

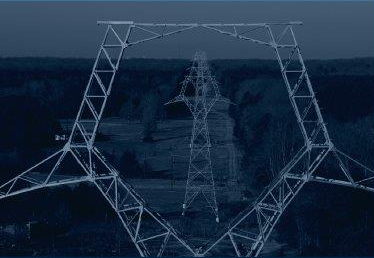
# Transmission Hosting Capacity Analysis & Beyond

**Dominion Energy**

Katelynn Vance & Amirreza Sahami

**Simple Thread**

Nick Agliano



# Introduction

**About Dominion Energy**

**Problem Statement**

**Technological Innovation: Hosting Capacity Analysis & Heatmap Platform**

**Implementation Strategy: From Concept to Deployment**

**Future Directions & Industry Collaboration**

**Conclusion & Audience Q&A**

# ET at a Glance

Dominion Energy Virginia's Electric Transmission operates in Virginia, North Carolina, & West Virginia

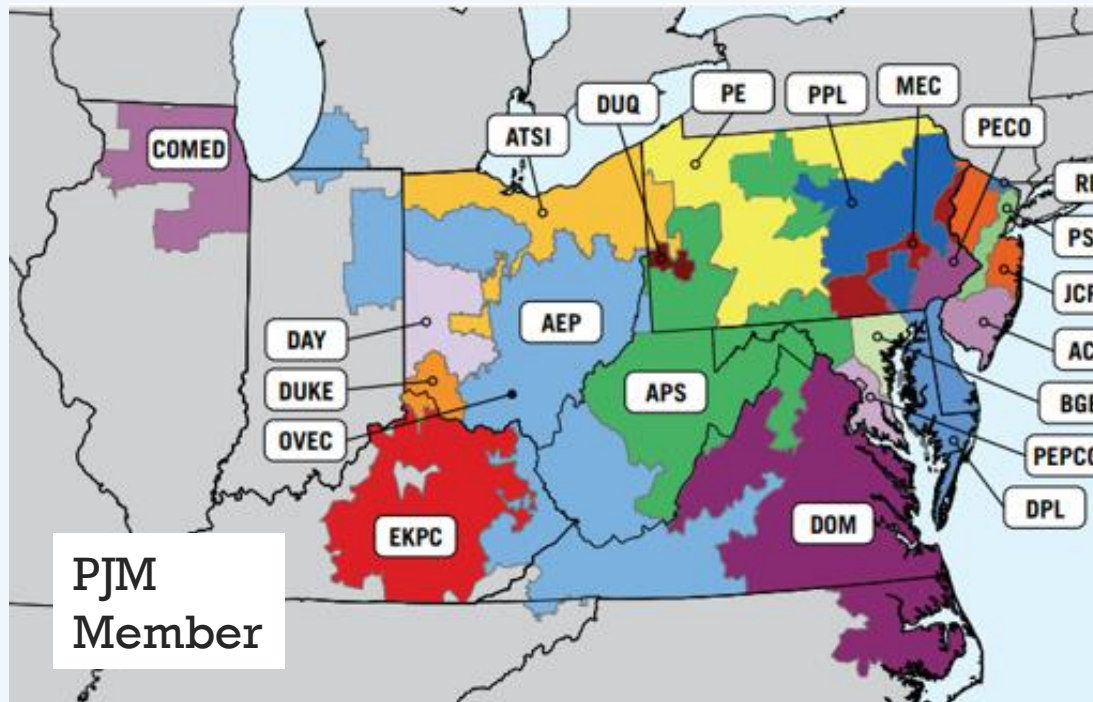
**\$7.8 billion assets in service**

**Operates in Virginia, North Carolina and West Virginia**

- 6,800 miles of transmission lines
- 500 kV – 1,300 miles
- 230 kV – 2,927 miles
- 138 kV – 64 miles
- 115 kV – 2,311 miles
- 69 kV – 78 miles

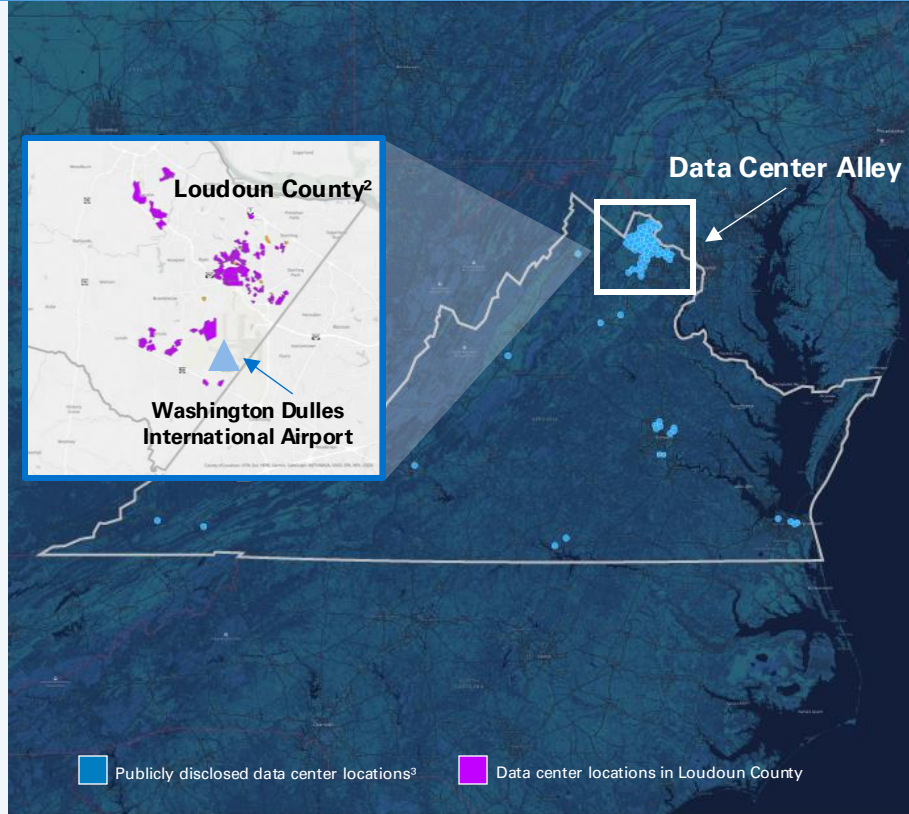
**More than 900 substations**

**~50,000 transmission structures**



# Data Centers in Dominion Energy VA

Northern Virginia boasts the largest data center market in the world<sup>1</sup>



## Northern Virginia

2020 **2,518MW\***

2028 **8,346MW\***

a 231% increase

Delivery Point Requests **63**

Total Projects **107\*\***

Doubling of area substations

## Central/Southside

2020 **402MW\***

2028 **2,953MW\***

a 634% increase

Delivery Point Requests **24**

Total Projects **24\*\***

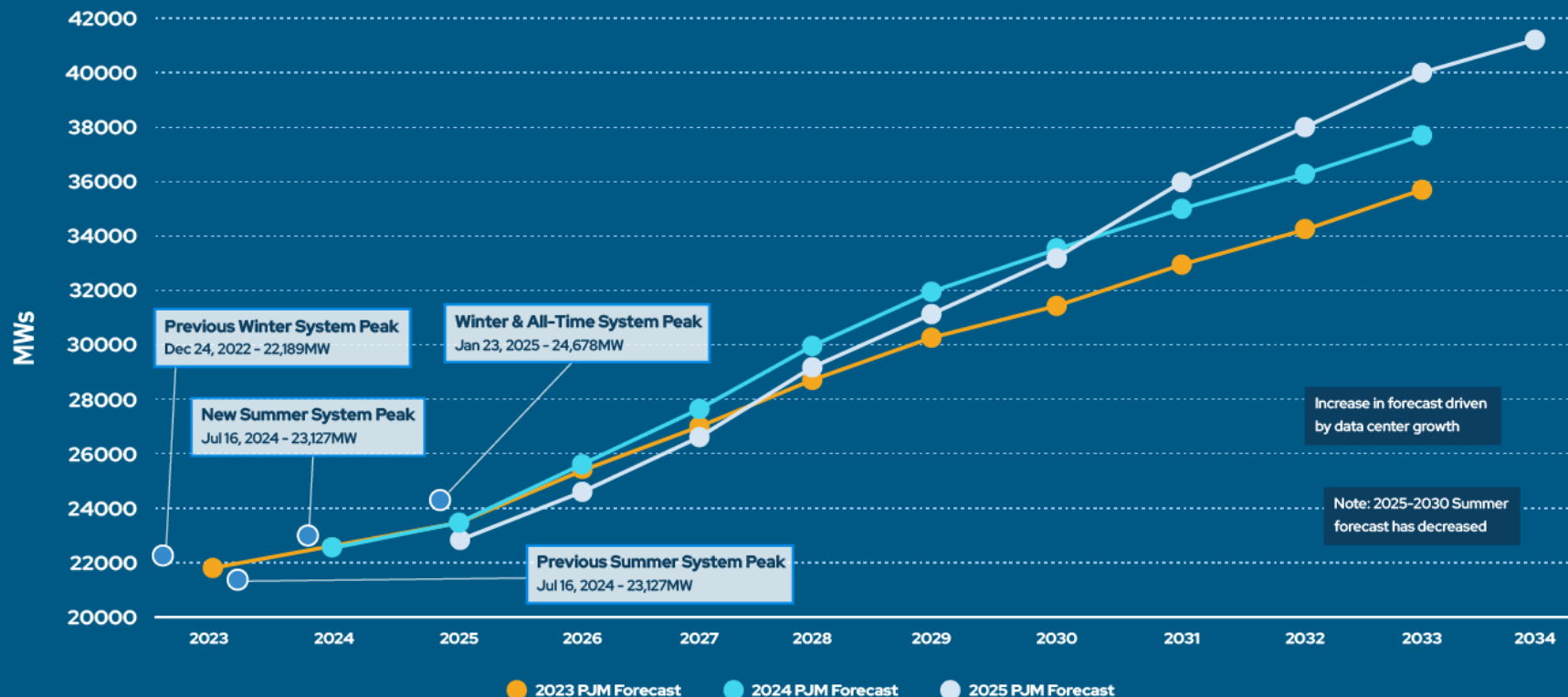
Quadrupling of area substations

\*Includes Co-Op load projections \*\*Project count reflective of the 2024 5-yr plan as of Nov 2023

<sup>1</sup> <https://www.vedp.org/industry/data-centers> <sup>2</sup> Feb 2022 Loudoun County Data Center Study

<sup>3</sup> Data Center locations provided by Data Center Hawk

# Yearly PJM Summer DOM Zone Load Forecast



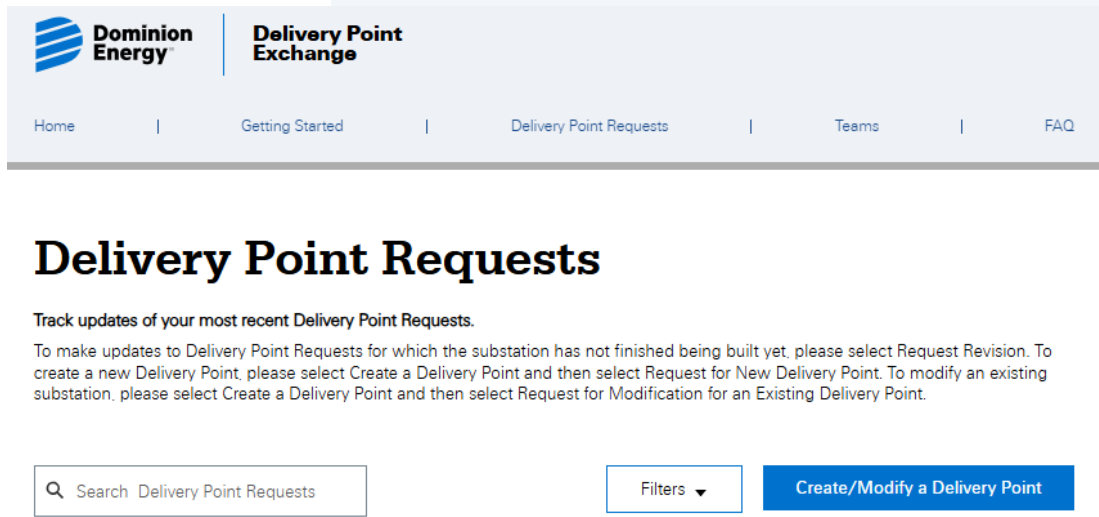


# Delivery Point (DP) Exchange

Platform to track load interconnection requests

Live 10/22/24

Helps prepare for if NERC regulates large loads



The screenshot shows the web interface of the Dominion Energy Delivery Point Exchange. At the top is a navigation bar with the Dominion Energy logo on the left and the text "Delivery Point Exchange" on the right. Below this is a horizontal menu with links for "Home", "Getting Started", "Delivery Point Requests", "Teams", and "FAQ". The main content area has a heading "Delivery Point Requests" followed by a sub-heading "Track updates of your most recent Delivery Point Requests." Below this is a paragraph of instructions: "To make updates to Delivery Point Requests for which the substation has not finished being built yet, please select Request Revision. To create a new Delivery Point, please select Create a Delivery Point and then select Request for New Delivery Point. To modify an existing substation, please select Create a Delivery Point and then select Request for Modification for an Existing Delivery Point." At the bottom of the main content area is a search bar with the placeholder text "Search Delivery Point Requests", a "Filters" dropdown menu, and a blue button labeled "Create/Modify a Delivery Point".

**Delivery Point Exchange**

Home | Getting Started | Delivery Point Requests | Teams | FAQ

## Delivery Point Requests

Track updates of your most recent Delivery Point Requests.

To make updates to Delivery Point Requests for which the substation has not finished being built yet, please select Request Revision. To create a new Delivery Point, please select Create a Delivery Point and then select Request for New Delivery Point. To modify an existing substation, please select Create a Delivery Point and then select Request for Modification for an Existing Delivery Point.

Search Delivery Point Requests

Filters ▼

Create/Modify a Delivery Point

# Load Curtailment Program

**Voluntary Program for Data Center Customers in the Northern Virginia constrained area**

**Executed During Non-Emergency Conditions**

## **Targeted Data Center Customers**

- Near or at contracted firm load level
- Enables participating data centers to add curtailable load beyond their contracted limit and use it during non-constrained hours

## **During Events Customers must:**

- Transfer load from utility supported source and remain off-line until instructed to return
- Curtailable load cannot transfer to an alternate feed in the constrained area

## **Anticipated Customer Experience:**


- 190 hours of curtailment
- 55 calendar days
- Average duration of 1.63 hours



# Facility Interconnection Requirement (FIR) Updates

Updated **FIR** requires significantly more load information

- Attachment 2 – Customer Request Form
  - [Largely based on NERC Data Center Information Collection Questionnaire](#)

 <b>Dominion Energy®</b>	<b>Dominion Energy Virginia - Electric Transmission Facility Interconnection Requirements</b>		
	<b>Attachment 2 - Customer Request Form</b>		
Electric Transmission Planning	REVISION 1.0	Effective Date: 09/01/2024	Page 9 of 13

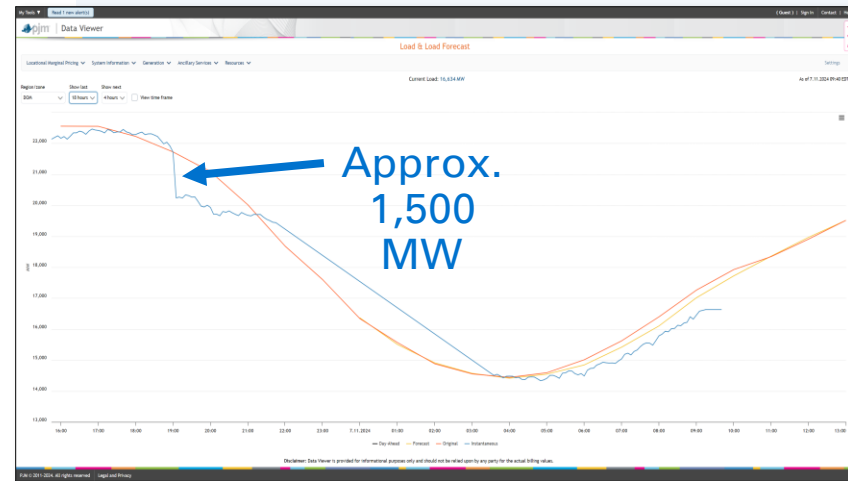
**Noteworthy Load Characteristics Form**



# Data Center Load Transfer Events in July & February

Two line lockout events after normal reclosing cycles on the transmission network caused 1500 MWs of load to be transferred to onsite back-up generation on July 7, 2024 and February 17, 2025

- All load in Northern Virginia – as far as 30 miles from fault location
- Without high resolution data at the facility point-of-interconnection (POI), impossible to determine individual facility performance
- NERC published a Reliability Vignette on the event
- Risk associated with clustering data centers could be alleviated with spreading out data center load using information from the Hosting Capacity Analysis Tool



# Planned 2025 FIR Updates

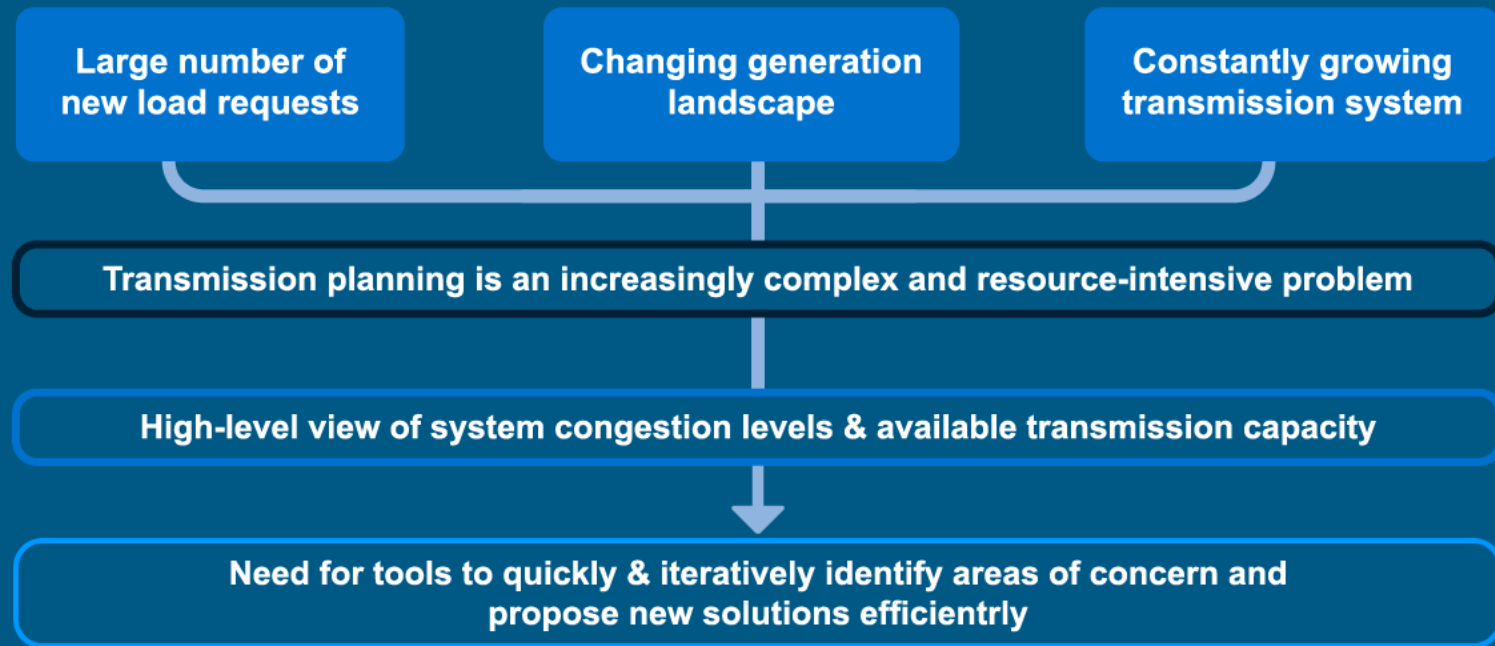
## **Asking for dynamic load models in 2025 revision**

- Either composite load or EPRI, ISO-NE developed EV charging models
- Need to perform studies to determine impacts of possible future events

## **Currently developing fault ride through requirements**

## **Requiring installation of high-resolution sensors at data center point-of-interconnection (POI)**

# Need for high-level system overview



# Innovate: Transmission Hosting Capacity

When transmission lines upgraded, there is some additional capacity available after alleviating the initial violations because equipment sized at standard intervals

**Want to know where there is transmission capacity available to add load**

- Cannot cause reliability violations as evaluated by N-1, N-1-1 contingency analysis

**DEV has a distribution voltage hosting capacity map**

- Easier for distribution because the network is radial rather than networked

# First Iteration - AutoEDR

## Automated Economic Development Request Study (AutoEDR)

- Determines transmission line available capacity
- In-house developed, non-graphical automated screening tool
- Iteratively examines different loading levels only with N-1 and N-1-1 analysis working for larger areas
- Applied reduced contingency set to reduce computation

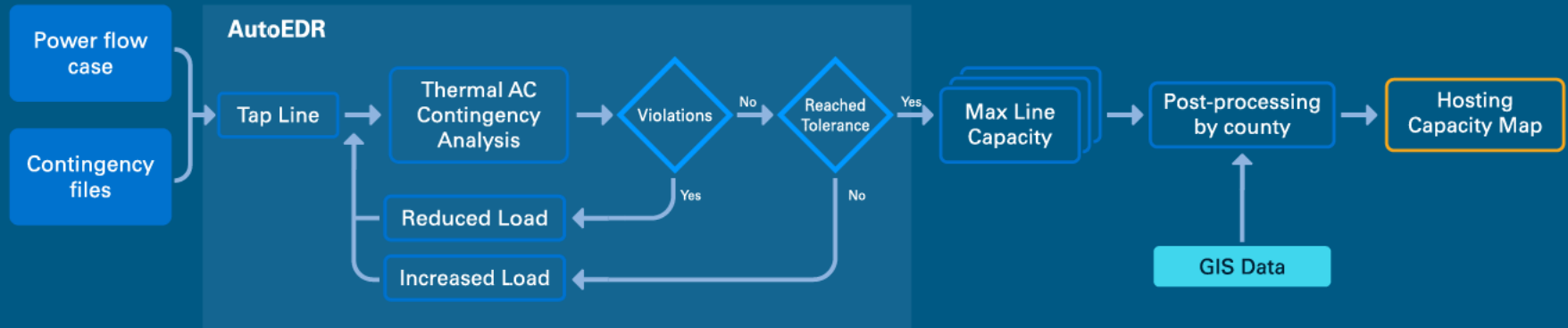
**Very slow – no distributed computing**

**Acceptable for zonal analysis**

The screenshot shows the AutoEDRstudy application window. The title bar reads "AutoEDRstudy". Below the title bar are "Help" and "About" buttons. The main window has a header with the Dominion Energy logo and the text "Electric Transmission Planning & Strategic Initiatives". The interface is divided into several sections:

- Study Case:** A text input field.
- Contingency Files:** A section with buttons for "Bus", "Line\_FB", "Single", and "Tower", each followed by a text input field. Below these is a checkbox labeled "Add single branch contingency (target zone)." which is checked.
- Study Engine:** A dropdown menu set to "PSS/E 33 & PowerGEM TARA".
- Study Size:** A dropdown menu set to "Area", a "Precision:" field set to "5 MW", and fields for "Area Number:", "Zone Number:", "From Bus:", "To Bus:", and "ID:".
- Bus Location (%):** A slider bar set to "50%".
- Study Violations:** A dropdown menu set to "Thermal Only" and a checkbox labeled "Convert Fixed to Switched Capacitors" which is unchecked.
- Load Flow Solutions:** A section with "Solution method:" set to "Fixed slope decoupled", "Tap Adjustment:" set to "Lock taps", "VAR limit:" set to "Apply immediately", "Shunt Adjustment:" set to "Enable all", and "Area Interchange:" set to "Disabled".
- Contingency options:** A section with "Base Case Rating:" set to "Rating A" and "100 %", "Rating", "Contingency Case Rating" set to "Rating B" and "100 %", "Rating", "Lines Thermal Limit Mode:" set to "MVA rating", and "Transformers Thermal Limit Mode:" set to "MVA rating".
- Parallel Processing:** A section with "Number of Cores:" set to "CPU cores" and "12".
- Contingencies:** A section with "Scenarios:" set to "N-1, N-2, and N-1-1".
- Output File:** A section with a "Save" button, a text input field, a "Report all simulation steps" checkbox which is checked, and a "RUN" button.
- Starting Load:** A section with a dropdown menu set to "Percent (Base Case)" and a text input field set to "110 % of initial remaining capacity".
- Initiate default options:** A button.

## Second Iteration – Using AutoEDR to create maps



High-level geographical view of system congestion levels and available capacity



# We wanted more

## ...enter Transmission Automated Hosting Capacity Calculator (AutoHCC)

- **Reliability** evaluated based on TPL-001 definitions on N-1, N-1-1, and N-1-1 SCRD contingency analysis
- **Available line/bus capacity across entire Dominion Energy footprint** = amount of additional load that can be tapped on a line/bus, without causing reliability issues
- **County hosting capacity** = largest available capacity of any line or bus in a county
- Each line/bus and county are studied individually
- **Concurrent load addition** where multiple counties can safely add the load values simultaneously is under development

# Implementation Strategy

**Graduating away from AutoEDR framework**

**Engaged Right Analytics to support power systems development**

**Engaged Simple Thread to support tool user interface, distributed computation, and productionalization**

**Looked at current capabilities on the market**

- PowerGEM's HEAT MAP software not available when started
- Even still, wanted more comprehensive analysis that this offers alone

**Utilizes PSSE APIs and PowerGEM's Transfer Limit Analysis module**



---

simple  thread



# AutoHCC – Assumptions

## **Equipment ignored for load additions**

- Voltages below 100kV
- Radial lines
- Generator buses

## **Monitoring element**

- All equipment 69kV to 765kV in DVP area
- All tie lines with neighbors

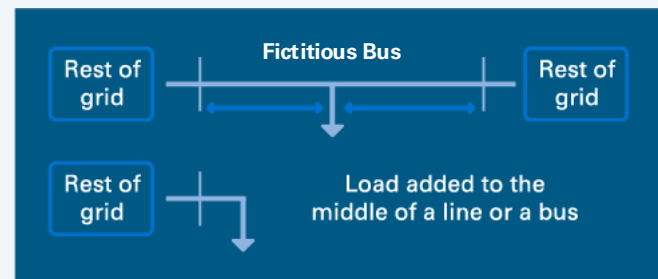
# AutoHCC Methodology

**AutoHCC calculates how much load could be added to the middle of a transmission line or a substation before reaching any thermal limits.**

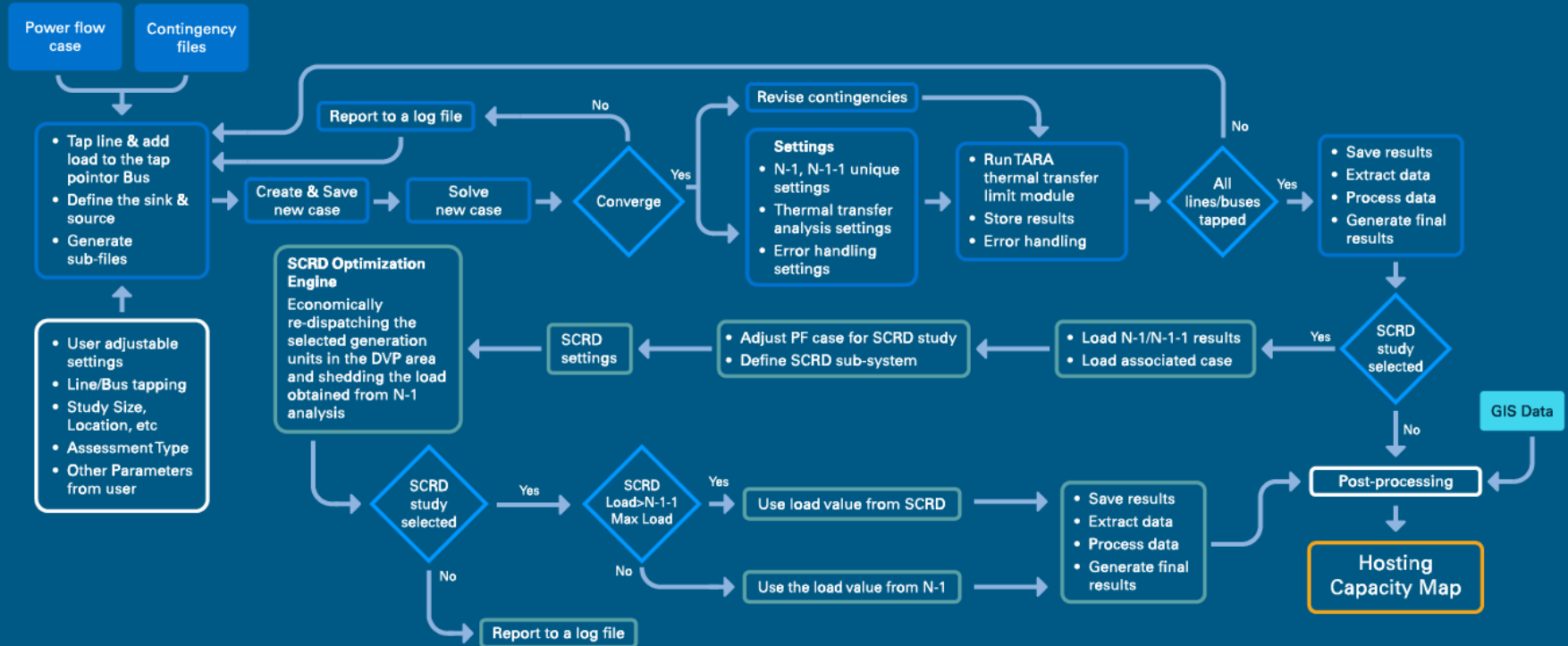
- It takes a power flow model and corresponding contingency files as input
- Automatically revises the contingencies
- Runs all the necessary calculations using predefined parameters
- Generates detailed results and a summary report

**Load addition locations could be as large as all the lines and/or substations in a zone or the entire DVP area.**

**TARA software is the main power flow and thermal transfer analysis engine of the AutoHCC while the power flow module of the PSSE and its API are used for some pre-power flow analysis.**

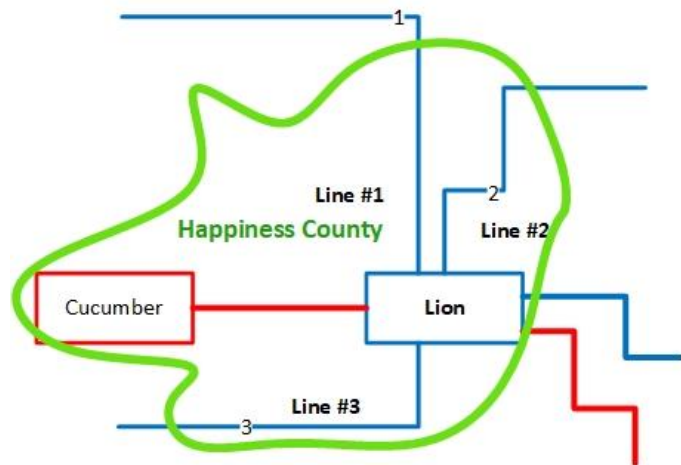


# AutoHCC Workflow



# AutoHCC – Example for Line Tapping - Happiness County

Line Number	Voltage (kV)	Mileage (in county)	County coefficient	N-1 (in county)	N-1-1 (in county)	N-1-1 SCRD (in county)	Minimum of (N-1)&(N-1-1) & (N-1-1 SCRD)	Total N-1	Total N-1-1	Total N-1-1 SCRD
1	230	5	0.1	65	21	20	20	650	210	200
2	230	10	0.5	250	100	95	95	500	200	190
3	230	25	0.3	120	54	45	45	400	180	150



95 MW is the available capacity assigned to Happiness county.



# AutoHCC – Example for Bus Tapping by Kindness County

Tapped Bus	Bus Name	Bus Base (kV)	MaxLoad	Ctg Scenario	Min of (N-1) & (N-1-1) & (N-1-1 SCRD) for each bus	Monitored Facility	AC %Loading (No Transfer)	AC %Loading at Tested Limit	Base Case Thermal Violation
1	3ALPHA	115	108.2	N-1-1 SCRD	108.2	2 6ALPHA 230 1 3ALPHA 115 2	68.74	100.06	No
1	3ALPHA	115	119.4	N-1-1		2 6ALPHA 230 1 3ALPHA 115 2	68.74	100.06	No
1	3ALPHA	115	165.6	N-1		2 6ALPHA 230 1 3ALPHA 115 1	62.87	100.01	No
2	6ALPHA	230	711	N-1-1 SCRD		5 8ALPHA 500 2 6ALPHA 230 2	75.37	100.01	No
2	6ALPHA	230	731.3	N-1-1		5 8ALPHA 500 2 6ALPHA 230 2	75.37	100.01	No
2	6ALPHA	230	1142.5	N-1		5 8ALPHA 500 2 6ALPHA 230 2	53.33	100.05	No
3	3BETA	115	125.9	N-1-1 SCRD		1 3ALPHA 115 8 3KAPPA 115 1	45.78	100.01	No
3	3BETA	115	135.7	N-1-1		1 3ALPHA 115 8 3KAPPA 115 1	45.78	100.01	No
3	3BETA	115	157.8	N-1		1 3ALPHA 115 8 3KAPPA 115 1	34.12	99.98	No
4	3GAMMA	115	50.7	N-1-1 SCRD	50.7	6 8DELTA 500 7 6DELTAGT2 230 1	93.04	99.86	No
4	3GAMMA	115	62.9	N-1-1		6 8DELTA 500 7 6DELTAGT2 230 1	93.04	99.86	No
4	3GAMMA	115	85	N-1		9 3ZETA 115 1 3GAMMA 115 1	7.89	99.82	No

## County capacity:

Max of [Min (N-1)&(N-1-1)&(N-1-1SCRD)] of each bus in county= **700 MW**

# Examples and use cases

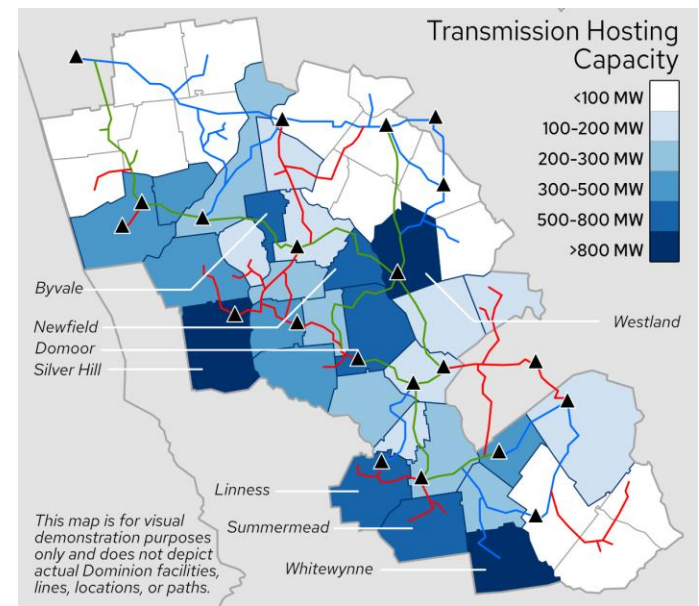
Over 6600 miles of transmission lines

1,014 substations

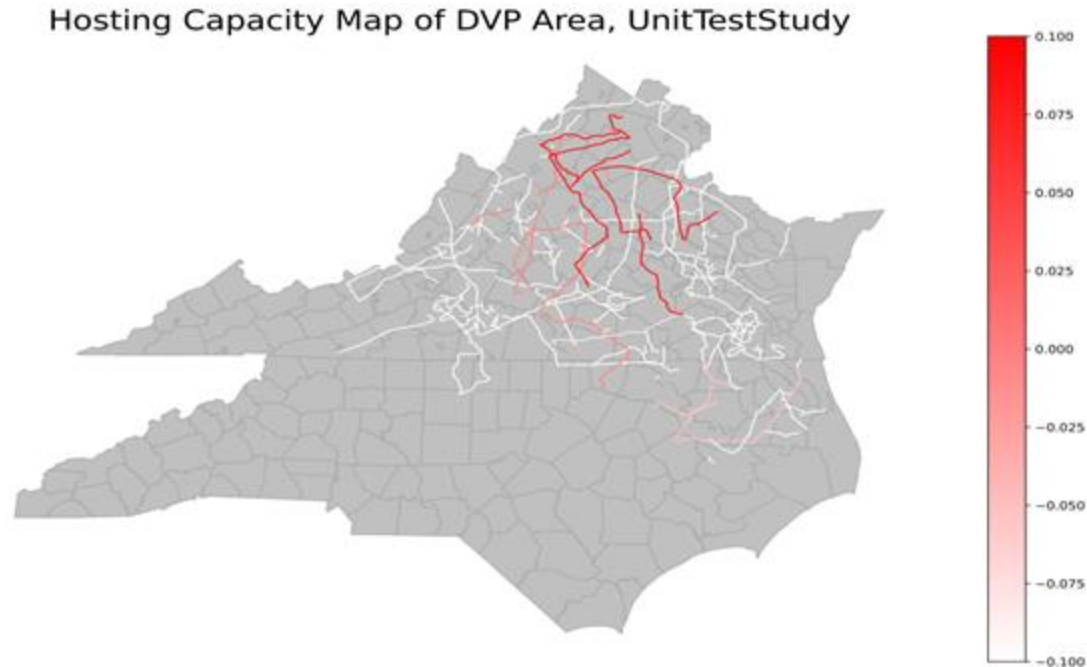
- ≈ 1,100 branches to study

Detailed results of contingency analysis available to gain further insight

County	Tapped line	Line capacity	Limiting contingency		
			Outage	Monitored element	Case
Silver Hill	200	456 MW	TX 31	Line 200D	N-1-1
Silver Hill	201	812 MW	Line 500A	Line 200A	N-1-1
Silver Hill	165	120 MW	Line 200C	Line 100A	N-1-1
Virlands	284	32 MW	Line 200B	TX 84	N-1-1
Virlands	116	4 MW	Line 100A	TX 84	N-1



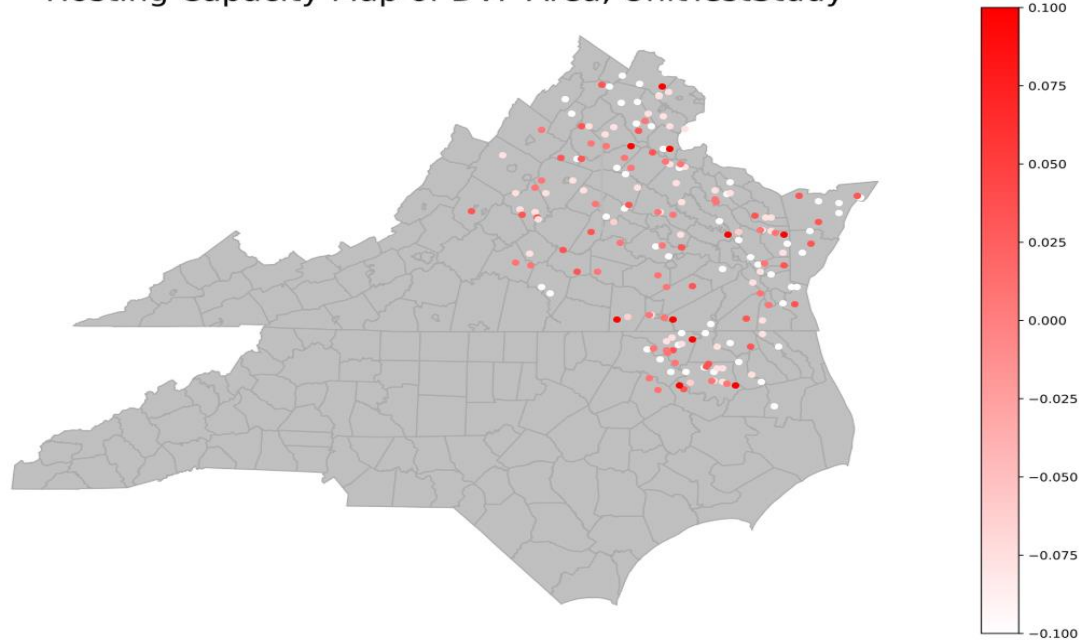
# Example Map – Line tapping capacity map



**For demonstration purposes only. Not actual data.**

# Example Map – Bus tapping capacity map

Hosting Capacity Map of DVP Area, UnitTestStudy



**For demonstration purposes only. Not actual data.**

# AutoHCC Modules

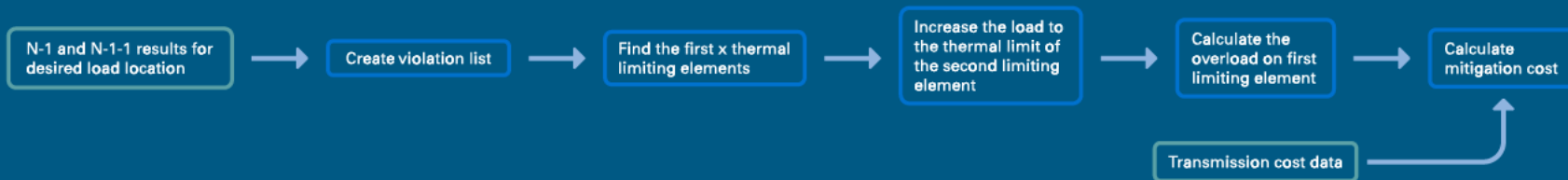
**AutoHCC goes above and beyond in calculating load hosting capacity, with distinct modules that each add unique and insightful features to the results**

- Thermal Mitigation Cost Calculation Module
- Concurrent Load Hosting Capacity Calculation Module

# Thermal Mitigation Cost Calculation Application

The results of this module indicate the load that can be added to a location by upgrading the main thermal limiting element.

The results offer valuable insights into areas of the system where load hosting capacity could be expanded with minimal investment in upgrades.





# Thermal Mitigation Cost Calculation Methodology

First/main thermal limiting element

Maximum load that could be added to the study location before reaching any thermal limit

Monitored Facility					DC TrLim	AC TrLim	Status Message AC TrLim	Dfax DC
999001 Apple	230	999002 Orange	115	1	260	260	Limit Found OK	1
999003 Banana	230	999004 Kiwi	230	1	360	370	Limit Found OK	0.99733
999005 Domingo	230	999006 Lunes	230	1	420	424	Limit Found OK	0.99658
999007 Day	230	999008 Night	230	1	430	435	Limit Found OK	0.51244
999009 North	230	999010 Pole	230	2	750	NA	No Tested AC	0.62371
999001 South	230	999010 Pole	230	1	810	NA	No Tested AC	0.99186
999013 Sugar	500	999012 Salt	230	1	850	NA	No Tested AC	0.62562
999015 Bitter	230	999014 Moon	115	2	890	NA	No Tested AC	0.61238

Second thermal limiting element

Potentially maximum load value at the study location could be increased from **260 MW** to **370 MW** at the cost of mitigating first thermal limiting element

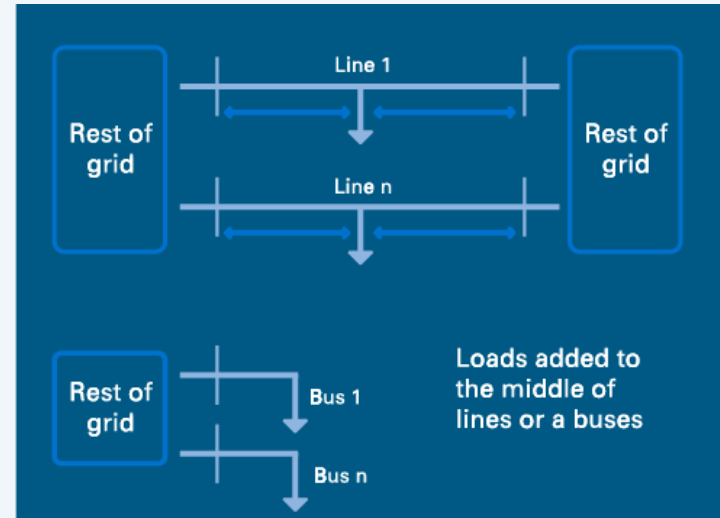
# Concurrent Load Hosting Capacity Calculation Goal

**What if multiple loads connect simultaneously? How will the maximum load calculated for each individual location be affected when multiple projects are implemented at the same time?**

- What is the maximum thermal transfer test level when tapping load at multiple locations?
- How should loads be scaled up when multiple projects are involved?

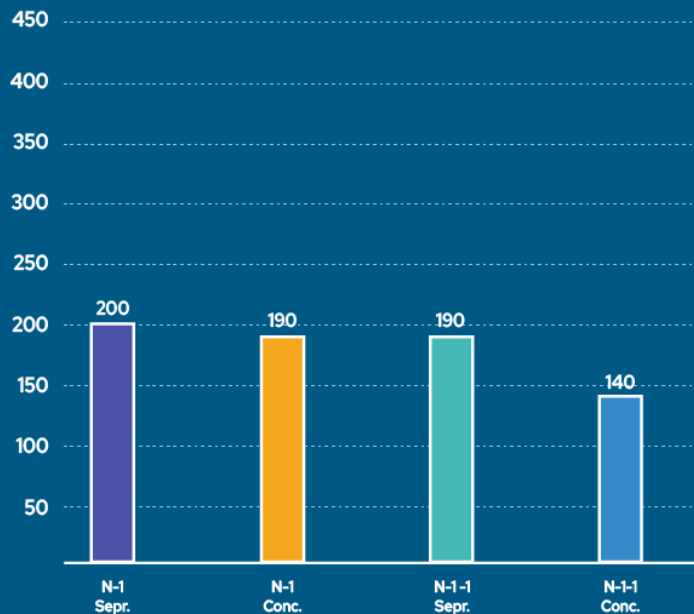
**Calculates N-1 and N-1-1 to determine load**

**No N-1-1-SCRD-based analysis or thermal mitigation cost calculation for concurrent load hosting capacity calculation, at this stage.**

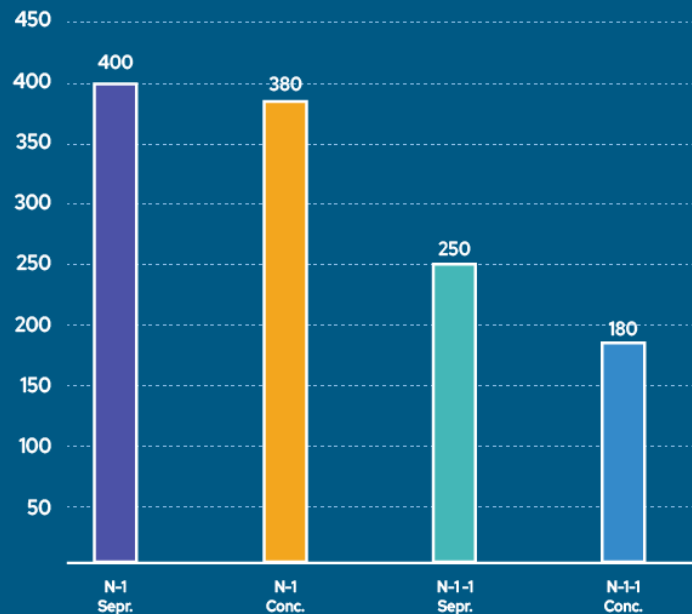


## Example of Concurrent Results — Bus Tapping

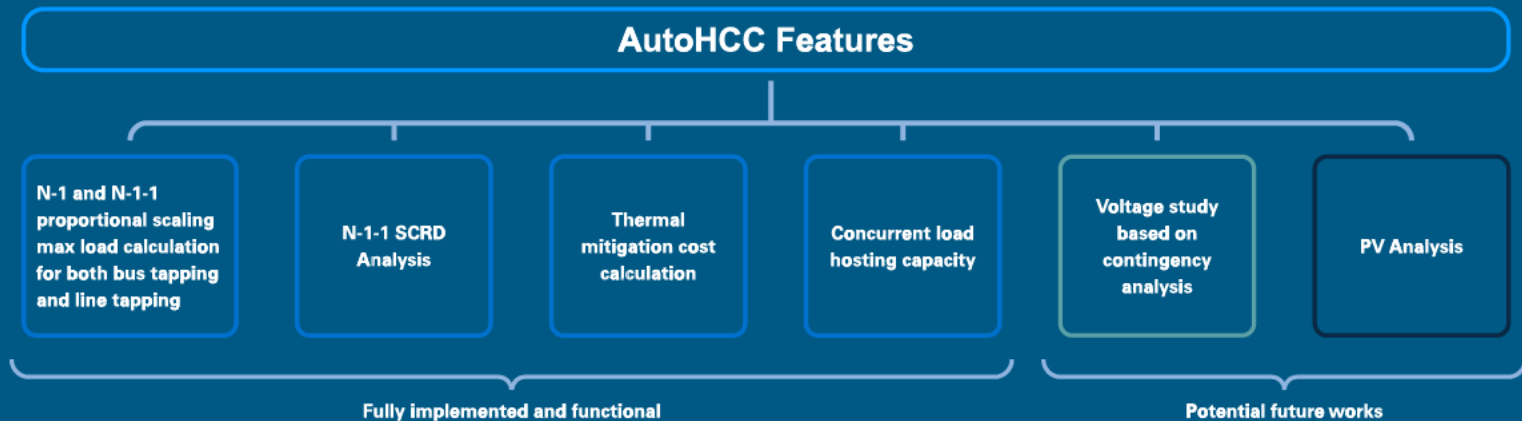
Bus 999111



Bus 999222



# AutoHCC Modules



# AutoHCC and Hosting Capacity Map Benefits

**Provide insights on the locationally-based transmission network insights to be utilized by leadership, business development, and engineers alike.**

- Understanding the available infrastructure in each county will assist the state leaders and policymakers in better planning financial incentives.

**Reveal the gaps between system capacity and predicted load growth to meet customer needs.**

**Defining an index of incremental capacity to cost helps ensure that decisions are made transparently and in the best interest of Dominion Energy, ratepayers, and key accounts.**

**A modified version of AutoHCC can be used to study the entire USA grid, aiding in NIETC studies.**

**Integration of data sources for spatial post processing utilized in other projects.**

**Fast critical contingencies screening for N-1, N-1-1 network constraints and outage assessments that may impose limits for operation.**

# Introduction to AutoHCC, Tech Stack, System Design

**Main task: Turn the existing tool into a modern web application, which runs in a reasonable amount of time.**



- Simple Thread was a familiar, trusted partner
- Leverage existing architecture as much as possible





## HOSTING CAPACITY



# AutoHCC – User Interface

 HOSTING CAPACITY 

OVERVIEWARCHIVENEW STUDY AMIRREI 

## New Study Request

⚙️ ADVANCED SETTINGS

**Study Name** 

Add a study name

**Study Type** 

Add a study type 

**Tags**

Add optional tags to sort or search against

**Description**

Add an optional description to detail or clarify request

**FILE UPLOAD**

**Study File** 

Choose the study file here 

**RAW File** 

Choose the raw file here 

**Line File** 

Choose the line contingency file here 

**Single File** 

Choose the single contingency file here 

**Bus File** 

Choose the bus contingency file here 

**Tower File** 

Choose the tower contingency file here 

RESET FIELDSRUN STUDY



33

# AutoHCC – User Interface – Advanced Setting

**Advanced Settings**

**Study Details**

**Contingency Info**

**Study Size**

Area

**Area Number**

345

**Study Violations**

Thermal Only

☐ Add Single Branch Contingency (target zone)

**Define Lines By County**

**SET TO DEFAULT** **CONFIRM**

**Study Size**

Area

Single

Single Zone

Region

Area

**Define Lines By County**

**ET Lines By County File**

DEFAULT

**Study Engine**

PSS/E 35 & PowerGEM TARA

**Bus Location**

0% 100%

%

# AutoHCC – User Interface – Contingency Info

**Advanced Settings** ✕

**Study Details**

**Contingency Info**

## Contingency Information

**Contingency Scenario**

N-1 and N-1-1 with SCRD

**Base Case Rating**

Rating A

**Contingency Case Rating**

Rating B

**Lines Thermal Limit Mode**

MVA Rating

**SET TO DEFAULT** **CONFIRM**

**Contingency Scenario**

N-1 and N-1-1 with SCRD

N-1 and N-1-1 with SCRD

N-1 and N-1-1

N-1

Single

**Lines Thermal Limit Mode**

MVA Rating

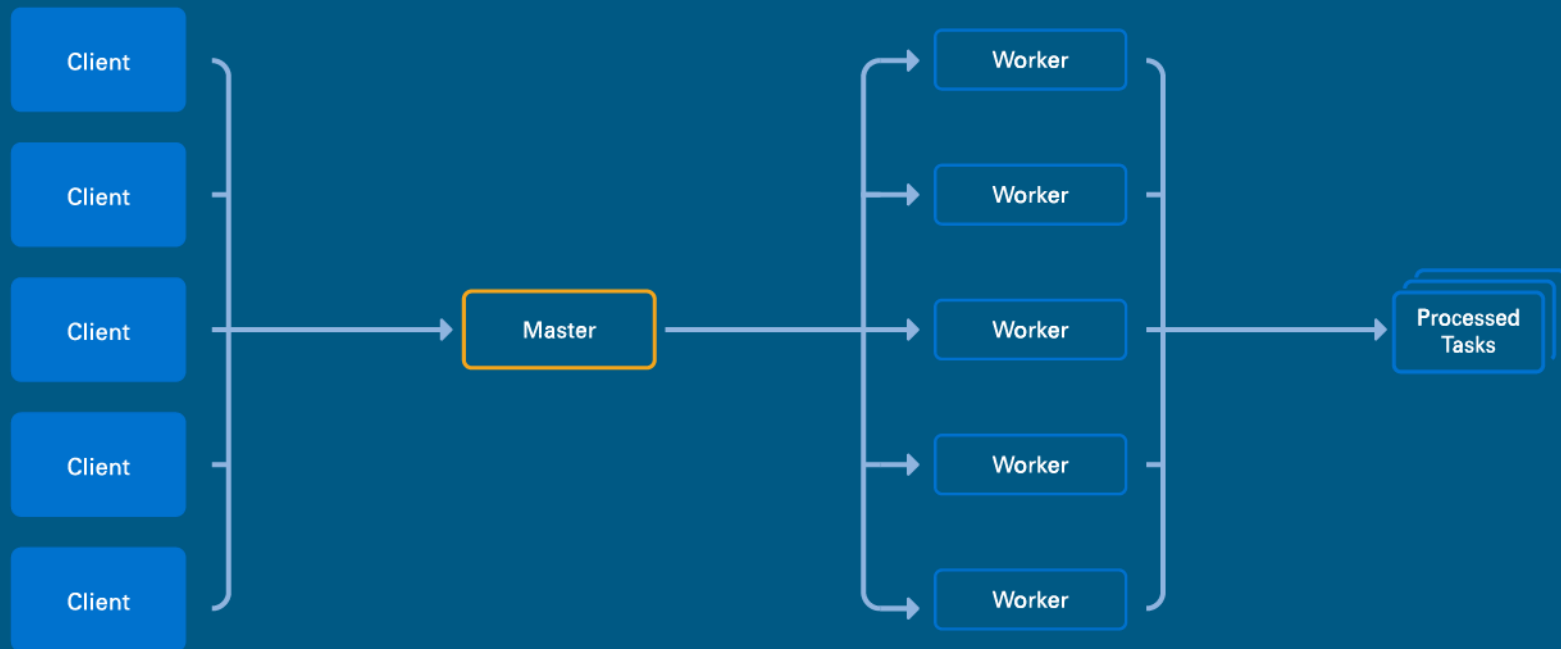
**Transformers Thermal Limit Mode**

MVA Rating

**Starting Load** **% Initial Remaining Capacity**

Percent (Base Case)

# Introduction to AutoHCC, Tech Stack, System Design



# Future Directions & Industry Collaboration

**Discussions with legal on how to frame disclaimers**

**Working with business development teams, state and local governments**

**Actual data center customers do not get a copy of this!**

**Socialization within the organization (leadership, engineers, etc.)**

**NERC Large Load Task Force**

**IEEE Industry Technical Support Leadership Committee (ITS LC) on large loads**

# Industry & Regulatory Landscape

**Growth spurts come with growing pains but have tools to help**

**Data centers are likely coming to a substation near you**

## **FERC Order 2023**

- All of this load needs generation
- Can use AutoHCC for generation interconnection even as a member of an RTO
- This includes more options than what FERC Order 2023 requires to extend beyond the letter of the law
- Includes more geographic information which may be difficult for RTOs/ISOs to gather

# Thank you