PRESENTATION FOR PJM’S DER RIDE THROUGH TASK FORCE MEETING

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DER TRIP IMPACT STUDY

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U.S. DEPARTMENT OF ENERGY
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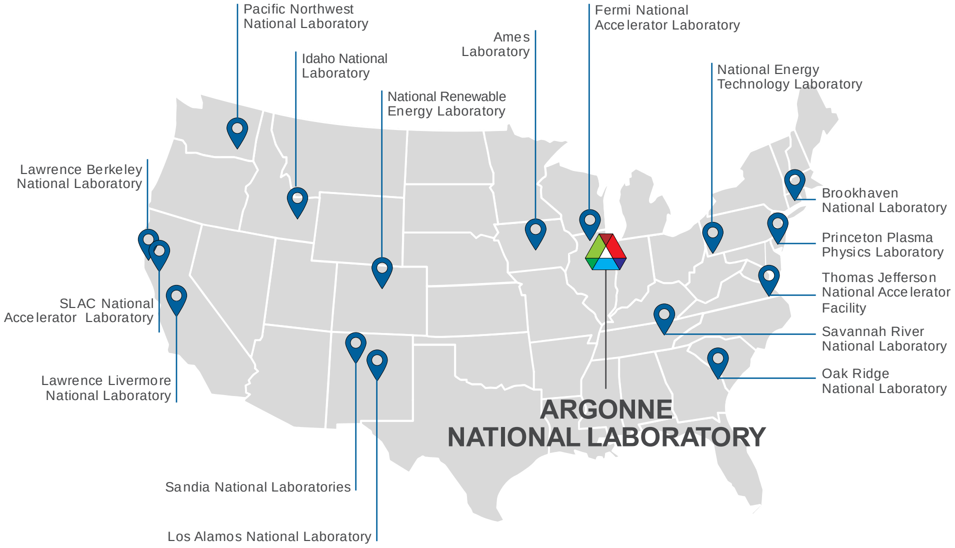
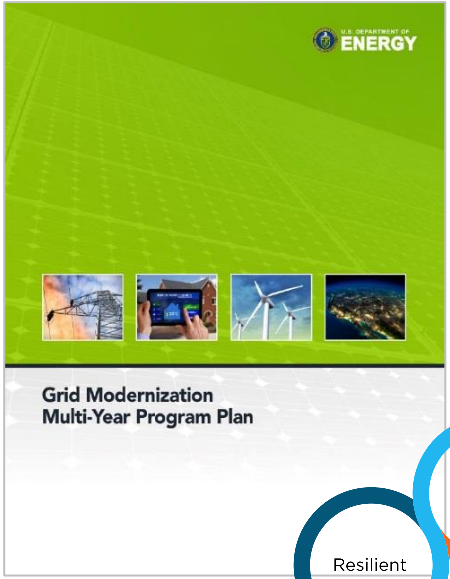
ARGONNE IS PART OF LARGE MULTI-YEAR DOE GRID MODERNIZATION INITIATIVE





GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

ARGONNE GRID RESEARCH IS BASED ON EXTENSIVE COLLABORATION WITH INDUSTRY

Utilities/ISOs

- ComEd, Exelon, PECO
- WAPA
- APS
- Altalink
- SPP, NYSIO
- ERCOT, MISO, PJM
- EDP, GDF, EDF
- Dynegy
- Aboitiz Power (Philippines)
- GSE (Georgia)
- HECO, PG&E

Vendors

- Siemens PTI
- Alstom Grid
- Electrocon
- McCoy Energy
- Energy Exemplar
- Schneider Electric
- S&C Electric
- Eaton
- Schweitzer Engineering Laboratories

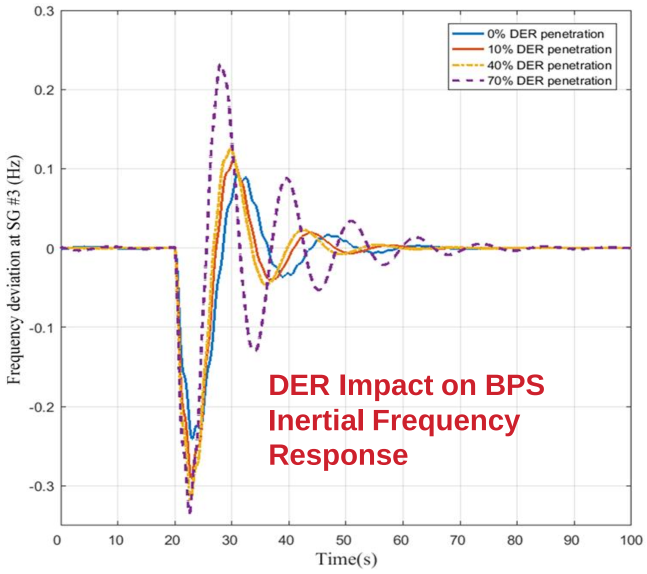
Others

- Consulting
  - Fichtner
  - Deloitte
- Engineering/Design
  - Mead Electric
  - MWH
- EPRI
- EEI
- NERC
- USEA
- USAID
- IAEA

SUPPORTING NERC'S NEW WORKING GROUP ON "SYSTEM PLANNING IMPACTS OF DER (SPIDER)"

- NERC SPIDERWG addresses aspects of key points of interest related to system planning, modeling, and reliability impacts to the Bulk Power System (BPS)
- One of the top priority initiatives at NERC
- Argonne supports all 4 subgroups with our new **T&D Co-simulation** Platform
  - Steady-state and dynamic simulations for transient stability and disturbance ride-thru studies
  - Scalability to model realistic interconnections and distribution networks
  - Flexibility to implement DER interconnection standards
  - Flexibility to implement advanced DER control functions

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION



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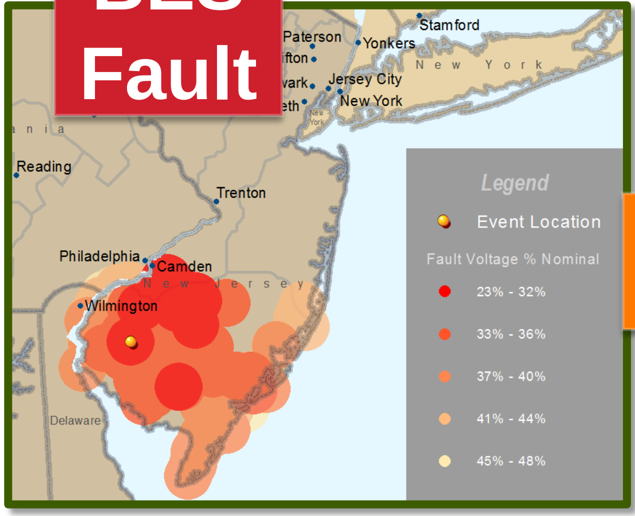
PURPOSE AND SUMMARY OF DER TRIP IMPACT STUDY FOR PJM

- **Summary**: PSS/E dynamic study of transmission (and equivalent distribution) for response of DER and transmission network to a 3-phase transmission fault.
- **Purpose**:
  - Understand severity and nature of the transmission impact of fast-trip (and lack of ride through) under high DER scenario.
  - Compare the impact under the status quo IEEE 1547-2003 trip settings (and lack of ride through) with the impact given alternative trip settings including ride through and momentary cessation (under IEEE 1547-2018).

SEQUENCE OF STUDY

BES Fault



(“BES” = “Bulk Electric System” = the transmission system)

~100 ms → TRIP or other → ~ 10,000 ms →

BES Fault → DER Trip or other → BES Fault Clearing → BES Response → DER recovery

Source: www.PJM.com

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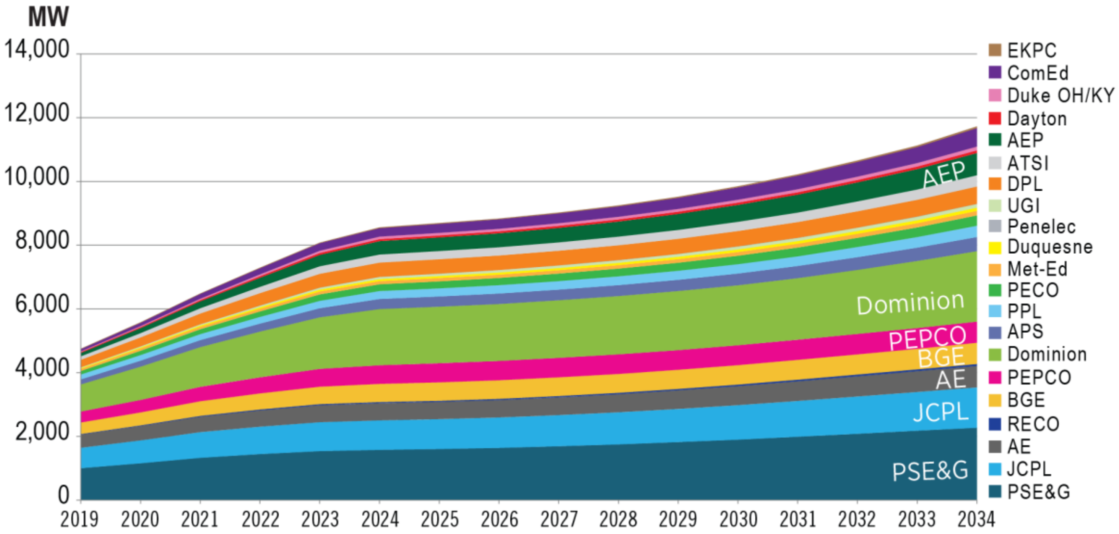
DRAFT STUDY DER DEPLOYMENT SCENARIOS

Three cases for DER deployment in 2031 (nameplate solar DER MW):

- **High**. Current PJM deployment forecast of ~4 GW nameplate (< 10% of annual NJ load from solar DER).
- **Higher**. Range up to 10 GW (< 20% of annual NJ load from solar DER).
- **Highest.** Range up to 15 GW nameplate (< 30% of annual NJ load from solar DER).



Note: New DER model added only in state of NJ for the purpose of this study.

For each case DER on a particular bus proportionally scaled.

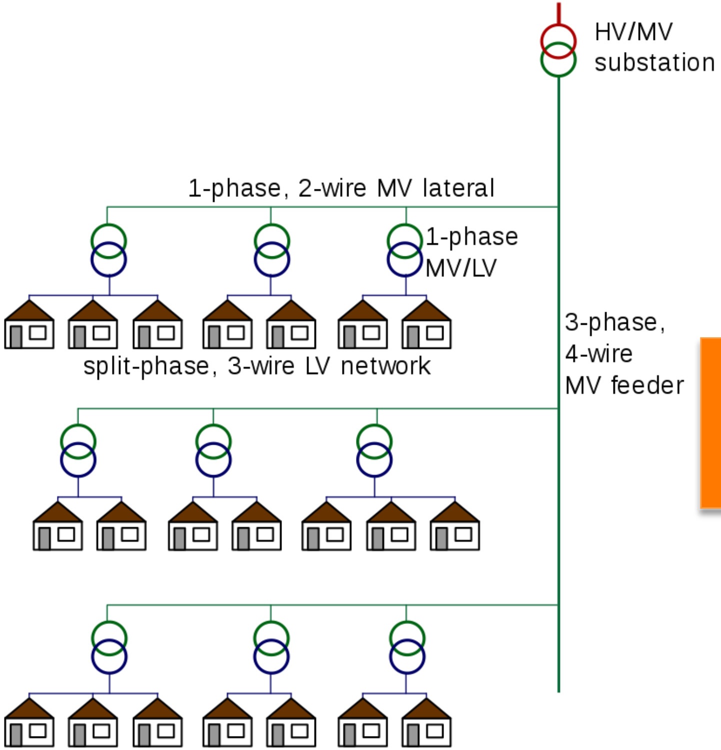
DRAFT STUDY SYNCHRONOUS GENERATOR DEPLOYMENT SCENARIOS

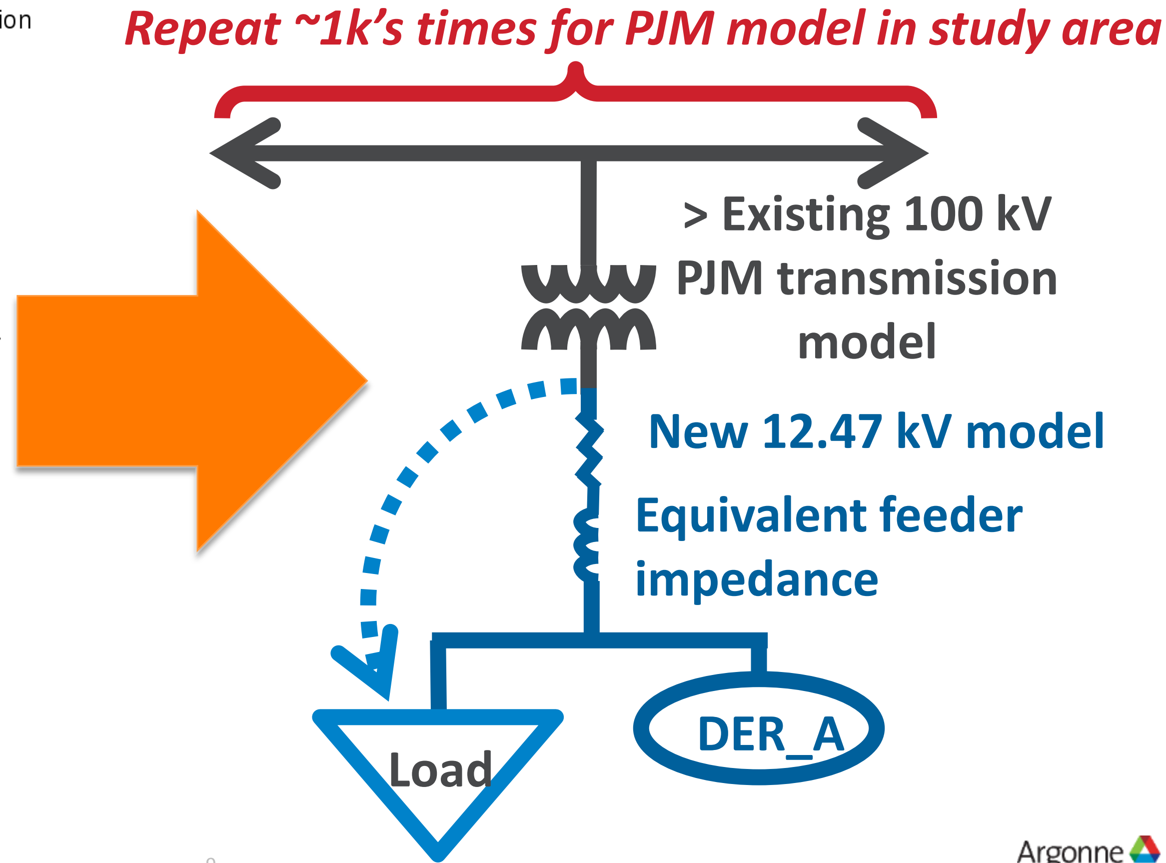
Three cases for Synchronous Generators (SGs) deployment in 2031 considered for state of NJ and within PJM territories :

- **High**. Almost all existing SGs remain connected in the system (1.8 GW of SG taken off NJ and total of 2.6 GW within PJM territories)
- **Mid**. Most of the conventional fuel based generation taken off from NJ (3.0 GW of SG taken off NJ and total of 6.9 GW within PJM territories)
- **Low.** Almost all of the conventional fuel based generation taken off from NJ (4.2 GW of SG taken off NJ and total of 8.9 GW within PJM territories)

Note: Nuclear power plants and hydro power plants within the state of NJ remain connected for all the cases considered.

DISTRIBUTION SYSTEM IMPEDANCE ACCOUNTING





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DISTRIBUTION SYSTEM IMPEDANCE ACCOUNTING

The model accounts for impedance in these distribution elements:

1. Transmission substation load stepdown transformer (steps down High Voltage transmission (e.g. 230 kV) → Medium Voltage primary distribution (e.g., 12.47 kV)
   - Mostly already in base model.
   - Explicitly represented on an ~individual basis.
2. Downstream distribution components:
   - Entire medium-voltage feeder main and laterals
   - Equivalent impedance of service transformers (steps down Medium Voltage primary distribution (e.g., 12.47 kV) to Low Voltage at customer service voltages (e.g., 480V, 240 V)
   - Equivalent impedance of secondary from service transformer → customer load & DER.
   - All modeled impedances moved from Complex Load Model & DER_A parameter into explicit modeling. I.e., Complex Load & DER_A model object impedance parameters → 0.
   - All are represented as a single aggregate equivalent impedance per transmission bus.
   - Generally a single representative number is used across each utility in the model.

DISTRIBUTION SYSTEM IMPEDANCE ACCOUNTING

- We looked into the existing complex load model that PJM has which takes into consideration various distribution system components like substation load tap changer, distribution of motor loads (large and small) and lighting loads, along with equivalent feeder impedance consideration.

From the complex load model, the range of equivalent feeder impedance observed for various TOs within PJM were observed in the following range:

- Range for R = 1-4.5% and X = 5-14%.

We also considered IEEE standard feeders, (IEEE 13 node, IEEE 34 node, IEEE 8500 node etc) and observed the following range:

- R = 3-10% and X = 4-19% on load MVA base.

PROPOSED DISTRIBUTION SYSTEM IMPEDANCE VALUES TO BE USED BY PJM

- Based on these background studies, PJM is suggesting to perform their studies based on two sets of data:

a. With R = 3% and X = 15%, a slightly higher X/R ratio but lower overall impedance.
b. With R = 9% and X = 18% lower X/R ratio, but higher overall impedance.

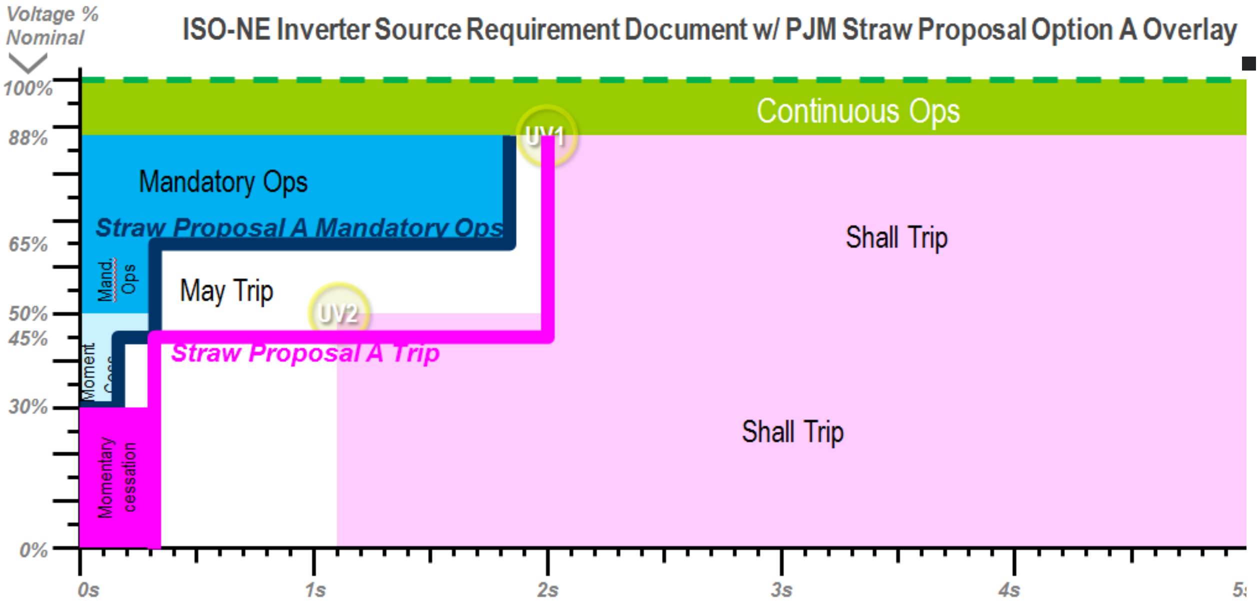
We will believe these two sets will cover the reasonable sensitivity scenarios concerning feeder impedance values.

Please comment on these parameters and let us know if you have any concerns regarding these numbers.

DIFFERENT CASES CONSIDERED

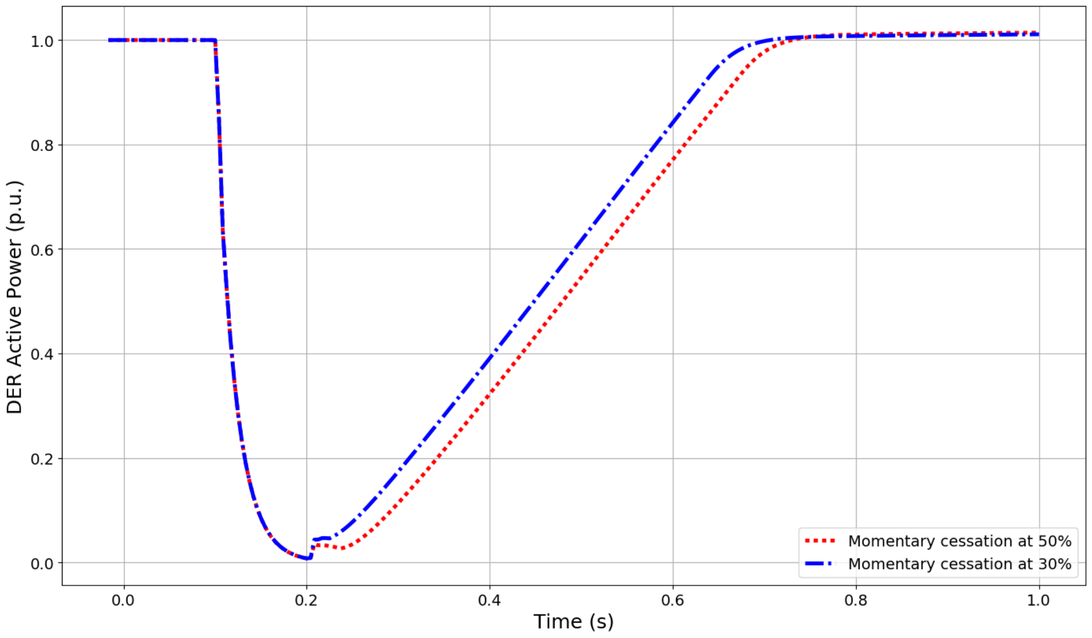
- Various combination of cases based on the followings will be studied:
- 1. Availability of Synchronous Generation in NJ: High, Medium and Low
- 2. DER penetration in NJ: High, Medium and Low
- 3. Different mix of interconnection standard for DERs:
  - IEEE 1547-2003 with no ride through, DER trip faster than BES fault clearing
  - IEEE 1547-2018 Cat II with a) full ride through, b) momentary cessation at 30% voltage, and c) momentary cessation at 50% voltage.
- 4. Different parameters for equivalent feeder impedance: based on EPRI's generic parameter, utility specific parameters
- 5. Voltage support from DER: on and off
- Few examples:
  - Low SG in NJ with high DER with 2018 IEEE 1547 implemented without voltage support
  - Low SG in NJ with medium DER with 2018 IEEE 1547 implemented with voltage support and DER entering momentary cessation at 30%.
  - High SG in NJ with medium DER with 2018 IEEE 1547 implemented without voltage support and DER tripping faster than BES fault clearing.

RESULTS FROM CASE STUDIES AND ITS IMPLICATION TO PJM'S STRAW PROPOSAL



- For High DER cases, if entering momentary cessation at 50% shows detrimental impact to the stability of the system (e.g. delayed voltage recovery, larger frequency excursion and so on), compared to entering momentary cessation at 30%, PJM will favor its straw proposal A compared to ISO-NE approach.

DER RESPONSE TO SAME FAULT WITH TWO DIFFERENT MOMENTARY CESSATION SETTINGS



- Figure aside shows the response of DER for a same fault with two different momentary cessation settings. With the 50% momentary cessation settings, it can be observed that power output of DER recovers later than the case when DER enters momentary cessation at 30%. This delayed power output from large number of DER can be stability implications on the power grid.

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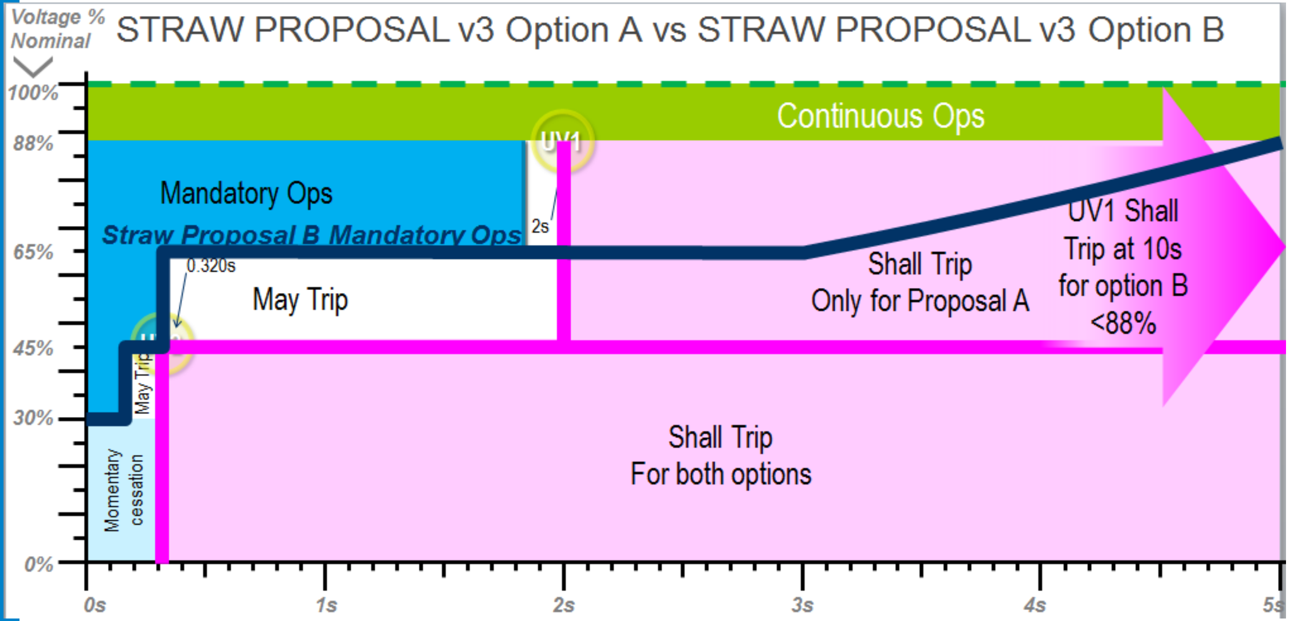
RESULTS FROM CASE STUDIES AND ITS IMPLICATION TO PJM'S STRAW PROPOSAL



- If the study shows that NJ system suffers from fault induced delayed voltage recovery (FIDVR) and more DER trip after 2 secs due to slower voltage recovery, the study will suggest implementing Option B as opposed to Option A as proper DER settings.

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ONGOING STUDY

- PJM and Argonne are continuing the case studies to inform PJM’s DER Ride Through Task Force on the implications of different DER ride through settings on the stability of BES.
- More results and findings will be presented in the next Ride through task force meeting.

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Work supported by U.S. DOE and PJM Interconnection

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