Transmission Hosting Capacity Analysis & Beyond

Dominion Energy
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Simple Thread
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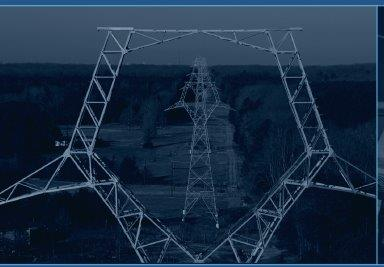


Richmond, VA USA

3/25/2025

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

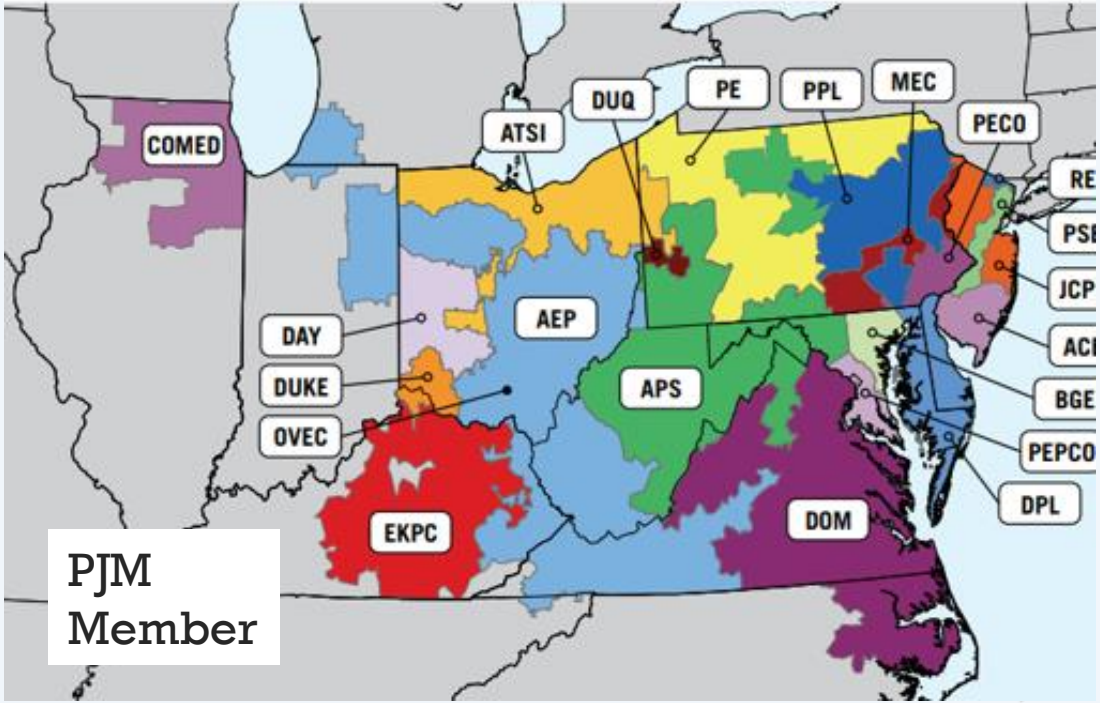
$7.8 billion assets in service

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

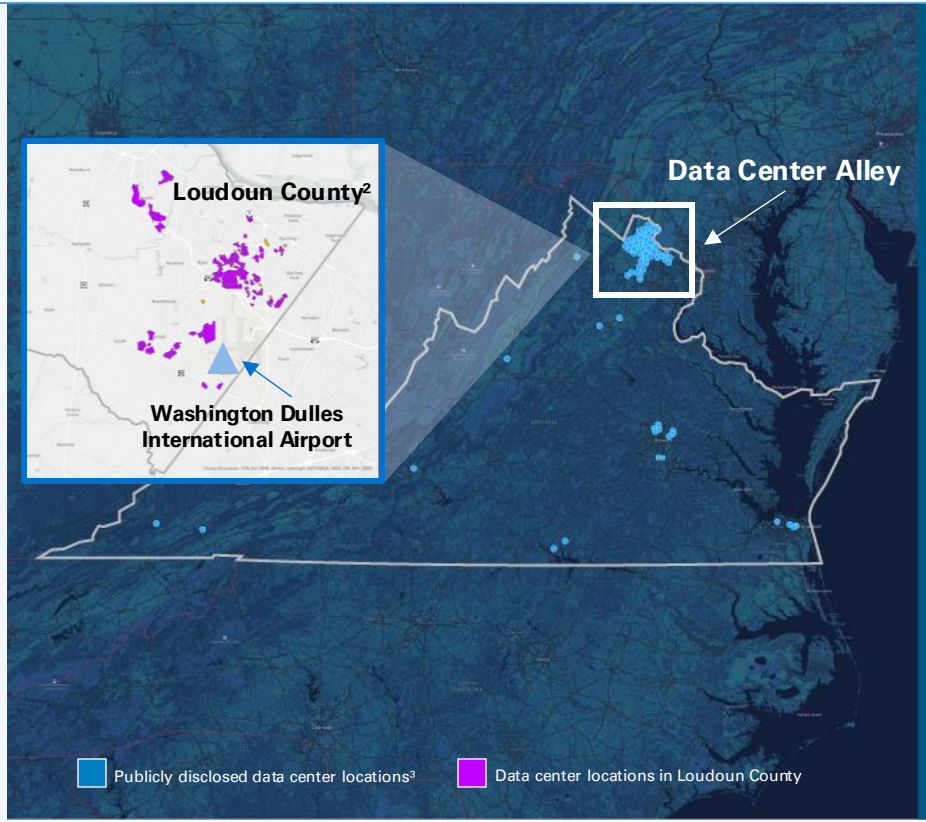
More than 900 substations

~50,000 transmission structures



Data Centers in Dominion Energy VA

Northern Virginia boasts the largest data center market in the world[1]



Northern Virginia

2020 **2,518MW***

2028 **8,346MW***

a 231% increase

Delivery Point Requests **63**

Total Projects **107****

Doubling of area subsations

Central/Southside

2020 **402MW***

2028 **2,953MW***

a 634% increase

Delivery Point Requests **24**

Total Projects **24****

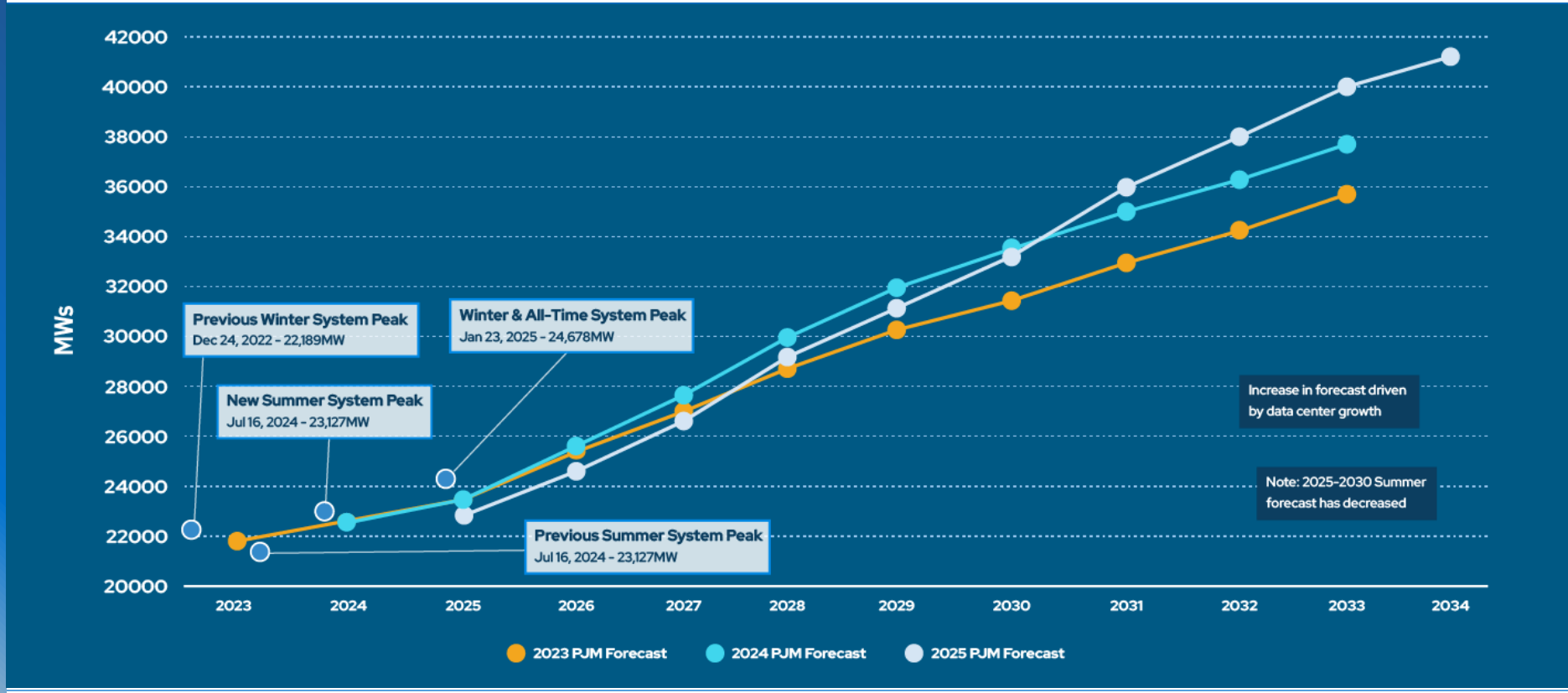
Quadrupleing of area subsations

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

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

[3] Data Center locations provided by Data Center Hawk

Yearly PJM Summer DOM Zone Load Forecast

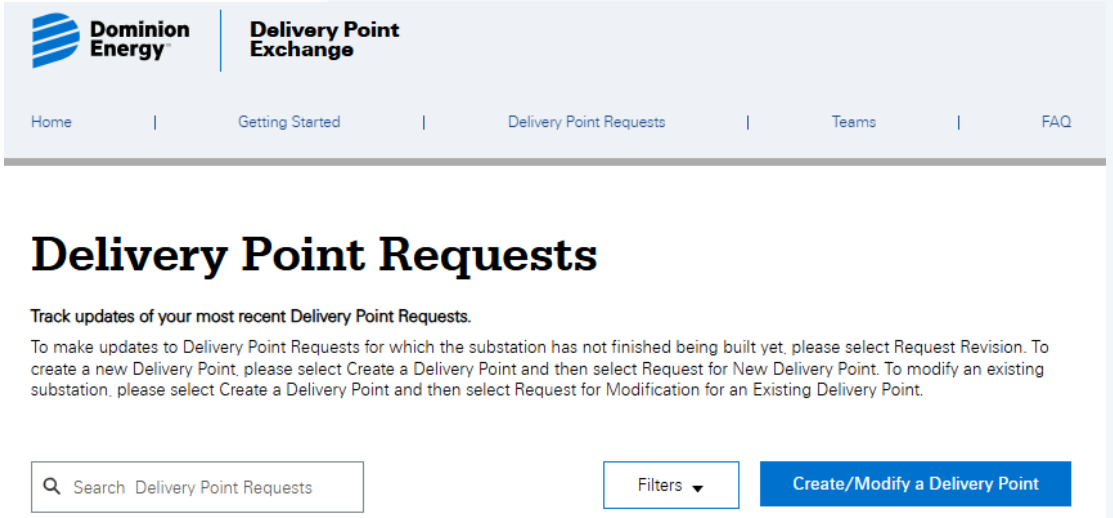


Delivery Point (DP) Exchange

Platform to track load interconnection requests

Live 10/22/24

Helps prepare for if NERC regulates large loads



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

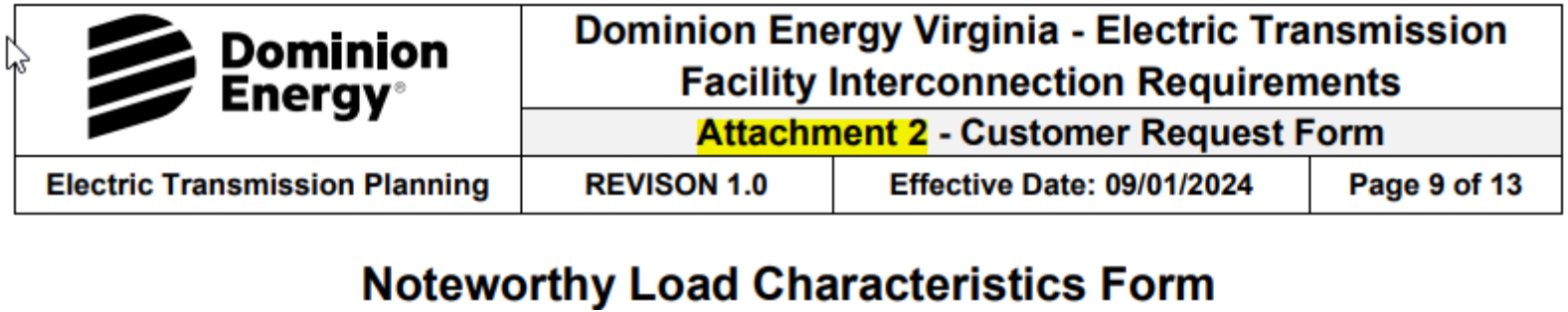
Anticipated Customer Experience:

- 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



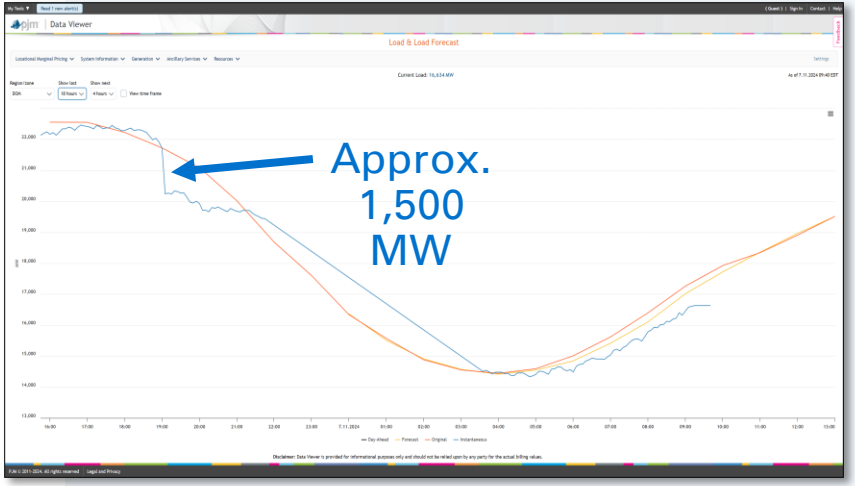
Dominion Energy	Dominion Energy Virginia - Electric Transmission Facility Interconnection Requirements		
	Attachment 2 - Customer Request Form		
Electric Transmission Planning	REVISON 1.0	Effective Date: 09/01/2024	Page 9 of 13

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

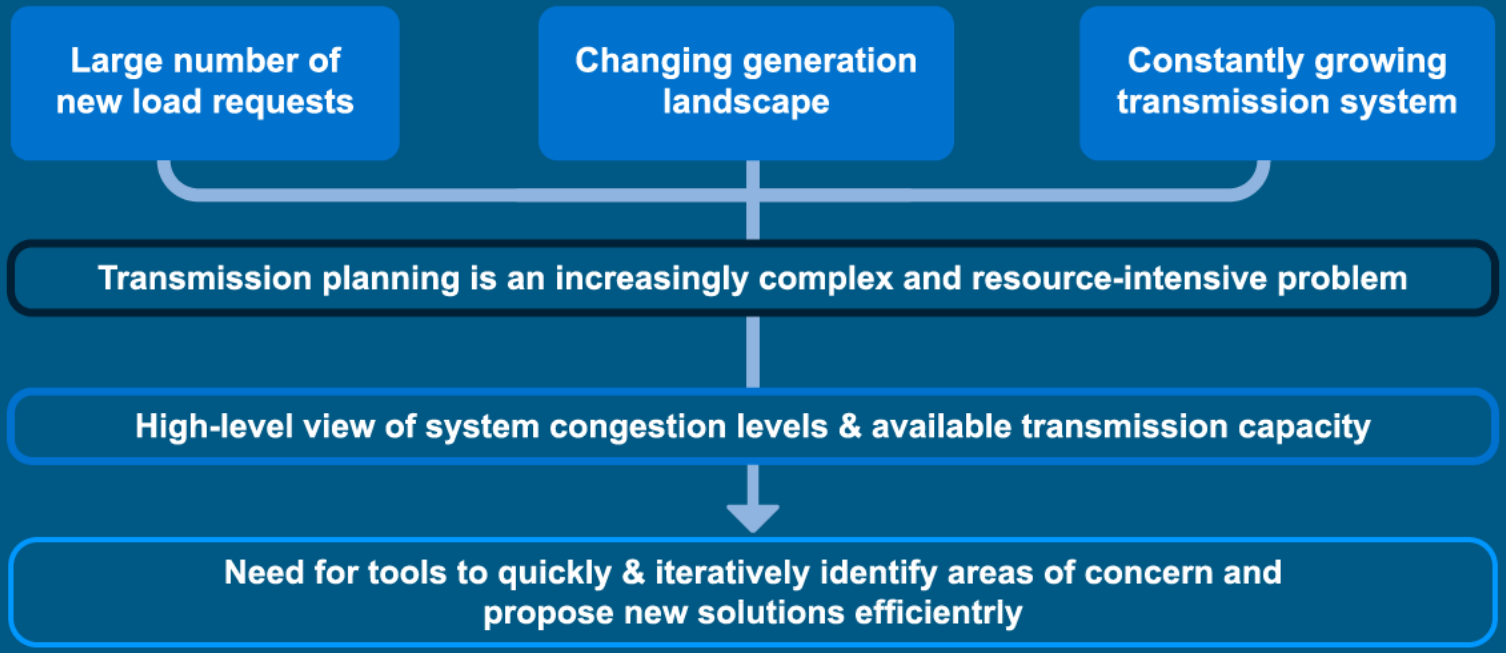
Asking for dynamic load models in 2025 revision

- 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

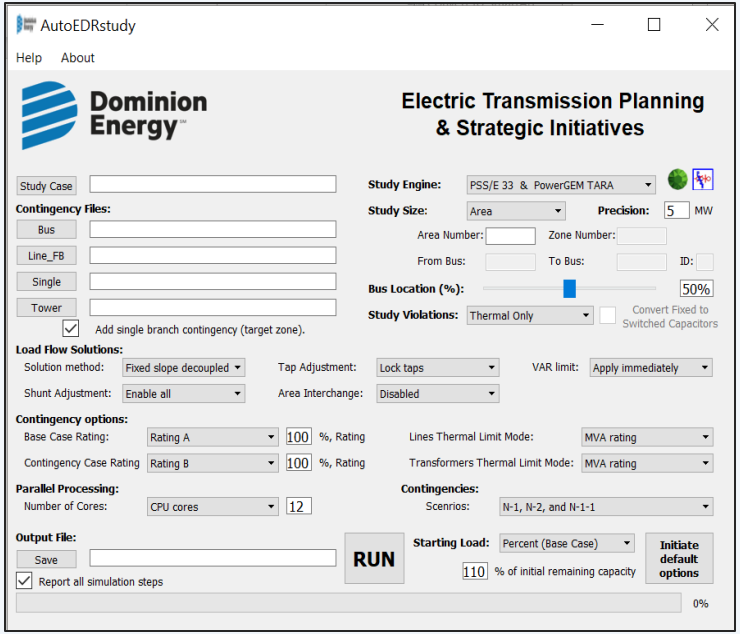
First Iteration - AutoEDR

Automated Economic Development Request Study (AutoEDR)

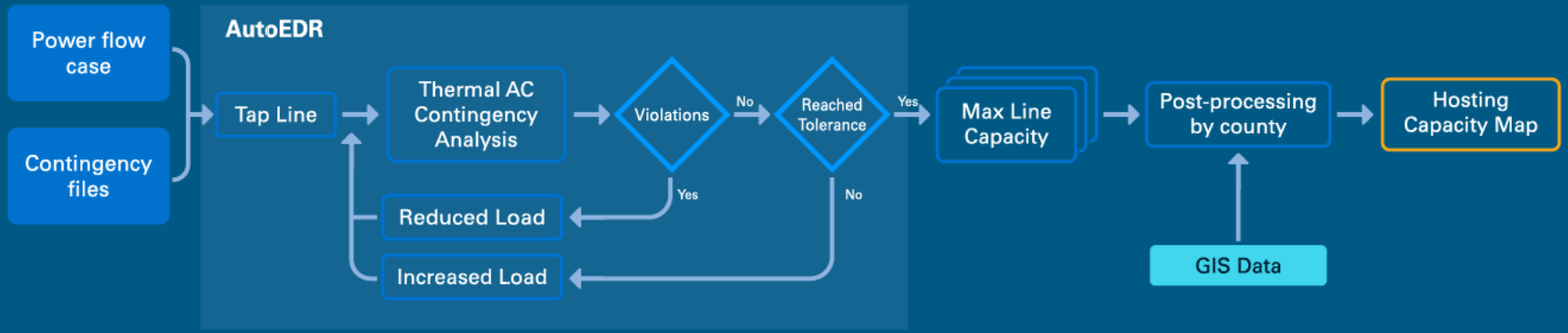
- Determines transmission line available capacity
- In-house developed, non-graphical automated screening tool
- Iteratively examines different loading levels only with N-1 and N-1-1 analysis working for larger areas
- Applied reduced contingency set to reduce computation

Very slow – no distributed computing

Acceptable for zonal analysis



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

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

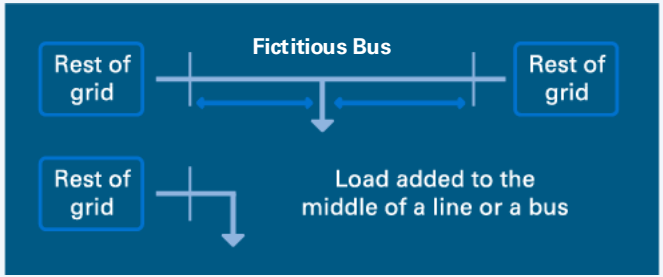
AutoHCC Methodology

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

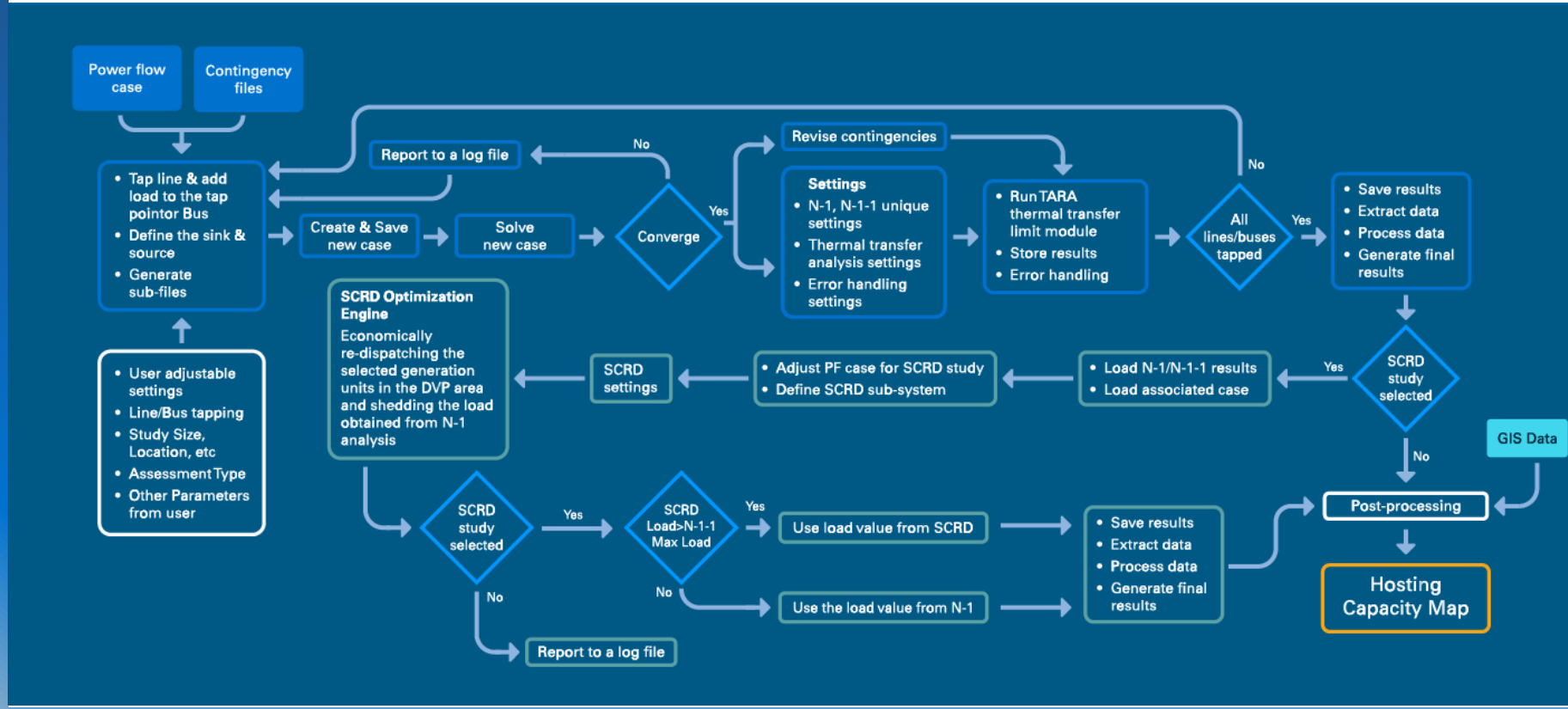
- It takes a power flow model and corresponding contingency files as input
- Automatically revises the contingencies
- Runs all the necessary calculations using predefined parameters
- Generates detailed results and a summary report

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.

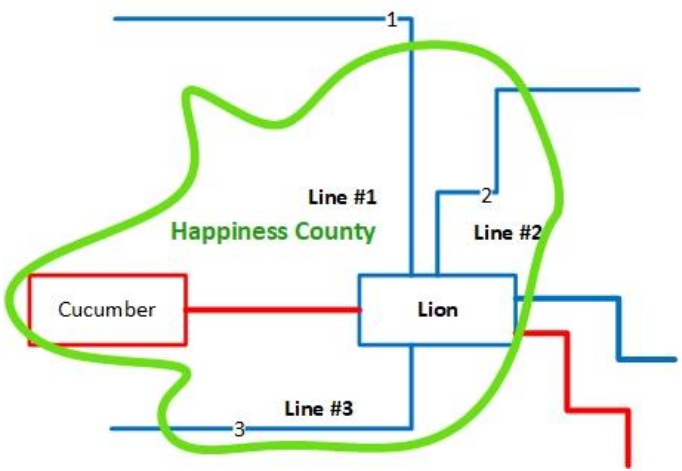


AutoHCC Workflow



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



<u>95 MW</u> 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	**700**	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	125.9	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

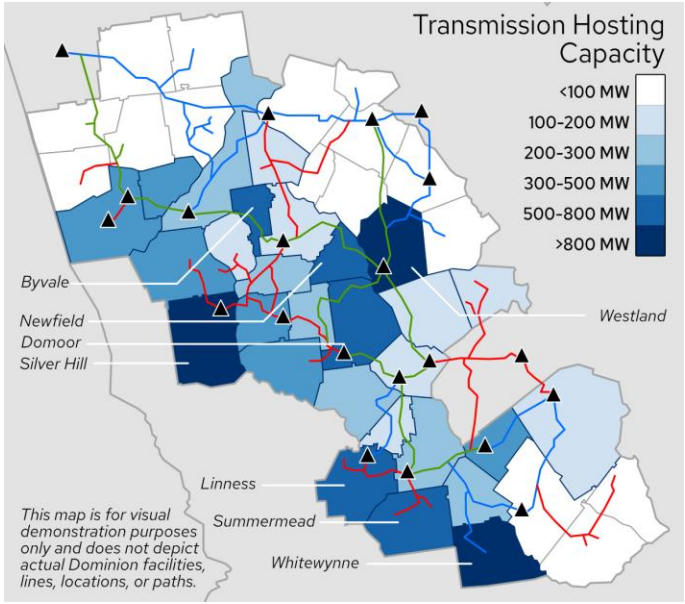
Over 6600 miles of transmission lines

1,014 substations

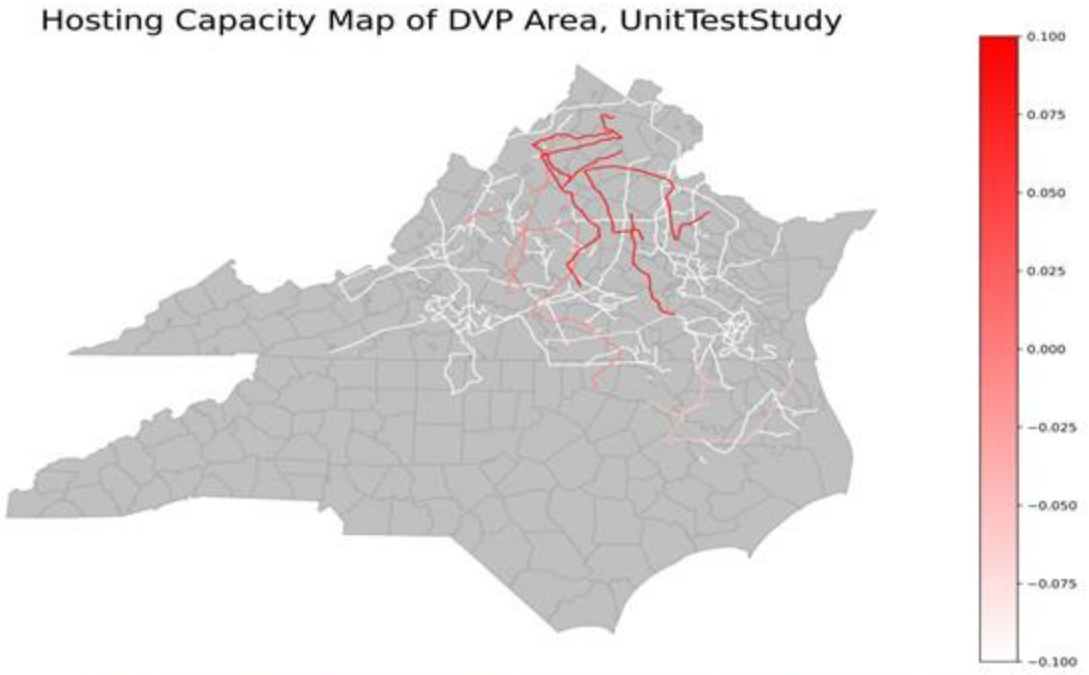
- ≈ 1,100 branches to study

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

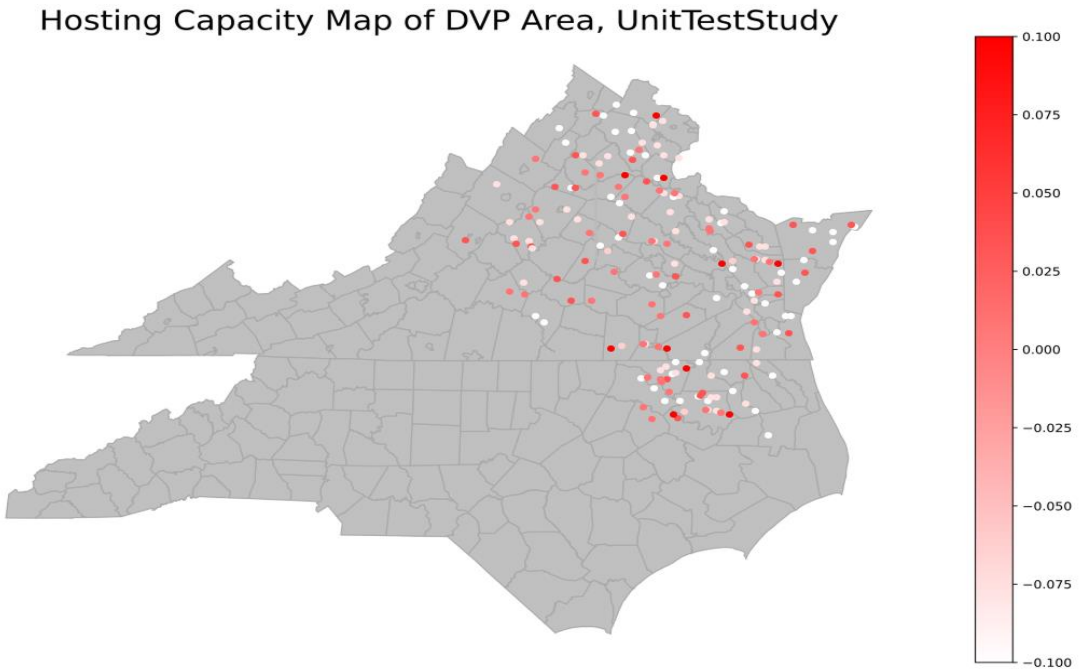


Example Map – Line tapping capacity map



For demonstration purposes only. Not actual data.

Example Map – Bus tapping capacity map



For demonstration purposes only. Not actual data.

AutoHCC Modules

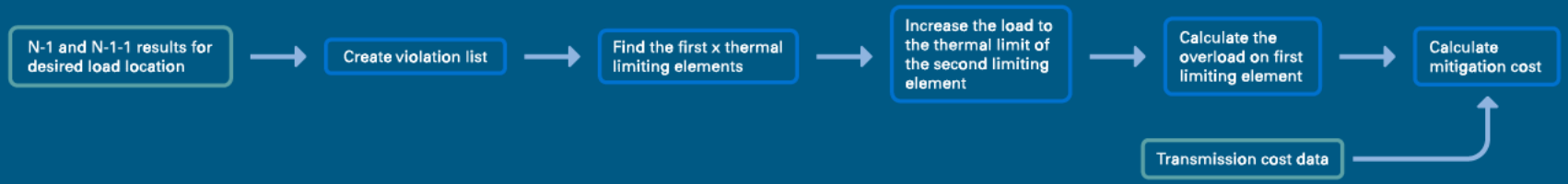
AutoHCC goes above and beyond in calculating load hosting capacity, with distinct modules that each add unique and insightful features to the results

- 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

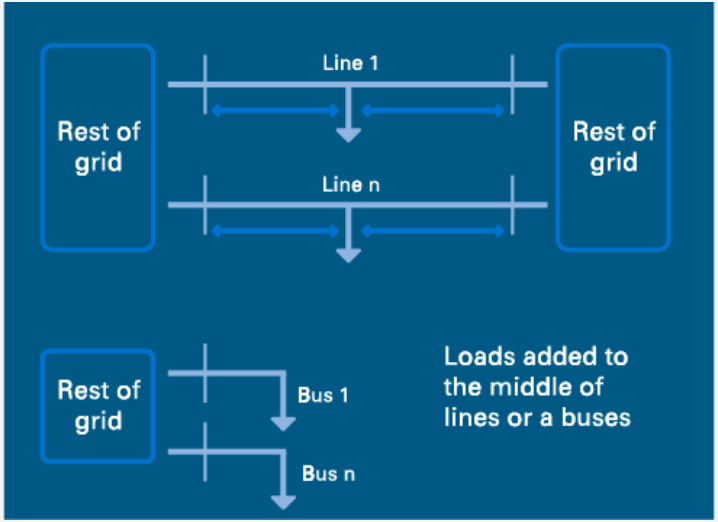
Concurrent Load Hosting Capacity Calculation Goal

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?

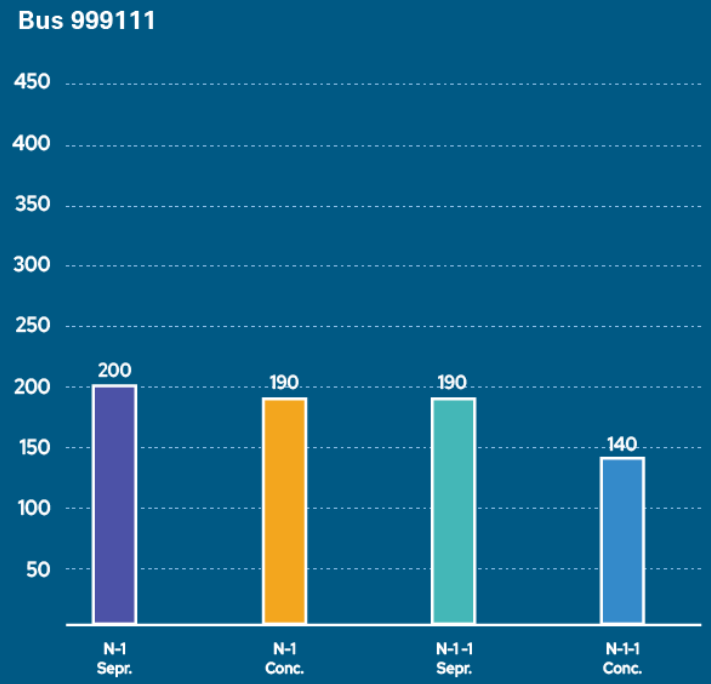
- What is the maximum thermal transfer test level when tapping load at multiple locations?
- How should loads be scaled up when multiple projects are involved?

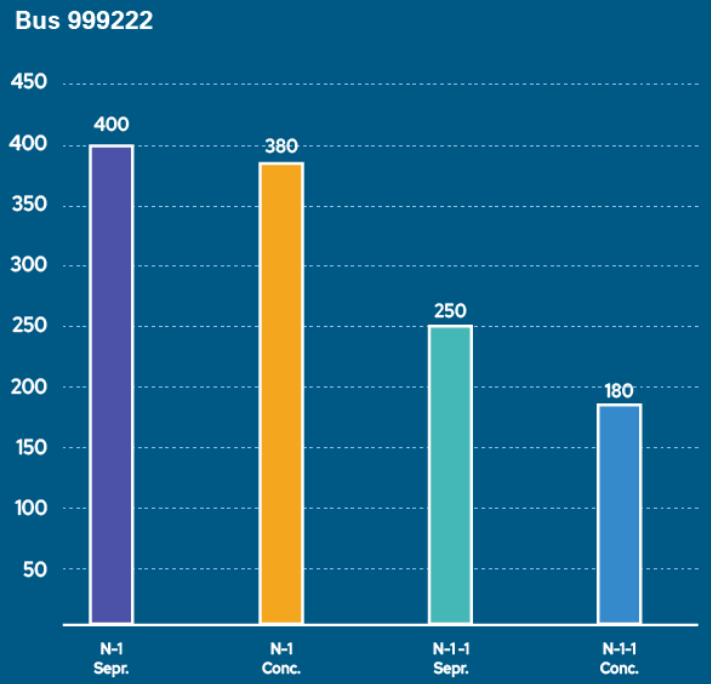
Calculates N-1 and N-1-1 to determine load

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

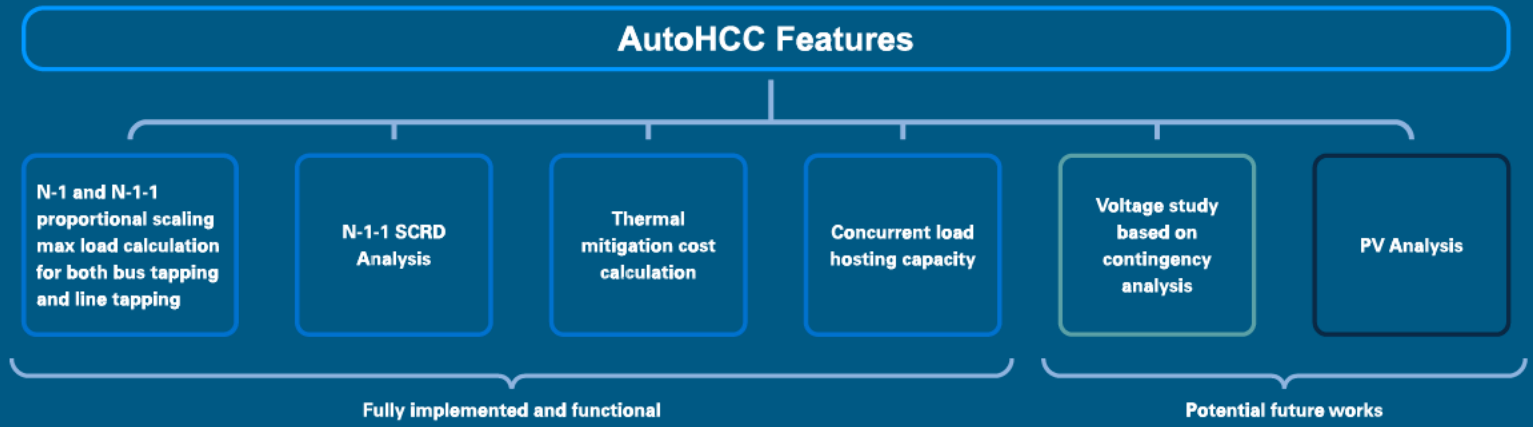


Example of Concurrent Results — Bus Tapping





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.

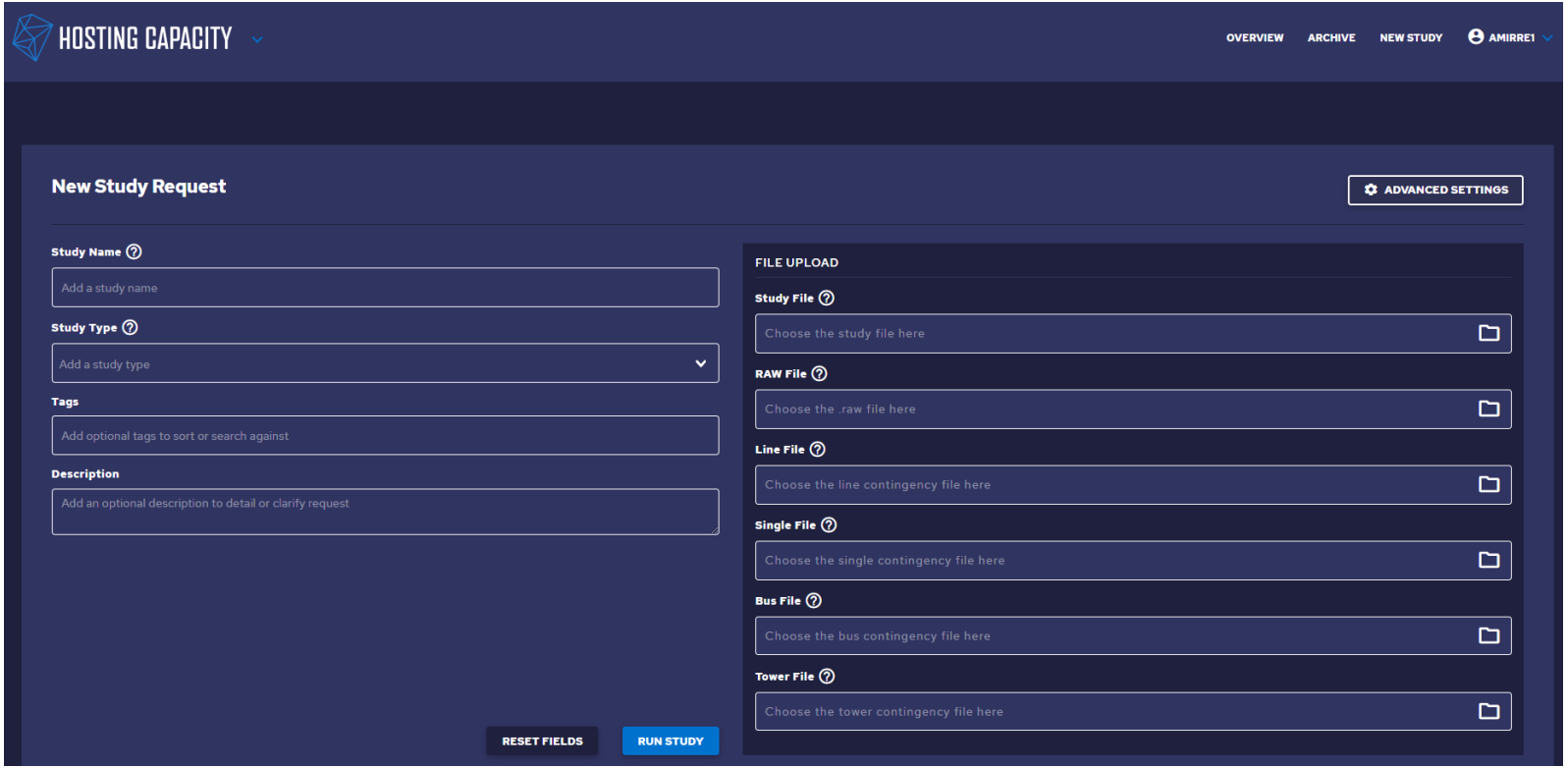
Fast critical contingencies screening for N-1, N-1-1 network constraints and outage assessments that may impose limits for operation.

Introduction to AutoHCC, Tech Stack, System Design

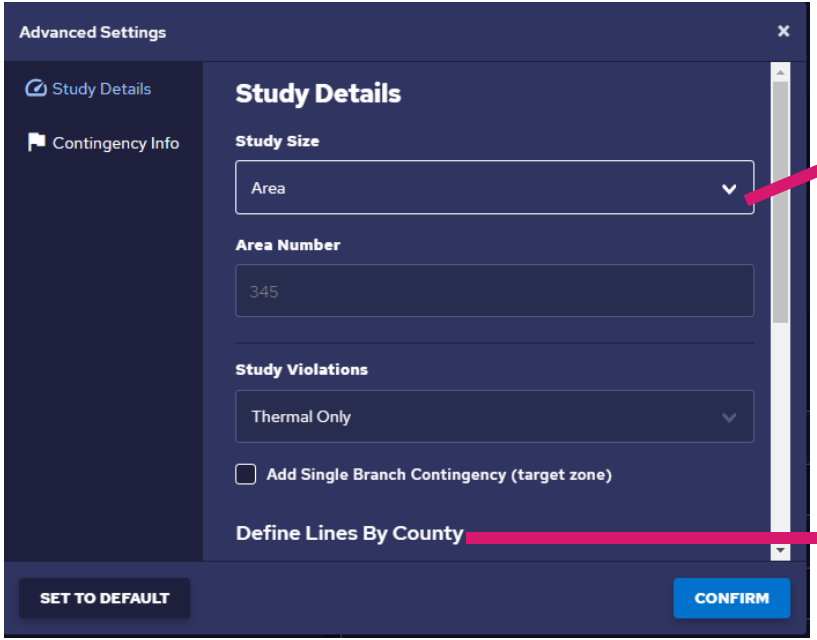
Main task: Turn the existing tool into a modern web application, which runs in a reasonable amount of time.

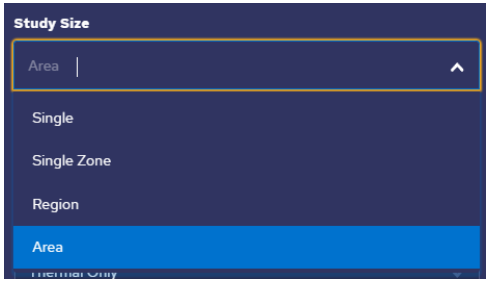
- Simple Thread was a familiar, trusted partner
- Leverage existing architecture as much as possible

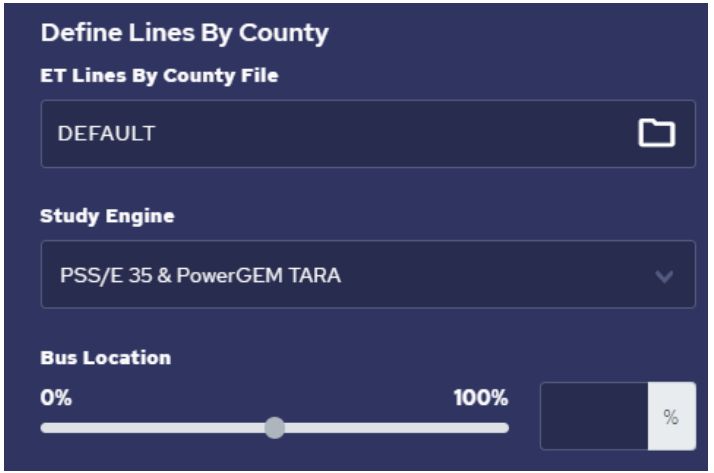
AutoHCC – User Interface



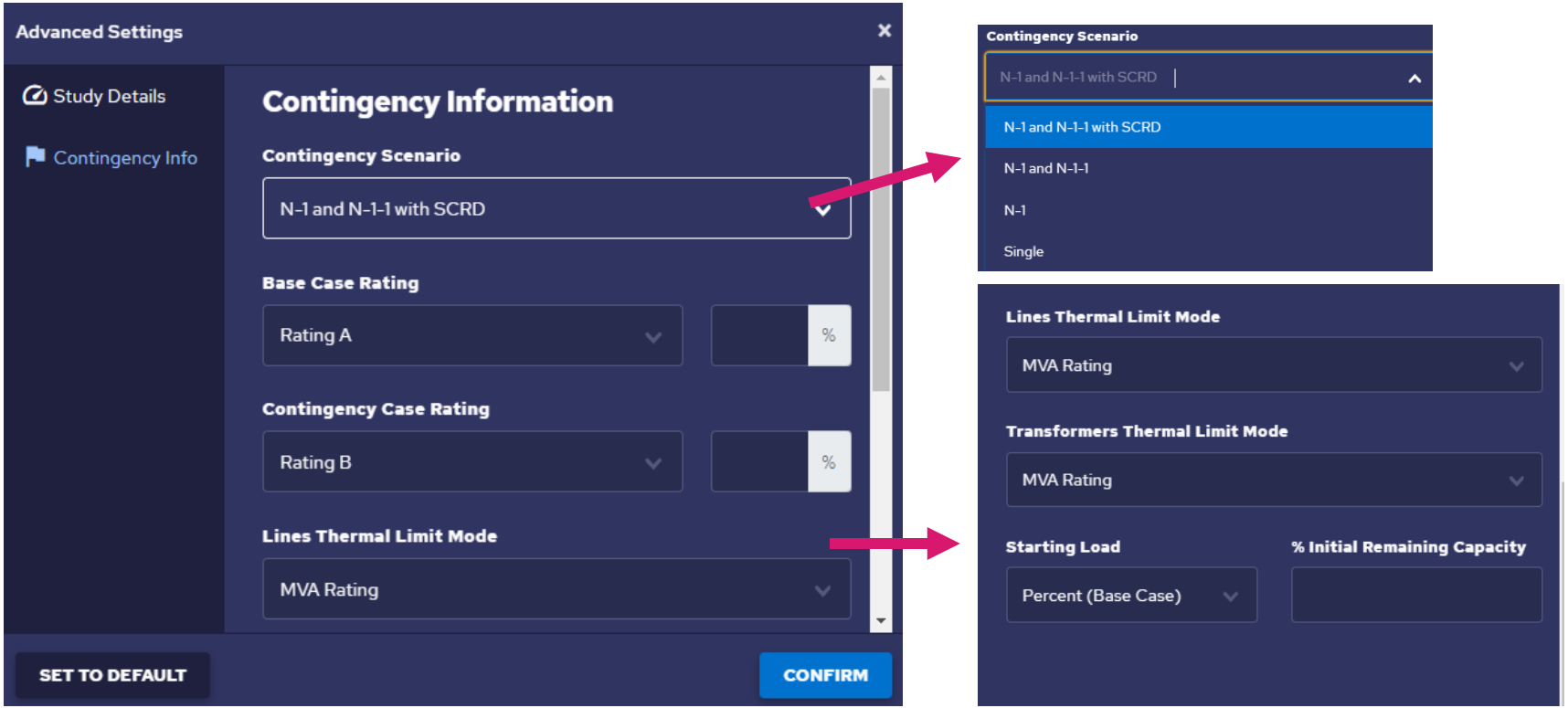
AutoHCC – User Interface – Advanced Setting



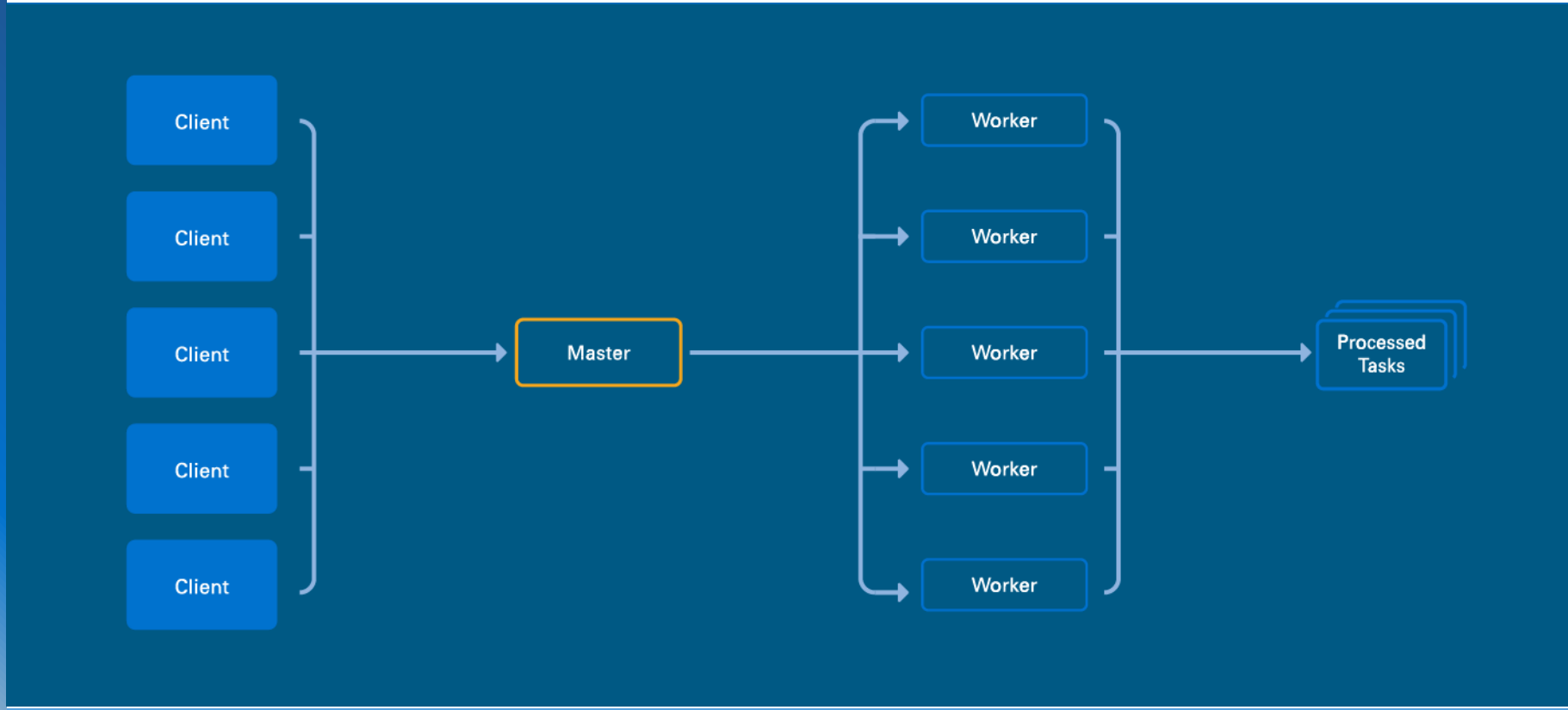




AutoHCC – User Interface – Contingency Info



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 (ITSLC) 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