Automatic Voltage Control
Performance and Applicable Reliability Requirements

Introduction

This Quick Take describes methods and procedures which generator owners and operators can implement to ensure that their generating equipment is in voltage control mode as per the relevant NERC requirements and IESO Market Rules.

Background

Voltage control is an integral part of power system operation. Controlling voltages on the power system allows for the efficient transmission of power whilst respecting equipment limitations. One of the most efficient ways to control voltages on the power system is to place generators in voltage control mode. This requires generating equipment to measure a voltage, compare the measurement to a reference and increase/decrease the reactive power flow out of the generating equipment. This can be accomplished by increasing/decreasing the excitation in the field winding for a synchronous machine or changing the firing angle of inverter based equipment. The aforementioned methods of controlling voltage have been commercially available for both types of equipment are performed automatically on a continual basis without operator intervention provided the automatic voltage control is enabled. Both NERC and the IESO have implemented standards which require generating units to be in voltage control which will be discussed below.

The IESO has recognized a number of generator operators are unknowingly operating generating equipment in modes other than voltage control. The following sections will provide tips such as: monitoring, change control process, and performance tracking all of which will enhance generator owner and operator's ability to achieve compliance with the subsequent standards.

Requirements

NERC VAR-002

"The Generator Operator shall operate each generator connected to the interconnected transmission system in the automatic voltage control mode (with its automatic voltage regulator (AVR) in service and controlling voltage) or in a different control mode as instructed by the Transmission Operator unless: 1) the generator is exempted by the Transmission Operator, or 2) the Generator Operator has notified the Transmission Operator of one of the following: That the generator is being operated in start-up, shutdown, or testing mode pursuant to a Real-time communication or a procedure that was previously provided to the Transmission Operator".

IESO Market Rules Chapter 4 Appendix 4.2

"Regulate automatically voltage within ±0.5% of any set point within ±5% of rated voltage at a point whose impedance (based on rated apparent power and rated voltage) is not more than 13% from the highest voltage terminal. If the AVR target voltage is a function of reactive output, the slope $\Delta V / \Delta Q_{max}$ shall be adjustable to 0.5%".

Requirements Summary

- The IESO requirement places performance metrics on the AVR requirement.
- The IESO requirement is more stringent and more detailed than the NERC requirement and therefore if a generator meets the IESO requirement you meet the NERC requirement.

Methods of Achieving Success

The following are recommendations which will help market participants ensure proper AVR functionality.

Appropriate Level of Knowledge of Facility Capability

- Operators should be knowledgeable and be able to have conversations about the:
    - The status of the voltage controller,
    - Location of voltage measurements for use in voltage controller (I.E. HV,LV, remote bus) ,
    - Voltage controller reference voltage,
    - Main output transformer tap changer automatic or manual capabilities, and
    - Equipment operating ranges.

Appropriate Monitoring Capability

- Operators should have continuous monitoring that provides AVR status and audible alarms that require acknowledgement when the AVR ceases to function properly.

Procedures and change control processes

- Facilities should have proper procedures in place with respect to
    - Handling AVR related alarms or improper functioning of an AVR and

  - Restoring equipment from an outage when the equipment removed from service has and impact on AVR functionality.

- Facilities should have an appropriate change control process which will ensure AVR settings and functionality is not changed as a result of vendor (or third party) software updates or maintenance. The change control process should also include instructions to submit an outage slip to the IESO indicating a software update is taking place but electrical performance will not change.

Performance Tracking

Performance tracking is perhaps the best method of ensuring the AVR is functioning properly. This method can provide real-time feedback as to the status of the AVR functionality despite non-functioning alarms. Plotting the voltage and reactive power at the point of control (source of voltage and reactive power measurements) shows whether or not the AVR is functioning properly.

One way of doing this is two lines can be plotted with the formulas:

$$\mathrm{V(kV)} = \left(\mathrm{Q(Mvar)} * \mathrm{Reactive\_droop(kV/Mvar)} + \mathrm{Vsetpoint(kV)}\right) * 1.005$$
$$\mathrm{V(kV)} = \left(\mathrm{Q(Mvar)} * \mathrm{Reactive\_droop(kV/Mvar)} + \mathrm{Vsetpoint(kV)}\right) * 9.995$$

Where Reactive_droop is defined as %voltage change in kV /reactiveoutput in Mvar
For example if a 100MW facility connected at 240kV has a reactive droop setting of 4% which results in 33Mvar out then Reactive_droop = $240 * \frac{0.04}{33} = 0.2909$.

All measured points should fall between these lines with the exception of points when the equipment is not generating active power. Should measurements fall outside these lines it is a good indication that the AVR is not functioning properly and notification and investigation should be carried out.

There are other ways of plotting performance to demonstrate proper AVR functionality.

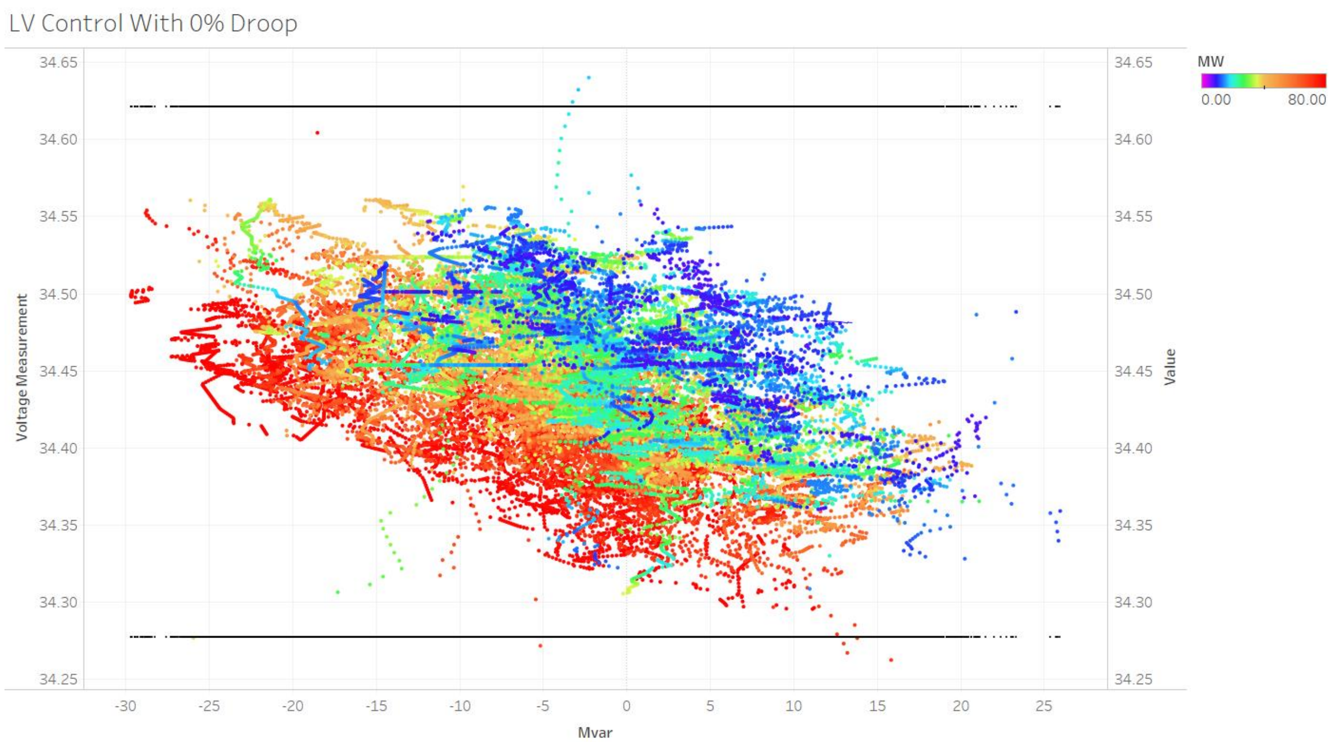
Note: Reactive Current Compensation or Droop is only required in the following cases:

- When controlling the voltage on the HV side of the main output transformer. For example a wind farm controlling the 230kV side of its main output transformer. An example of this is shown on the next page.
- When multiple synchronous machines are controlling the same bus voltage. I.E. multiple synchronous machines connected to the same bus.

Two examples follow using the method described above.

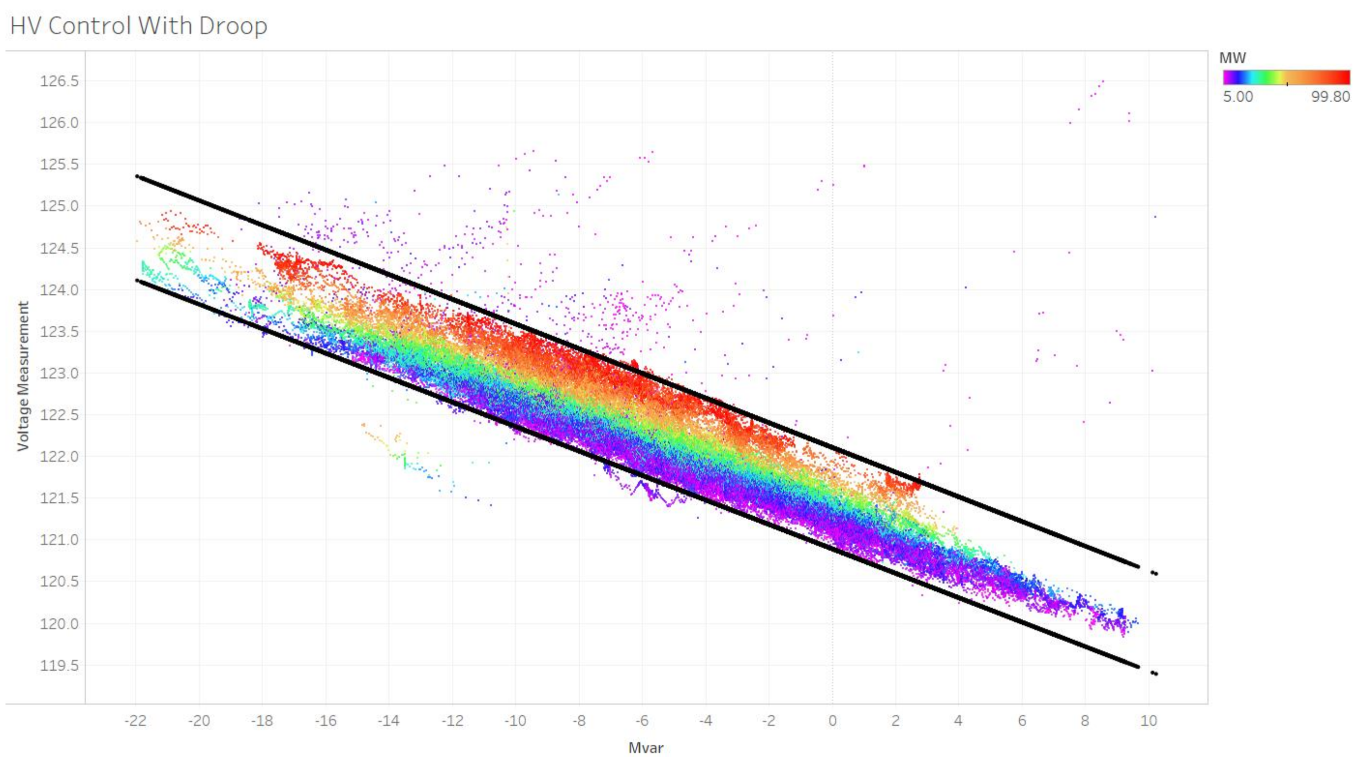
Performance Tracking Example 1: LV control with 0% droop

In this example a 80MW facility connected to the 230kV system; controls its LV (34.5kV) terminal with a droop of 0% and a setpoint of 34.45kV is plotted. The measured values fit inside the required 0.5% dead band lines and therefore this indicates that the AVR is functioning properly.



Performance Tracking Example 2: HV control with 4% droop

In this example a 100MW facility connected to the 115kV system; controls the HV terminal with a droop of 4% (4% voltage change = 33Mvar) and a setpoint of 121.5kV is plotted. The measured points fit inside the required 0.5% dead band lines and therefore this indicates that the AVR is functioning properly. The points that do not fit inside the lines indicate when the facility is not generating.



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