Preparing Dynamic Databases for the Coming of Renewable Energy-Based Generation

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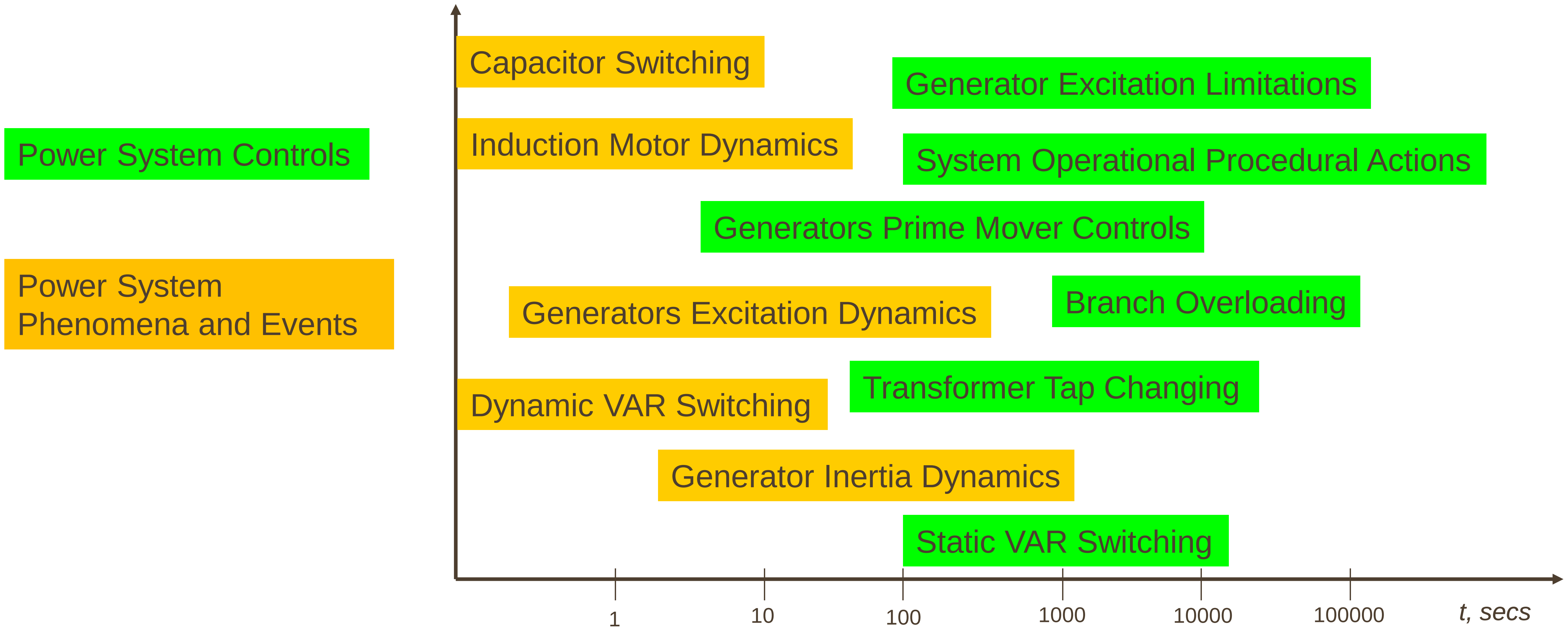
Introduction

- Computer simulation of dynamic model database is needed to evaluate stability and resiliency of electric power system
  - As part of transmission planning process (5-10 year master plan)
  - New generator interconnections
  - Adding HVdc modulation signals for damping power system oscillations
  - Static Var Compensator (SVC) for dynamic voltage support
- Target simulation frequency depends on various electrical components included in the dynamic model database
  - 0.2 – 10 Hz for Rotor Angle and Voltage Stability studies for systems supplied by rotating machines

Review of Power System Phenomena Timeframes



Commercial Transient Stability Programs

- Siemens PTI PSS/E
- GE PSLF
- DigSIlent PowerFactory
- PowerWorld Simulator

- Programs are based on positive-sequence representation of electric system.
- Initially developed to address issues on electric power system predominantly supplied by synchronous machines.

Renewable Energy-Based Generation

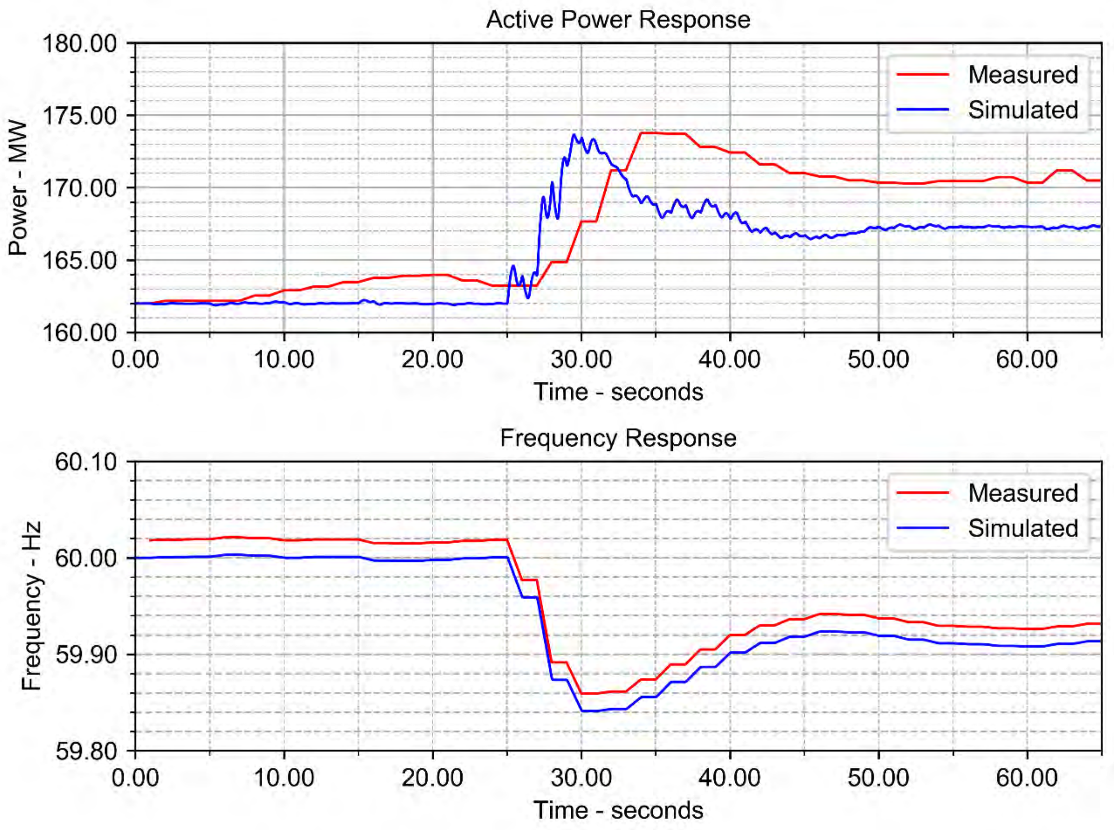
- Dynamic characteristics differ from conventional energy sources
  - Wind turbines have limited thermal capacity to provide transient reactive power support
  - Solar PV capable of independent active and reactive power control
  - Batteries can store (charge) and inject (discharge) active power depending on system conditions
- Specific Dynamic Model Renewable Generation (SDMRG)

Existing Dynamic Databases

- Dynamic models of South Asia and Southeast Asian National Grids comprise of conventional generator models.
  - India, Bangladesh, Myanmar, Philippines
- Static load models and HVdc converter dynamics included with some model instances of power system stabilizers and SVC.
- Duplicity of dynamic models for conventional units
  - Based on fuel type of similar size
- All dynamic models selected from program's standard library
  - No user-written models
  - Authors suggests to maintain the use of standard library models.

Existing Dynamic Databases

- Setting-up a model validation process is an important aspect of preparing dynamic databases for the influx of significant amount of SDMRG.
- The role of rotating machines becomes critical and accurate modeling is important as more SDMRG is included in the database.



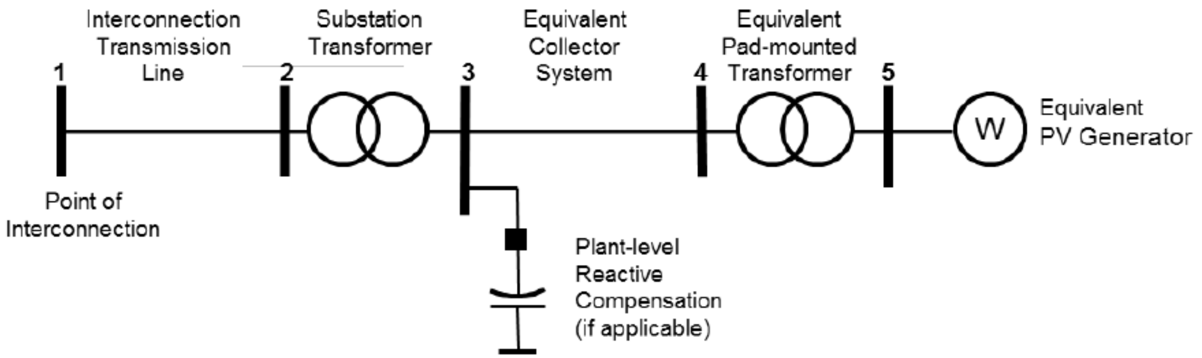
Filtering Dynamic Databases and Preparing for the Addition of Renewable Generation

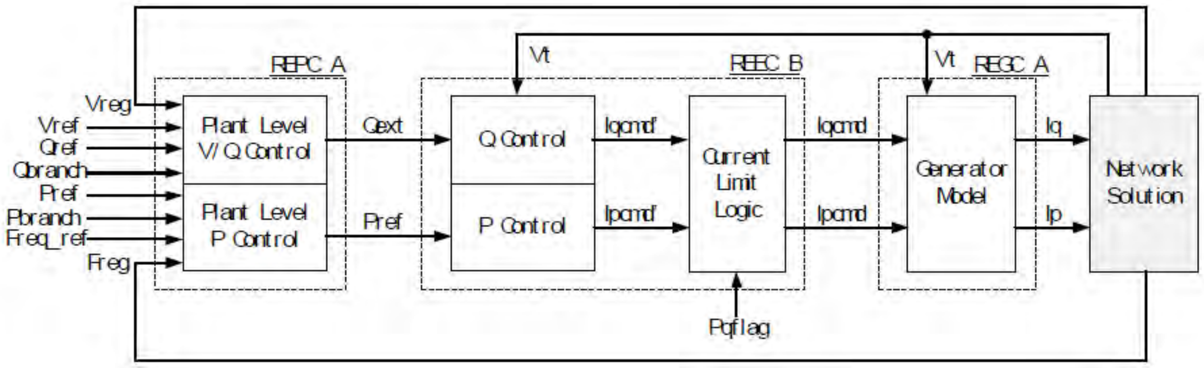
- Target simulation for stability studies ranges in the order of 0.1 to 10 Hz
- Impact of the addition of SDMRG to an existing dynamic database
  - Potentially requiring increase in upper frequency of study interest.
  - Static controls of renewable generation leads to very fast processes resulting to very high frequency response.
- North American Practice
  - WECC[1] suggested the use 5 ms (25 Hz) time step for simulating stability of systems with SDMRG.
  - Broader movement in the stability purview.

[1]WECC Renewable Energy Modeling Task Force (REMTF), WECC Solar Plant Dynamic Modeling Guidelines, Modeling and Validation Work Group, Western Electricity Coordinating Council, Salt Lake City, Utah, April 2014

Dynamic Modeling of Renewable Generation

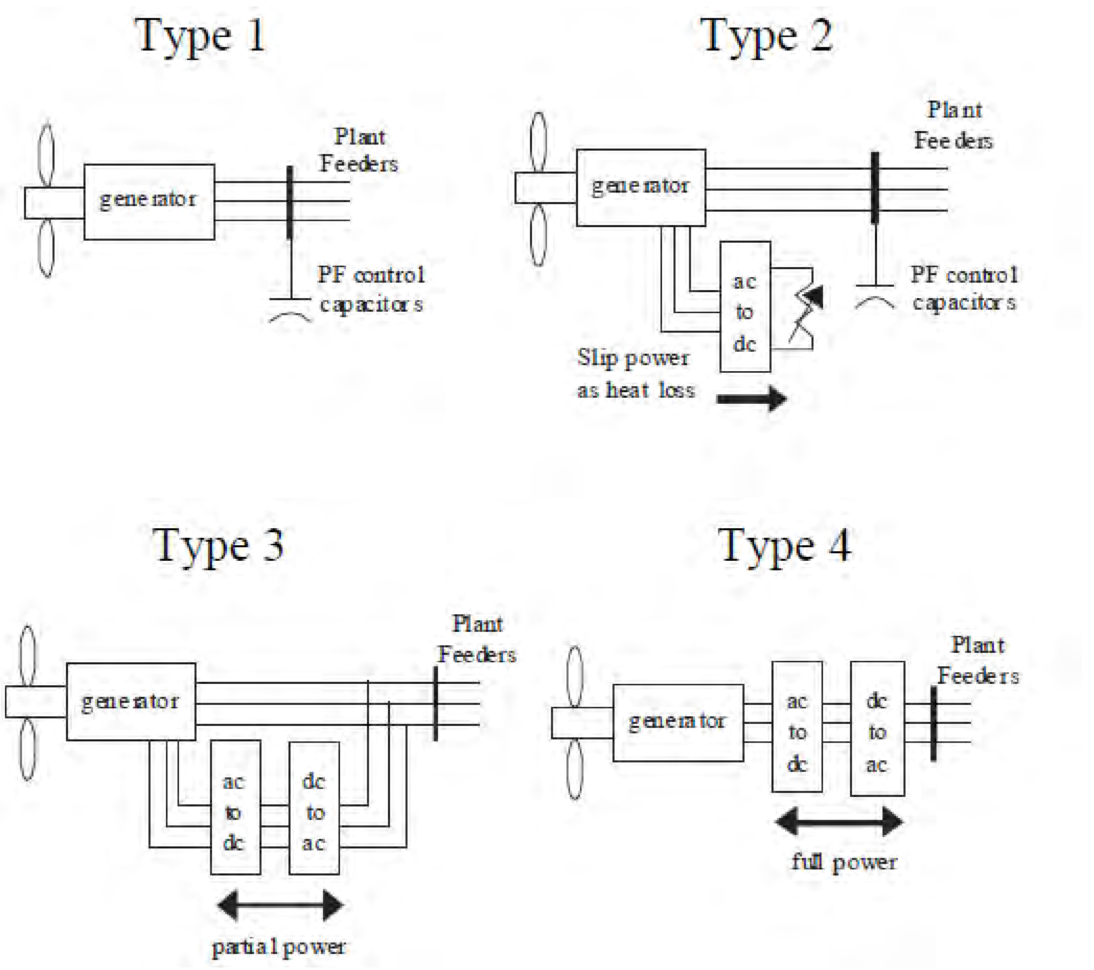
- Solar PV
  - Aggregate model is used in power flow and stability studies
    - Improve computational process
  - A generic PV dynamic model consist of
    - Inverter interface to the Grid
    - Inverter electrical controls
    - Power plant controller
    - Independent P and Q control
    - Protection and ride-through settings





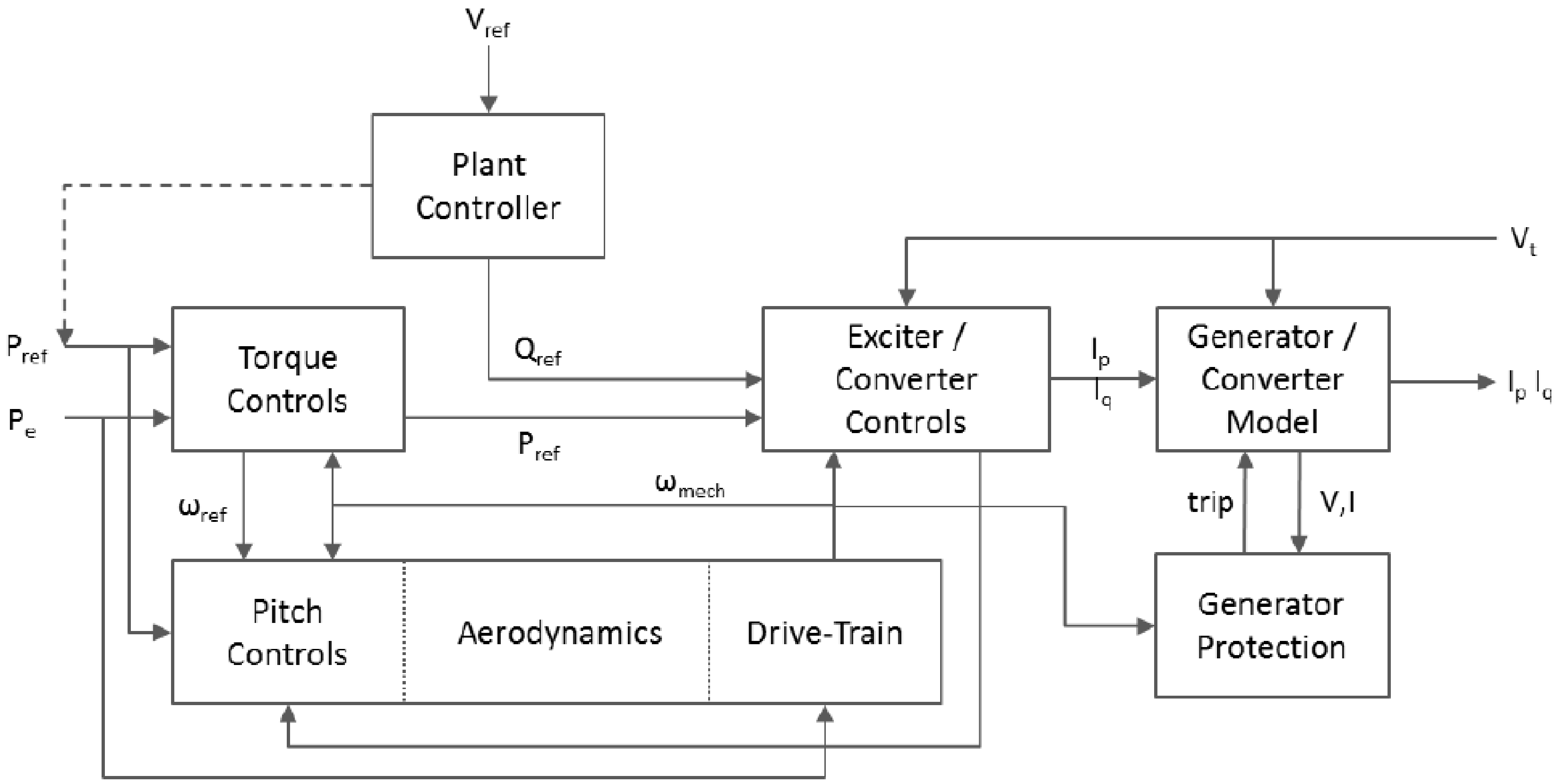
Dynamic Modeling of Renewable Generation

- Wind Turbine Generators (WTG)
  - Type 1
    - Fixed-speed induction machine
  - Type 2
    - Variable-slip induction machine with variable rotor resistance
  - Type 3
    - Variable-speed, doubly-fed induction machine with rotor side converter
  - Type 4
    - Permanent magnet synchronous machine with full inverter controls



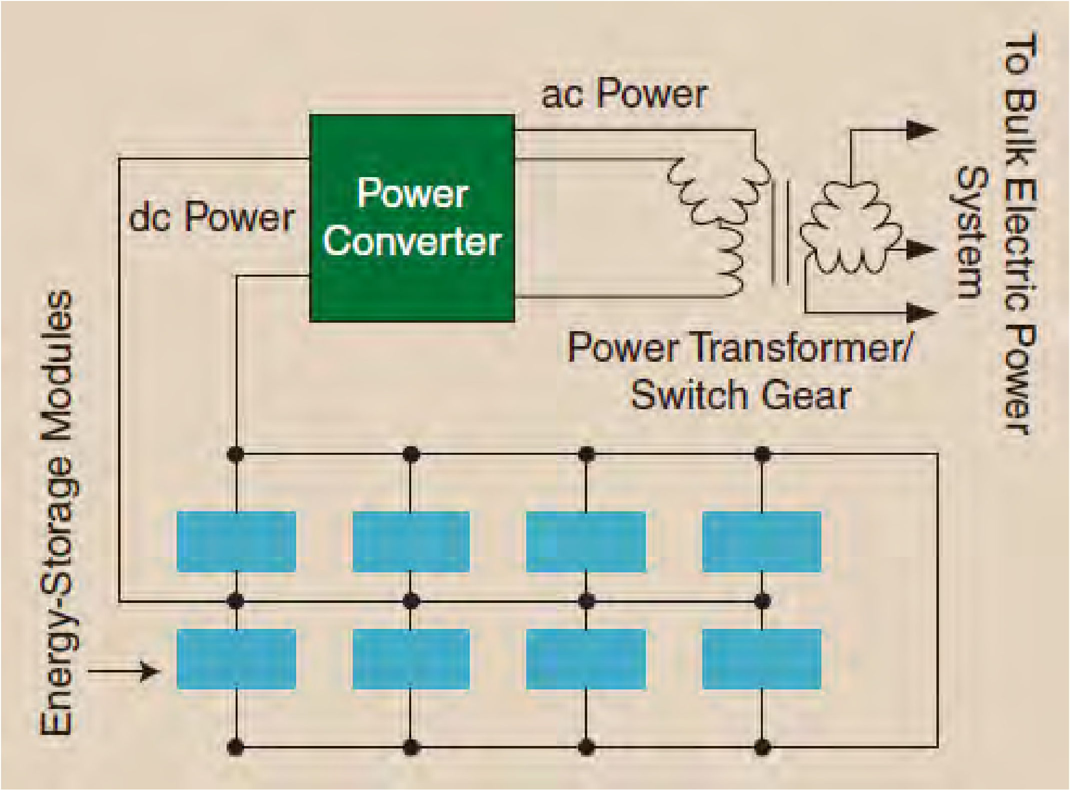
Filtering Dynamic Databases and Addition of Renewable Generation

- Generic WTG dynamic model



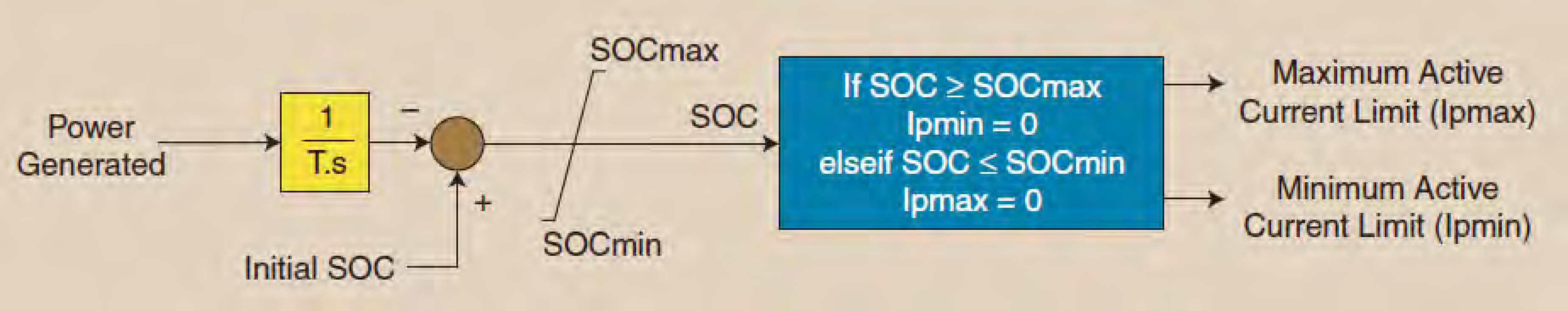
Dynamic Modeling of Renewable Generation

- Battery Energy Storage System (BESS)
  - Consist of the following components
    - Energy-storage module
      - Series-parallel connection of battery cells
    - Power converter
      - Semiconductor devices and fast switching insulated gate bipolar transistor (IGBT)
    - Controls



Dynamic Modeling of Renewable Generation

- Generic BESS Charging/Discharging Operating Modes

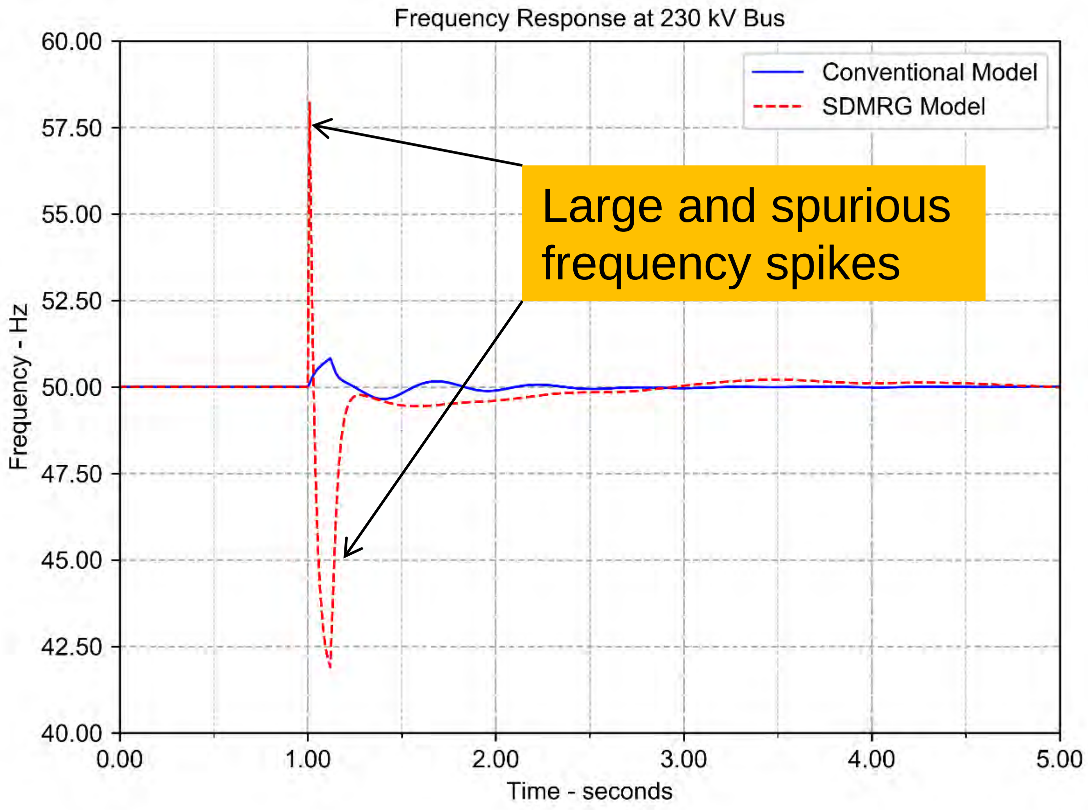


Sample Dynamic Simulations

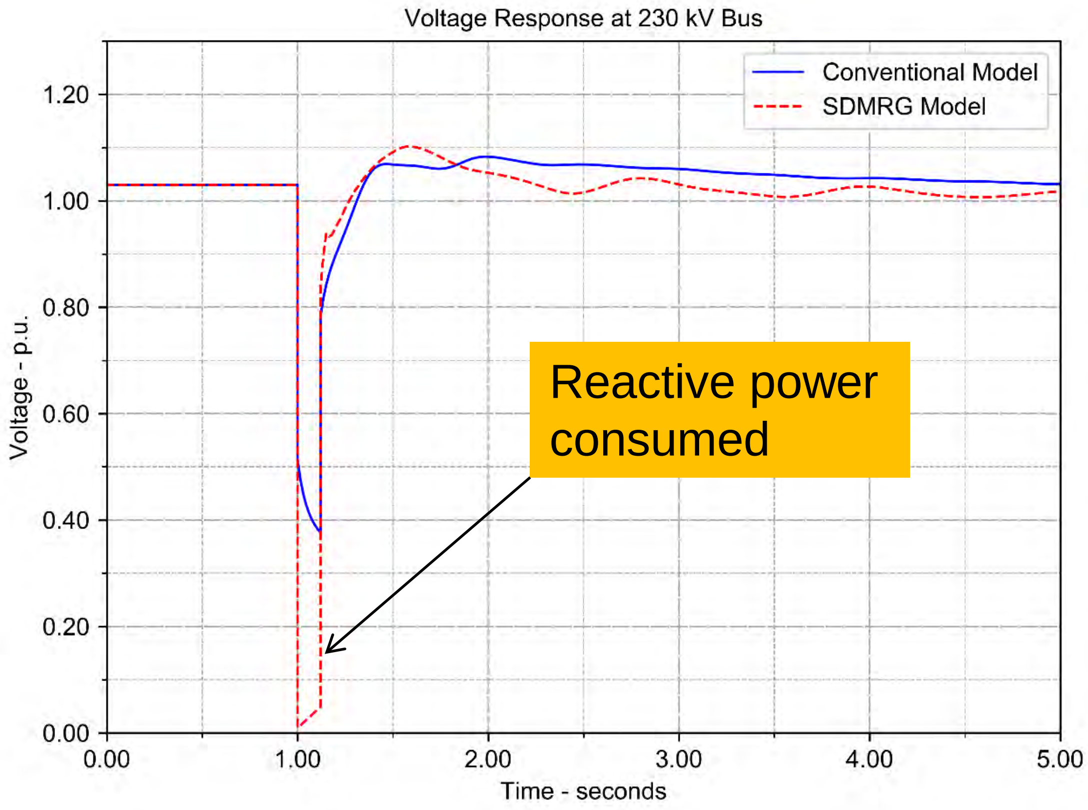
- Simulation 1 - Comparison of frequency and voltage response characteristics
  - Database with conventional dynamic models
  - Similar database where 25% of the total generation replaced by SDMRG
- Simulation 2 – Renewable generation response during system disturbance
  - Three-phase fault on 69-kV radial sub-transmission system

Simulation 1

- Frequency

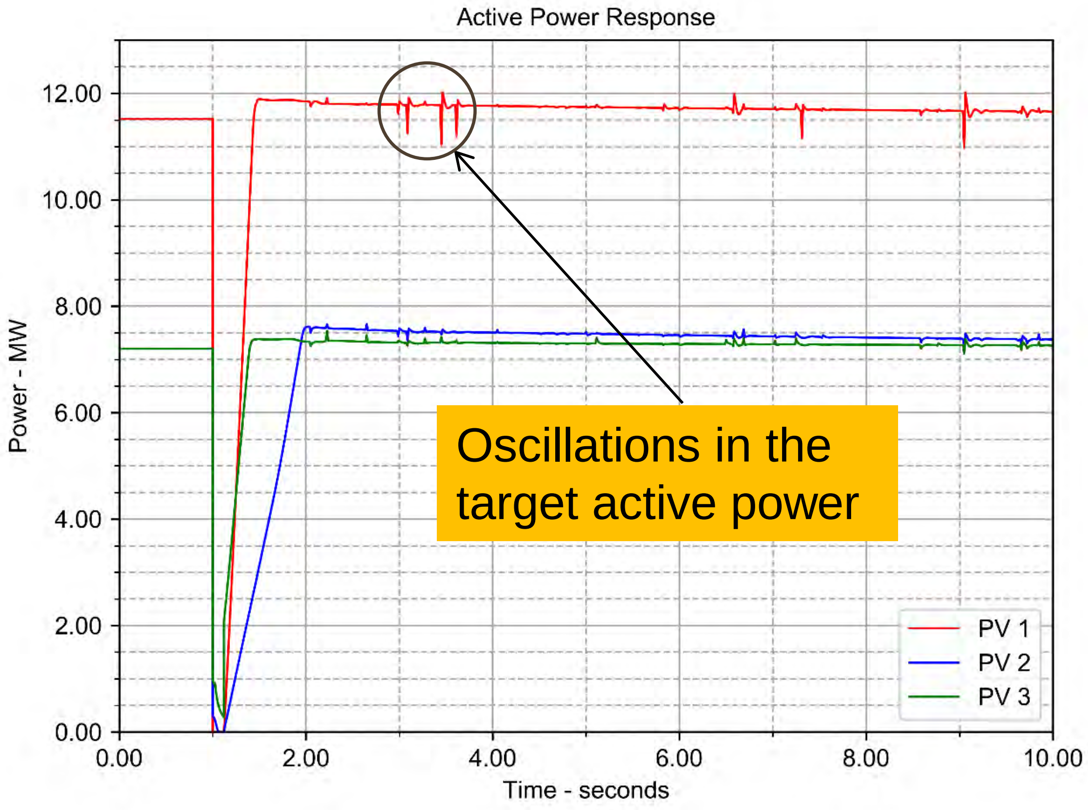


- Voltage

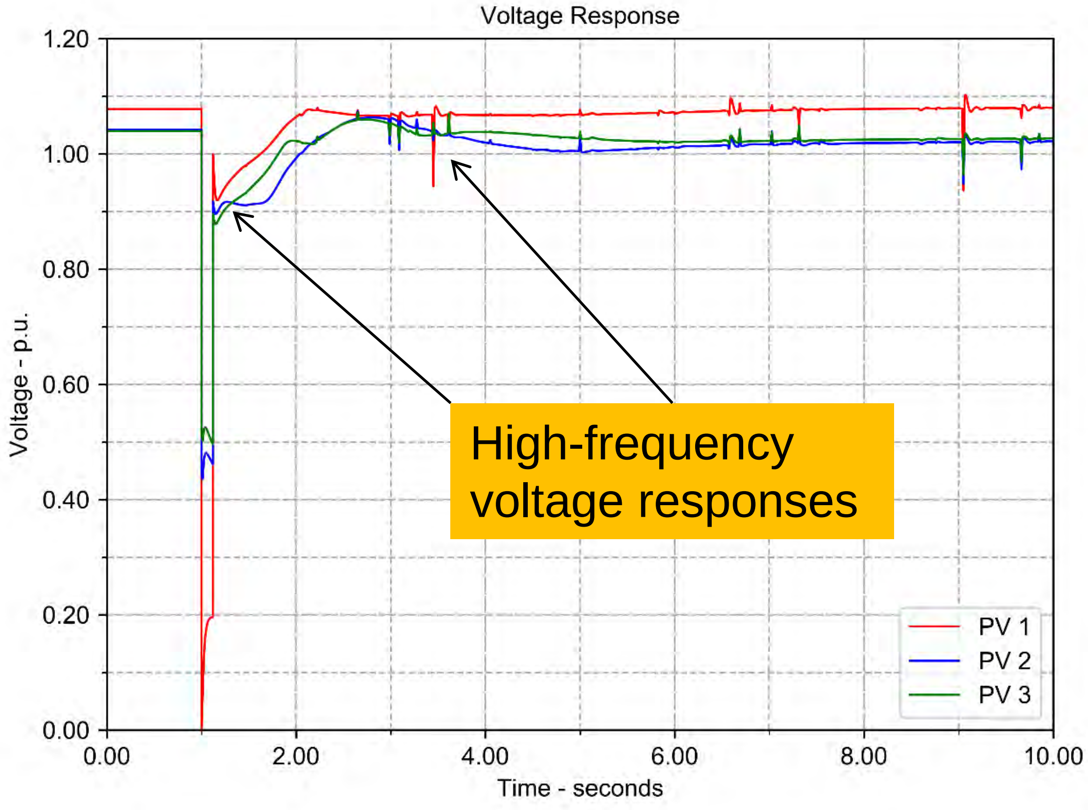


Simulation 2

- Active Power



- Voltage



Conclusions and Recommendations

- Improve the fidelity of dynamic simulation for databases containing conventional and SDMRG models
- Review dynamic databases to capture high frequency phenomena brought about by SDMRG
  - Review explicit and implicit time constants (e.g. generator and exciters)
  - Appropriate selection of integration time steps
- Perform model validation process, even to dynamic databases that do not have large components of SDMRG.
  - Verification of model parameters based on tests or via disturbance record from and actual system event.

Thank you for listening!
Questions?