Interconnection Issues in Weak Grid

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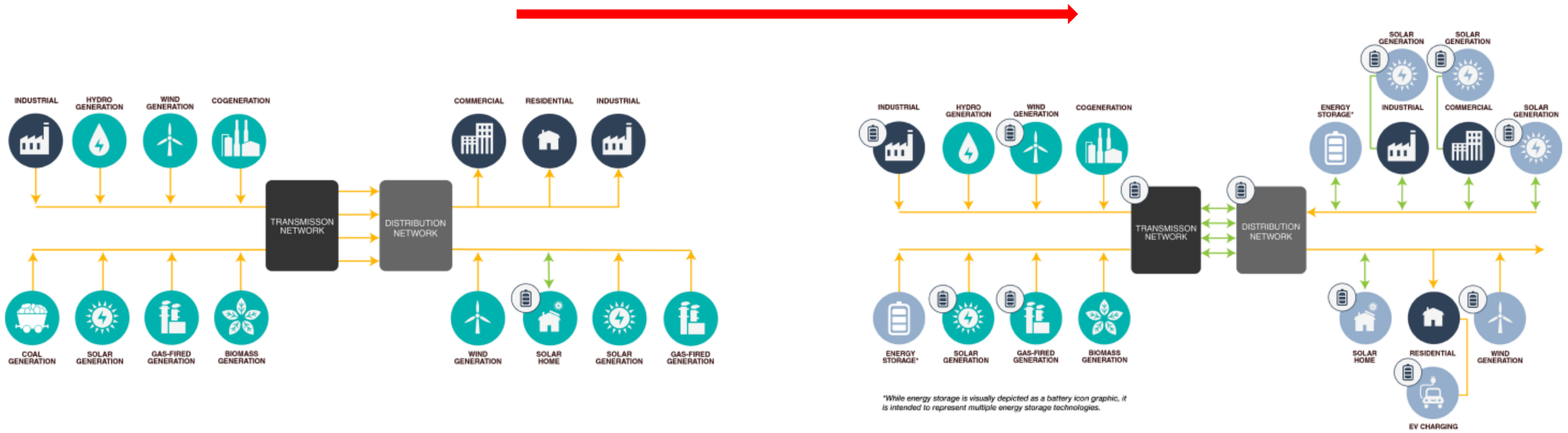
Agenda

- Background
  - Grid Transformation
  - Emerging Reliability Challenges
- System Strength and Attributes of Weak Grid
- Inverter-Based Resources in Weak Grid
- Low System Strength Mitigation
  - Grid Forming Inverters
- Take Aways

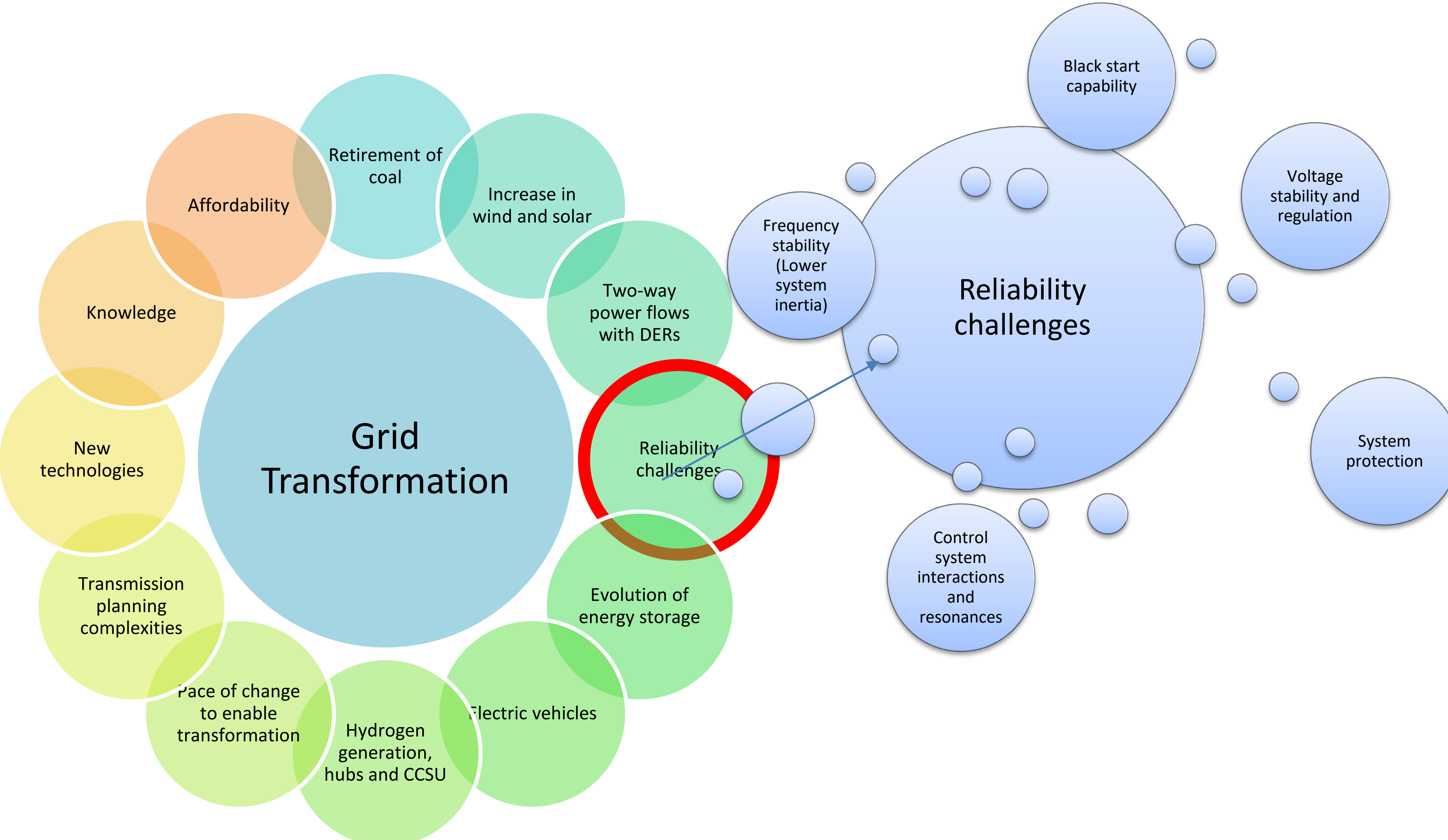
Grid Transformation

Time



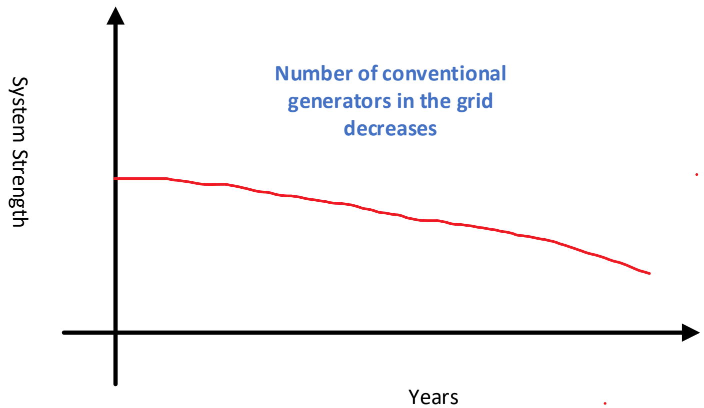
Central synchronous generators are being replaced by transmission and distribution connected invert-based resources , primarily wind, solar, and battery energy storage systems

Grid Transformation (Cont.)



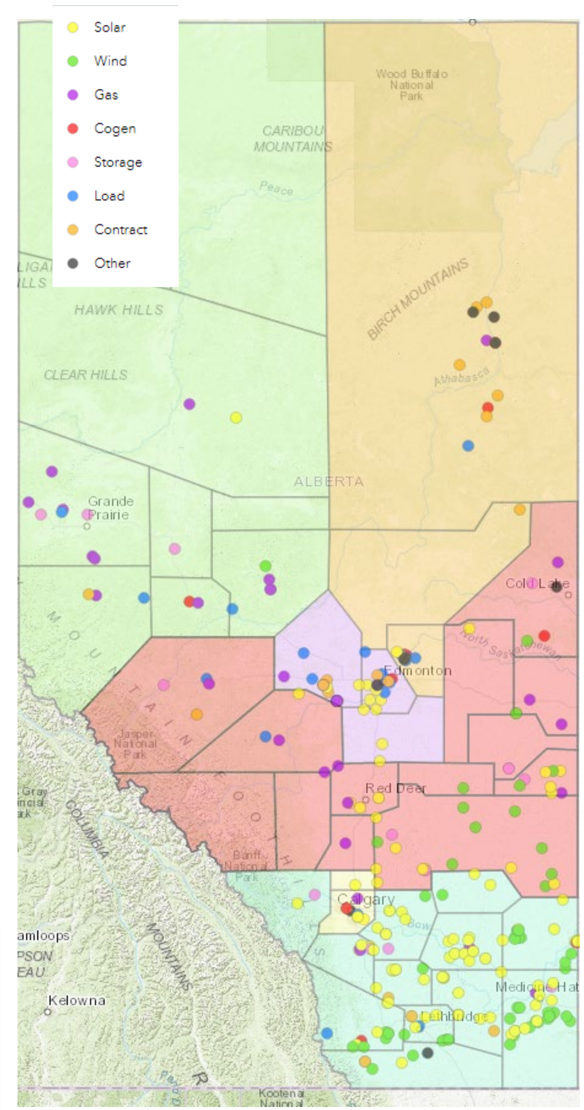
Grid Evolution in Alberta

- Displacement of conventional generation and rapid integration of Inverter Based Resources (IBRs) in Alberta's system leads to lower system strength and inertia (weak grid condition)



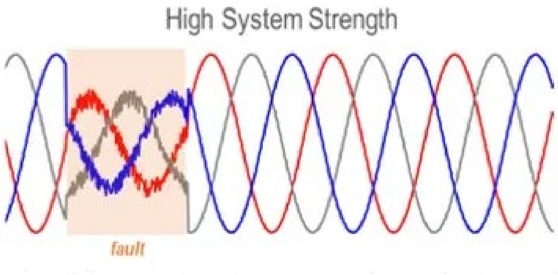
Weak grid condition can pose challenges for connecting new resources and particularly for connecting IBRs.

It becomes more difficult and less economical to connect more IBRs particularly in weak areas of the grid

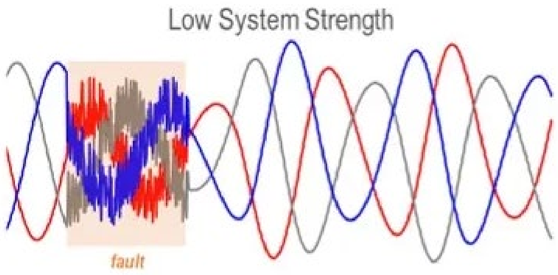


Definition of System Strength

- **System Strength** is the ability of the system to maintain and control voltage waveforms during both normal and abnormal (disturbance) operating conditions



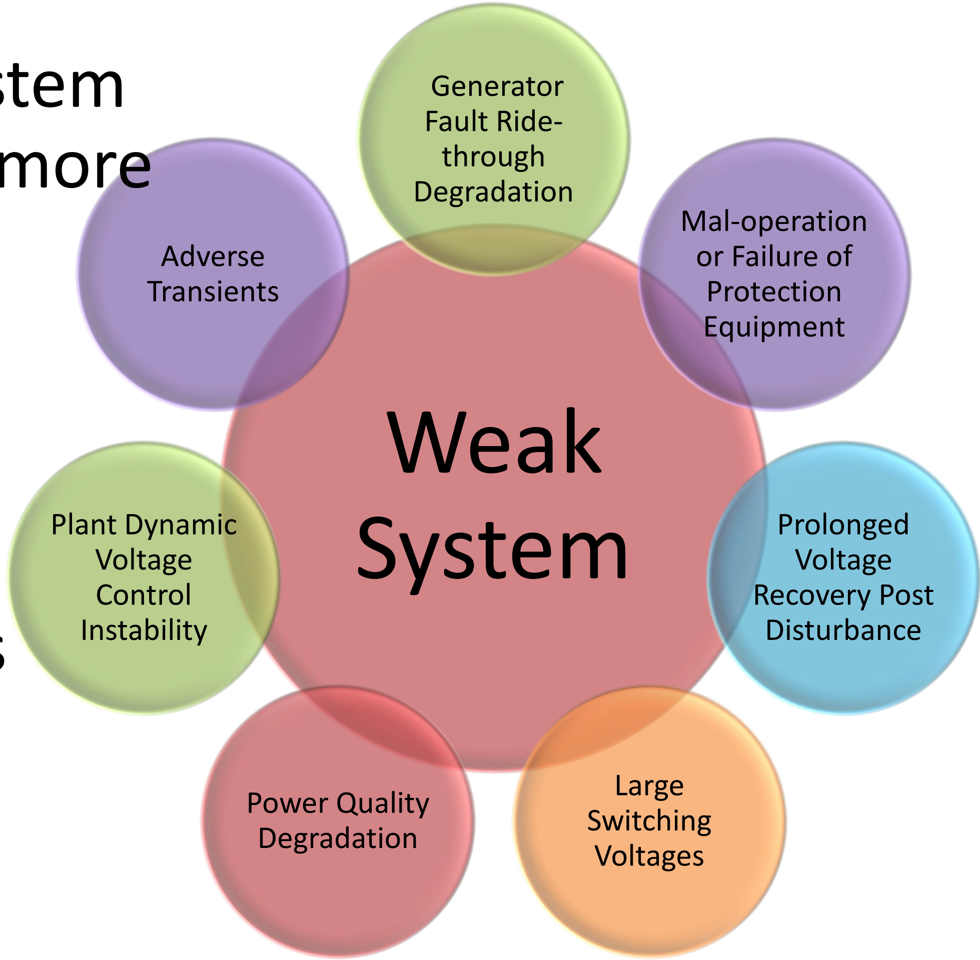
- System strength is closely related to fault level at any given location in the power system



Attributes of Low System Strength

- A power system with low system strength may exhibit one or more of these adverse impacts

- The weaker the system is, the more severe the impacts

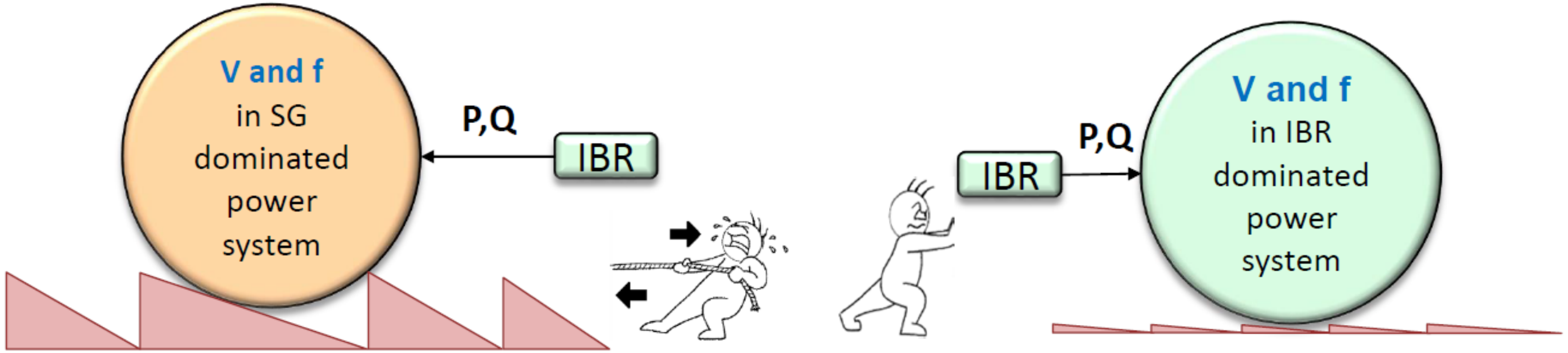


Need for System Strength

Adequate system strength is required to ensure:

- Stable operation of Inverter Based Resources (IBRs)
- Voltages remain stable and within standard ranges following:
  - Switching operations and energization (capacitors, reactors, and transmission elements)
  - Load variation
  - Network disturbances
- Reliable operation of protection systems
- Power quality
- Reliable operation of HVDC LCC
  - Lower risk of commutation failure
- Rapid and stable voltage recovery after faults and disturbances

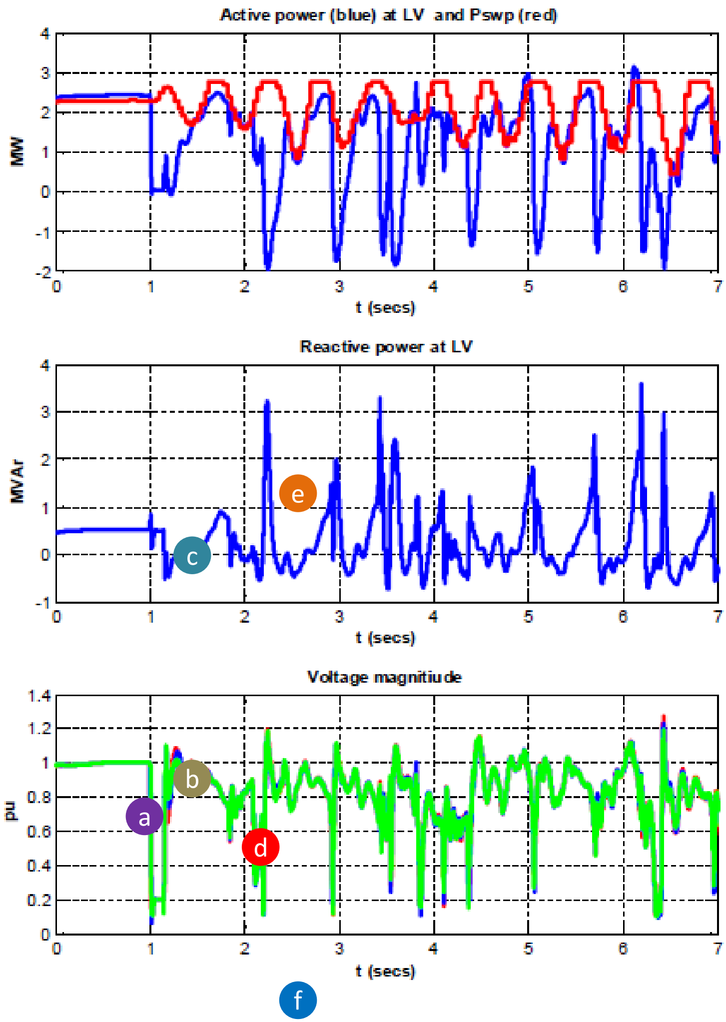
Weak Grid and IBRs



- Most existing IBR controls are designed to operate in strong systems (stiff voltage)
- IBRs need to synchronize to the network voltage to operate reliably (grid following)
- A change in IBR output moves the system quickly if the system is weak
- System changes cause IBR to move in tandem (fast control response)

Increases risk of interaction or instability

Example: Control cycling between modes in Weak grid

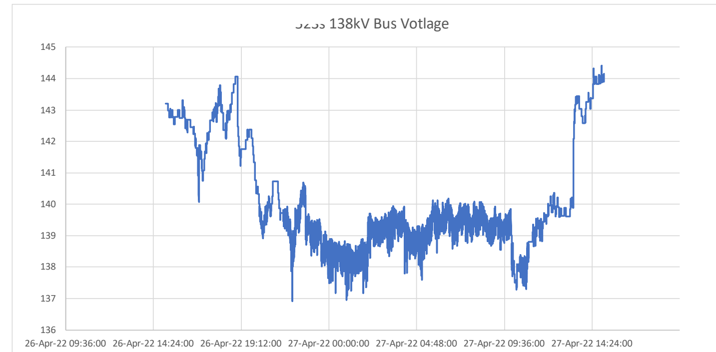


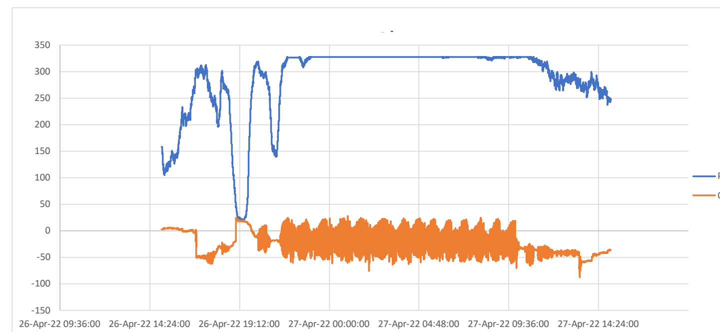
Sequence of events/control actions

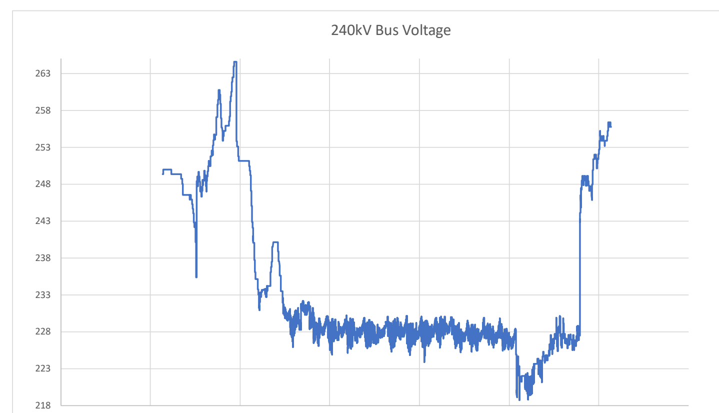
a) 3-phase fault is applied at 1s.
b) After fault is cleared, the turbine ramps up the output active power
c) The turbine output reactive power dropped quickly
d) The grid voltage lose wind plant support and get another dip
e) Wind turbine in Fault Ride Through (FRT) mode again, which gain more reactive power/voltage support
f) FRT in-out is repeated to cause the oscillation

Example: Wind Turbine Voltage Oscillation Event

- An uncontrolled voltage oscillation happened under a planned outage (N-1)
- Wind Power Plant Controller (PPC) was identified as the root cause of the oscillation
- Low System strength under N-1 condition triggered the oscillations
- The Facility's control needs to be tuned for the weak operating condition as well as other expected operating conditions







Mitigation

- To achieve desired performance under low system strength conditions mitigations may be needed
- Mitigation may include:

  - Network Reinforcement
    - Additional lines or network reconfiguration
    - Series compensation
    - Synchronous condensers
    - FACTS (STATCOM, SVC)
    - Remedial Action Schemes
  - Controls modification
    - Reduce power recovery after fault
    - Slower control response time
    - Plant level control coordination
    - Grid Forming Inverters

Grid Forming IBR

Definition as per NERC*:

> ***"Grid Forming Control for BPS-Connected Inverter-Based Resources*** *are controls with the primary objective of maintaining an internal voltage phasor that is constant or nearly constant in the sub-transient to transient time frame. This allows the IBR to immediately respond to changes in the external system and maintain IBR control stability during challenging network conditions. The voltage phasor must be controlled to maintain synchronism with other devices in the grid and must also regulate active and reactive power appropriately to support the grid."*

*https://www.nerc.com/comm/RSTC_Reliability_Guidelines/White_Paper_Grid_Forming_Technology.pdf

Characteristics of Grid Forming Inverters

- Similar to synchronous generators, the voltage source characteristic of a Grid-Forming Inverter (GFI) allows it to:
  - Provide system strength,
  - Provide frequency control,
  - Adjust output power nearly instantaneously to balance loads,
  - Enable interoperability with other types of synchronous and non-synchronous generation,
  - Set and instantaneously regulate local voltage levels,
- GFMIs yield in benefits similar to those of synchronous generators.
- GFMIs with more advanced control capabilities emerged as a promising solutions for several reliability issues tied to high share of IBRs and weak grid conditions

Grid Forming Technology

- Today's dominated IBR technology is Grid Following (GFL) which do not provide inertia or system strength

- Grid Forming (GFM) Inverters with more advanced control capabilities emerged as a promising solutions for several reliability issues tied to high share of IBRs and weak grid conditions

- Batteries are low hanging fruits for implementation of GFM controls:
  - Much higher flexibility of the energy buffer compared to wind and solar
  - Only software modifications required to implement GFM control structure (low cost)
  - There are already many BESS and hybrid projects in the interconnection queue (30 projects with over 1700 MW capacity)
  - Many of these projects are already located in weak areas of AIES
    - An opportunity to leverage the GFM capabilities to address weak grid reliability issues and integrate more GFL IBRs at a lower cost
  - Tier 1 equipment manufacturers such as SMA, TESLA, and Hitachi already have commercial offerings of GFM BESS

Take Aways

- Grid transformation may lead to emergence of new reliability issues in the power system
- Weak grid conditions driven by grid transformation may adversely impact the operation and integration of new resources particularly IBRs
- The weak locations in the system need to be identified so that mitigation measures can be deployed and planned in a timely manner
- Grid Forming Inverter is a potential solution to alleviate some of the weak grid issues

Thank you