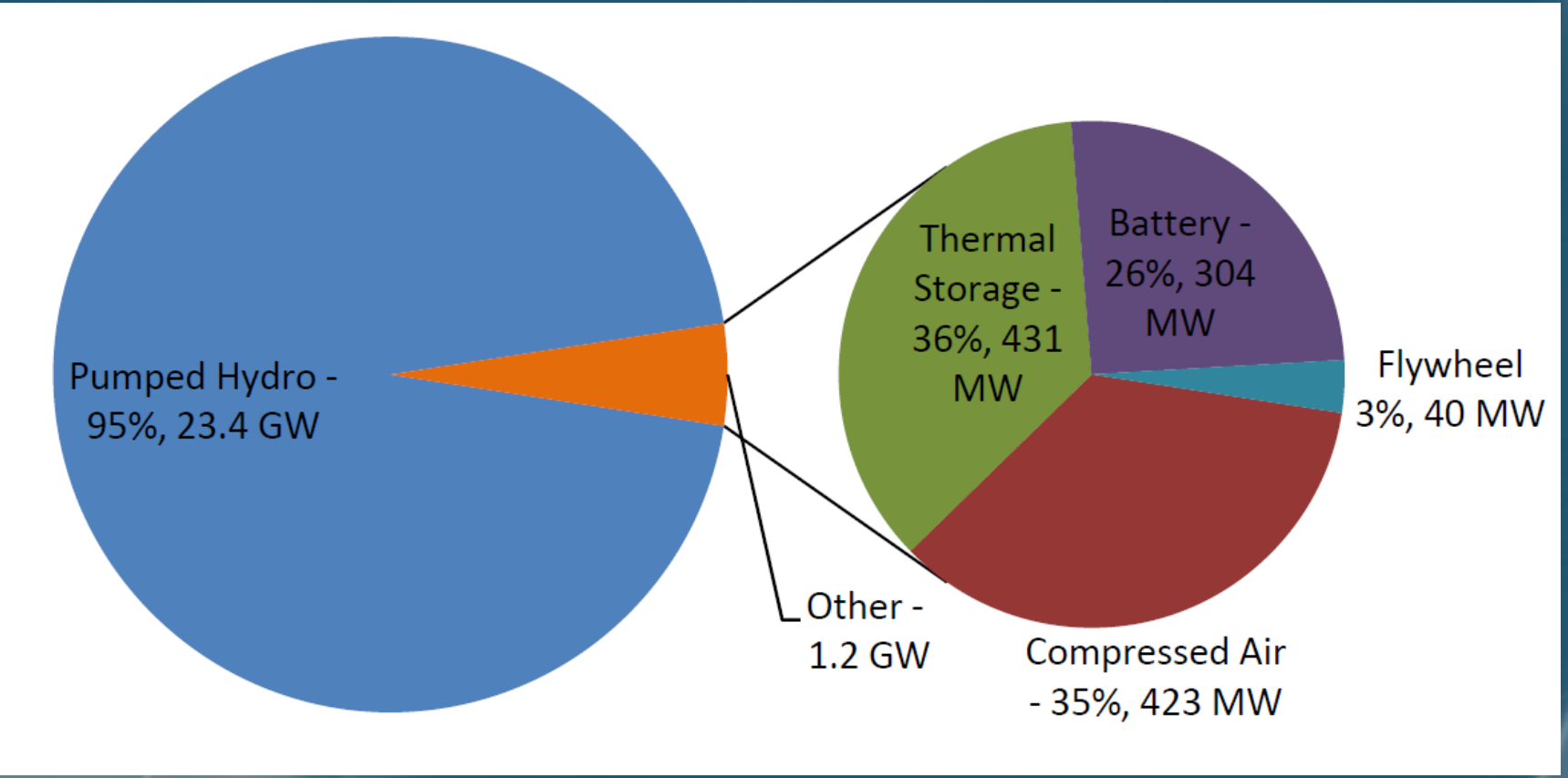
Modeling and Simulation of Battery Energy Storage Systems for Grid Frequency Regulation

X. Xu, M. Bishop and D. Oikarinen
S&C Electric Company
Franklin, WI, USA

Outline of Presentation

- Overview of energy storage projects in US
- Energy storage applications with renewables and others
- Modeling and simulations for grid regulations (frequency regulation, voltage control, islanding operations, reliability, etc.)
- Case studies
- Real project examples

Energy Storage Projects and Capacity in US (from DOE Database as of August 2013)



Source: Grid Energy Storage, DOE Public Report, December 2013

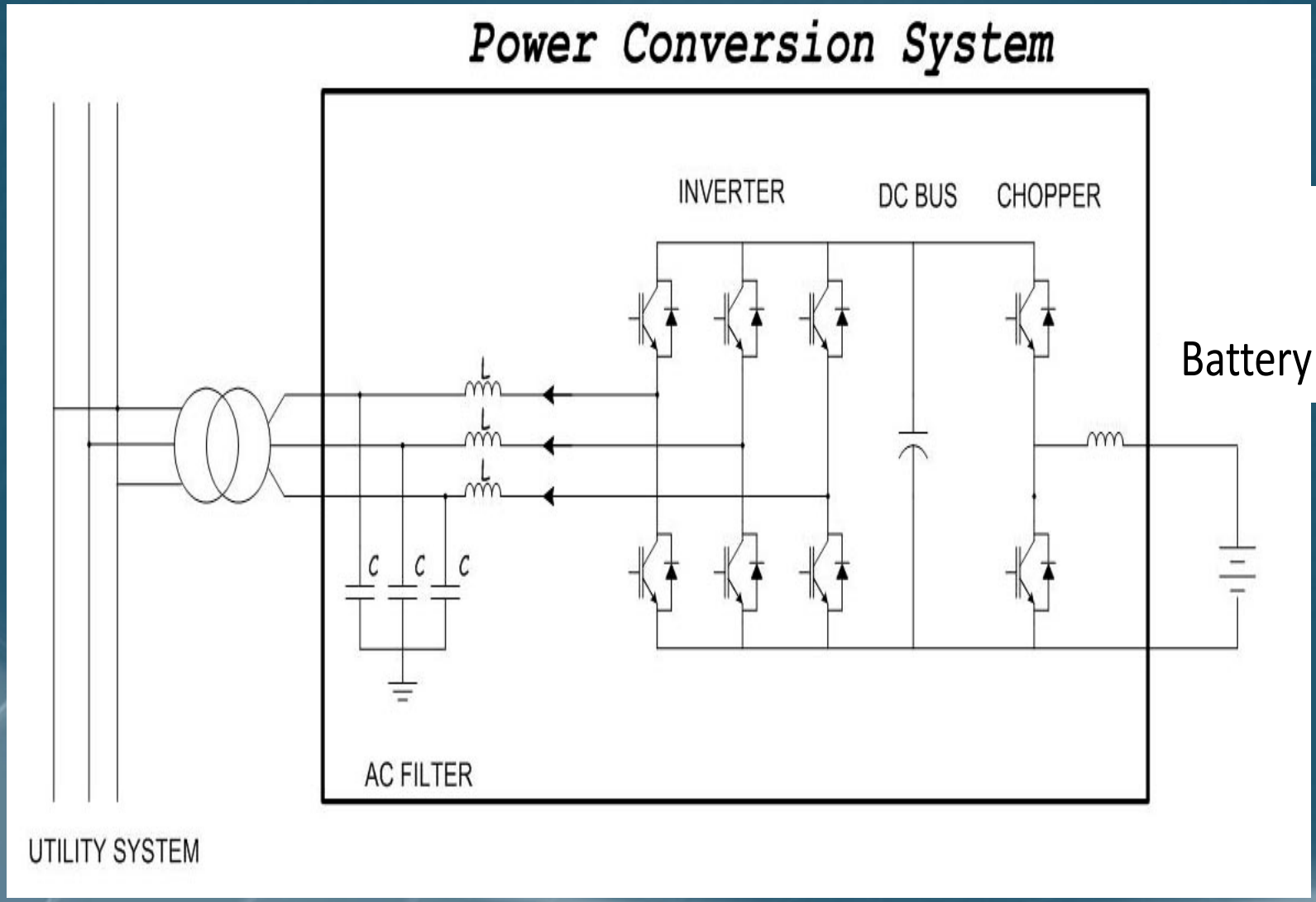
Major Applications of Battery Energy Storage System (BESS)

Bulk Energy Services
Electric Energy Time-Shift (Arbitrage)
Electric Supply Capacity
Ancillary Services
Regulation
Spinning, Non-Spinning and Supplemental Reserves
Voltage Support
Black Start
Other Related Uses

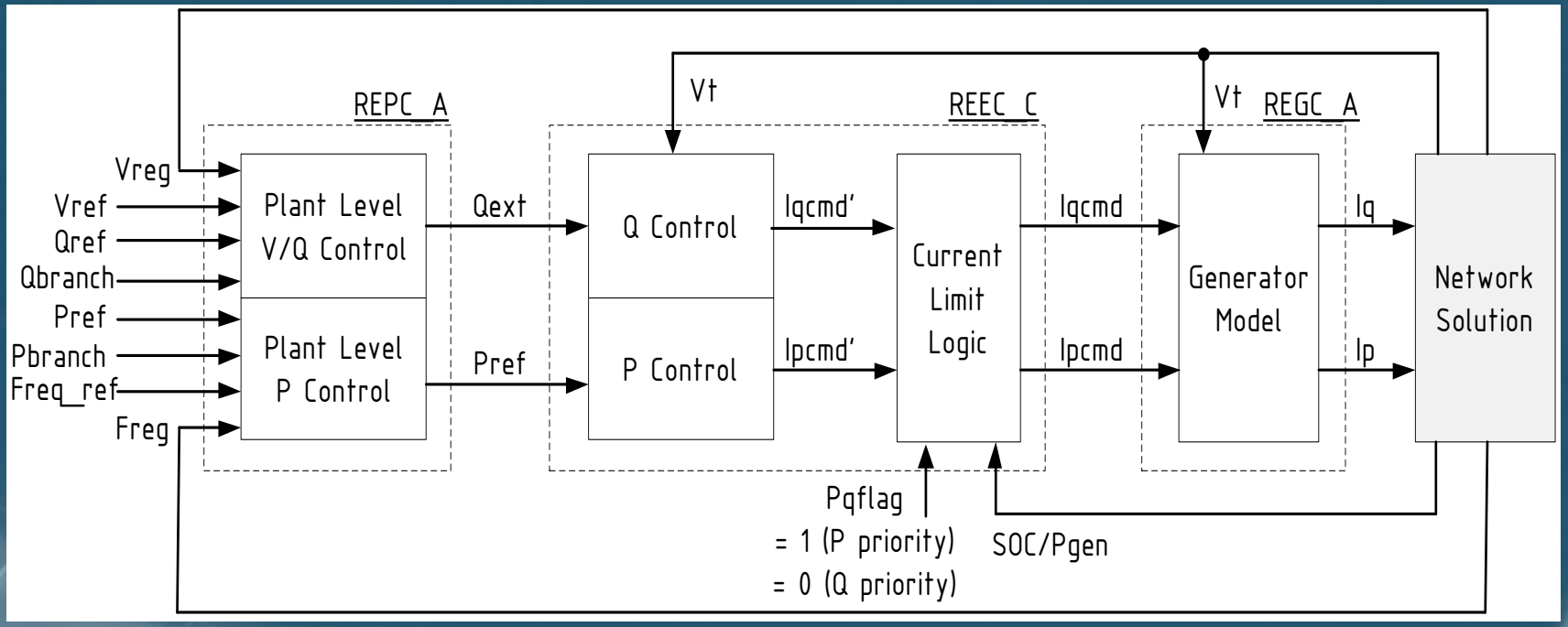
Transmission Infrastructure Services
Transmission Upgrade Deferral
Transmission Congestion Relief
Distribution Infrastructure Services
Distribution Upgrade Deferral
Voltage Support
Customer Energy Management Services
Power Quality
Power Reliability
Retail Electric Energy Time-Shift
Demand Charge Management

Source: 2013 Edition of the DOE/EPRI Electricity Storage Handbook

Schematic Diagram of a Typical BESS



Modeling of BESS for Grid Level Applications - WECC Overall Model Block Structure



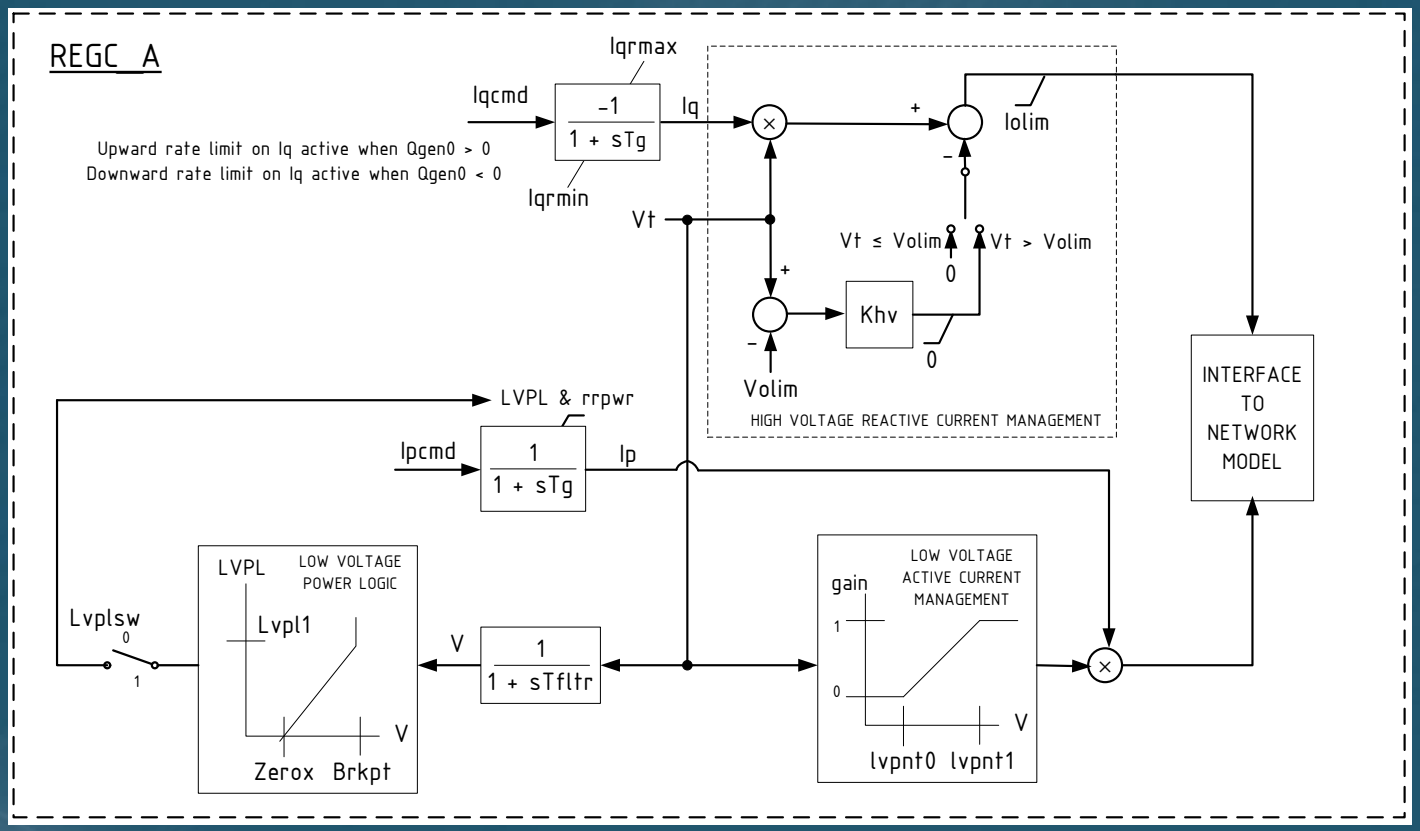
Modeling of BESS for Grid Level Applications - WECC Overall Model Block Structure (Cont'd)

Generator/converter module (REGC_A) – This module processes real and reactive current commands from the electrical control module, with feedback of terminal voltage for lower voltage active current and high voltage reactive current management logics, and outputs real and reactive current injections into the network model.

Electrical control module (REEC_C) – This module acts on active and reactive power references from the plant controller module, with feedback of terminal voltage for specification of a prescribed reactive control response during voltage dip and feedback of generator power output for monitoring the state of charge (SOC) of battery and setting appropriate active current limits. This module provides real and reactive current commands to the generator/converter module with selection of real or reactive power control priority.

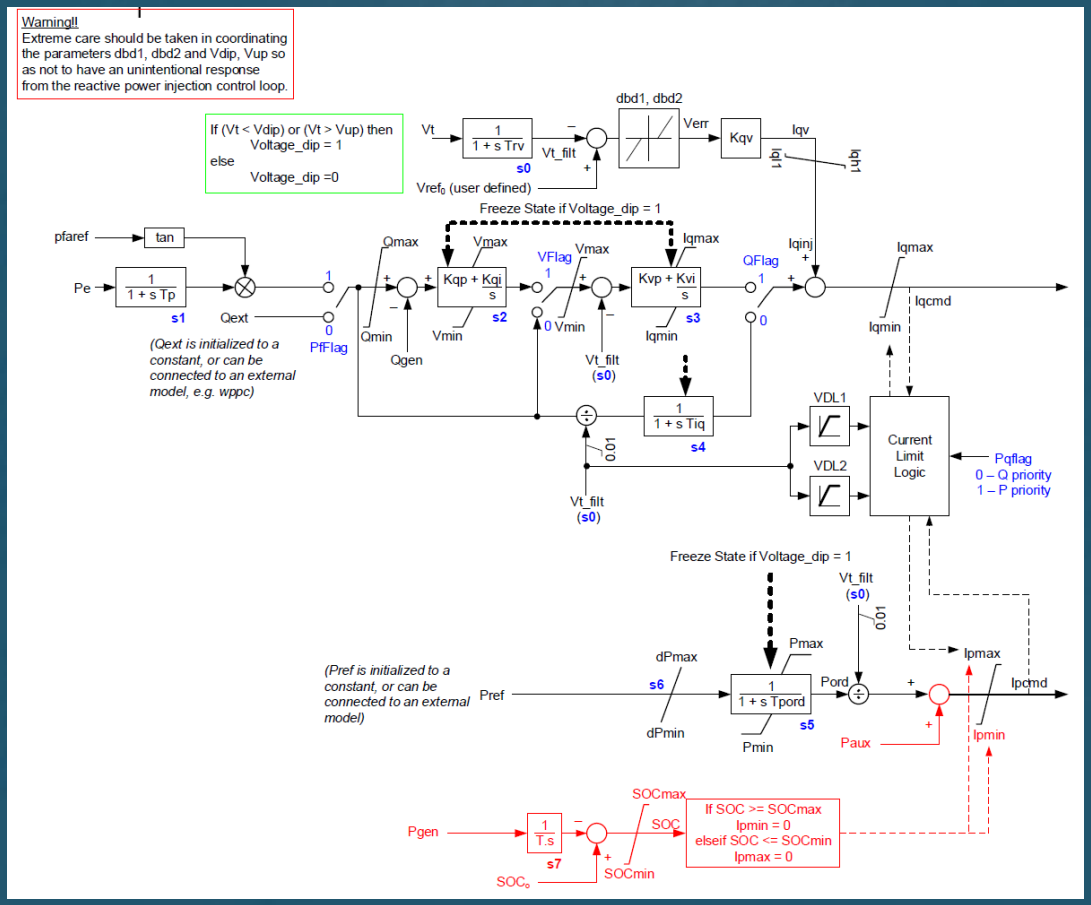
Plant controller module (REPC_A) – This module processes frequency and active power output of the BESS to emulate frequency/active power control. It also processes voltage and reactive power output of the BESS to emulate volt/var control at the plant level. This module provides active and reactive power commands to the electrical control module.

WECC REGC_A Model for BESS



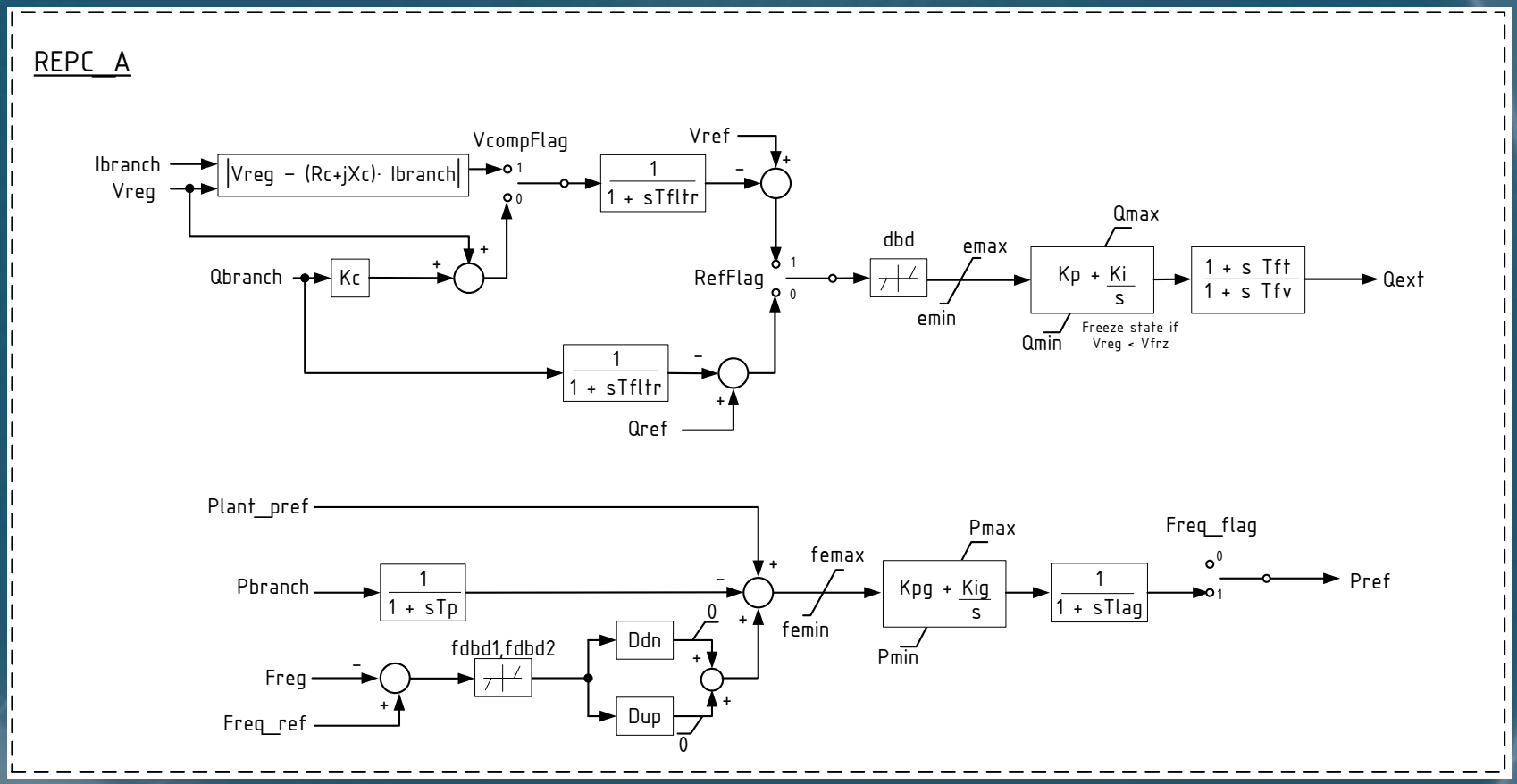
Source: "WECC Wind Plant Dynamic Modeling Guidelines," WECC Renewable Energy Modeling Task Force, WECC Modeling and Validation Work Group, April 2014 [Online]. Available: https://www.wecc.biz/Reliability/WECC%20Wind%20Plant%20Dynamic%20Modeling%20Guidelines.pdf

WECC REEC_C Model for BESS



Source: "WECC Energy Storage System Model – Phase II," WECC REMTF Adhoc Group on BESS modeling, WECC Renewable Energy Modeling Task Force, WECC Modeling and Validation Work Group, March 2015 [Online]. Available: https://www.wecc.biz/Reliability/WECC%20Approved%20Energy%20Storage%20System%20Model%20-%20Phase%20II.pdf

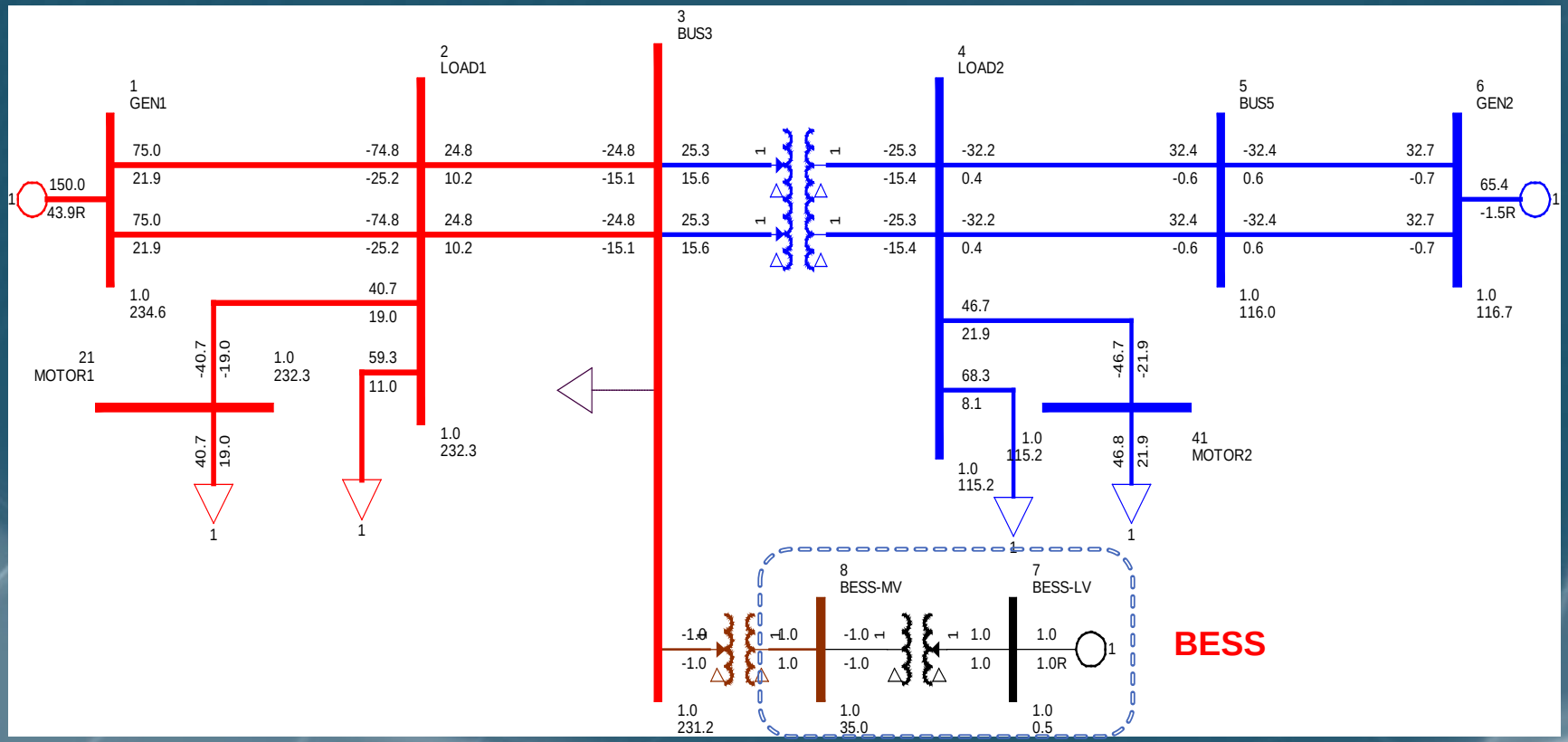
WECC REPC_A Model for BESS



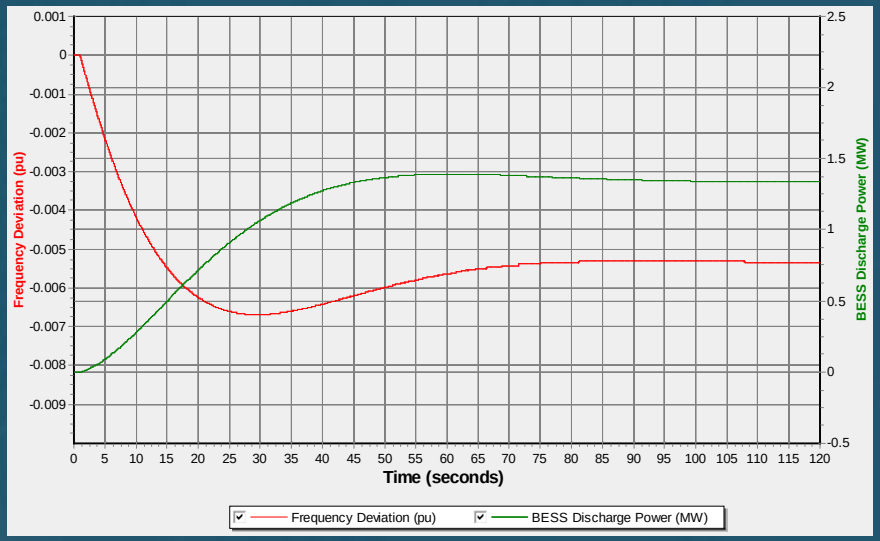
Source: “WECC Wind Plant Dynamic Modeling Guidelines,” WECC Renewable Energy Modeling Task Force, WECC Modeling and Validation Work Group, April 2014 [Online]. Available: https://www.wecc.biz/Reliability/WECC%20Wind%20Plant%20Dynamic%20Modeling%20Guidelines.pdf

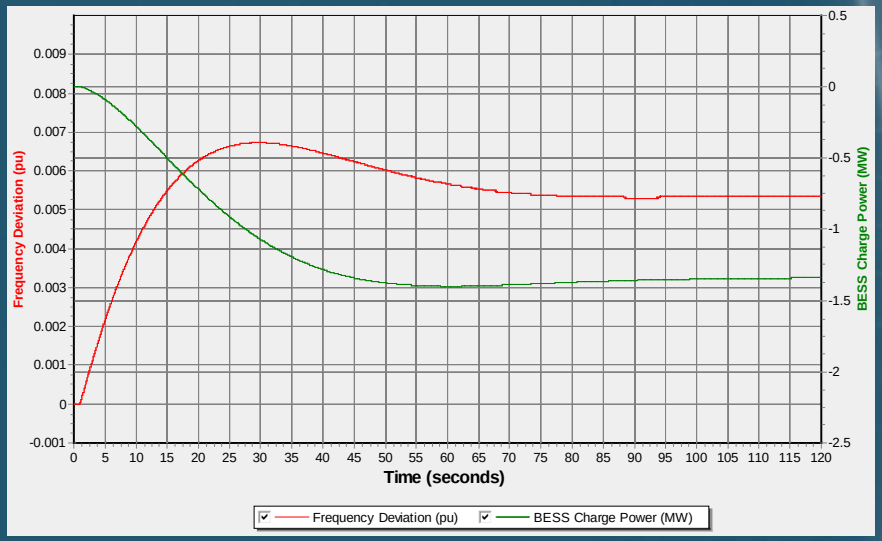
BESS Modeling and Simulation in PSS®E

WECC Benchmark Test System

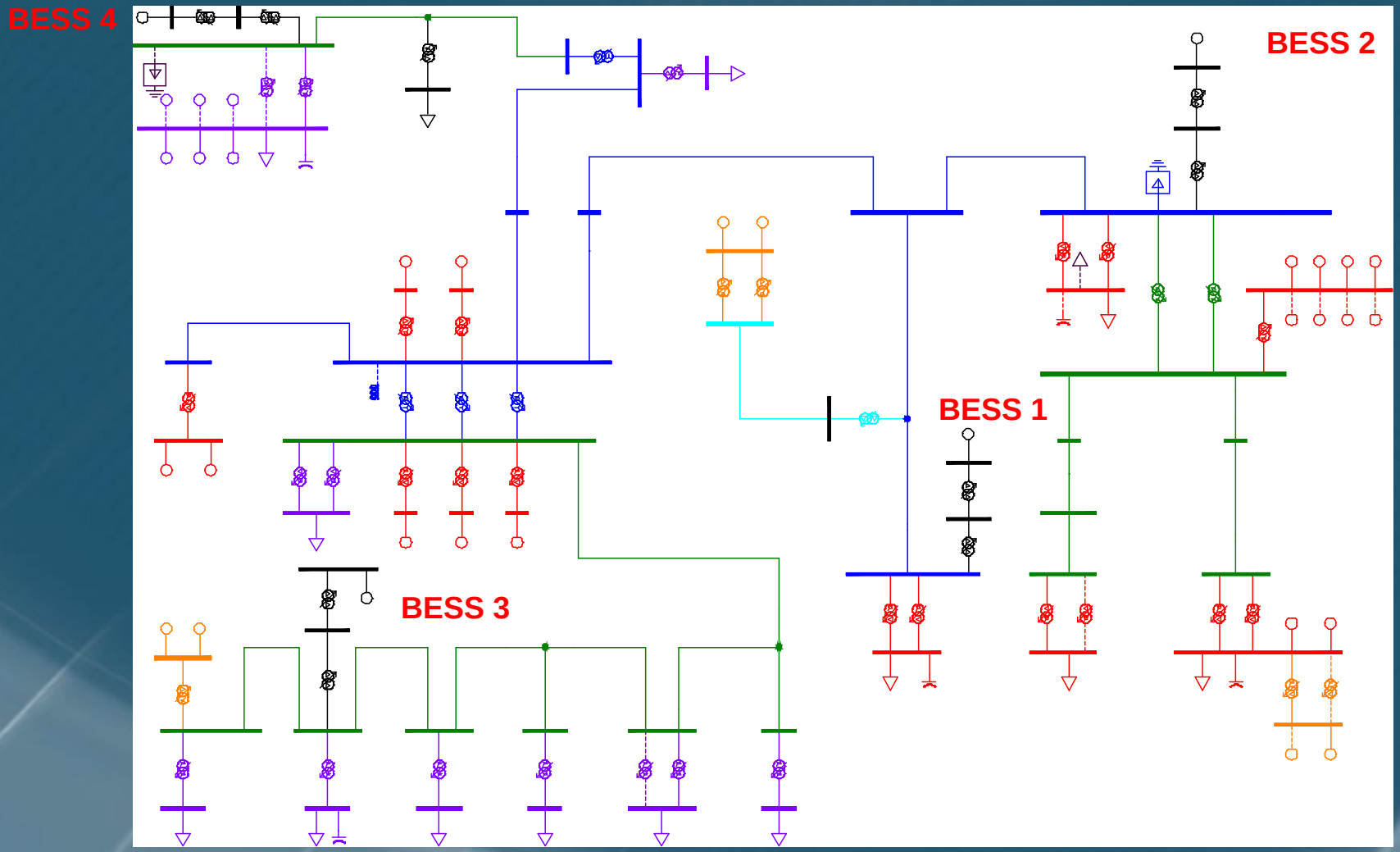


Simulation of Underfrequency or Overfrequency Condition

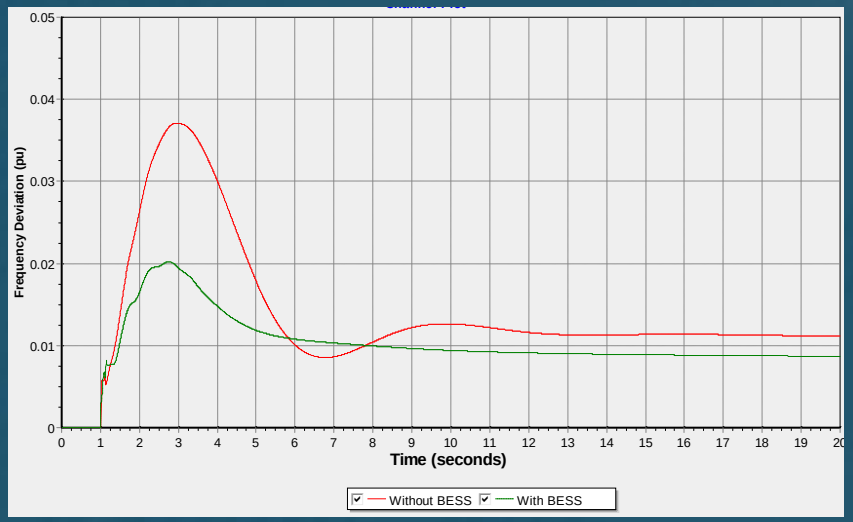




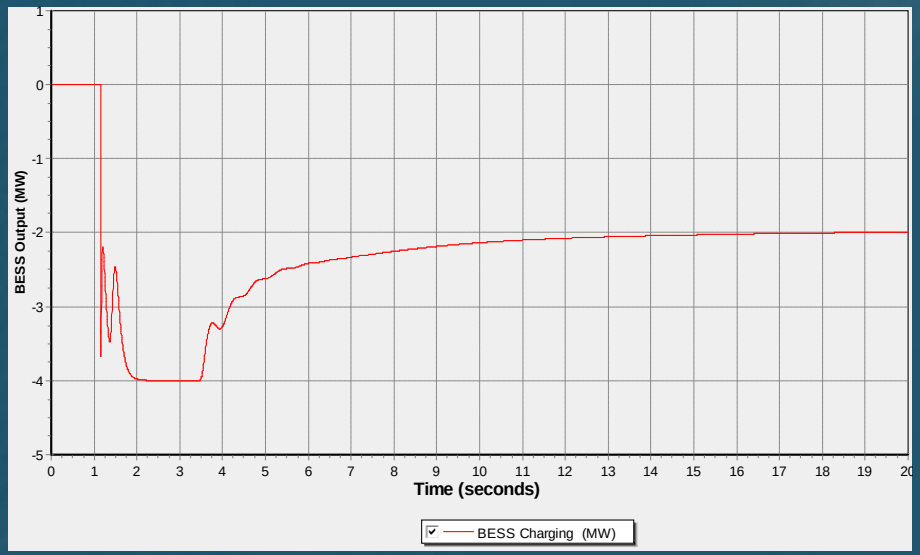
Real System Study with BESS Model

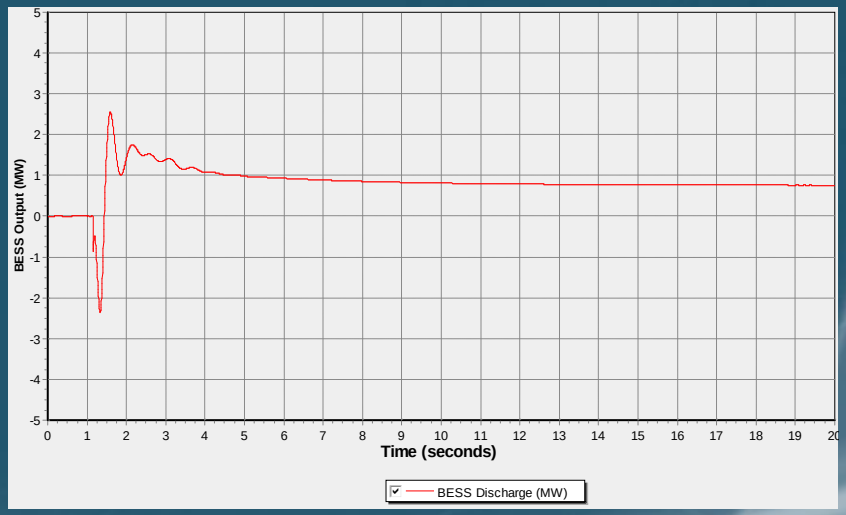


Simulation of Contingencies Causing Overfrequency or Underfrequency Conditions



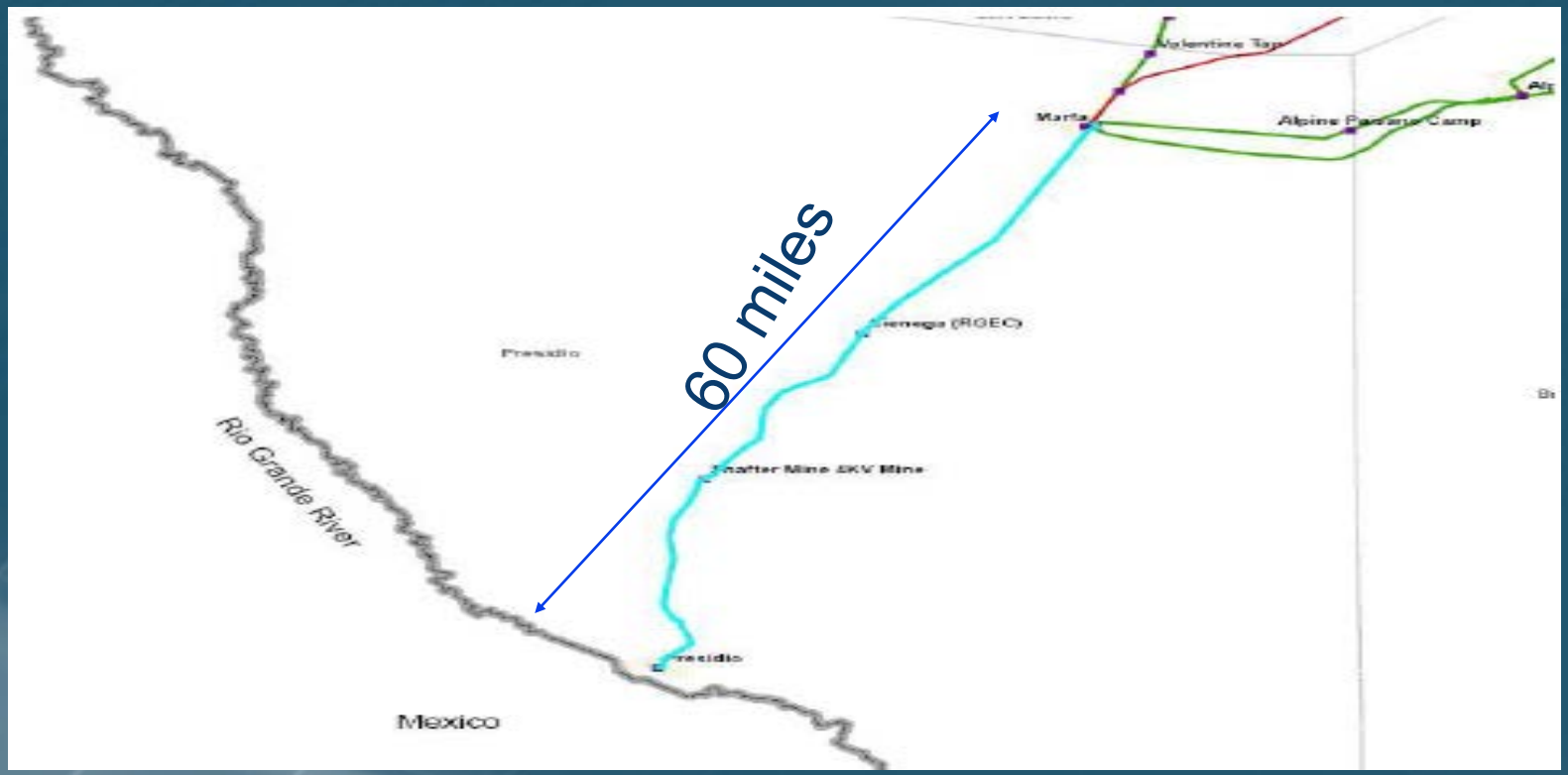
BESS Charge/Discharge with Overfrequency or Underfrequency Conditions





BESS Project in Presidio, Texas (Reliability Application)

- Power quality and high number of outages were major problems
- Repairs to troublesome 69-kV line took a long time
- Peak loads can exceed the weather-normalized load forecast



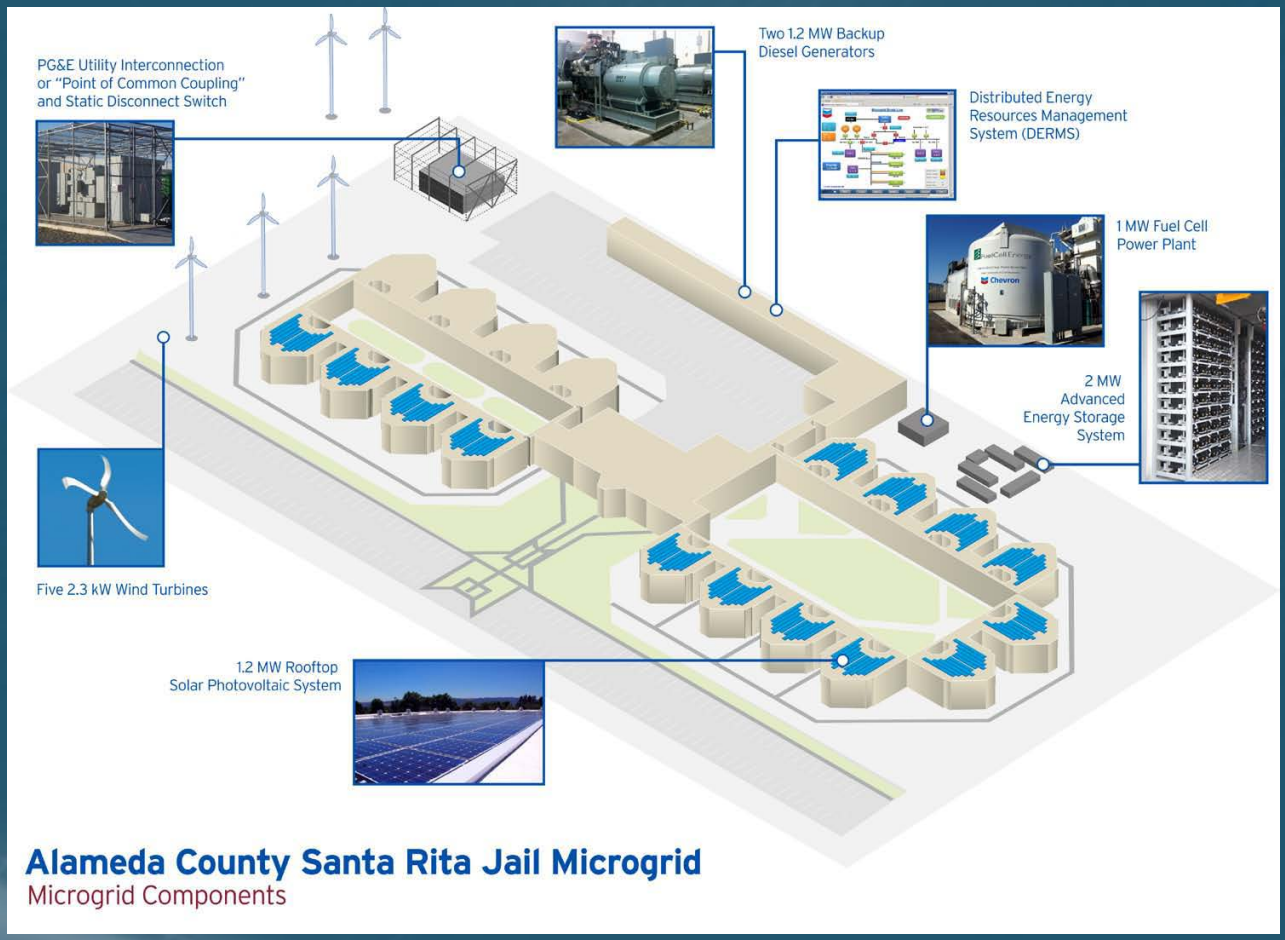
Project in Presidio, Texas (Reliability Application) (Cont'd)

- 4-MW, 24-MWh S&C PureWave® Storage Management System, installed indoors
- System can back up entire town for 6 hours

S&C's Project in Santa Rita Jail, Dublin, California

- Average daily power demand of 3 MW in the correction facility
- Needed way to store excess power produced by on-site generation, operate indefinitely without connection to local grid
- Needed way to purchase power off-peak and use it during high-cost peak demand periods

Project in Santa Rita Jail, Dublin, California (Cont'd)



www.acgov.org/smartgrid

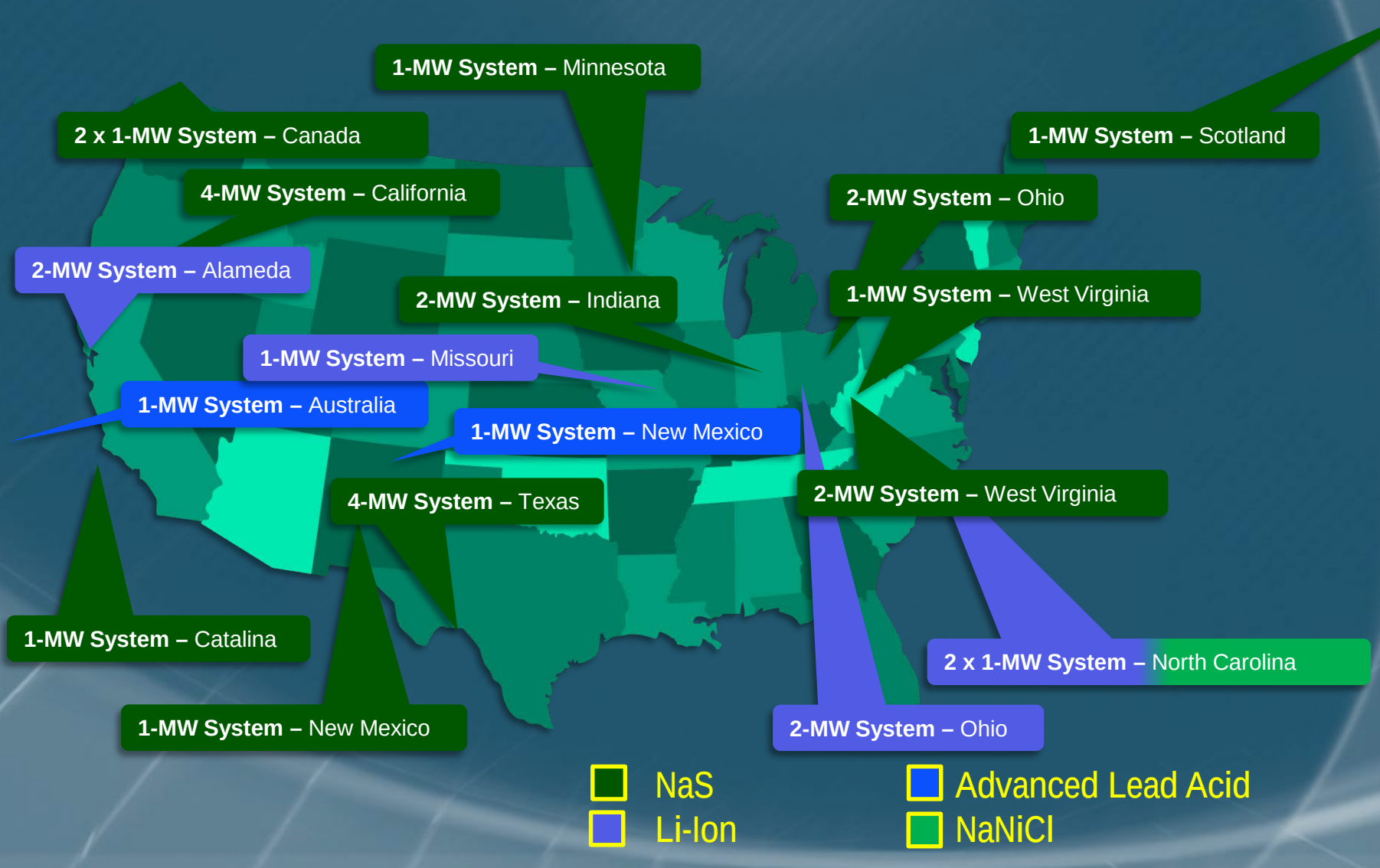
Project in Santa Rita Jail, Dublin, California (Cont'd)

- 2-MW PureWave® Storage Management System; can power this facility for up to 2 hours
- Facility expects to save nearly $100,000 a year

XCEL Energy Storage Project

- 1 MW, 6 MW-hour Sodium-Sulfur Battery Storage System
- Peak Shaving, Wind Farm Output Smoothing, Energy Dispatching and Arbitrage

S&C Delivered BESS Projects



Thank you!!

Xiaokang Xu, Ph.D.
Principal Engineer
S&C Electric Company
xiaokang.xu@sandc.com
(414) 448-4048