SPP-ESIG Workshop

IBR Stability in Low System Strength Applications

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Outline

- What controller performance are affected in an IBR plant with low system strength
- Examples of stability risks
- Tradeoff between speed-of-response at IBR and BPS reliability
- Mitigation of stability issues – discussion and project experience
- Few additional points on EMT models

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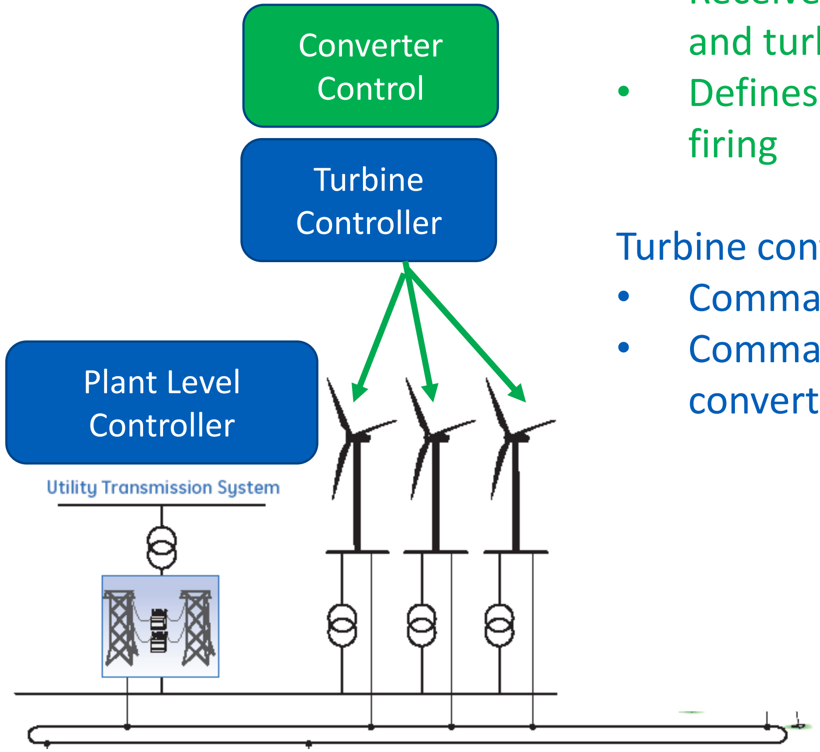
What is affected by System Strength in an IBR plant?

- Controllers affected by grid strength
  - Response times of voltage regulator affected
  - System ability to absorb active power
  - **Mostly Converter or Inverter control**
- Product (Inverter, WTG) design processes
  - Short product cycles
  - Range of system conditions
  - Project specifics are usually unknown
- Project (solar plant, wind plant , etc)
  - Interconnection processes
  - Modeling needs



Converter control
- Receives commands (Plant and turbine control)
- Defines power electric device firing

Turbine controller
- Command to pitch
- Commands torque to converter control

Established design processes and product improvements
Project interconnection efforts becoming more involving

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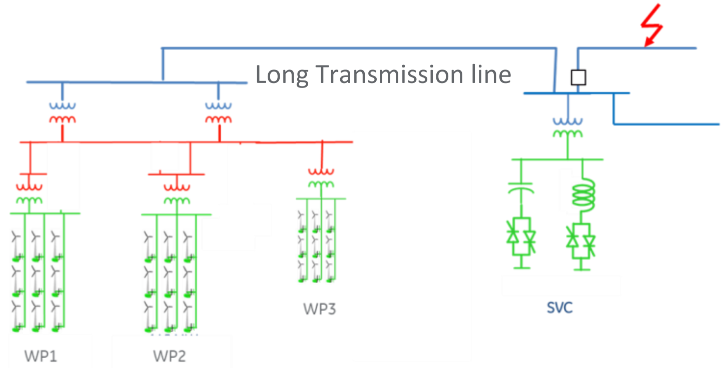
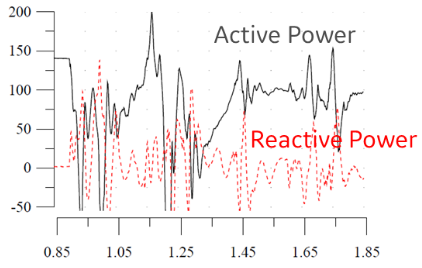
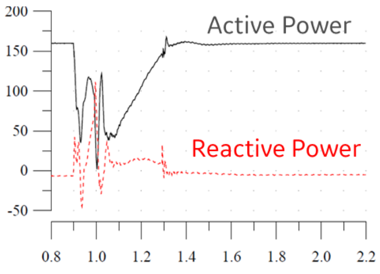
Stability risk examples and mitigations

Fast Control Interaction





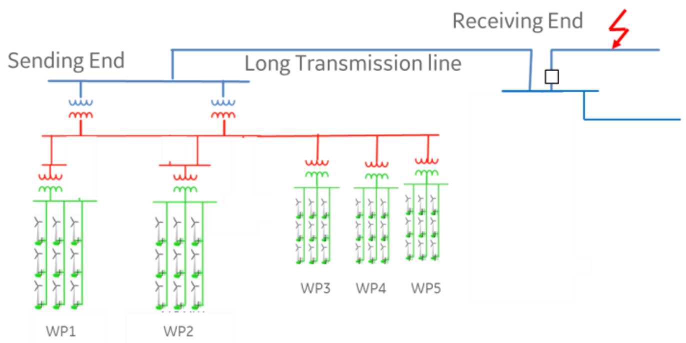
WTG settings for normal system strength



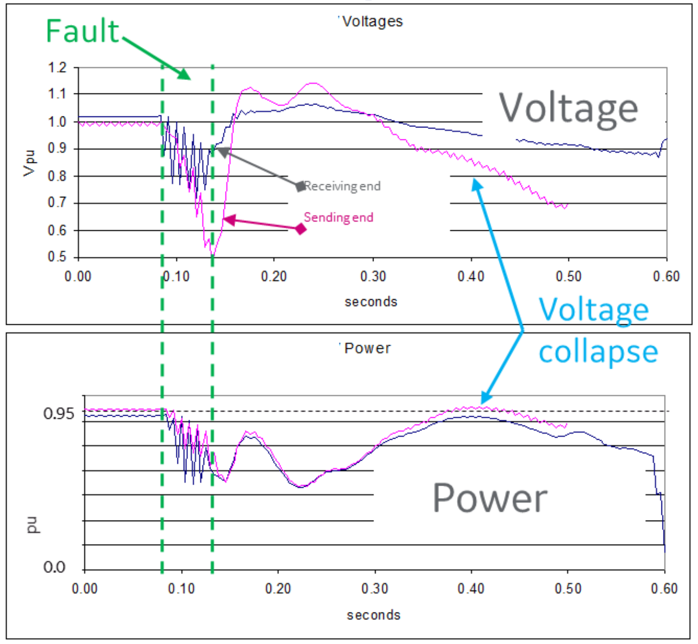
WTG settings and features for low system strength

- Extreme low SCR
- 5-20Hz interactions between IBR and SVC only present in weak condition
- Voltage controls at renewable converters and SVC

Voltage Collapse



Field Recordings



- Extreme low SCR
- Remote Fault
- Fast voltage collapse during power pickup
- IBR trips or line protection operations (without fault)
- Adjustment of reactive power to sustain power transfer was possible from IBR to resolve this risk

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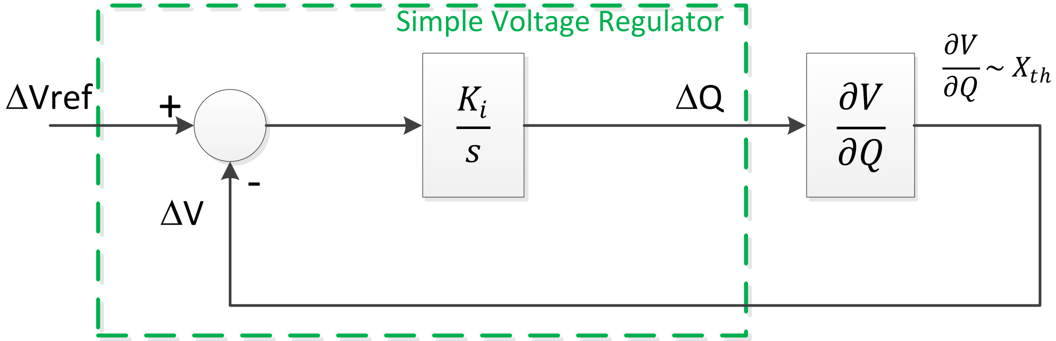
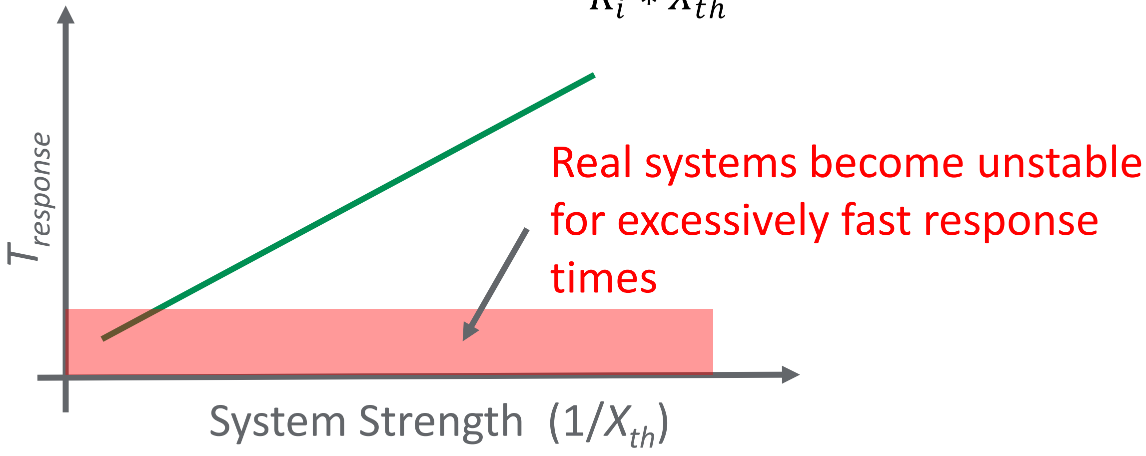
Response Times and System Strength

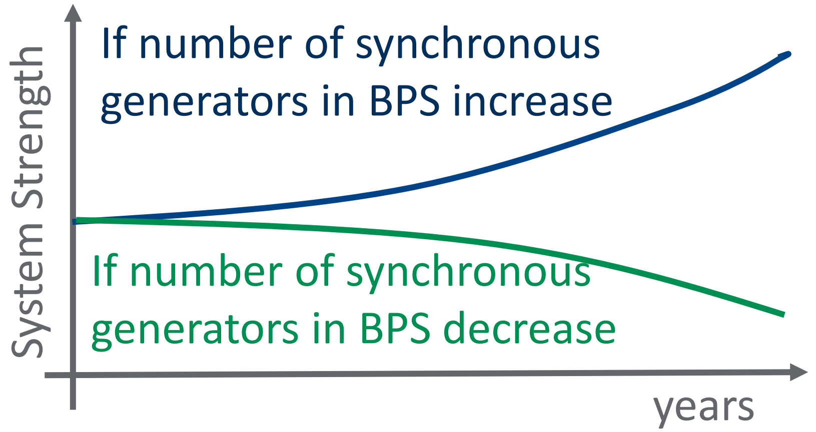
Equipment Considerations

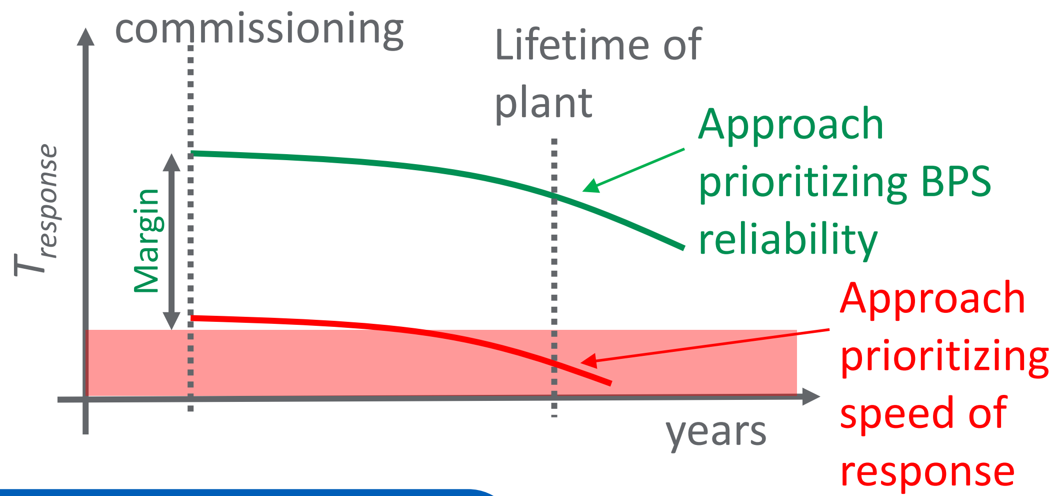


$$T_{response} \sim \frac{3}{K_i * X_{th}}$$



Planning/Requirements Approach





Priority on BPS reliability over speed-of-response is recommended

Important details on N-1 vs N-0, effect of additional IBR plants close-by, different regulators affected, plant level vs IBR unit level responses

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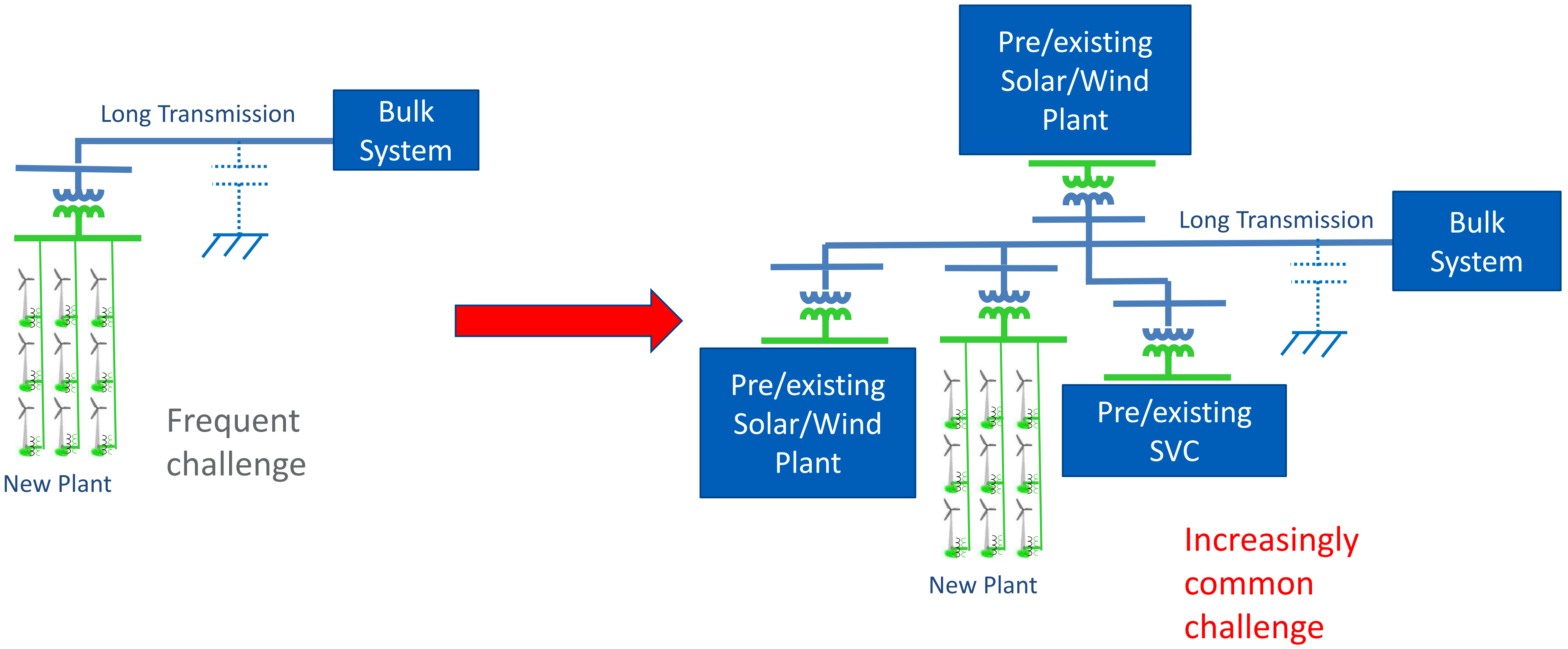
Evolution of the system strength challenge



Evolution of the problem affecting pre-existing equipment

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More on Stability Risk Mitigations

General view –OEM oriented

- Some applications ***may*** need mitigations to achieve desired system performance under very low system strength conditions
- Mitigations can include
  - Transmission upgrades
    - Additional 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)
- IBR may have control features to improve performance in low system strength conditions
- Plant level control coordination

Project experience shows….

- IBRs are highly controllable. Most developers prefer to explore IBR control modifications first. Control and interaction complexity and time to find solutions may demand a different approach.
- On the potential issues:
  - Large signal over small signal. Most challenges are on recovery after faults. Steady state operation is not usually a concern, even for extreme low system strength.
  - Requirements that demand "maximum and fastest ~~capability~~ response" have projects with lengthy process that lead to slower and less responsive IBR configurations
- On IBR or other power-electronic control modifications
  - Reduce IBR active power recovery after fault (for systems that require fast recovery)
  - Reaction to high voltage magnitude on fault recovery
  - Control adjustments in new IBR plant vs old IBR plant close-by
  - Undo setting modifications based on unrealistic grid conditions (usually infinite system strength at POI)
  - Slow down SVC/STATCOMS

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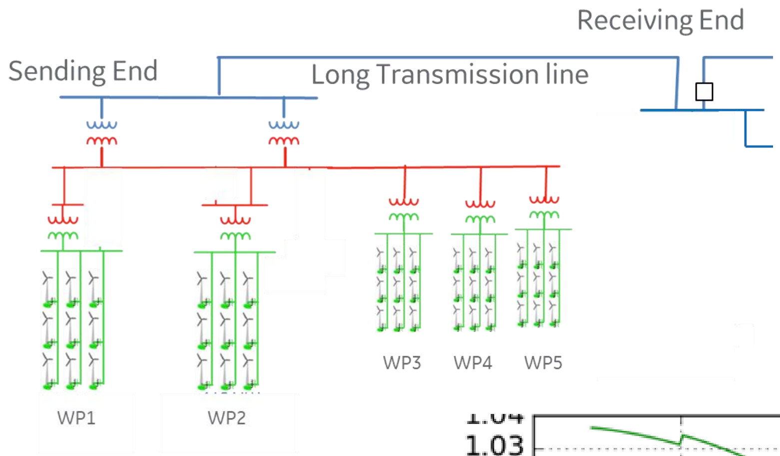
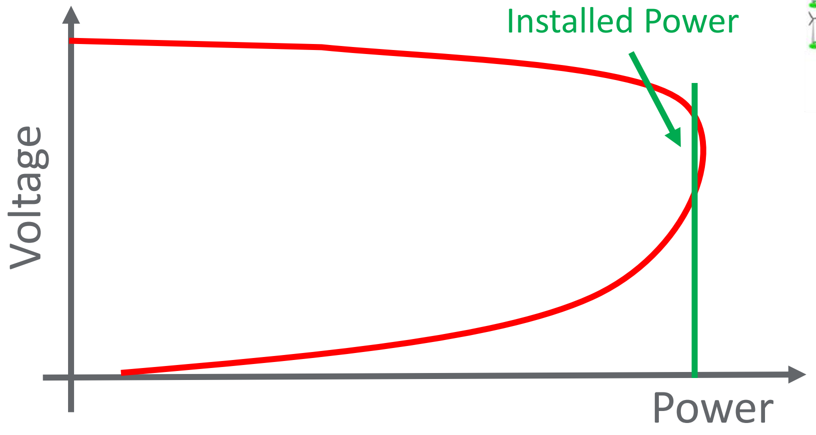
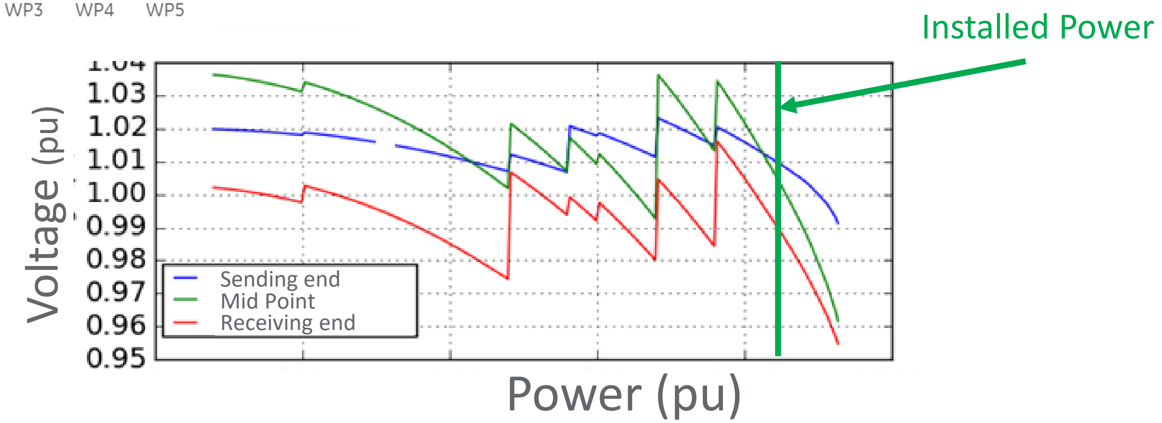
Stability risk examples and mitigations

IBR and transmission system can be designed to operate closer to the voltage stability power transfer limits





PV curve of an IBR project - Conceptual graph



PV curve of an IBR project – Actual graph

Power transfer verifications continue to be a relevant analysis and design verification

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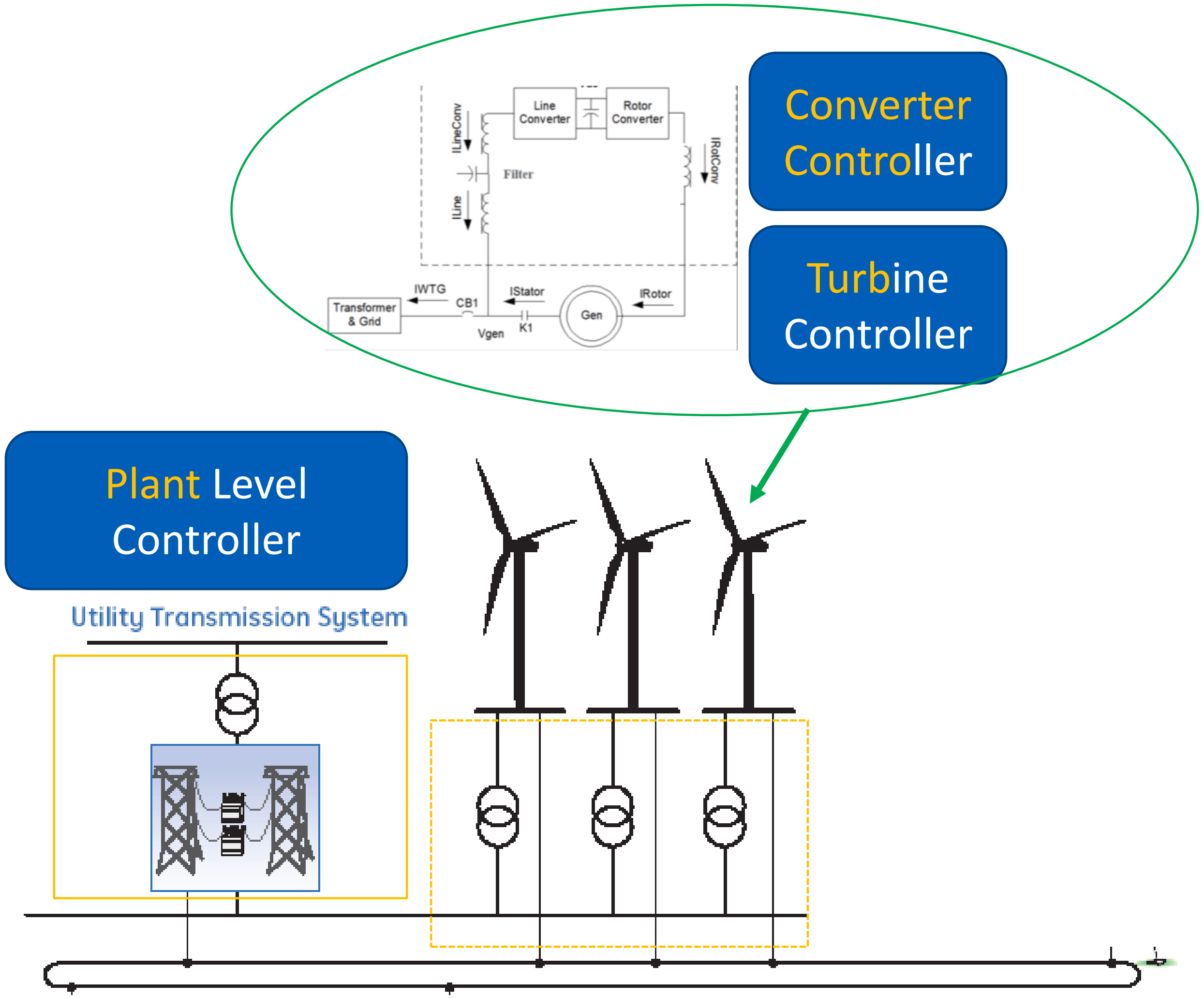
What is typically represented in an IBR EMT model?

Yellow letters indicate detail reflected in EMT models

Other Considerations

- High Frequency Damping
- Electrical Machine
- Numerical interphases
- Aggregation of IBR
- Aggregation of collector system
- Controller software versions and configurations
- Initialization
- Drive Train



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Trends on IBR EMT models (OEM viewpoint)

- Increasing complexity of BPS EMT simulation cases used in control verifications during product design efforts
- Increasing customer/utility/operator requests for EMT models to be used for performance compliance verifications (weak systems, SSCI, just-in-case, etc)
- Customer-type EMT models expected to include increasing detail
- Institutional realization that "EMT + more detail" results in:
  - Increased engineering hours required to get models to run in BPS studies
  - Need for longer study times before decision making
  - Unintended consequences of "tweaking" EMT detailed manufacturer model parameters during a study

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FINAL REMARKS

- Several controls in an IBR plant. Converter control most affected by low system strength
- Several forms (some new) of stability risks and interactions
- Choosing reliable BPS over fast IBR. System strength may decrease over time
- Large signal performance aspects tend to be more challenging for low system strength performance. Project experience influences IBR product design
- EMT models. What comes after receiving very detailed models?

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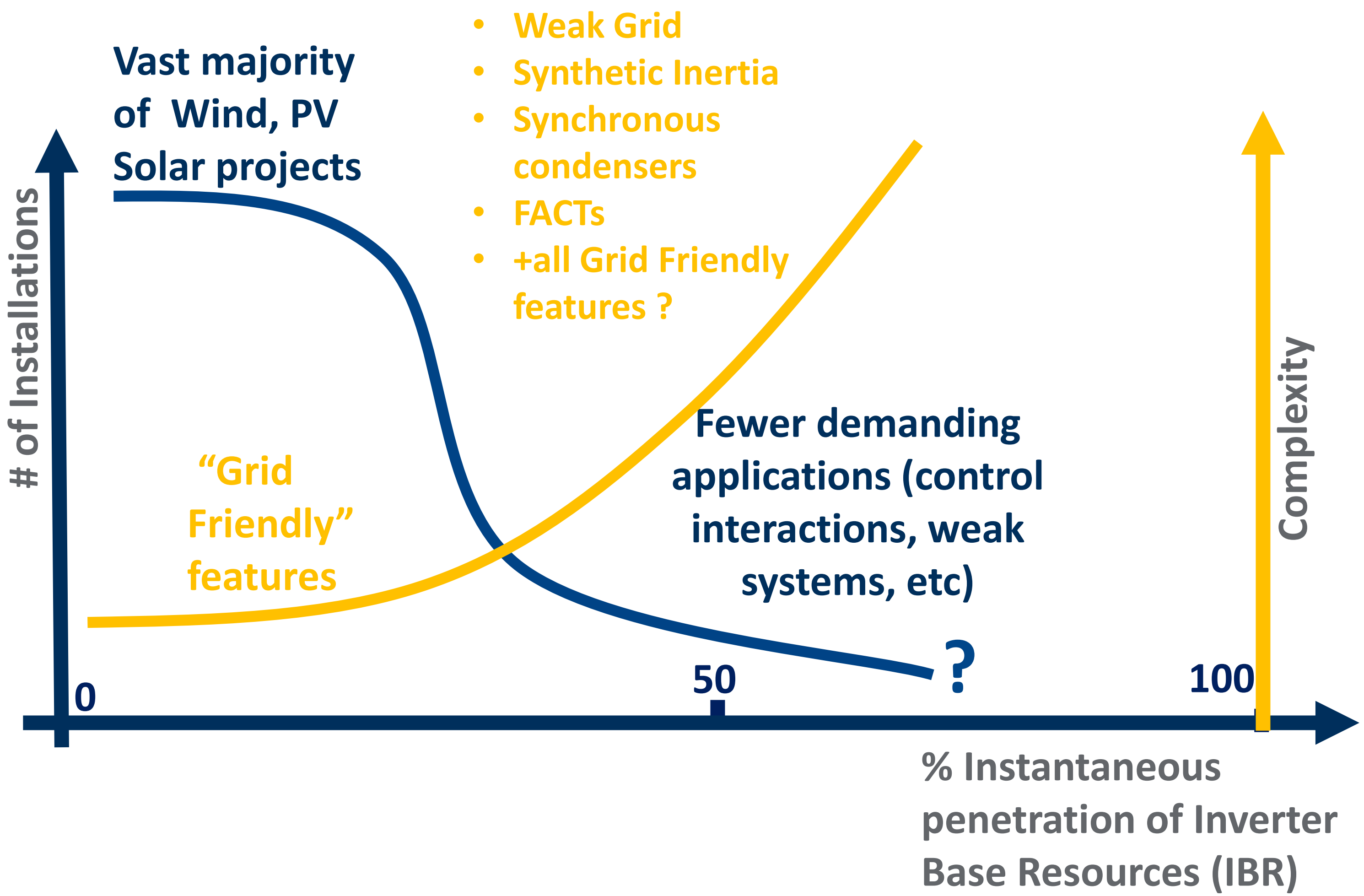
Physics…what else is going on



- What are the manifestations of these challenges:
  - Curtailments based on reliability
  - Delays/cancellation of projects
  - Increased cost of equipment
- Complexity and schedule are correlated
- How can the pace of installations be maintained with same processes and higher penetration
- Owning the risk of increased complexity
- Grid Code:
  - Simpler for low % penetration
  - Practicalities of connection processes
- Is demanding "cumulative" new features to vendors the solution
- Old projects operation limitations with higher % penetration than planned could prevent new installations

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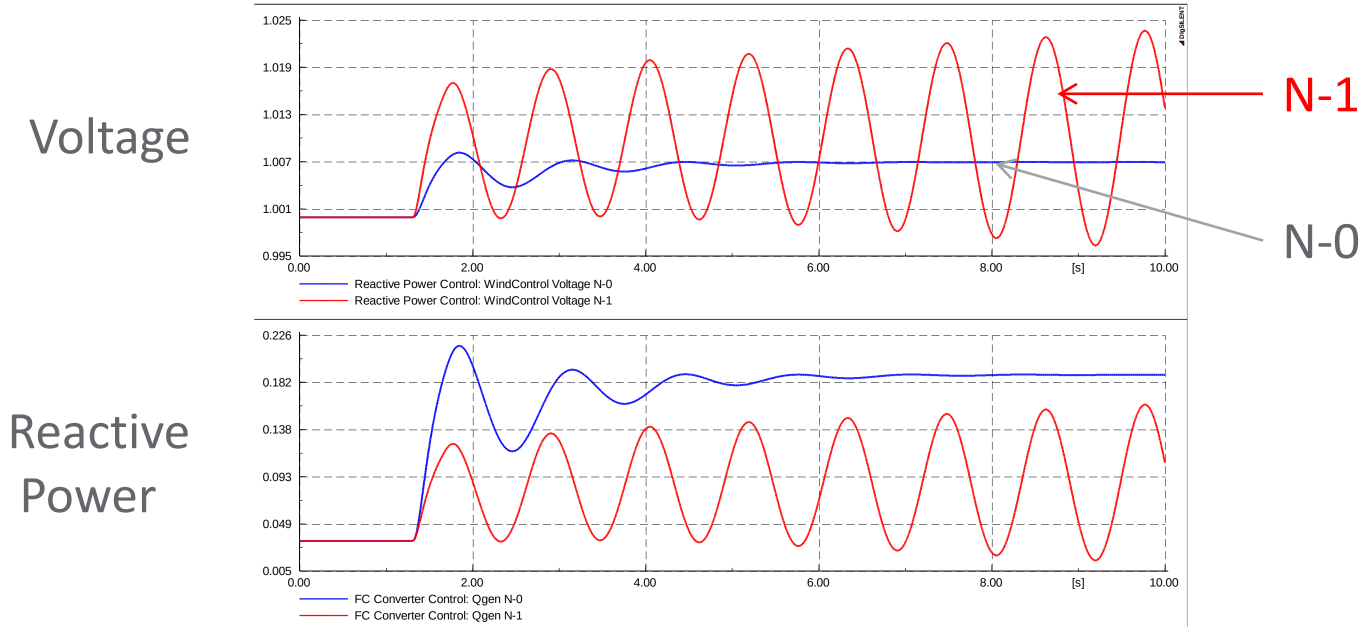
Weak grid applications



- Close loop voltage regulators are affected by system strength
- Systems tuned for fast response in strong conditions may become oscillatory in weak conditions
- **Typically not a power transfer limitation**
- Plant level controllers are more sensitive
- Not related to fault conditions
- **Less complex than previous application examples**

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