2023 ESIG Fall Technical Workshop
Session 4: Grid Code Interconnection Requirements Assessment

Grid Code Compliance
A Vendor Perspective

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Outline

- IBR Product design and plant deployment
- Trends …as seen from OEM
- Example: prescriptive grid requirement and system stability
- Final Comments

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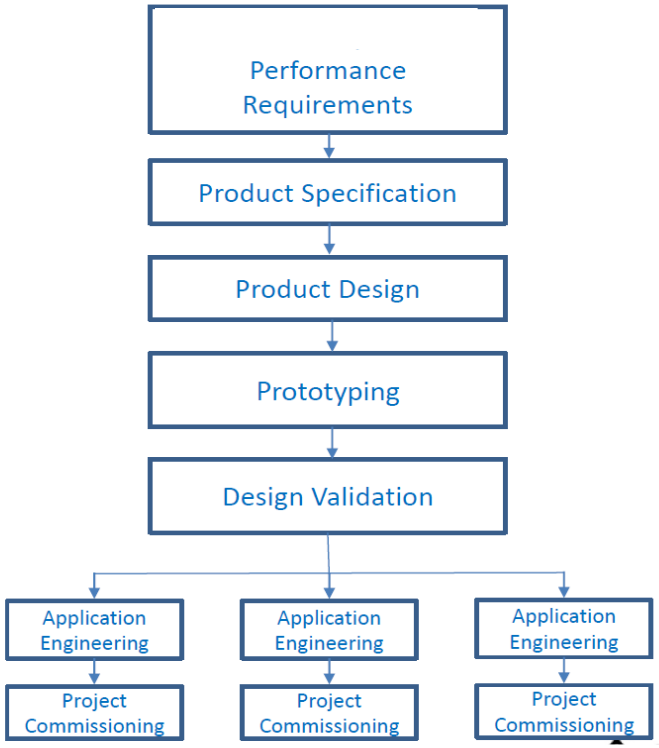
IBR Product Design/IBR Plant

- IBR product design precedes IBR plant project
- These processes include **many other aspects not related to grid compliance.**
- Performance Requirements and Design Validation include:
  - Global grid code requirements
    - Statements vs evaluation criteria
  - Prior application experience
- Product Design and Design Validation
  - Simulations in different platforms
  - HIL, full electrical system testing, container testing
  - Large set of operating conditions, grid strength and disturbances
  - Customer modeling and validation
- Adjustments of design processes for new products do not affect old products

High level design process



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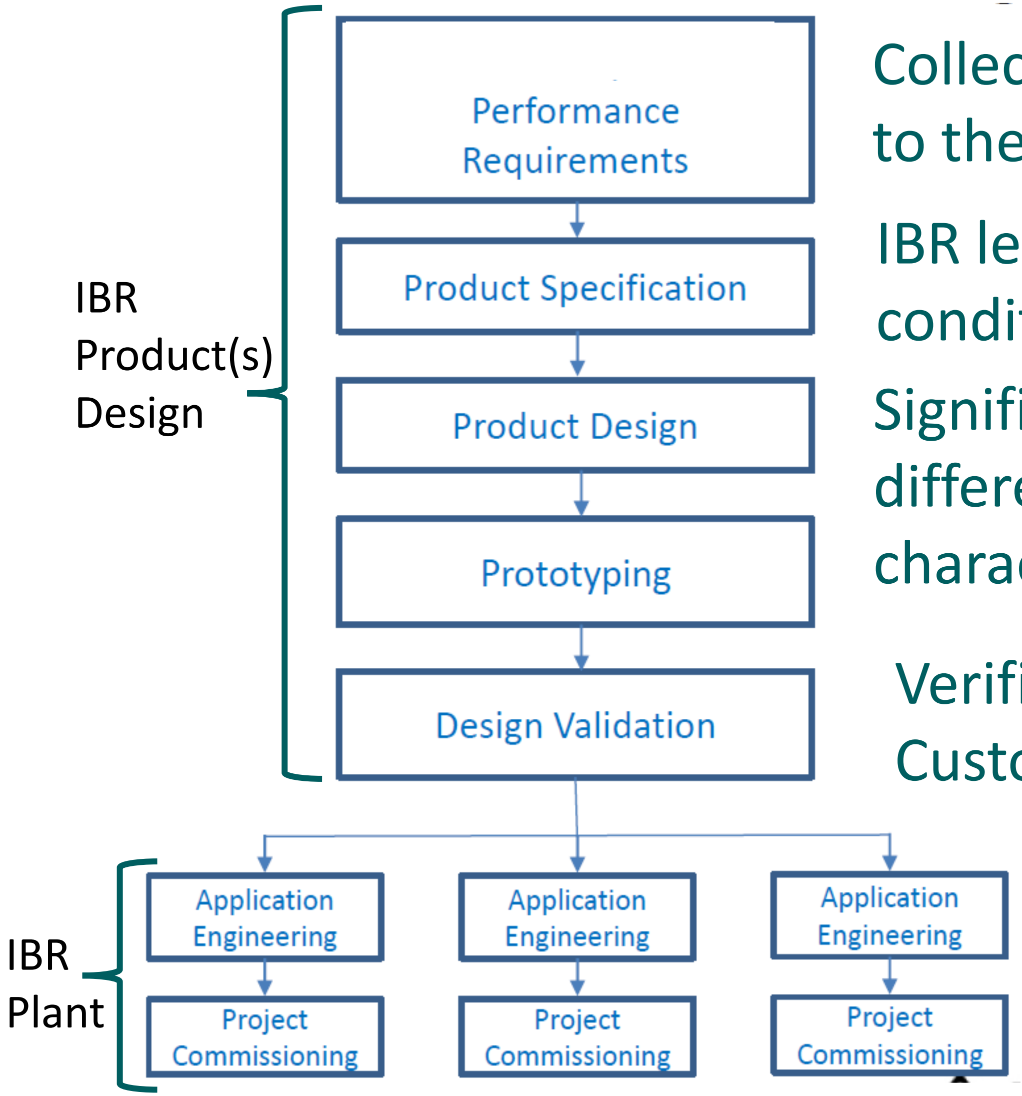
IBR Product Design/IBR Plant (cont)



Grid compliance activities

Collection and grouping of grid requirements applicable to the product

IBR level/plant level requirements. "corner points", grid conditions

Significant simulation verifications. IBR/IBR generic plant, different operating points, system strength, special grid characteristics (Series comp, etc)

Verification of grid compliance based on part of the tests. Customer model validations.

Support/Verification of grid compliance

Plant level GC testing and model validation

Trends

- Grid compliance activities are increasing in number and complexity
- Grid requirement related testing for performance validation and model validations continue to demand more attention from OEMs
- Increasing number of grid requirements affecting mechanical systems in a Wind Turbine IBR
- Grid entities with more interest and expertise on IBR grid performance
- IBR plant developers are focused on proving compliance and moving on. Sensitivity to schedule risks.
- Globally,
  - Systems that had limited IBR requirements are applying new relatively prescriptive requirements, typically focused on fast speed of response
  - Systems that demanded fast speed of response for several years seem to be moving towards stability margins and functional requirements
- Increasing cases with misalignment of IBR grid requirements and practical stability requirements of IBR plant projects

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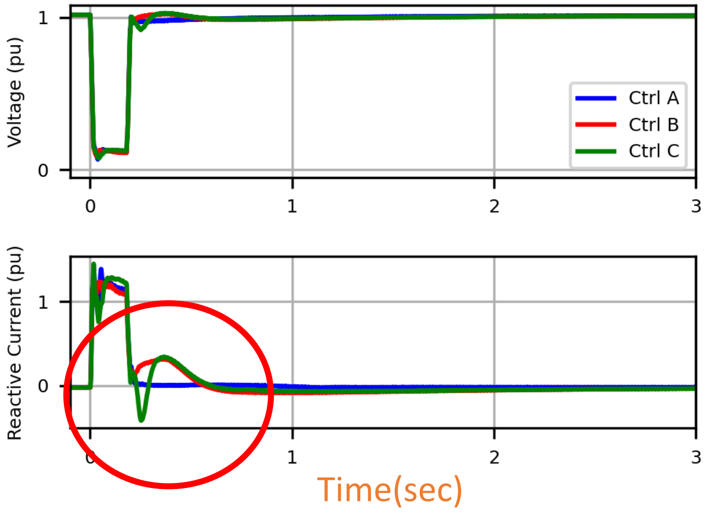
Example: Prescriptive Grid Requirement and System Stability

example criteria: post-fault reactive current settles to +10/-2.5% of final value within 100msec

- Input-Output Performance Assessment
  Three-phase fault and clear SCR > 20 before and after fault

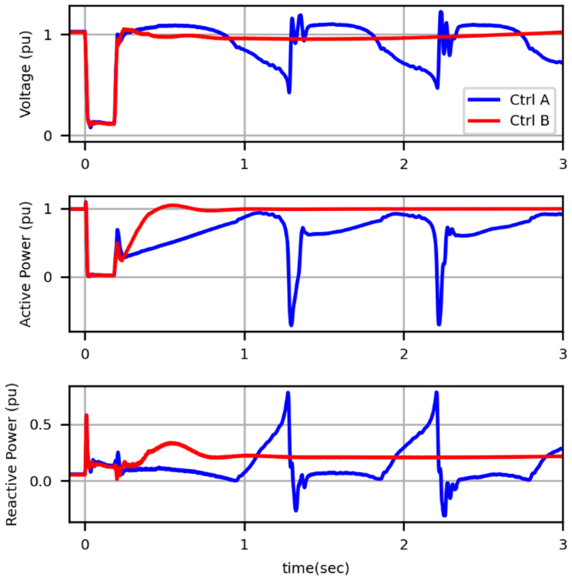


IBR with Control A ☑

IBR with Control B ☒

IBR with Control C ☒

- System-Level Performance Assessment – Weak Grid
  Three-phase fault and clear Pre-fault SCR = 2, post fault SCR = 1.5



IBR with Control A ☒

IBR with Control B ☑

"Improved Framework for Dynamic Performance Evaluation of Inverter-Based Resources". Dustin Howard et all. 22nd Wind & Solar Integration Workshop | Copenhagen, Denmark | 26 – 28 September 2023

In this example, advanced controls that adapt reactive current injection based on system conditions (Control B) fail on the I/O Performance Assessment and pass the System Level Performance Assessment

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Example: Prescriptive Grid Requirement and System Stability (cont)

- System-level performance requirements can help avoid interconnection challenges (for new projects)
- Deployment of large quantity of IBR plants based on I/O performance requirements can lead to system level issues
- Requirement documents and standards are typically long covering many aspects. This example focused on small section
- Requirements can be “negotiated” between developer/OEM and Grid authority to ensure system stability needs
  - Unusual. This may not the case in practice.
  - Developers/lenders are focused on proving grid compliance promptly and are typically under schedule pressure
  - Problems may manifest after commissioning
  - The default/faster path to prove or achieve compliance preferably prioritizes system-level stability over prescriptive Input/Output requirements

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Final Comments

- IBR OEMs have been modifying product design, incorporating grid compliance consideration in various stages to reduce deployment risks
- Grid performance testing, validation and modeling continue to be growing focus areas for OEMs designing new products
- Industry increased focus on IBR grid response
- Complexity of establishing IBR grid requirements. Prescriptive fast responses may result in unintended system level stability risks.
- We look forward for continue collaborations with developers, grid authorities and industry standard groups

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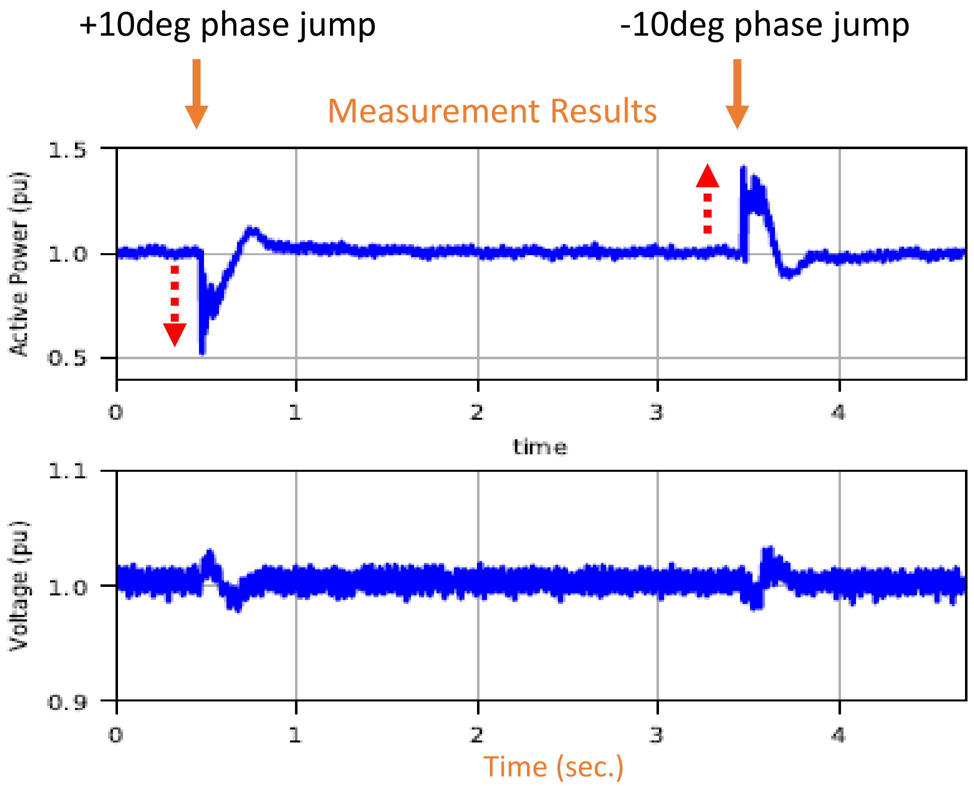
Grid Forming(GFM)… few comments on requirements

- Great progress in the Industry with GFM BESS. GFM Wind Turbines demonstrations
- Tremendous capability to mitigate key risks with energy transition like reduction of system inertia and weakening grid
- Grid requirements in drafting stage in several markets
- Advanced GFL and GFM IBRs features tend to be more impactful in System level performance assessments
- Operation close to limits of hardware capability evolving in requirement drafts



Simulation Results

Phase Jump Response Comparison b/w GFL and GFM