Volts and Amps
Future Session

ESIG Towards 100% Renewables Pathways Workshop

Jason MacDowell (GE) and Abraham Ellis (Sandia NL)

Ground Rules

- Chatham House Rules - participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.
- **Speak for yourself, not your company**

Scope of this session

- What *IS* in scope: voltage and frequency control, performance during/after disturbances and QSS, stability, protection, PQ, modeling, everything related…
- There is overlap with the *High DER* session on Grid-forming converters – *Volts and Amps* will take the lead on this topic and DER will expand
- There is slight overlap with *Flexibility and Operations* regarding performance & operational needs – F & O will take the lead
- This is not about incremental IBR penetration challenges. Those are important but not the topic for a futuristic visionary workshop like this.
- **This is about massive amounts of IBR and what the challenges and potential approaches are to enabling that.**

Agenda for this session*:

- Introductions – 10 minutes
- Setup of issues – 1 hour
- Envisioning the Future – 2 hours
- How do you get there from here? – 2 hours
- What do we need? What are the gaps? Brainstorming – 2 hours
- Wrap-up – 50 minutes

*open for suggestions

Introductions

Track 2: Volts and Amps Participants

- Moderator: Jason MacDowell, GE
- Rapporteur: Abraham Ellis, Sandia National Lab

- Thorsten Bülo, SMA Solar Technology AG
- Julia Matevosyan, ERCOT
- Nick Miller, HickoryLedge
- Mahesh Morjaria, First Solar
- Ryan Quint, NERC
- Goran Strbac, Imperial College

Questions to encourage discussion…

- What are the main system performance challenges of inverter-dominated systems based on operating experience with weak grids and zero/low inertia systems?
- What should performance be during and following disturbances, system restoration/black start and to assure control stability and voltage/transient stability?
- What are the key enabling technologies and their relative significance? Grid forming inverters? Synthetic inertia? Synchronous condensers? Advanced controls and protection? Other?
- What are the most significant modeling challenges to properly study system stability and other performance aspects at the bulk system scale?

Questions to encourage discussion…

- What are the new aspects of reliability to consider with high penetration of inverter-based resources (such as impact of DER on bulk power system, controllability/observability, others)?
- How should grid codes, interconnection standards and system reliability standards evolve?
- Are we missing any issues or subjects that we need to focus on?

System issues & challenges to tackle

- Weak grids (low/zero short circuit ratio; high impedance networks)
- Low inertia / high RoCoF
- Frequency Control: Fast, Primary, Secondary (reg/reserves) and Tertiary … speed, MW, direction and headroom!!!
- Control stability/coordination and performance during/following disturbances (including momentary cessation and PLL stability); shunt & series resonances (including SSCI, induction gen effect);
- Physical stability (voltage, transient, small signal/oscillatory) and damping
- System restoration and black start
- Power quality
- Protection coordination – low fault current, selectivity/security with IBR, unbalanced faults, detectability
- Reactive power & voltage control with no wind/sun
- Modeling – planning (Pos Seq Fund Freq - PSFF), interconnection design (EMT) and protection/SC (V behind Z)
- Interoperability with existing paradigm
- Situational awareness – what is real time inertia and grid strength?
- T&D operations – coordinated and seamless; how will reg, reserves & dispatch change?

Envisioning the Future

What would it look like if we designed a 100% renewables grid with very high penetrations of IBR? 100% IBR? Getting there is different than being there.

- Voltage and frequency control performance: speed, precision & philosophy
- What new technologies are needed (grid forming, protection, etc.)
- What does the system architecture look like? How do we operate this new autonomous system?
- How to interface with DER?
- How will planning and operations change? New methods/tools?
- Will modeling need to change? How?
- Role of storage, condensers and FACTS?
- Role of metering/PMU/WAMS?
- What will loads look like when we get there? Controllability & technology (i.e. all power electronic, predictability/observability)?

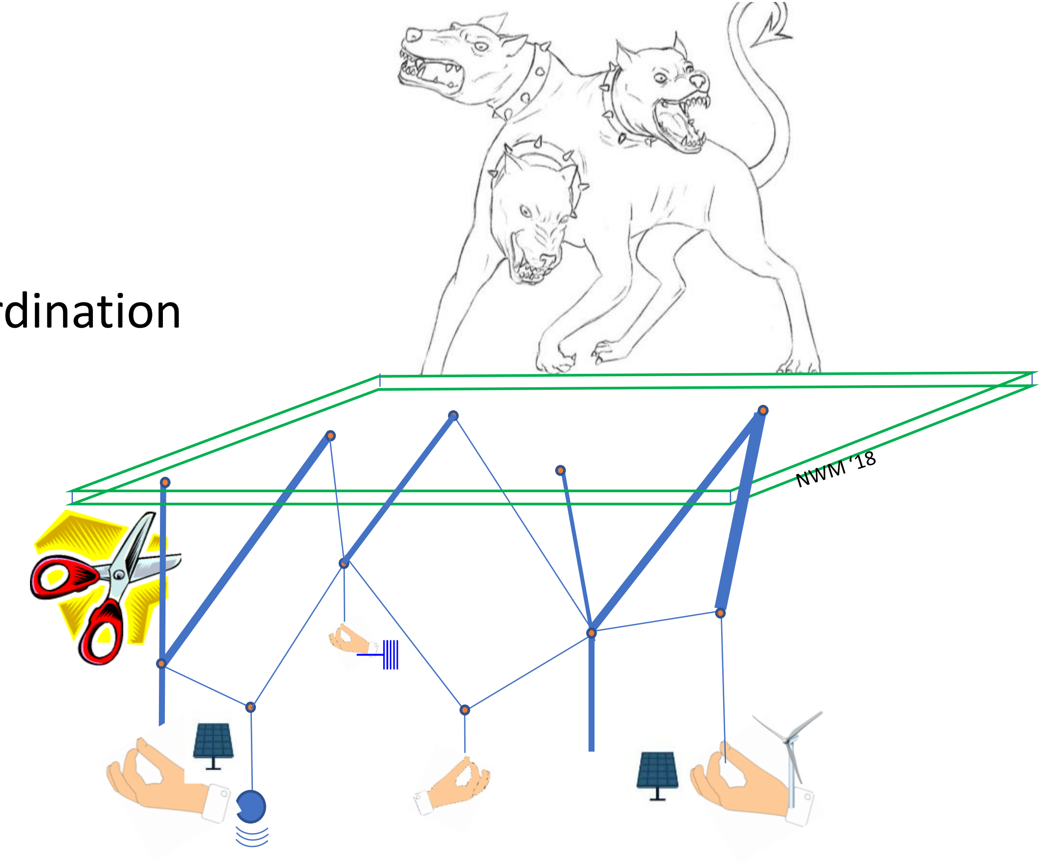
The pathway/transition

How do we get from today to this grand future?

- Issues already faced regarding high IBR penetrations: weak grid, control coordination & interactions (including SSCI), voltage and frequency control, protection coordination
- Grid forming vs. grid following… why, when and how much? When is grid forming not enough? Looking beyond PLL…
- New paradigm of protection… how to reset 100+ years?
- Storage, condensers and FACTS as a bridge (note *a* bridge, not *the* bridge)?
- Enhanced awareness with metering and monitoring?
- Interoperability of autonomous energy grids (DER) and conventional power systems
- What about non-IBR generation? How will it need to change to accommodate high IBR penetration?

Solution brainstorming

- Performance needs – rethinking speed/precision/coordination
  - Voltage
  - Frequency
  - Stability
  - Protection
- Technology needs
  - Grid forming
  - Protection
  - Flexibility from non-IBR
  - Others?
- Modeling needs
  - Planning Models – Pos Seq Fund Freq vs. EMT
  - Protection/Short Circuit
- Tool needs (link between PSFF and EMT? …link between power flow & production cost?)
- Practice/procedural needs (planning/operational practice, protection practice, round trip?)
- Grid code, technical & regulatory standards needs



Art courtesy of NW Miller, HickoryLedge