The Advent of the Inverter-Based System

Will We Be Ready for a Future Without Synchronous Machines?

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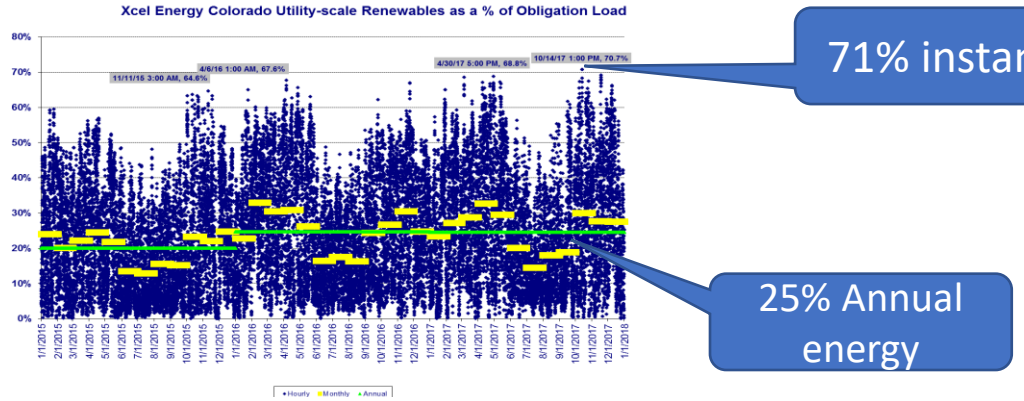
Sebastian Achilles
sebastian.achilles@ge.com
GE Energy Consulting

About the Question

Will We Be Ready for a Future Without Synchronous Machines?

- Are we? -> No
- Will we? -> May be
- **Without (?)** Synchronous Machines
  - Will We Be Ready for a Future **with significantly less** Synchronous Machines
- Motivation to address the question



71% instantaneous

25% Annual energy

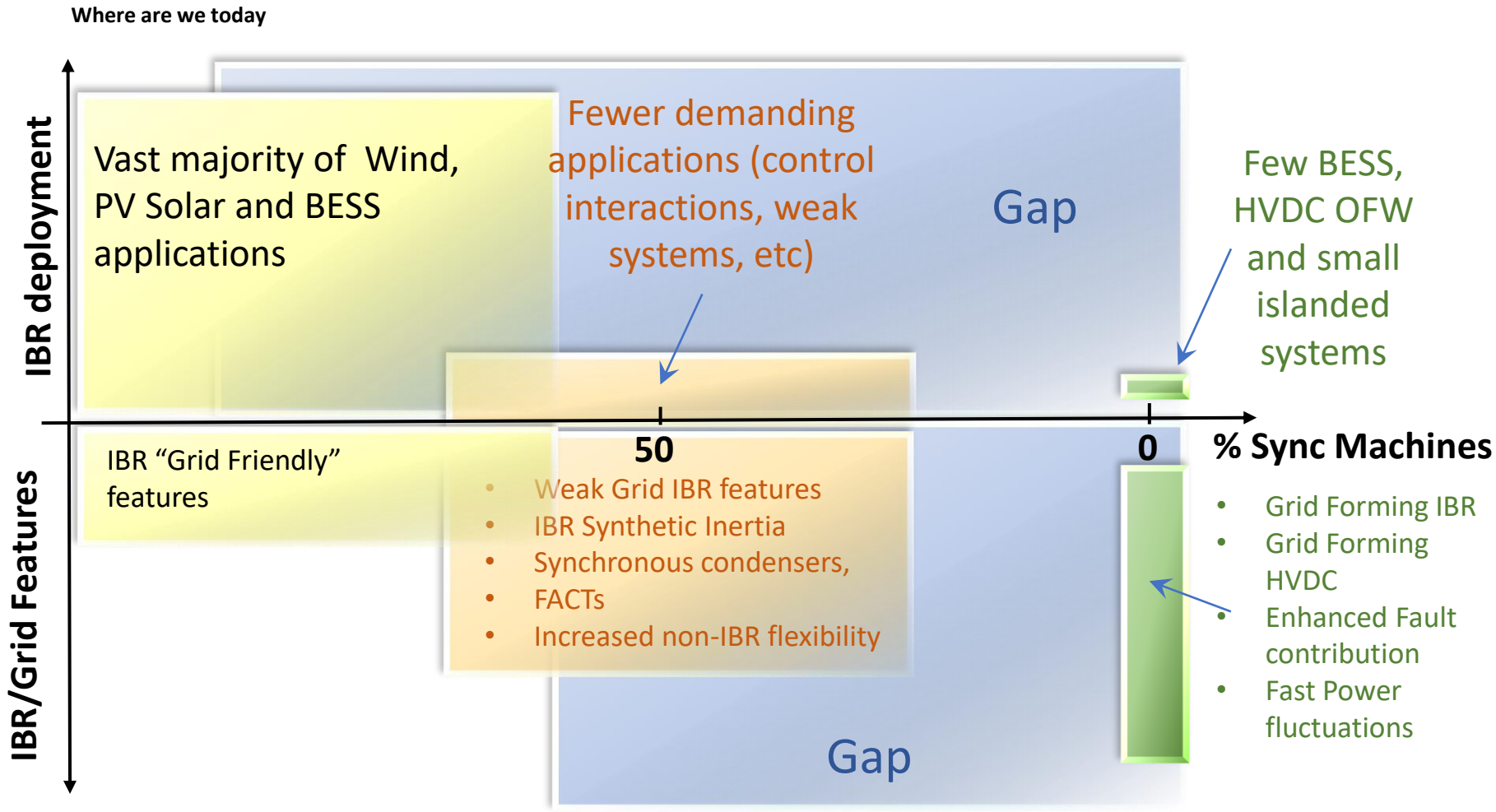
Moderate annual averages translate to high instantaneous penetrations

Source: Drake Bartlett, PSCO, 2018

About the Question

- Since I do not have a better answer available, will elaborate on:
  1. Technology readiness and gaps
  2. System reliability, tougher requirements and deployment pace…. A balancing act
  3. Motivation, framework and value

Technology Readiness and Gaps



- Deployment and technology gaps (blue)
- Modularity vs tailor-made industry

Technology Readiness and Gaps

- Who owns the gap? Generation and/or network infrastructure
- Interoperability related to stability -Grid forming (GFM) technology
  - Several levels of GFM features.
  - Technology development and requirement definitions
  - Grid forming inverter vs grid forming sources
  - Single GFM source (Offshore wind HVDC example) and multiple GFM sources (Distributed BESS systems)
  - What equipment was deployed with some GFM features: BESS and HVDC
  - What equipment could be designed with ***some*** GFM features: BESS, HVDC, PV, WTGs, STATCOMs
  - Potential hardware modifications from GFL to GFM: energy buffer and fault current contribution magnitude
- Protective relaying
  - Reliable and secure fault detection with lower (different) fault contributions
  - Require GFM to contribute to faults like sync machines vs modifying protection schemes and technology
- Orchestration of assets in a BPS - GFM is not enough
  - GFM helps addressing fast interoperability risks, but not all risks
  - EMS, curtailment, BESS SOC , ancillary services associated with stability features

System reliability, tougher requirements and deployment pace…. A balancing act

- This subject is already a challenge in several markets/regions globally
- System operators, RTO, Reliability **entities responsibilities of maintaining BPS reliability** with "significantly less synchronous machines" in the system during increasing number of hours
  - Updates to interconnection processes and other reliability verifications –
  - Increase or modified performance requirements
  - More and more difficult simulations and test requirements to verify performance
  - *With prior processes system interoperability risks may be missed*
- **Developer and OEM supporting high pace of IBR deployments**
  - Interconnection requirements can increase cost and schedule
  - Uncertainty when processes get more complex
  - Unfulfilled commitments, penalty payments and LDs
  - Increased product compliance verification
  - *Long and uncertain processes slow down deployments*
- **What needs to be balanced?**
  - Length and complexity of processes and simulation requests
  - Focus on aspects critical to system reliability
  - Performance requirements that are not unnecessarily prescriptive

Motivation, framework and value

- **Lower energy capture expected** for Wind and PV :
  - PV systems and Wind Turbine design/control based on **maximum energy capture**
    - Create value stream based on IBR reliability features to compensate for revenue of energy not captured
- "Technology" of interest to developers and OEM engineering organizations are typically focused on aspects affecting LCOE
- OEM organizations tend to be driven by large market needs

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