market Operator
Email: contact.connections@aemo.com.au

Dear Sir/Madam,

Re: NER S5.2.5.10 Guideline Consultation

Thank you for the opportunity to provide feedback on the NER S5.2.5.10 Guideline Consultation. We acknowledge this is an important consideration to operate and manage the security of the power system. Vestas has reviewed the Technical Note and present our key observations as outlined below:

- Equation (3) ($V = C + D$) in the Technical Note is not representative of a closed loop control system;
- The proposed block diagram does not consider the impact of the Grid;
- The angle θ in Equation (5) is defined as the angle between disturbance D and compensation C. However, this angle does not have a practical meaning, since in reality only the angle between voltage V and compensation C can be measured on the power system;
- There are mathematical edits which may require to be reviewed in the tech note, for example, the magnification ratio based on Equation (6) can be defined by $\frac{\sqrt{K^2+A^2+2KAcos(\theta)}}{A}$ vs $\frac{Kcos(\theta)+A}{A}$ or $\frac{-|Kcos(\theta)|+A}{A}$

Please refer Schedule 1 below for the detailed technical analysis of our key observations.

If you have any questions or comments, please do not hesitate to contact Dr Roozbeh Kabiri, Grid Specialist, via email rookb@vestas.com, mobile 0419 254 872 or the undersigned. Vestas would welcome the opportunity to discuss and elaborate our comments with your team.

Yours faithfully,

Transmitted electronically

Ragu Balanathan
Head of Power Plant Solutions
Global and Asia Pacific
Telephone: 0439 630 289
Email: rabln@vestas.com

Schedule 1

1 Introduction

AEMO have published S5.2.5.10 Consultation Technical Note to establish a technical basis on assessing whether the generating system is damping a voltage oscillation or exacerbating it by using the phase angle difference between voltage measured at the connection point and reactive power from a generating system. The proposed assessment methodology intends to assist timely actions to prevent adverse impacts on the power system or the generating system.

This report provides technical analysis on the AEMO's assessment methodology, highlights the shortages/gaps in the approach and proposes changes/corrections to the assessment methodology. This report is not investigating the primary assumptions made in the AEMO's technical note to conclude whether the approach is comprehensive or not.

2 Technical analysis

2.1 Closed loop control system

As per Figure 1 in AEMO's Technical Note, Equations 3 to 5 are not conclusive since a close-loop voltage control system is described. Therefore, the relationship between disturbance and controlled voltage should be defined as:

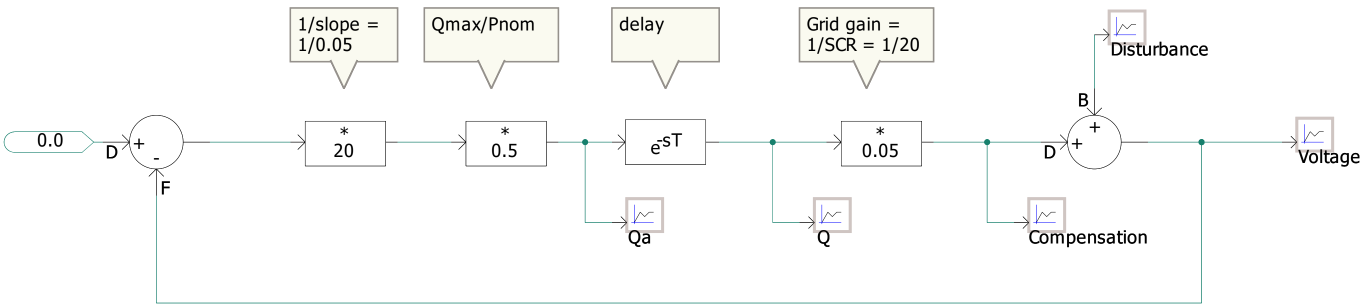
$$V = \frac{1}{1+G} \times D \ or \ H = \frac{V}{D} = \frac{1}{1+G}$$

In addition, it is implied from $C = K * Q$ equation that K is considered as the grid gain relating reactive power to voltage compensation. However, the gain of G includes both the voltage droop gain as well as the grid gain.

The angle θ in Equation 5 is defined as the angle between disturbance D and compensation C. However, this angle does not have practical meaning, since in reality only the angle between voltage V and compensation C can be measured.

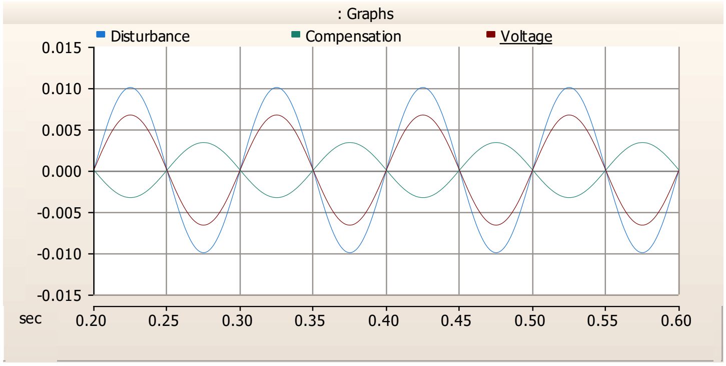
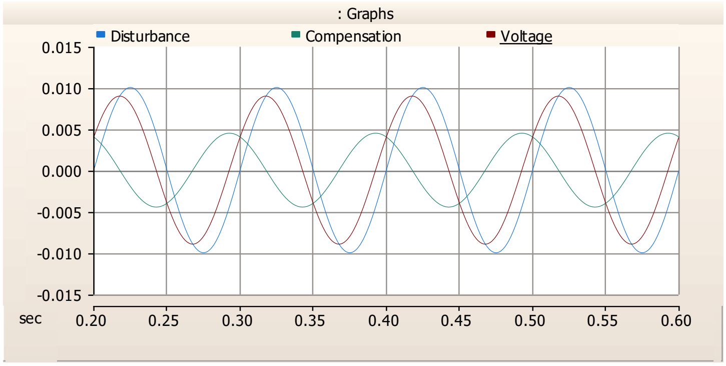
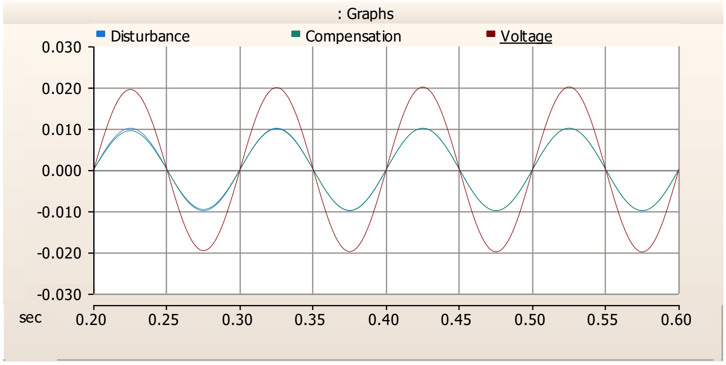
2.2 Simplified Voltage control System

As an example, a simplified voltage control system of a wind power plant is displayed in the figure below.



It is important to note that the above system performance can be investigated based on the angle which is defined between Voltage and Compensation (and not between Disturbance and Compensation).

In the above example, the gain G would be $|G| = \left(\frac{1}{0.05}\right) \times 0.5 \times \left(\frac{1}{20}\right) = 0.5$, while the disturbance has a magnitude of $A = 0.01$.

$\theta = 180°$ (angle between Voltage and Compensation)	
$\theta = 270°$	
$\theta = 0°$	

2.3 AEMO's proposed methodology

As explained in Section 2.1, the control theory fundamentals should be used for evaluation of disturbance rejection in a closed loop system which have not been considered in the technical report. Furthermore, there are incorrect mathematical statements which disqualifies the outcomes. For example, based on Equation 5, the magnification ratio mathematically can be defined by $\frac{\sqrt{K^2+A^2+2KAcos(\theta)}}{A}$ not $\frac{Kcos(\theta)+A}{A}$ or $\frac{-|Kcos(\theta)|+A}{A}$. However, the derived ratios for amplification/cancellation in the AEMO guideline are incorrect as well since K value cannot be treated independent of A due to the nature of the closed loop system.

3 Conclusions

The following conclusion are made as per findings in this report:

- The control theory fundamentals should be used to evaluate disturbance rejection characteristics of a closed loop system.
- Based on the system transfer function, the impact of θ (defined as angle between Voltage and Compensation) and |G| (sensitivity of the grid voltage to reactive power) can be investigated.