Modular Solid-State Switch

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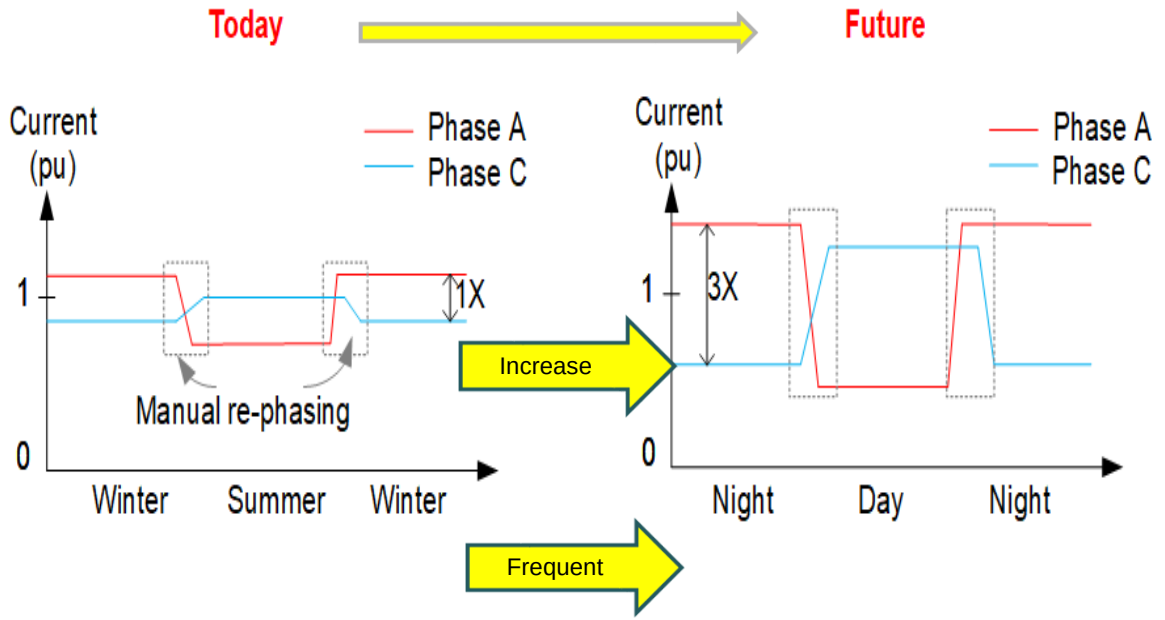
Project Summary

- **Background/Problem**
  - Distribution grid unbalance
  - Main causes:
    - Many distribution feeds use 2 phases
    - Actual loads are different than planned loads
  - How is unbalance changing:
    - More rooftop PVs, more EV chargers
    - Unbalance → expected to increase
    - More frequent: Multiple times/day instead of few times a year



- **Overall Objectives**
  - Increase network throughput by 20%
  - Defer network upgrades
  - Avoid manual re-phasing cost

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The Numbers

- DOE PROGRAM OFFICE:
  OE – Transformer Resilience and Advanced Components (TRAC)
- FUNDING OPPORTUNITY:
  Annual Operating Plan
- LOCATION:
  Raleigh, North Carolina
- PROJECT TERM:
  06/15/2023 to 06/14/2025
- PROJECT STATUS:
  Ongoing
- AWARD AMOUNT (DOE CONTRIBUTION):
  $499,945
- AWARDEE CONTRIBUTION (COST SHARE):
  $125,000
- PARTNERS:
  Oak Ridge National Laboratory

Technical Approach

Method	Maturity	Advantages	Disadvantages	Comments
Distribution planning software [1][2][3]	Existing approach	No new device needed; Mature planning procedure	Forecast is questionable with increasing DER integration	Likely to increase the planning frequency with more DER
Manual phase swapping [4][5][6]	Existing approach	No new device needed	Short outages, no control automation, repeated action is often required	Likely to increase the frequency of crew dispatching with more DER
Phase swapping using static transfer switch [7] or rotational switch [8]	Theoretical idea	Automated switching	Prohibitive high costs	Enable remote control
D-VAR [13] or D-STATCOM [14]	Commercial	Multiple grid support functions; flexible locations	Prohibitive high costs	Effective for VAR control
DER Control [15][16]	Theoretical idea	No new device needed	No regulation, increased OEM costs	Challenge to upgrade installed ones
Proposed Automatic Phase Selector	Theoretical idea	Potentially lowest cost and losses, connecting 1p loads and laterals	Customized design of mech switches; auxiliary power supply	Enable remote diagnostic, monitoring, and control

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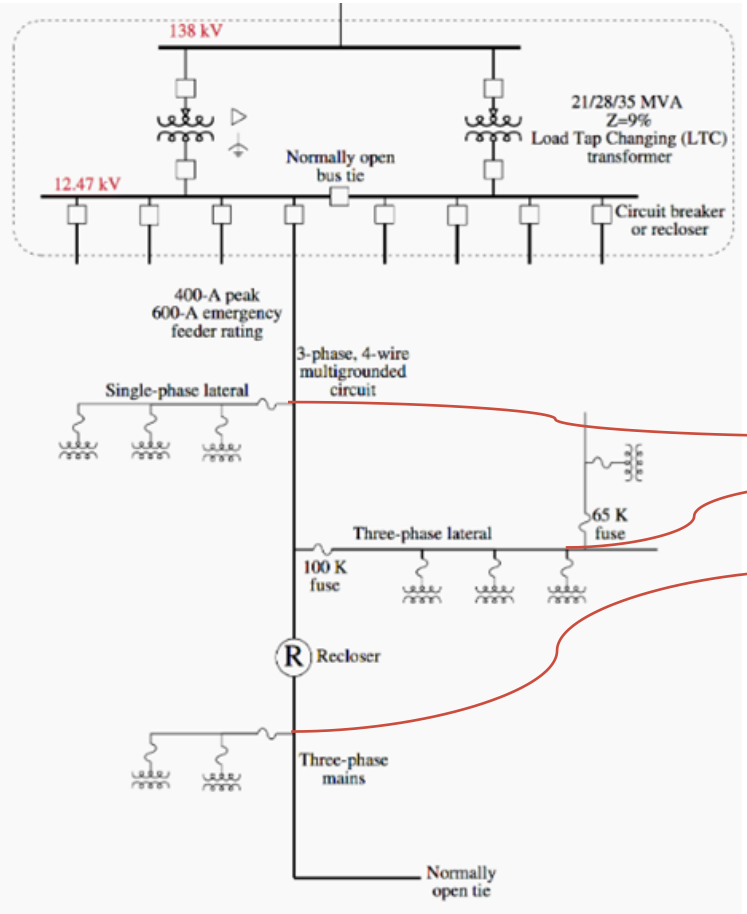
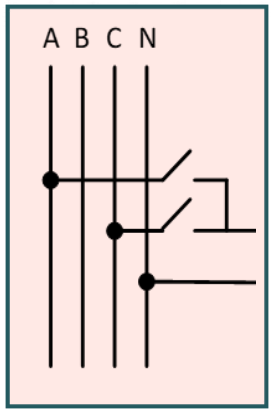
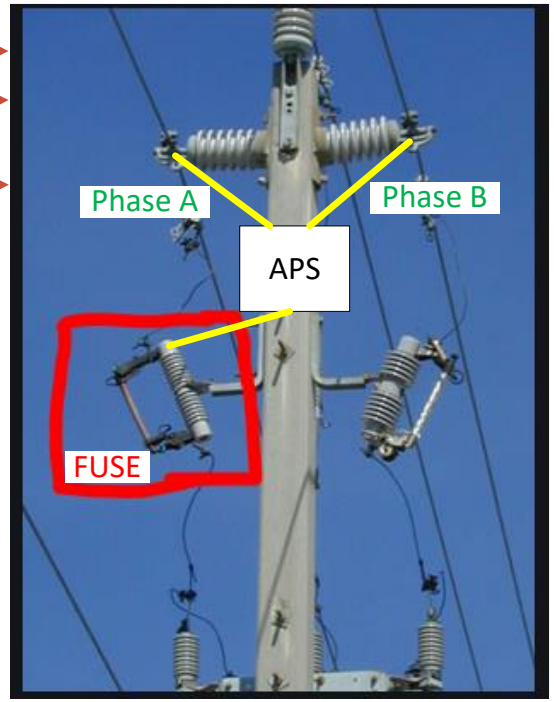
Distribution circuit and need for phase selector







- **MS3-based Automatic phase selector:**
  - Selectively connect a single-phase load or lateral to different phases
  - Low cost, low losses, modular design
  - Integration with DMS, substation or Feeder Automation systems

- **Value proposition:**
  - Reduce unbalance in distribution circuit → Enable hourly control instead of seasonal/yearly control
  - Eliminate the need for crew dispatch for rephasing
  - Enable integration and automation with DMS

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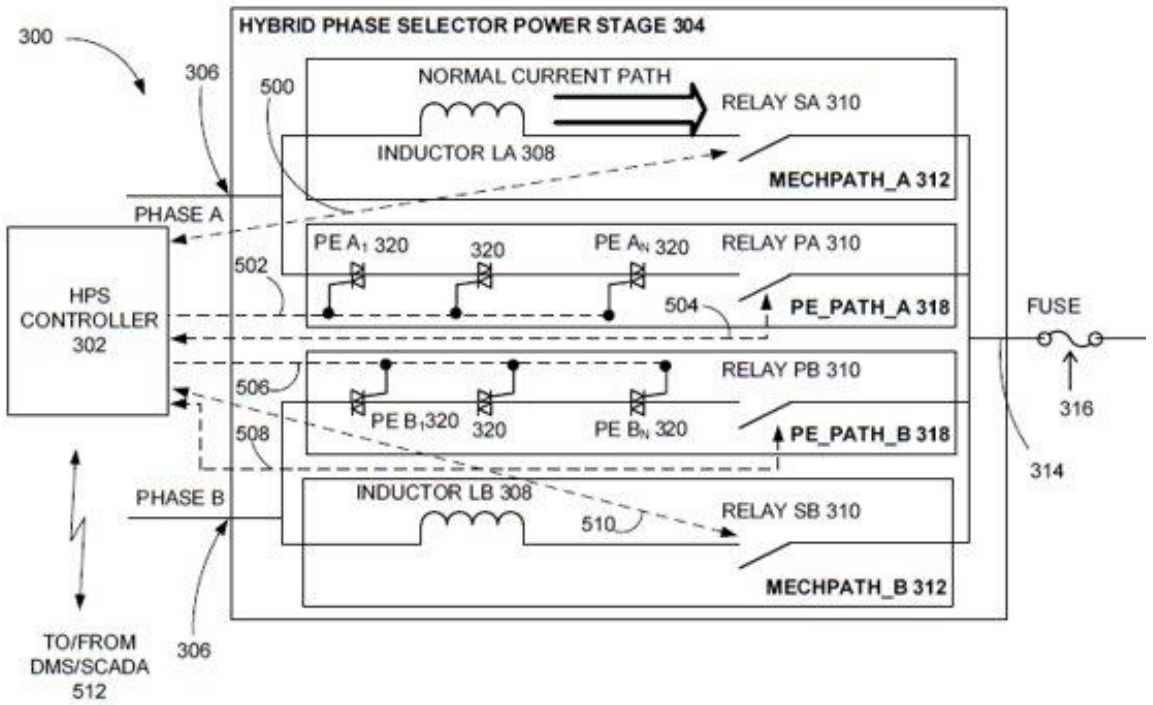
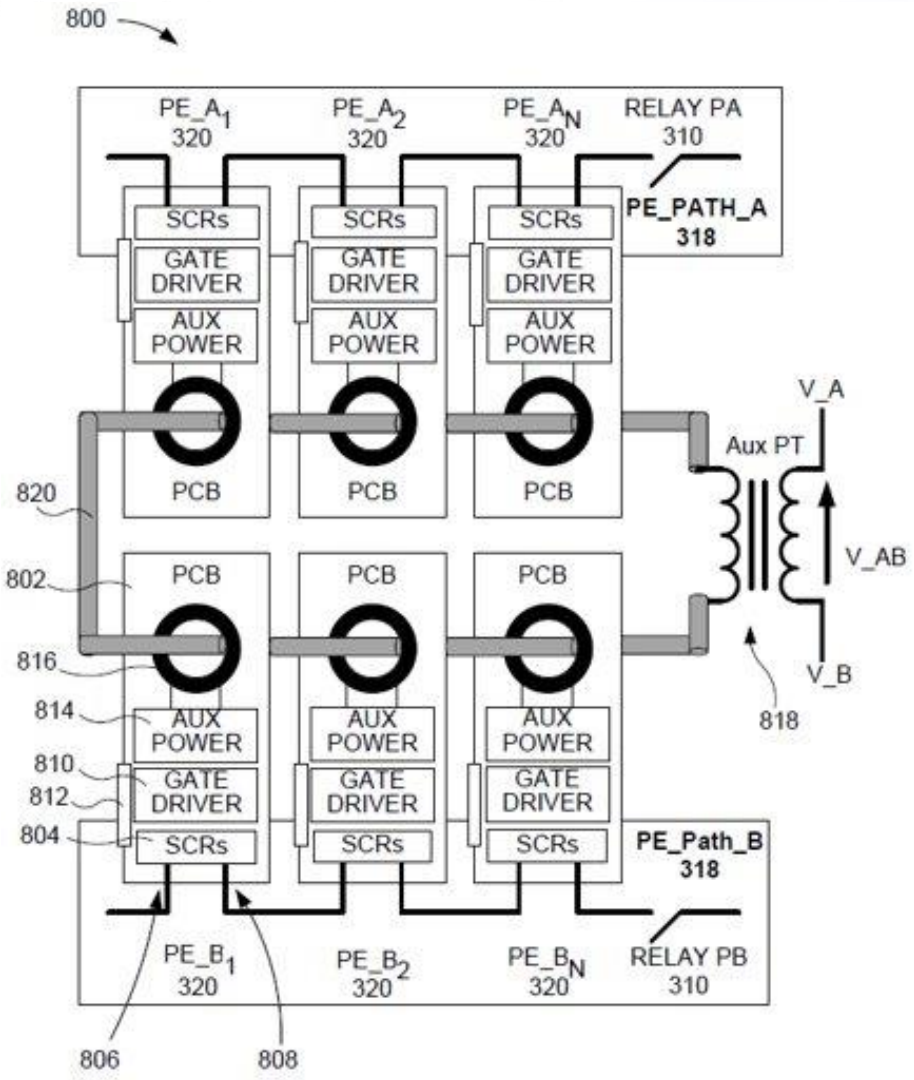
Modular Solid-State Switch for Automatic Phase Selector

- **MS3-based automatic phase selector**
  - Scalable for all voltage levels
  - Low cost and efficient approach
  - MS3 using series/parallel connection of LV discrete devices





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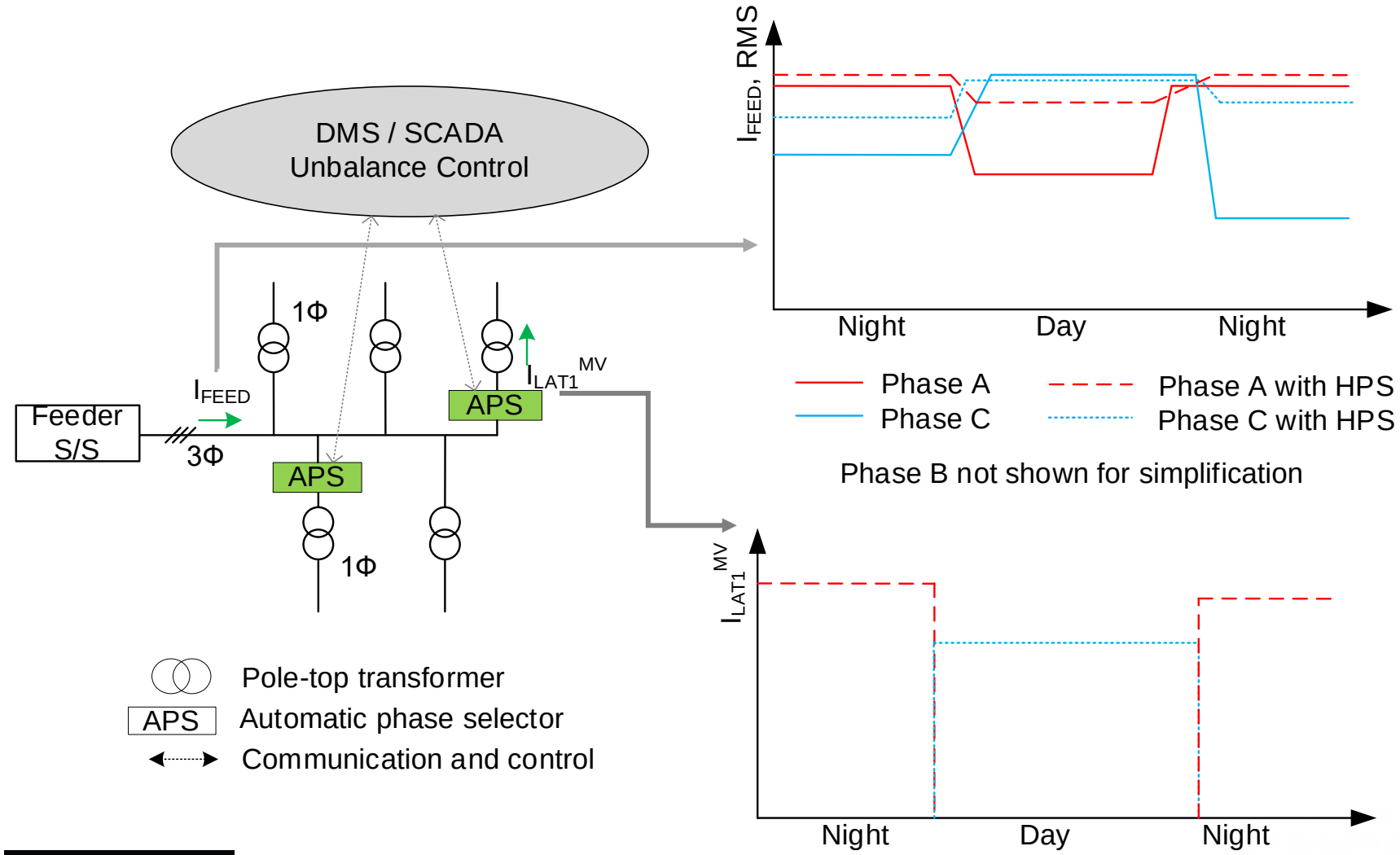
System Benefits



Timeline

Task	Name	Year 1	Year 2
1	**Simulations and design of main powertrain (Hitachi Energy)**		
1.1	Main phase switching mechanism		
1.2	Main phase switching mechanism – MV Design		
M1	Parameter optimization and component selection: Paper design report		
M2	Phase changeover strategy: Report summarizing simulation results		
M5	LV prototype ready		
2	**Power system distribution grid simulation (Hitachi Energy & ORNL)**		
2.1	Build testbench for system simulation		
2.2	Simulation of distribution system w/o and w/ automatic phase selector		
M4	System model development completed: Simulation model		
3	**PoC demo of main powertrain and benchtop prototype (Hitachi Energy & ORNL)**		
3.1	Build MV benchtop prototype		
3.2	Control and firmware development		
3.3	Test benchtop prototype at LV		
M3	Control hardware and firmware development: Code and test results		
M6	LV prototype testing completed: Report summarizing testing results		
M7	MV prototype ready		
4	**Project management**		
M8	Project report		

- **Go – No Go decision criteria**
- **Year 1:**
  - Subsystem design of MS3
  - Phase changeover strategy demonstration in simulation
  - Auxiliary power supply design
  - System level benefits validation through system simulations
- **Year 2:**
  - Thermal stability validation
  - Fault current handling capability
  - Benchtop design validation and phase changeover demonstration

THANK YOU

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