DOE Office of Electricity TRAC

Peer Review

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

SSPS Controller: Hardware in Loop Validation

PRINCIPAL INVESTIGATOR

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PROJECT SUMMARY

Project aims at validating the hierarchy (controls, communication & optimization) associated with SSPS in a controller hardware in the loop (CHIL) environment

- **Develop the SSPS controller and the associated framework**
- **Development of device controls for SSPS nodes/hubs**
- **Validation of the SSPS framework through use case**
- **Develop the required CHIL test benches to validate the framework**

The Numbers

DOE PROGRAM OFFICE:
OE – Transformer Resilience and Advanced Components (TRAC)

FUNDING OPPORTUNITY:
AOP

LOCATION:
Knoxville, Tennessee

PROJECT TERM:
09/01/2021 to 08/30/2023

PROJECT STATUS:
Ongoing

AWARD AMOUNT (DOE CONTRIBUTION):
$500,000

AWARDEE CONTRIBUTION (COST SHARE):
$0

PARTNERS:
N/A

Team - ORNL

Radha Sree Krishna Moorthy
Principal Investigator & System Integration

Madhu Chinthavali
SSPS Architecture

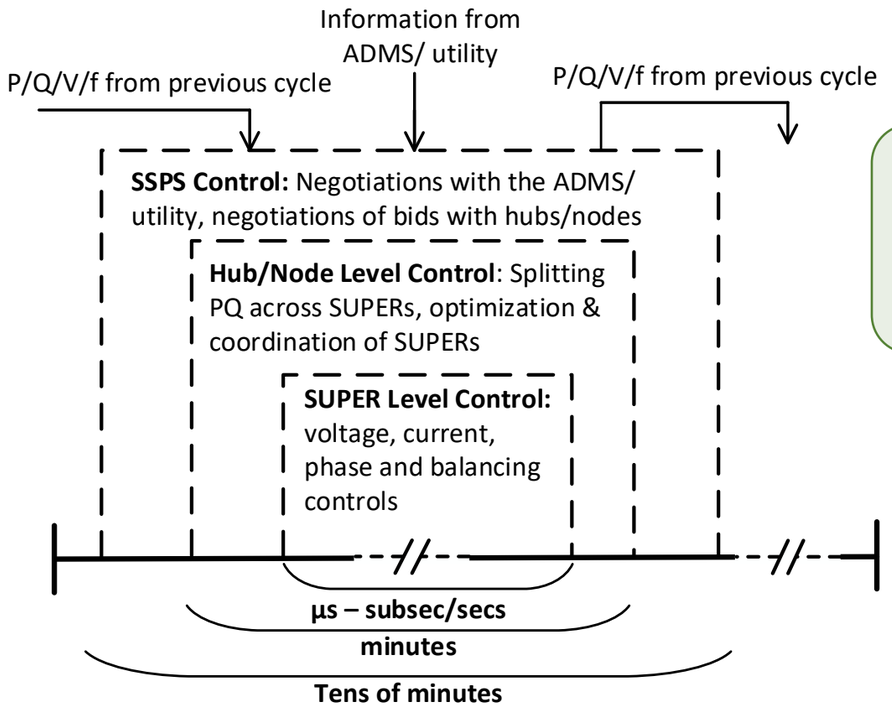
Michael Starke
Controls, Communication & Optimization

Joao Pereira
Advanced Algorithms Development

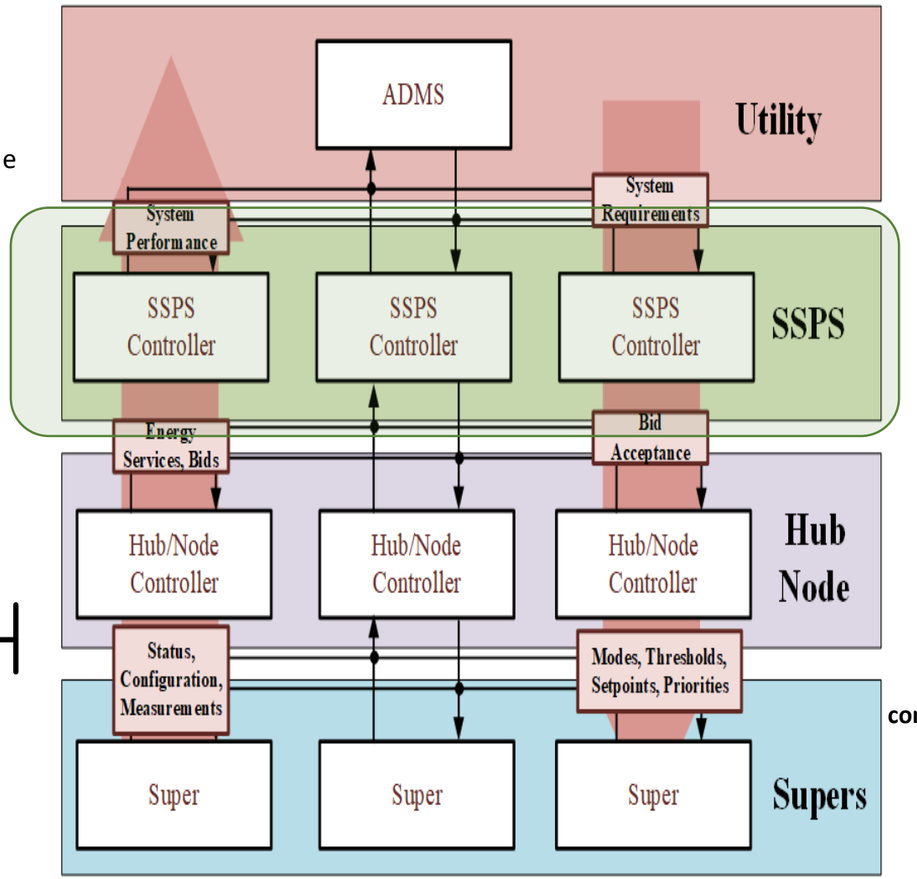
Benjamin dean
Communication & Software Development

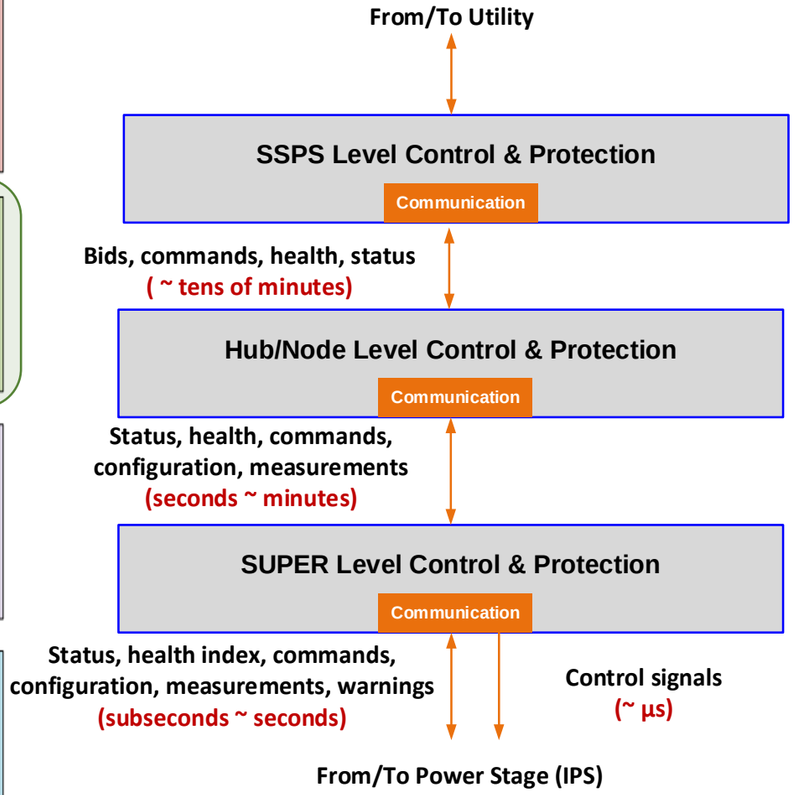
Innovation: Futuristic Grid Architecture

Architecture for decentralized control of grid to support futuristic assets, loads and hybrid ac/dc configurations



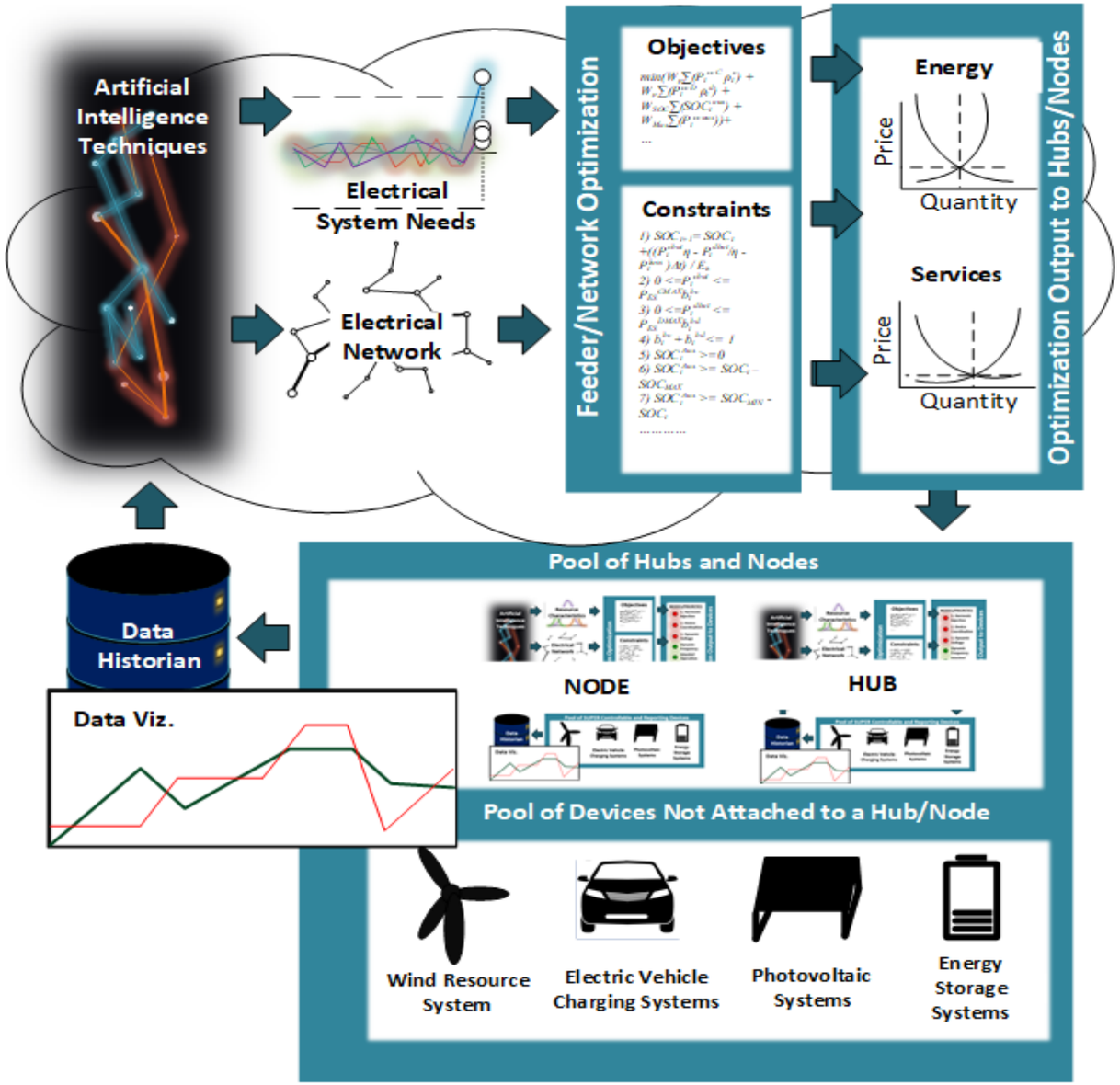
Control Hierarchy





Communication Hierarchy

Innovation: SSPS Controller Framework

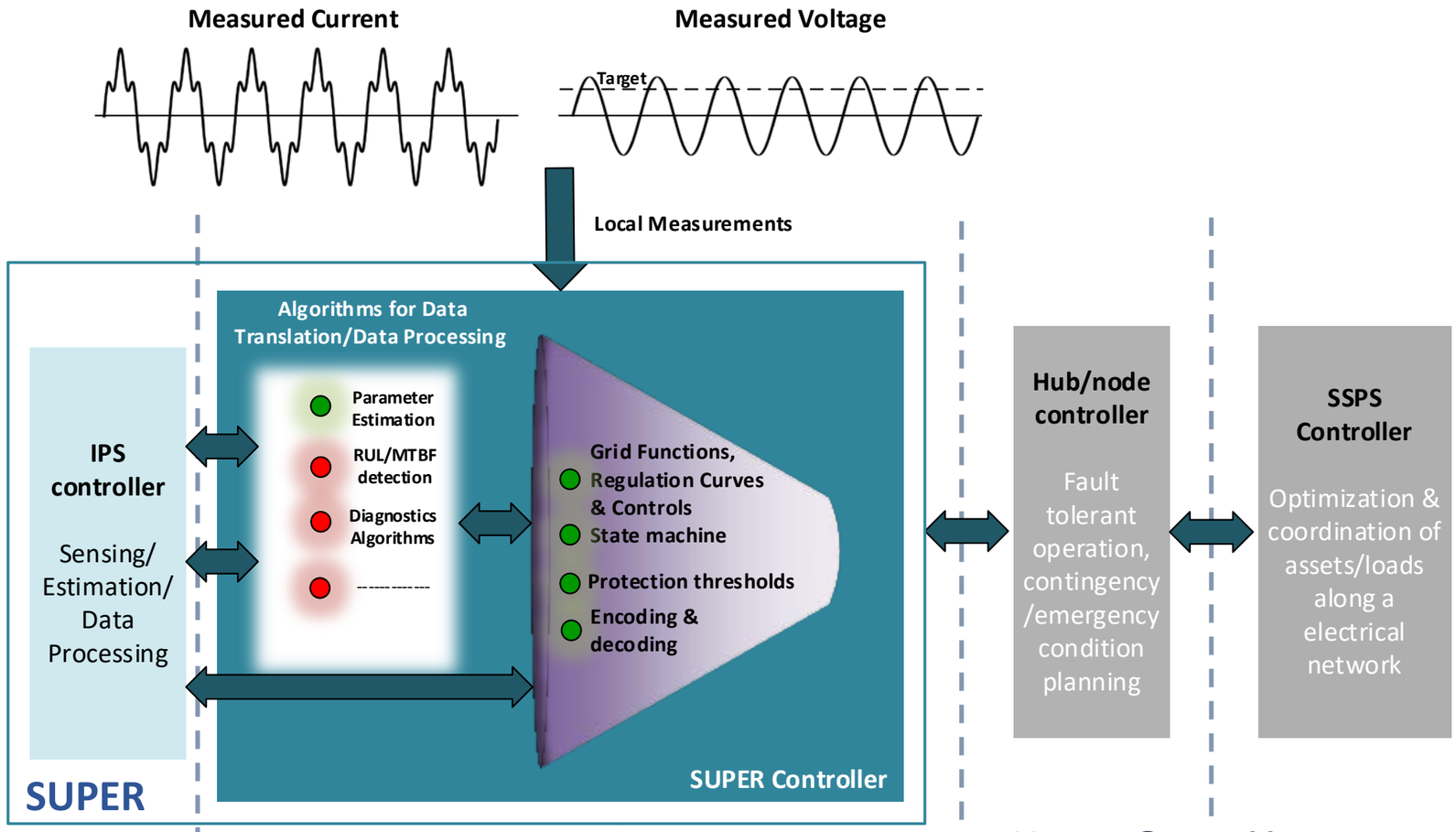


Potential Features:

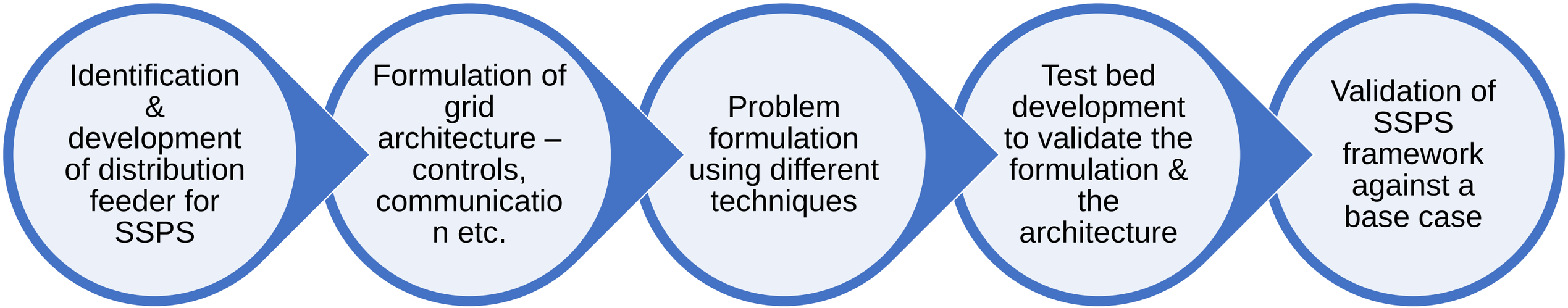
- ❑ **Steady-state and dynamic coordination to maximize the resource utilization & downstream system features**
- ❑ Cloud based computations
- ❑ AI techniques to learn and tune forecasts and identify system needs
- ❑ Transactive market for nodes & hubs
- ❑ Shares information with the distribution management system (DMS)/ Advanced Distribution Management System(ADMS)/ other hierarchical controller

Innovation: Generalized Framework for SSPS

Framework to effectively use the features of the downstream systems the nodes/hubs and the fundamental building blocks



Innovation Update #1: Technical Approach



Base Case: Operation of inverter-based resources without coordination to prove the need for coordination & to prove the need for hierarchical control.

Innovation Update #2: Controller Coordination Techniques

- **Problem Objective:** Coordinate the downstream nodes/hubs/other entities to regulate the voltage/balance phases/reduce distortions along the feeder under dynamic and steady-state conditions considering all uncertainties.

- Techniques: Mixed Integer Linear Programming (MLIP) & Advanced algorithm-based techniques

Mixed Integer Linear Programming (MILP)

- Optimization formulation considering economics i.e., cost of P & Q
- Allocation for reserves for dynamic conditions/operation
- Considers reserves, downstream nodes/hubs architecture, available control modes etc.

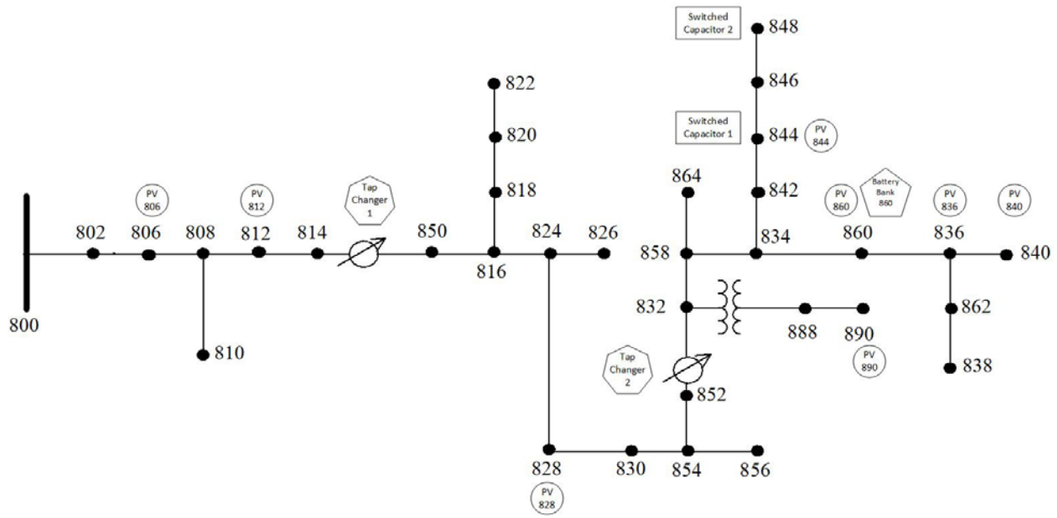
Advanced Algorithm-Based Techniques

- Hybrid techniques – AI & Machine learning
- Training data set generation for different operating conditions. Variables include grid parameters, hubs/node parameters etc.
- Problem formulation based on feeder losses, placement of the nodes/hubs.
- System training and testing

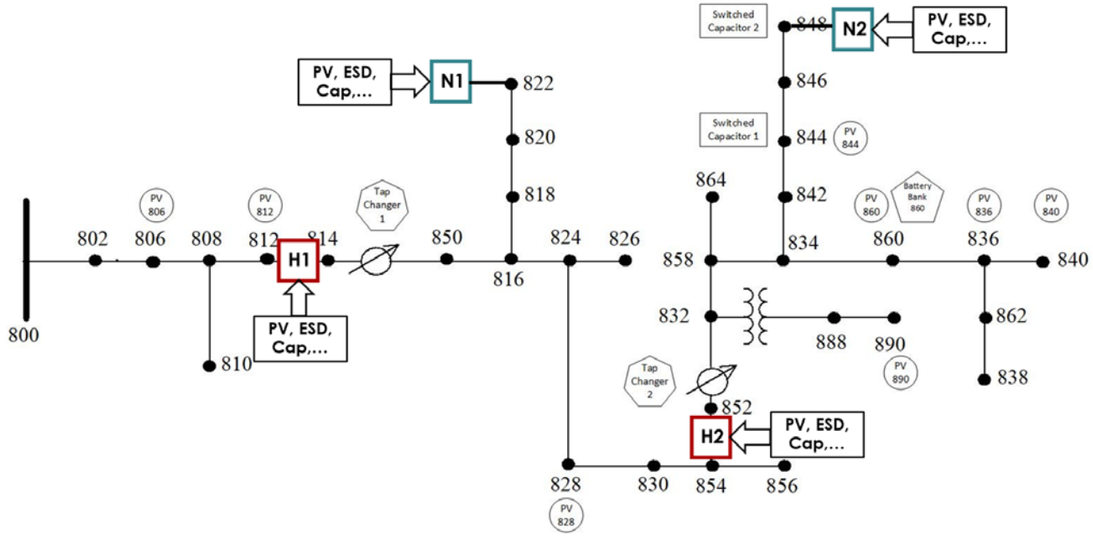
Innovation Update #2: Feeder Selection

- Modified IEEE 34 bus system has been selected based on the following criteria: small to medium sized feeder (complexity) with capability to emulate the need for grid functions (voltage regulation, phase balancing, power factor correction and harmonic filtering).

- Placement of the hubs/nodes has been decided on the feeder sensitivity



Modified IEEE 34 bus system



IEEE 34 bus system with the nodes and hubs

****A Distribution System Test Feeder for DER Integration Studies**, Dharmawardena, H. et all - 2018

Innovation Update

Milestone Update

Task: Development of required models in a real-time (RT) platform

Quarters	Tasks	Sept (21) – Nov (21)	Dec (21) – Feb (22)	Mar (22) - May (22)	Jun (22) – Aug (22)
BP1 - Q1	Identification of the reference feeder model to validate the framework & architecture	**Completed**			
BP1 - Q2	Development of optimization formulation for the feeder		**In Progress**		
BP1 - Q3	Development and validation of hub and node models in RT				
BP1 - Q4	Development of futuristic grid architecture				

Deliverable: Model and optimization framework for hierarchical/distributed controls

Innovation Update

Milestone Update

Task: Development and validation of SSPS controller

Quarters	Tasks	Sept (22) – Nov (22)	Dec (22) – Feb (23)	Mar (23) - May (23)	Jun (23) – Aug (23)
BP2 – Q1	Development and validation of node & hub controllers				
BP2 – Q2	Development and validation of the SSPS controller				
BP2 – Q3	Integration of SSPS controller with the nodes & hubs in RT platform				
BP2 – Q4	Demonstrate use case scenarios to validate the futuristic grid architecture				

Deliverable: SSPS controller and validation of futuristic grid architecture

Innovation Update

Risks

- No anticipated risks or delays

Innovation Update

Future Work

- Formulate the optimization problem/objective function and constraints for the problem
- Elaborate on the architectural details for SSPS
- Develop the test bed for the validation of the framework

Impact/Commercialization

Impact:

*Provide solutions for real world **grid modernization/integration** problems through advanced flexible integrated open research platforms*

Impact/Commercialization

Invention Disclosures Filed:

- M. Chinthavali, M. Strake and R. S. K. Moorthy, “SSPS Controller Architecture: Coordinated Optimization and Control of Multiple Solid-state Power Substations in Electrical Distribution Network”.

THANK YOU

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