



**SOLAR ENERGY  
TECHNOLOGIES OFFICE**  
U.S. Department Of Energy

# Solar Critical Infrastructure Energization (SOLACE) System

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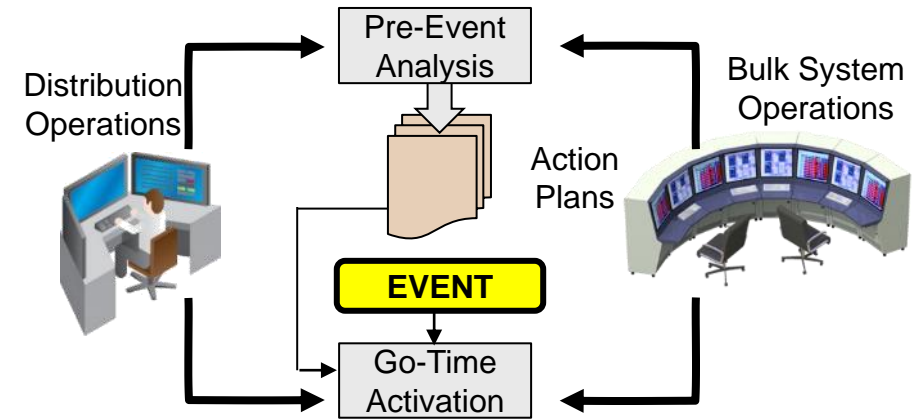
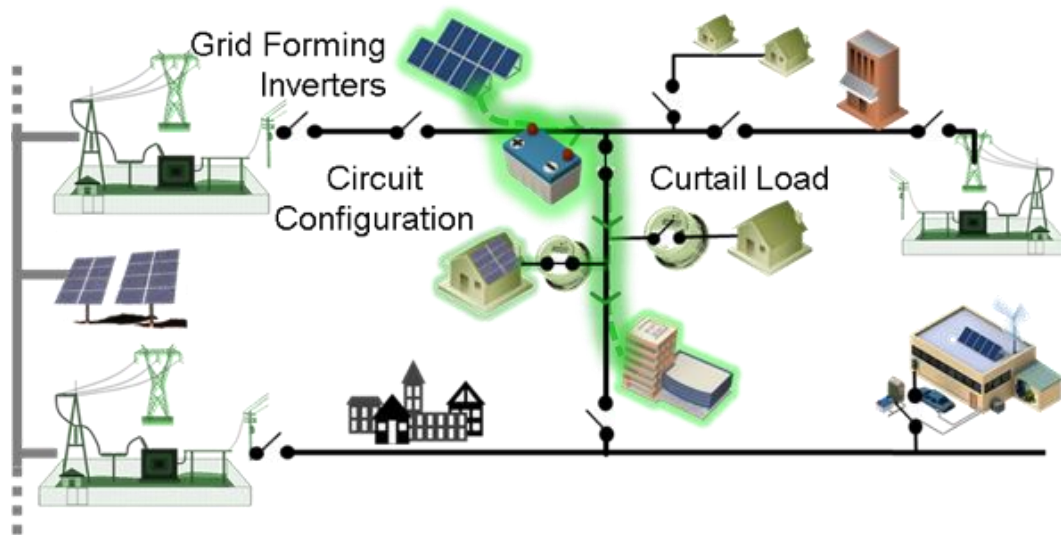
**Electric Power Research Institute (EPRI)**

**DOE Resilience Workshop Virtual Meeting**

**April 8<sup>th</sup>, 2021**

# SOLAr Critical infras Energization System (SOLACE)

Viability planning methods + Advanced grid controls + Secure local communication = Resilient local power ?



- **Pre-Event Planning methods:** Enable utilities to assess their T&D system to determine if and where *existing DER and grid* can be utilized for resilient local operation during time of crisis.
- **Controls & Operations:** Utilize centralized DMS functions to isolate and operate the local grids.
- **Technology Advancement:** Grid forming DER development, advanced load management, cyber-secure systems

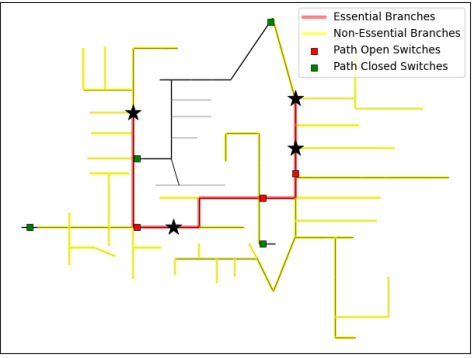
Work with the existing grid, not replace it. Utilize existing DER to provide resilience service to critical customers. Changes lie in where the control and monitoring layers are

# Resilience Planning Methodology – PERPA

## Step 0 - Determine Operational and Planning Criteria

- High-Level Operational Limits and Criteria for Different Analyses

### Analysis to Identify Pathways

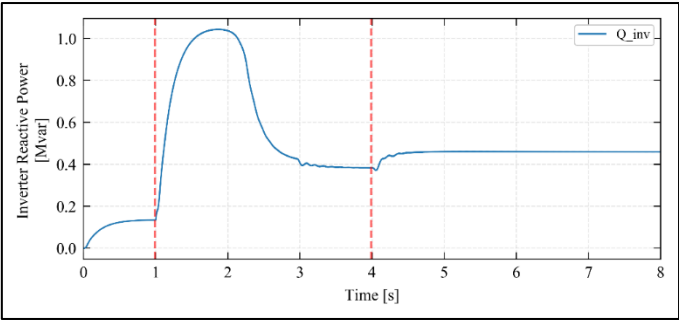


## Step 2 - Potential Pathways Identification

- Identification of potential paths
- Initial characterization of potential paths

## Step 4 - Pathway Dynamics Analysis (EMT)

- Protection Analyses
- Black-Start and Motor Start
- Generation, Large Load and Capacitor Switching



Criteria for Normal Operation	Reference Standards	Recommended Criteria for use in PERPA
Voltage Imbalance < 3%	ANSI C84.1	Might utilize range B (Service Voltage – 8.3% to4 +5.8%)
Harmonics	IEEE Std 519-1992	Can be relaxed within reason
Grounding	IEEE/ANSI C62.92	Can be relaxed up to the Dx arrested TOV assuming that...
...	...	...

## Step 1 - Critical Facility and DER Ident. and Characterization

- Identification and Characterization of Crit. Facilities and DER
- Combinations and filtering of Crit. Facilities and DERs
- Preliminary Power and Energy Adequacy Assessment
- Estimation of extra resources needed (if necessary)

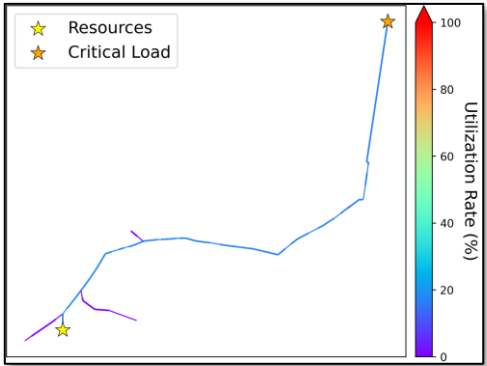
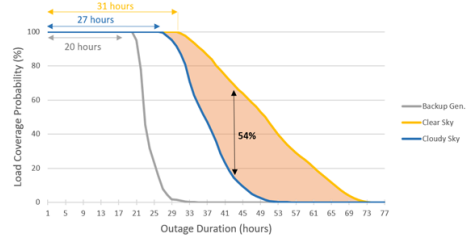
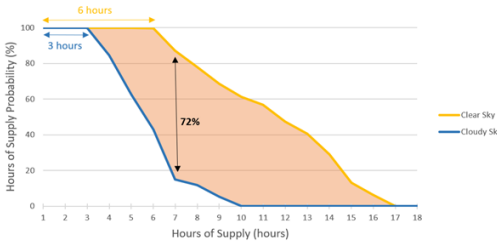
### Analysis of Each Identified Pathways

## Step 3 - Pathway Steady-State Analysis

- Power-Flow
- Thermal
- Reactive Power Supply
- Voltage and Load Balance
- Etc

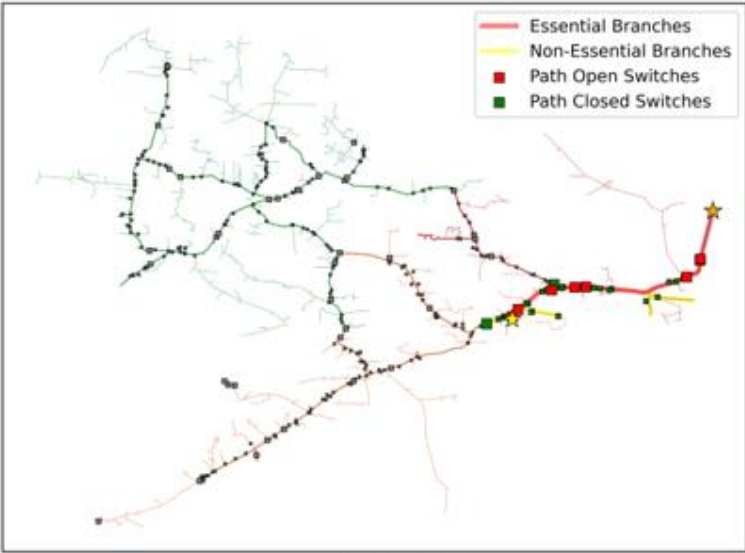
## Step 5 - Final Viable Plan Creation

- Creation of Pathways Ranking Matrix
- Solution Paths Characterization for Go-Time Activation

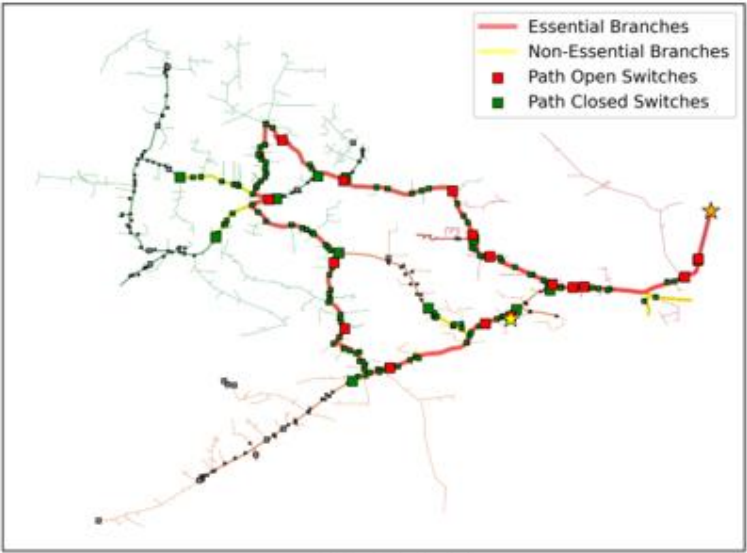


Path Name	Load Coverage Probability	Total Length	Total Sequence Impedance	# of Devices to be Adjust.	Cost (\$)	Path Ranking Position
1						
2						
3						

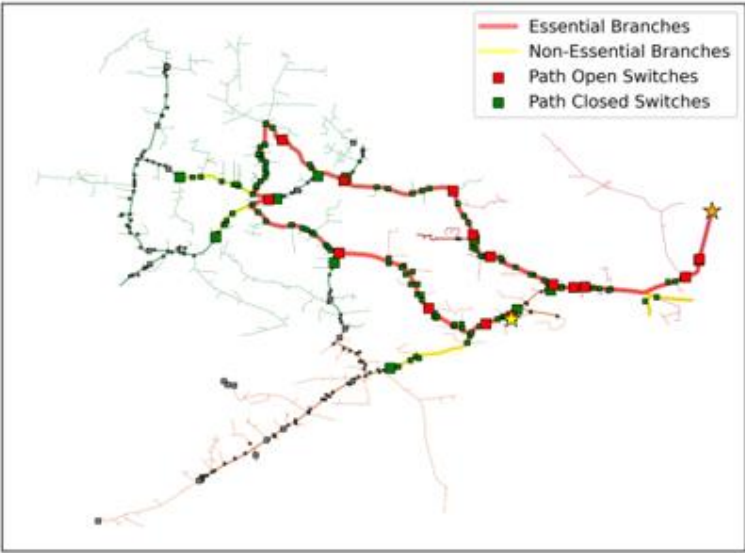
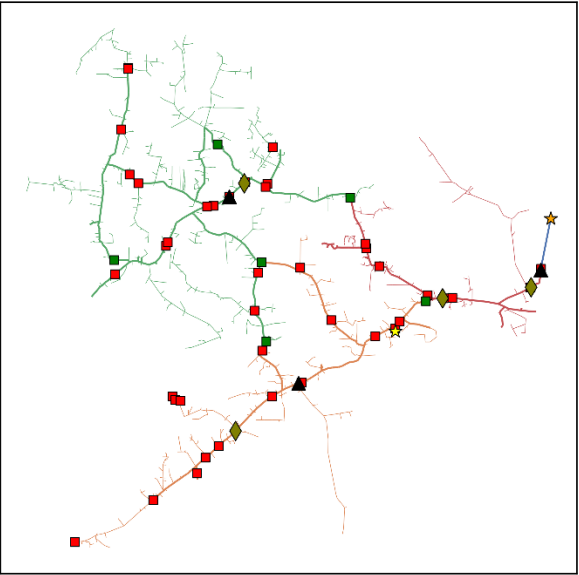
# Potential Pathways Connecting Critical Load to Resources



(a) Path 1

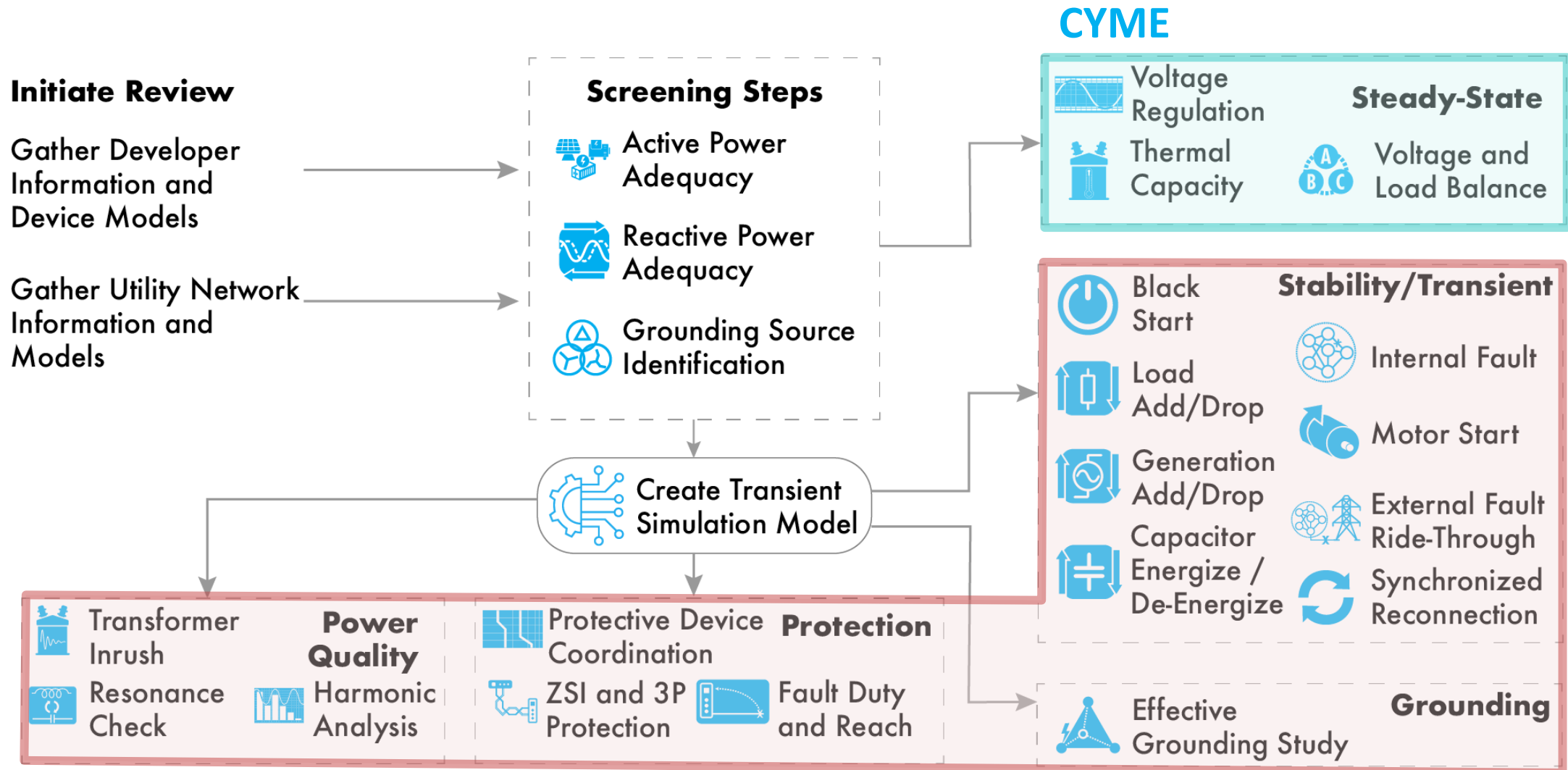


(b) Path 2



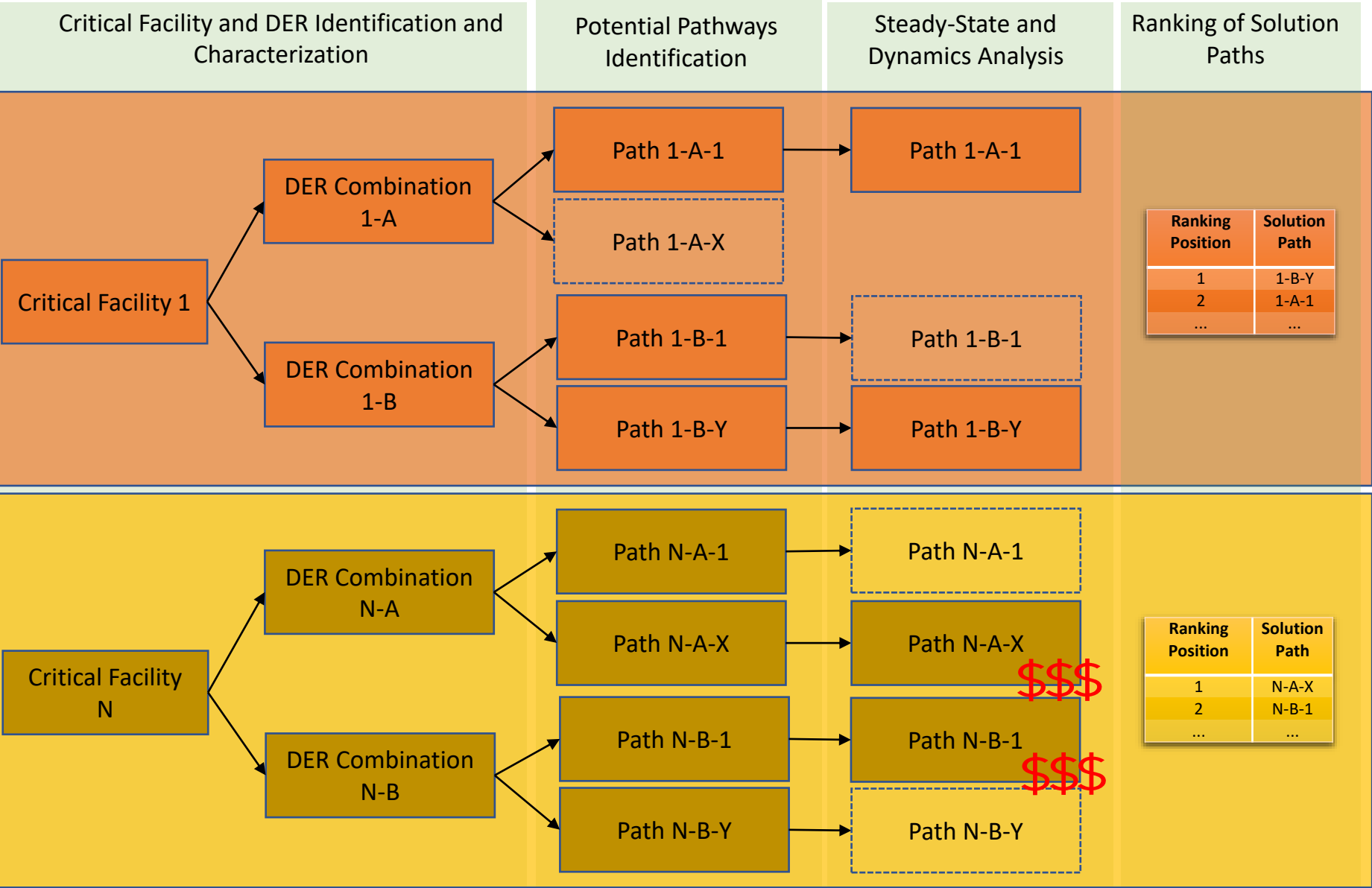
(c) Path 3

# Microgrid Interconnection Analysis Process





PSCAD

# Resiliency Planning Methodology – PERPA



### Go-Time Activation



Critical Facility Priorit. Position	Critical Facility	Solution Path Ranking Position	Solution Path
1	2	1	N-A-X
		2	N-B-1
2	1	1	1-B-Y
		2	1-A-1

- PERPA:
  - Critical facilities selected and ranked by third-party (e.g., Gov.)
  - Solution paths ranked by planning engineer
- Go-Time: operations engineer identifies a valid solution path to activate following the ranking matrix



# GFM Inverter Control and Hardware Development

## *Grid Following Inverter (GFL)*

- Current source (Current control)
- PLL is required to estimate grid phase angle and voltage magnitude
- No black start capability (anti islanding protection)
- Without frequency support
- Fast response to the intermittent irradiation levels (no buffer)



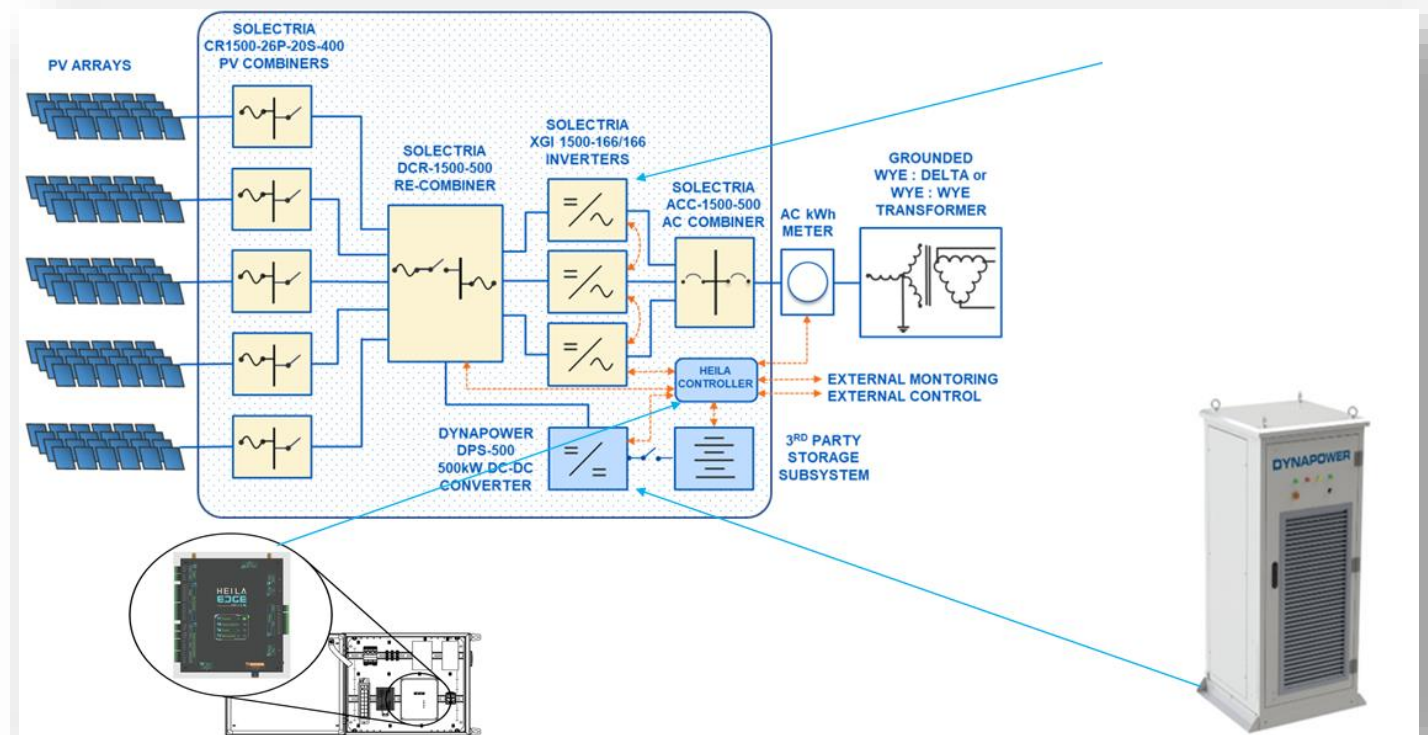
## *Grid Forming Inverter (GFM)*

- Voltage source ( can serve as PV bus or PQ bus)
- Operates like a synchronous generator
- Has its own voltage & frequency (Swing bus)
- No PLL required
- Black start capability
- Inertia support and primary frequency response

## *Proposed GFM Architecture: DC Coupled PV Synchronous Generator (PVSG)*

- Connect an energy buffer at the DC side (hardware change)
- Change the PV inverter controller for GFM
- System acts like a synchronous generator

- **Based on UT Austin PVSG Design**
- **Based on Solectria XGI-1500**
- **Upgraded control from GFL to GFM**



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# Thank You