Modelling and Simulation of Advanced Coordinated Control of Distributed Energy Resources with High Renewable Penetration

Panel Session: Impacts of DERs on the Distribution Grid

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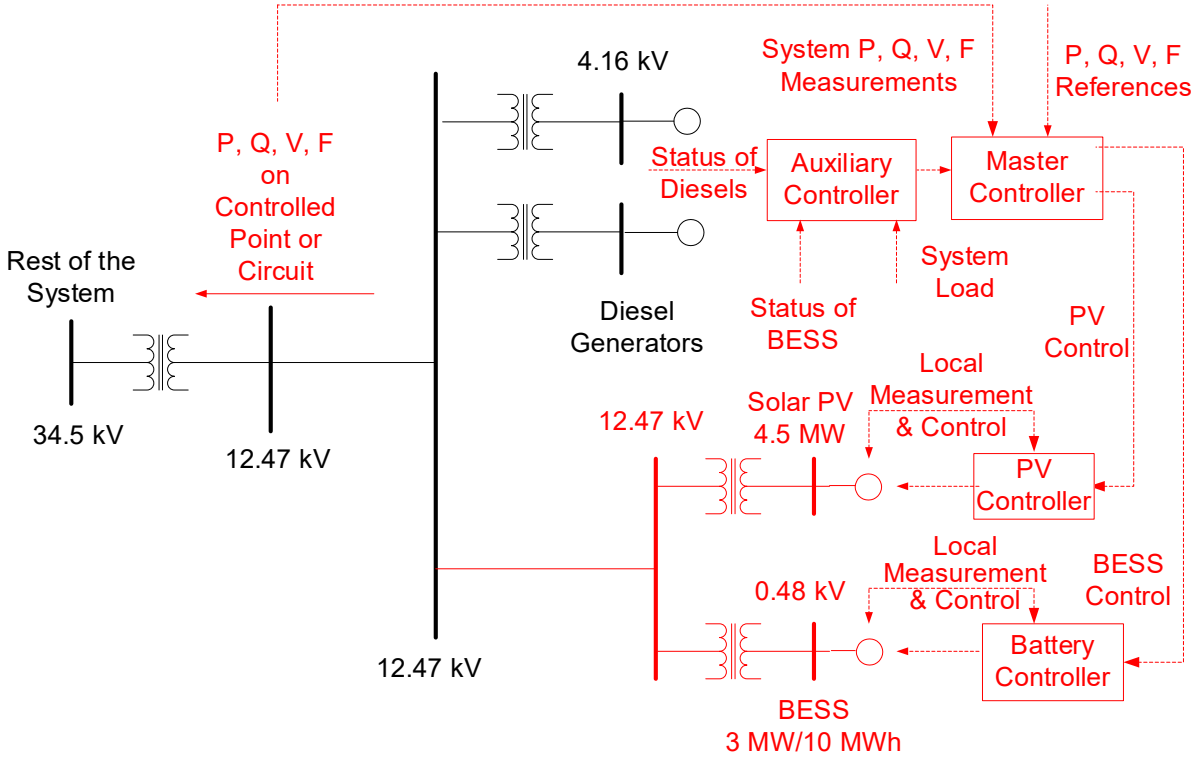
Introduction

- Distributed Energy Resources (DERs): BESS, PV, Wind, back-up generators, micro-grids, among others.
- Over the last decade, more and more DERs are integrated into the power grid which pose a challenge to power system planning, operation, and control.
- Modeling of Advanced Coordinated Control (ACC) for a power system with high PV penetration is presented.
- An Auxiliary Control model was developed to interface with WECC-approved 2nd generation renewable energy generic models.
- DER control objectives and model development and implementation are described.
- Dynamic simulation results for different contingencies are presented.

System Description



Control Description

- Primary Control-System Level: Master Plant Controller coordinates and controls the PV, the BESS, and the Diesel Generators to maintain specified system conditions:
  - Active and reactive power dispatch
  - Voltage and/or frequency setpoints
- Secondary Control-Device Level: built-in PV and BESS controllers for local frequency, active and reactive power.
- Diesel Generators operate on their own exciters and governors. A Master plant controller monitors minimum generation requests to achieve active and reactive power control in the system.

Control Objectives

- The control objectives for the system include:
  - Regulating system voltage and frequency
  - Maintaining constant net active power into the grid from the PV/BESS plant (renewable output smoothing)
  - Reducing the PV output to maintain constant net power into the grid when BESS trips (renewable curtailment).
  - Controlling active power and frequency when a diesel generator is out of service.
  - Controlling the reactive power into the grid from the PV/BESS plant with a constant proportion of total system load.
- A centralized controller was designed to achieve control objectives since the DERs were close to each other and close to loads.

Development, Modeling and Implementation: Master Plant Controller

- The master plant controller was modelled using the WECC generic model REPC_B. This model can control and coordinate with models for other devices such as BESS, PVs, WTGs, FACTS, and Synchronous Condensers.
- The master controller model was configured to operate in P-control. It monitors P, Q, V, and F, provides regulation via proportional-integral (PI) regulators and sends control commands to the auxiliary model that controls the PV and the BESS.
- Parameters of REPC_B model were selected and tuned based on the actual controls designed for the system.

Development, Modeling and Implementation: Auxiliary Controller

- Monitors the status of the diesel generators, the total system load, and the BESS.
- Maintains frequency, voltage, and power balance within the system.
- Interfaces with the master plant controller model to adjust the output of the BESS or to aid in the curtailment of the PV inverters, when necessary.

Development, Modeling and Implementation: PV Plant

- The PV plant was modelled using the WECC generic models REGC_A and REEC_B*.
- Model parameters were selected and tuned based on the actual equipment characteristics and typical engineering values.

DISCLAIMER: *The paper used REEC_B which is being removed from the WECC/NERC approved dynamic model list. But it was an approved model at the time the study was performed. It can easily be converted to REEC_A though.

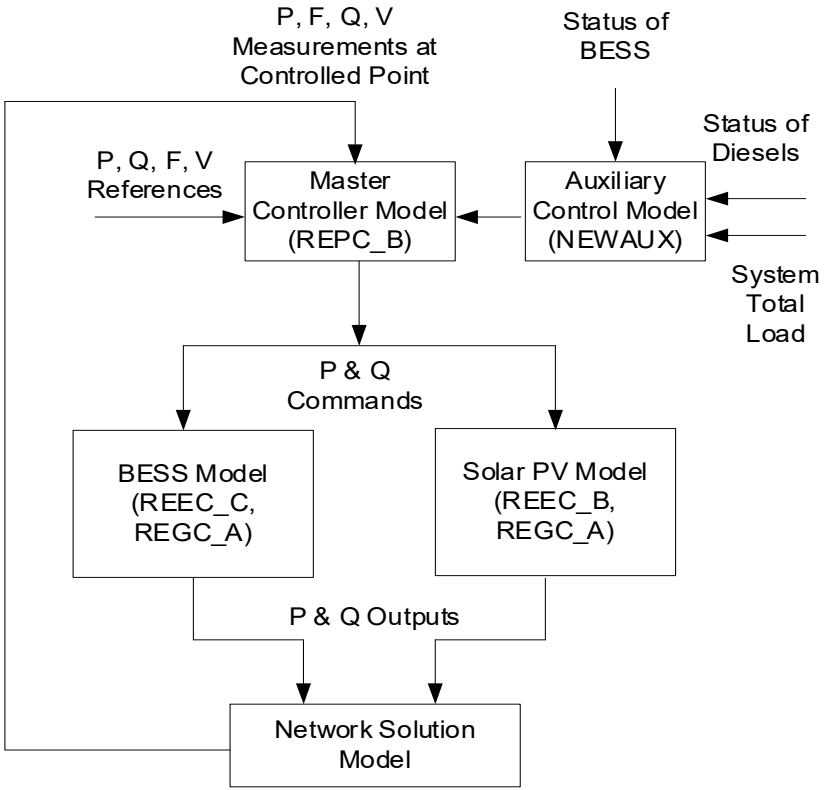
Development, Modeling and Implementation: BESS

- The BESS was modelled using the WECC-approved generic models REGC_A and REEC_C.
- REEC_C executes P and Q controls, monitors the state of charge (SOC) of battery and sets appropriate active current limits.
- P-priority control was selected for power and frequency control.
- Parameters of the BESS models were selected and tuned from actual equipment characteristics.

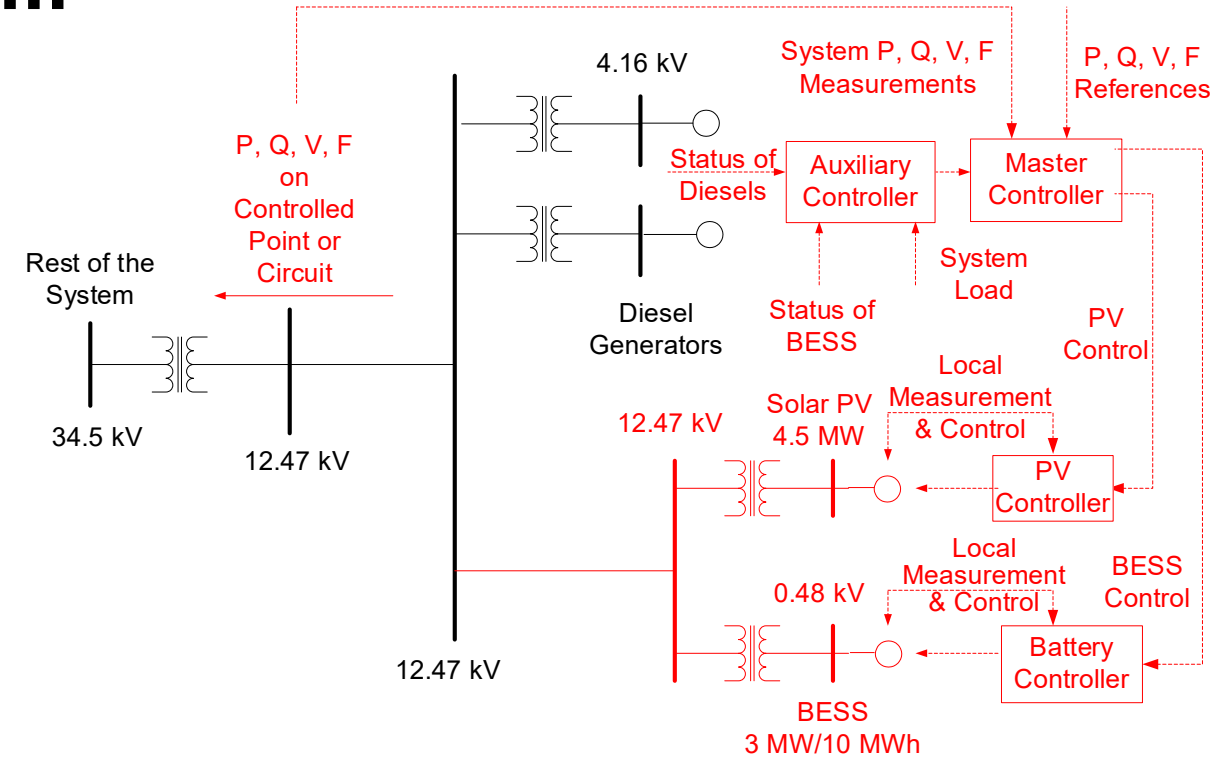
Development, Modeling and Implementation: Diesel Generators

- The diesel generators were modelled as conventional generators with exciters and governors with the parameters based on actual equipment characteristics.
- These models (named GENSAL, EXBAS, and DEGOV) are standard library models in PSS®E.

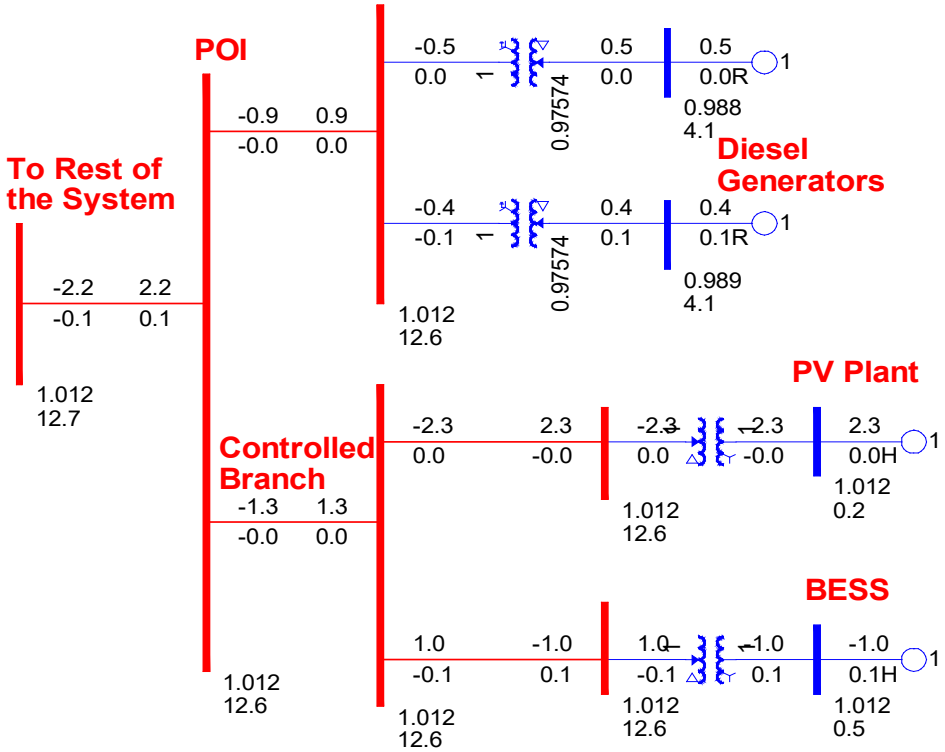
Coordinated Control of DERs – Model Interaction



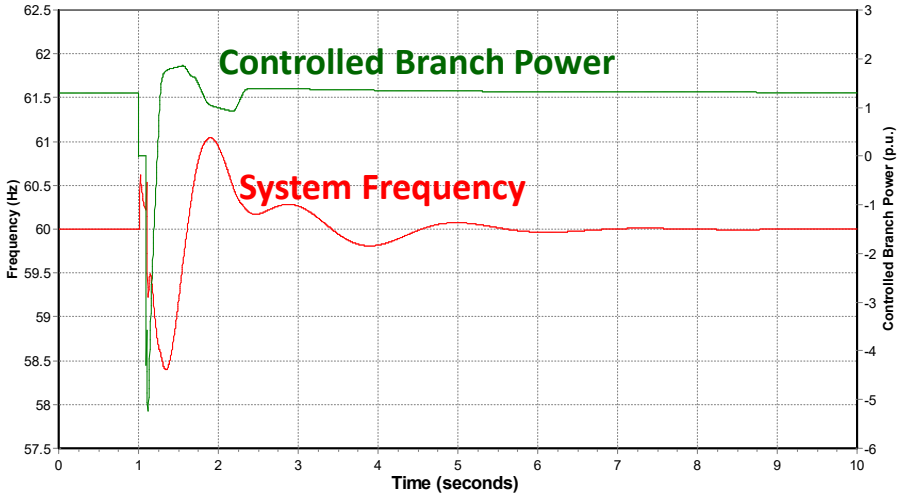
Coordinated Control of DERs – Oneline Diagram

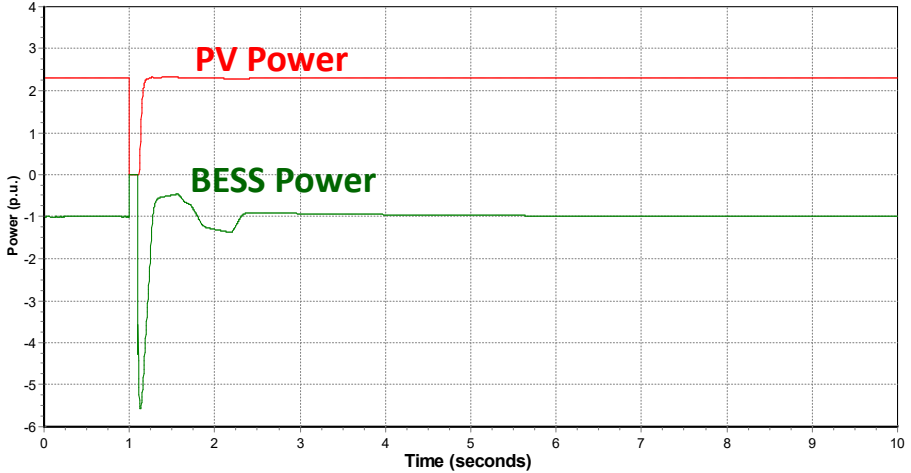


Dynamic Simulations – System Scenario

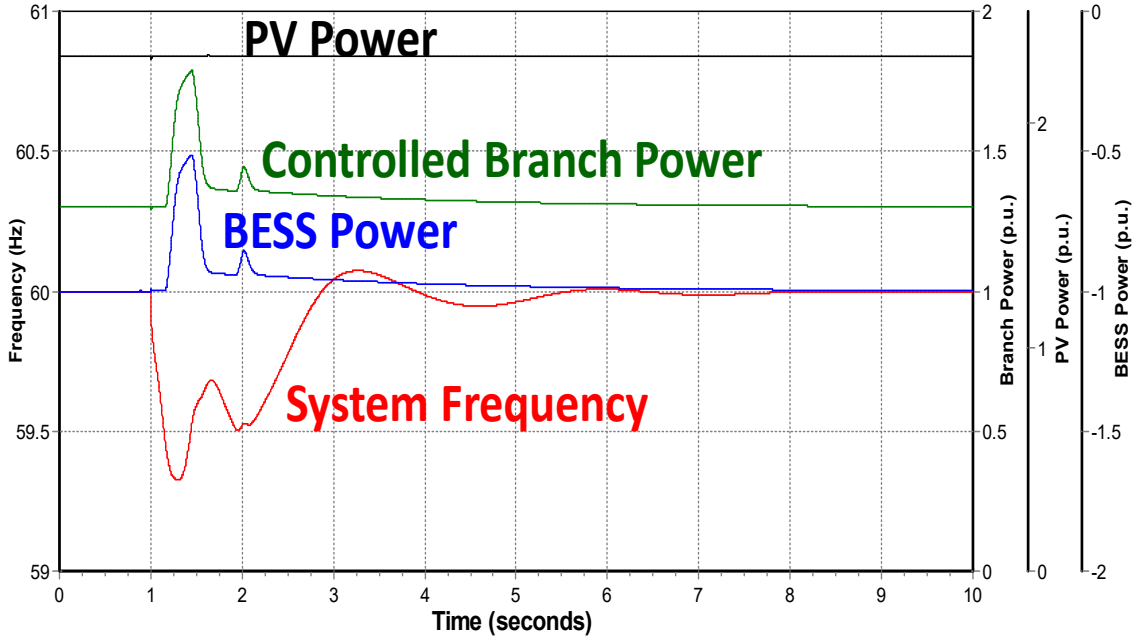


System Response to a Bolted Fault

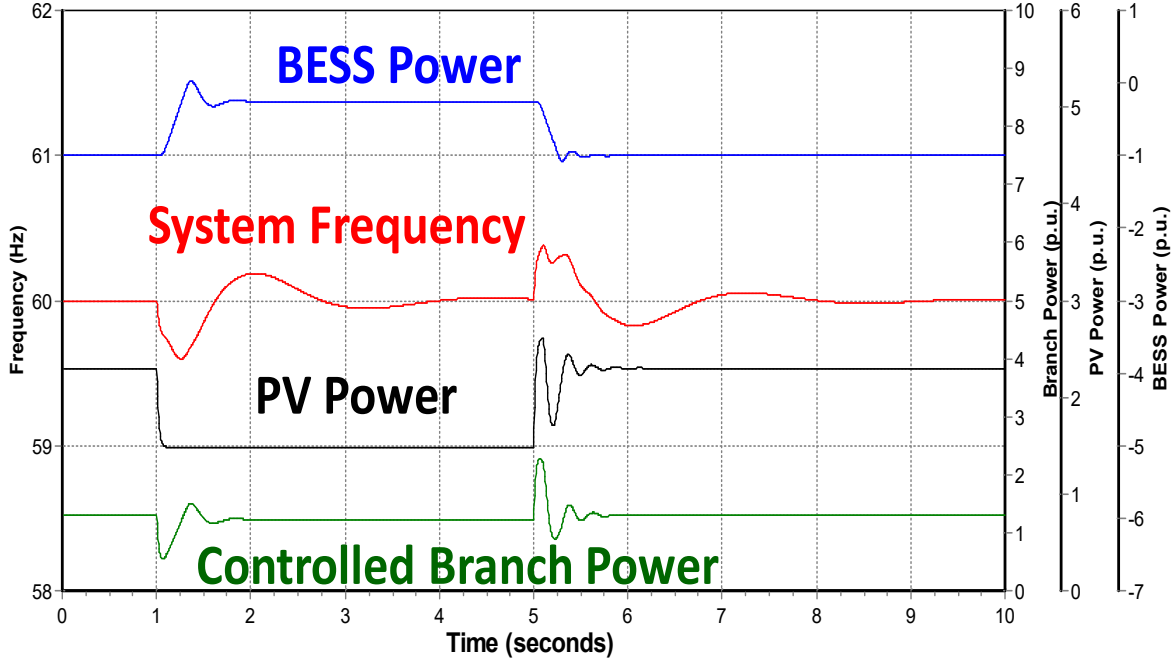




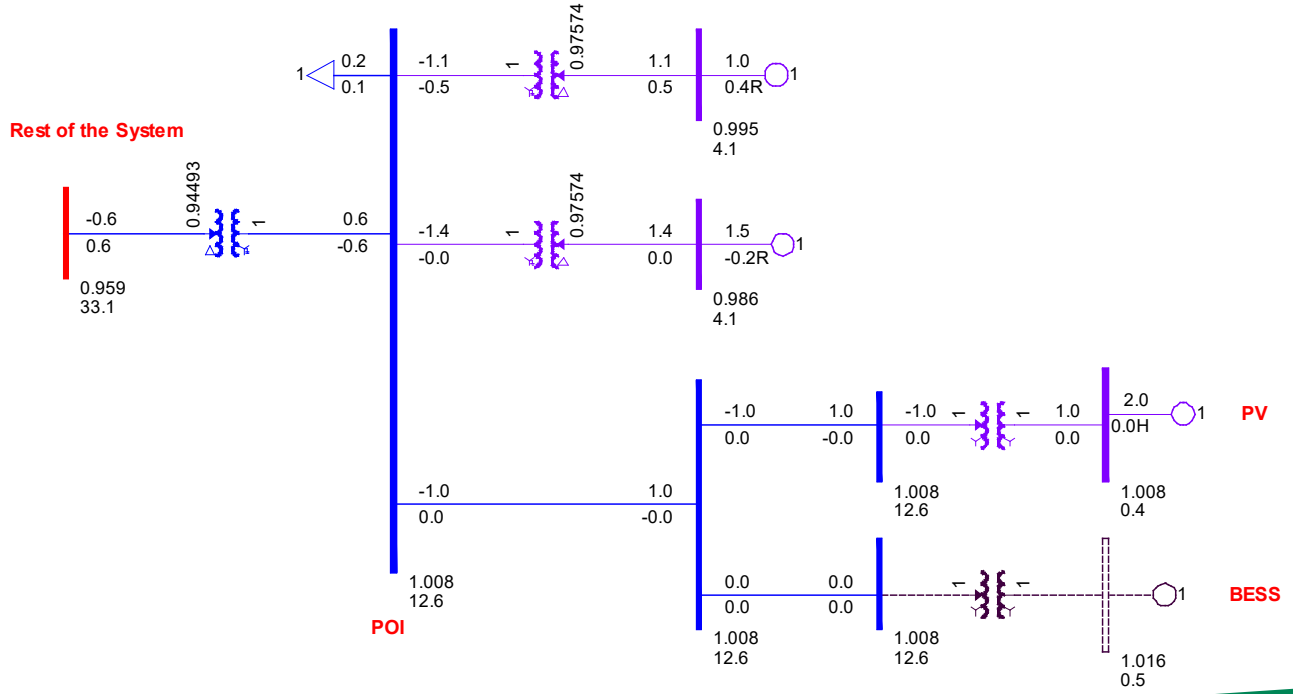
Active Power and Frequency Control due to Loss of a Diesel Generator



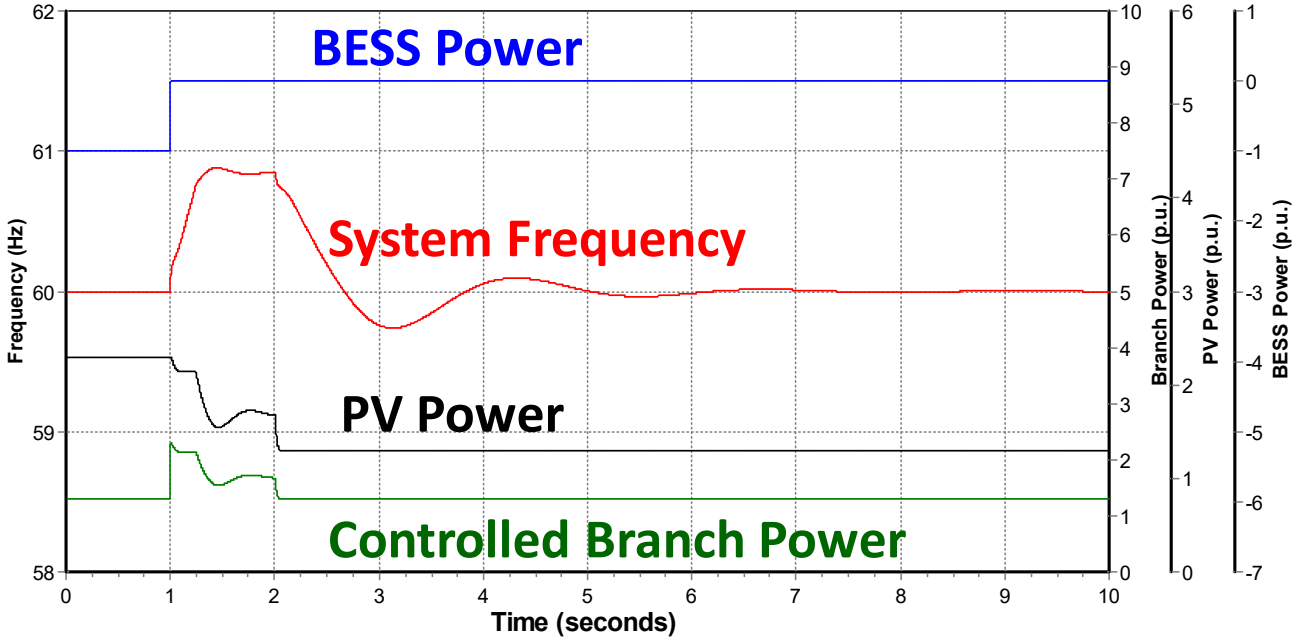
Active Power and Frequency Control due to Cloud Movement



Simulation of BESS Tripping and PV Output Curtailing



PV Curtailment following Tripping of BESS



Summary

- Advanced coordinated control of several DERs can be used in a power grid with high PV penetration where renewable PV production constitutes up to 60% of the total grid generation.
- Generic models along with a user-developed auxiliary controller model have been configured, parametrized and tuned to maintain a power balance, to regulate system frequency, to perform curtailment, and to meet system requirements of the renewable interconnection agreement of the grid code.
- These models are appropriate for system planning and operation studies. This paper contributes to the area of advanced DER modelling techniques for system analysis and planning with high renewable penetration
- Dynamic simulations show that these configured and parametrized models perform as expected under system contingency events.

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