Reactive Power Performance Requirements for Wind and Solar Plants

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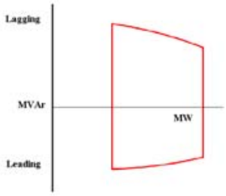
Opportunities and Challenges

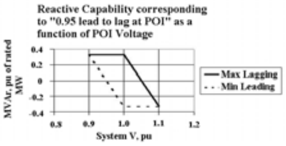
Background

- A current challenge faced by the electric utility industry is to determine how variable generation plants (wind and solar) should contribute to the reliable operation of the electric grid.
- Traditionally, bulk system voltage regulation has predominately been supplied by synchronous generators, and this is reflected in the language of industry requirements. Where variable generation is concerned the requirements are vague and unclear.
- The technology used in variable generation plants are capable of providing voltage support, but will require a shift from how these plants are traditionally operated.
- This paper discusses the capability of wind and solar plants to provide voltage regulation. It also examines the deficiencies in existing standards and provides recommendations to improve upon existing standards in order to clearly define the role of variable generation in providing voltage support to the bulk electric grid.

Reactive Capability of Synchronous Generators

- A typical requirement is for 0.95 power factor lag to lead at the Point of Interconnection, meaning that the machine should be capable of providing (lagging pf) or absorbing (leading) approximately 1/3 of its active power rating (MW) in reactive power (MVAr).
- This "lag to lead" specification originated from FERC Order 2000 (Large Generator Interconnection Agreement) and was suggested by NERC as a representative synchronous generator capability.
- Conventional synchronous generator reactive power capability is typically described by a "D curve" that covers the range from zero to rated output.

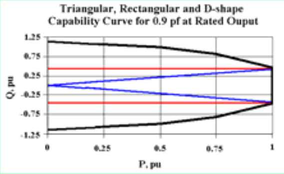


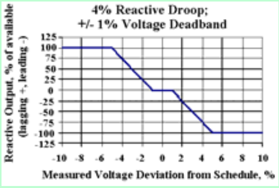


- A specification of "0.95 lag to lead at full power" is commonly stipulated for variable generation. However, terminal voltage limitations also affect reactive power capability of variable generators; therefore, to capture this effect, the reactive power versus voltage characteristic should be specified separately from the reactive range. For example, in addition to a "0.95 lag to lead" reactive range requirement, the chart to the left could be used to specify the reactive power capability versus voltage characteristic.

Reactive Capability of Wind and Solar PV Plants

- PV Plants and the latest wind turbines (Type III/IV) use power converters. The reactive capability of power electronic converters differ from those of synchronous machines because they are normally not power-limited, as synchronous machines are, but limited by the internal voltage, temperature, and current constraints.
- Doubly fed and full-converter wind turbines are often sold with a triangular, rectangular, or D shape reactive characteristic, shown in the figure to the right.
- Machines with rectangular or D-shaped reactive capability characteristic may be employed to provide voltage regulation service when they are not producing active power by operation in a STATCOM mode. However, this capability may not be available or may not be enabled by default.





- Another emerging practice is to adjust reactive output per a "reactive droop" characteristic, using the transmission voltage.
- Reactive droop capability has yet to be demonstrated in the field for solar PV plants although there are no technical impediments to the implementation of such a control scheme.
- Individual wind generators and solar PV inverters typically follow a power factor, or reactive power, set point.

Recommendations

Modification of Existing NERC Standards:

NERC should consider revisions to its Facility Design, Connections, and Maintenance (FAC) and Voltage and Reactive (VAR) standards to ensure that reactive power requirements for all generators are addressed in a technically clear and technology-neutral manner.

- Consider adding a clarification to FAC-001 expanding R.2.1.3 or as an appendix, stating that interconnection standards for reactive power must cover specifications for minimum static and dynamic reactive power requirements at full power and at partial power, and how terminal voltage should affect the power factor or reactive range requirement.
- Consider modifying VAR-001 to include the term "plant level volt/var controller" (in addition to "AVR"), which is more appropriate for variable generation.

General Recommendations for Standards Development and Reconciliation:

- NERC should promote greater uniformity and clarity of reactive power requirements contained in connection standards that Transmission Operators have issued pursuant to FAC-001. NERC, FERC, and other applicable regional standards should be reconciled.
- NERC should consider initiating a Standards Authorization Request (SAR) to establish minimum reactive power capability standards for interconnection of all generators, and provide clear definitions of acceptable control performance.

Technical Guidelines for Specification of Reactive Power Requirements:

- Generator interconnection requirement for reactive power should be clearly established for all generator technologies. NERC adheres to the notion of technology neutrality when it comes to reliability standards; however, certain unique characteristics of variable generation may justify different applicability criteria or appropriate variances. NERC should consider giving transmission planners some discretion to establish variance based on the characteristics of their transmission system.
- The reactive range requirement should be defined over the full output range. A Q versus P chart should be used for clarity. It makes technical sense to allow variable generation to operate within a permissive reactive power range (as opposed to a power factor envelope) when the active power level is below a reasonable threshold such as 20% of plant rating.
- A Q versus V chart could be used to describe the relationship between system voltage and reactive power. A reduced requirement to inject vars into the power system when the POI voltage is significantly above nominal and a reduced requirement to absorb vars when the POI voltage is significantly below nominal should be considered.
- The standard should clearly define what is meant by "Dynamic" Reactive Capability. The standard could specify the portion of the reactive power capability that is expected to be dynamic.
- Expected volt/var control performance should be specified, including minimum control response time for voltage control, power factor control, and reactive power control.
- Synchronization of generators to the grid should not cause excessive dynamic or steady-state voltage change at the point of connection. A 2% limit may be considered as a baseline.
- NERC should investigate whether transmission operators can, under some conditions, allow variable generating plants to operate normally or temporarily at an active power level where dynamic reactive capability is limited or zero. The possibility of operating in this manner could be considered as part of the interconnection study.

Conclusions

- As variable generation continues to grow in capacity on the electric utility grid it is necessary to transition from the operational practice of reactive support being solely provided by synchronous generators.
- Advances in the technology used for variable generation has now provided them with the capability for voltage regulation and reactive support, compared to older induction generators and line commutated devices.
- This paper provided a set of recommendations to changes in existing practices that can be used by industry in order to transition variable generation from being a non-entity in reactive power support to being a contributor to enhanced grid reliability.

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