Integration of Wind Generation into Weak Grids

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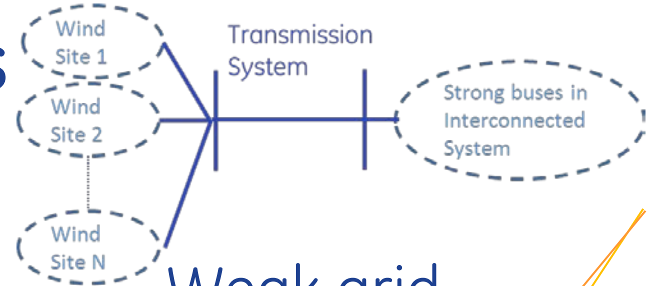
imagination at work

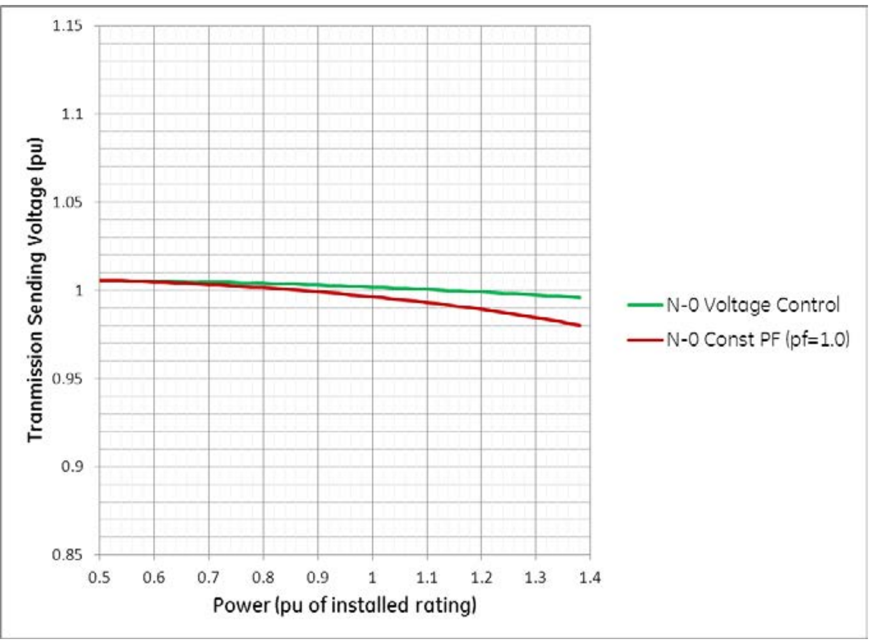
Outline

- Conventional and Power Electronic (PE) Sources
- Stability limitations of PE Sources
- Effect of control features
- Quantifying system strength
- Recommended Practice
- Summary

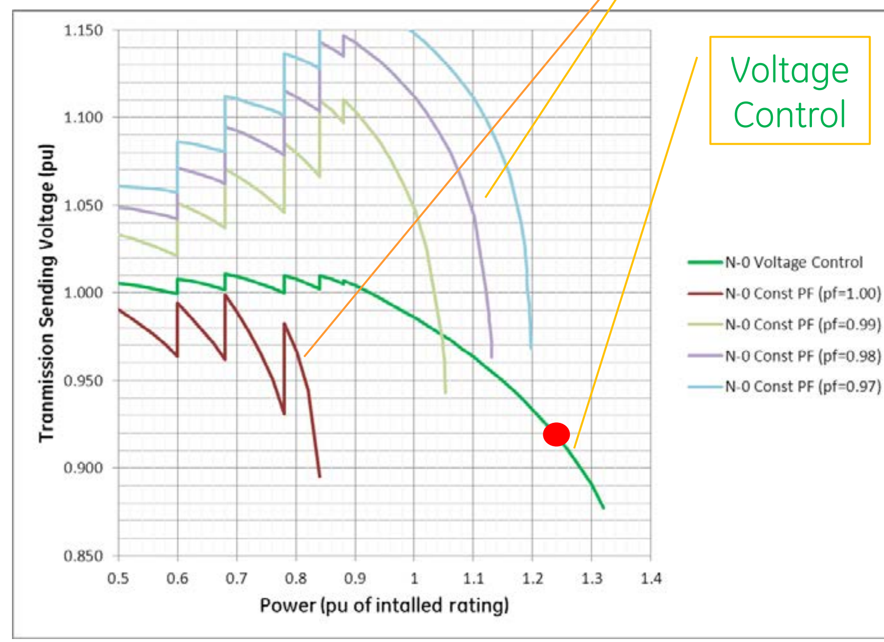
Steady State Considerations



Strong grid



Weak grid



PF Control

Voltage Control

● Insufficient margin and challenging operation in PF control

Plant level voltage control improves *network voltage stability* performance in constrained transmission systems

Conventional and PE sources

- Relevant electrical characteristics of Power-Electronic (PE) sources

Performance aspect	Conventional generation	Power-Electronic Sources
Short circuit contribution (system strength)	Around 3 pu	Small/none
Current sharing/distribution	Inherent to constructive characteristics. Sharing depends on size and impedances of the machines	Fast current controls force current sharing

- All current-controlled PE sources require grid strength to operate reliably and stably
- Grid strength is high when electrically close to conventional generation

Conventional and PE sources

- Long transmission corridors (low system strength) typically have power transfer limited below thermal limits due to stability challenges

Conventional generation	Power-Electronic Sources
Transient Stability Dynamic stability Voltage stability	Voltage stability Fast control stability

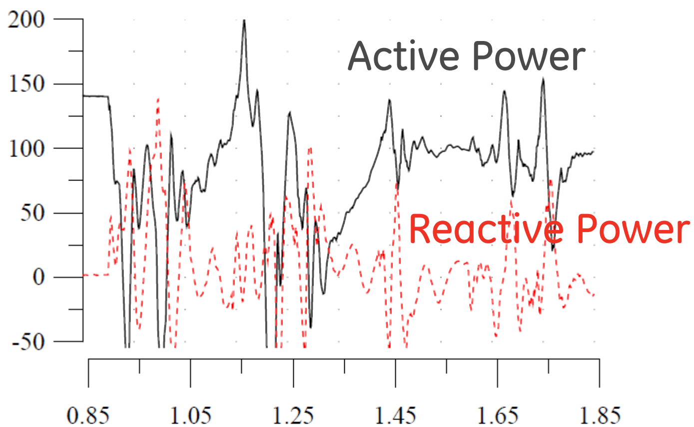
- Fast control stability refers to interactions between transmission system and PE sources (Wind Turbine Generators (WTG) , SVCs, STATCOMs, etc.)

WTGs and system strength

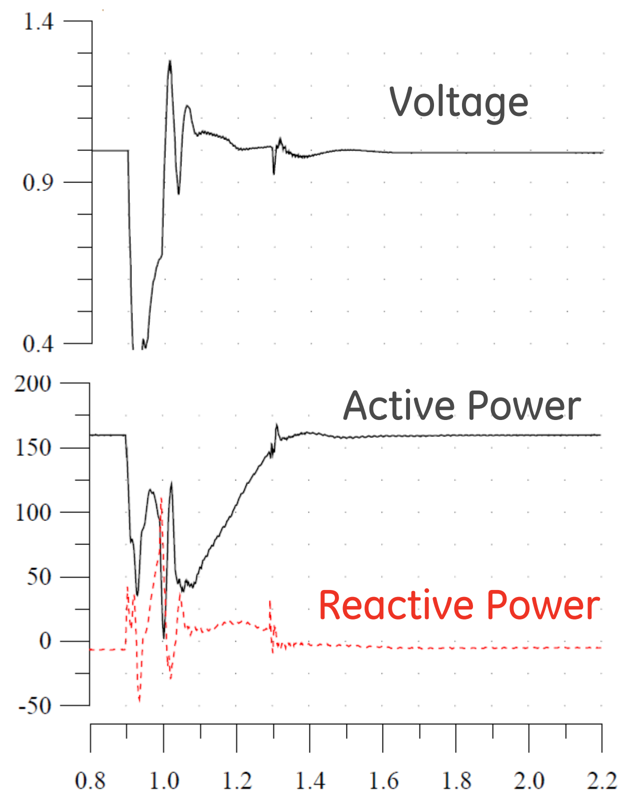
- Modern WTGs are PE sources
- Some applications *may* need mitigations to achieve desired system performance under very low system strength conditions :
  - Transmission upgrades
    - New lines
    - Meshed vs. radial
    - Series compensation
    - Synchronous condensers (System strength, dynamic VARs)
    - SVC, STATCOM (dynamic VARs, control challenges)
  - Special protection schemes (such as transfer trips)
- GE WTGs have control features to improve performance in low system strength conditions

GE WTG control features

- Detailed simulations of complex and extremely weak application
- Converter controls cannot solve all system stability issues, but have important impact
- Fault and clear with different control features



WTG settings for normal system strength

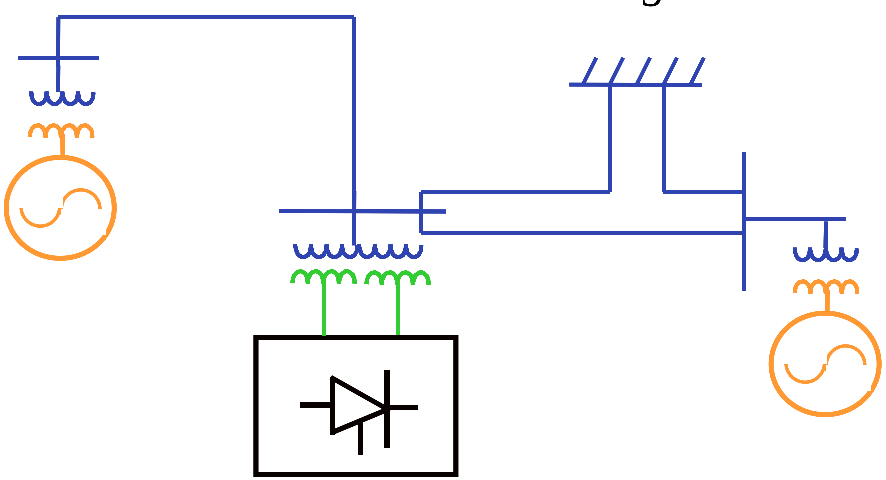


WTG settings and features for low system strength

How "strong" are grid conditions?

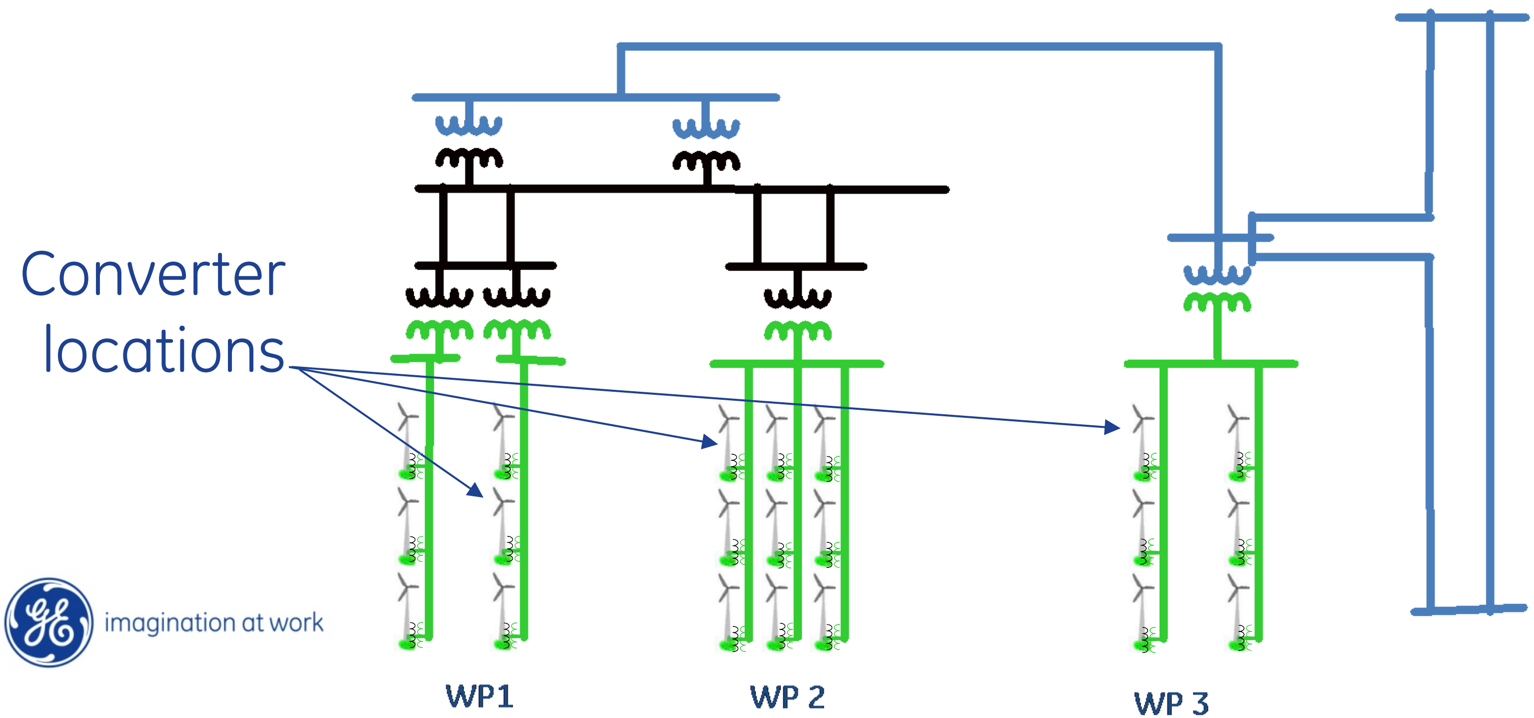
- The industry has used the Short Circuit Ratio (SCR) to assess the system strength for the connection of power electronic converters
- SCR varies with system conditions
- There are few different SCR calculations proposed in the industry

$$SCR = \frac{short\ circuit\ MVA\ of\ \ AC\ System}{converter\ MW\ rating}$$



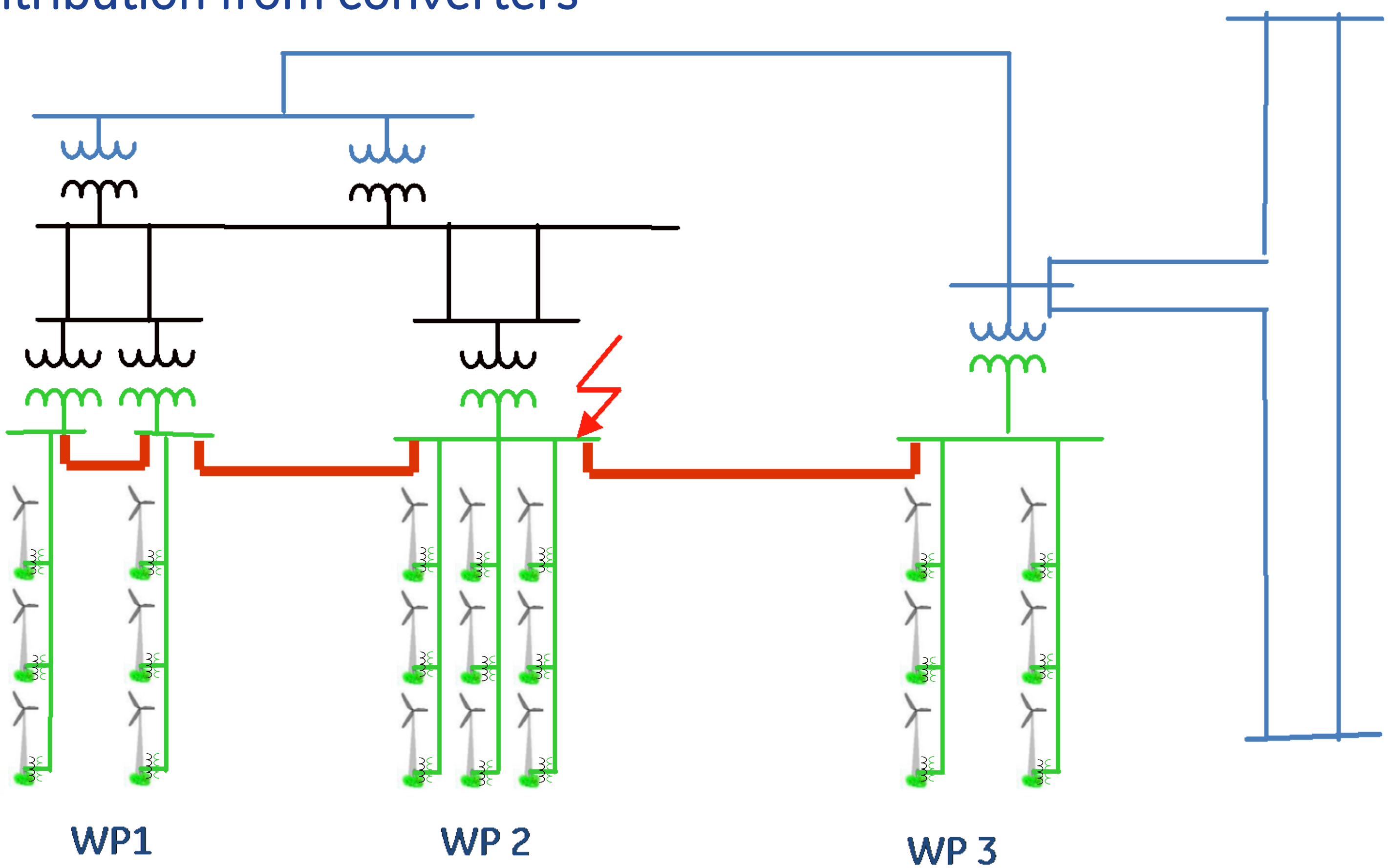
SCR applied to Wind Plants

- In the case of Wind Plants (WP), the characterization of system strength has to take into account all electrically close converters (**Multi-infeed**)
- *Composite SCR* (CSCR) considers the grid strength as seen by *all* electrically close converters and is used for wind plants.



Composite SCR

- Composite short circuit level (in MVA):
  - 3Ph short circuit at 34.5 KV buses - all interconnected
  - Low load conditions (low/realistic commitment of conventional generation)
  - Contingency conditions also considered
  - No contribution from converters



Composite SCR: Recommended Practice

$$CSCR = \frac{Composite\,SC\,MVA}{\sum converter\,MW\,rating}$$

- Composite SCR is useful to characterize grid strength and screen for system stability risks
- Understanding of the grid parameters, system operation and future wind projects is required to meaningfully estimate CSCR
- Grid entities should estimate this parameter for normal and contingency operation and communicate to developers.
- For very low CSCR applications, dedicated detailed analysis is recommended

Summary

- Large concentration of wind plants connecting to same (or close) transmission node can result in moderate to low grid strength
- Understanding and potential remediation of wind plant operation under very low grid strength requires collaboration between system operator, planners, developers and OEMs
- CSCR estimation is an initial step in such collaboration
- GE technology includes control features and settings to facilitate reliable operation in low CSCR sites

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