SCEP

STATE & COMMUNITY ENERGY PROGRAMS

Options for meeting data center demand in Virginia

Focus on GETs and reconductoring

Quick turnaround technical support to the Virginia Department of Energy

U.S. Department of Energy State Energy Office Direct Technical Assistance (TA) Program

July 2024

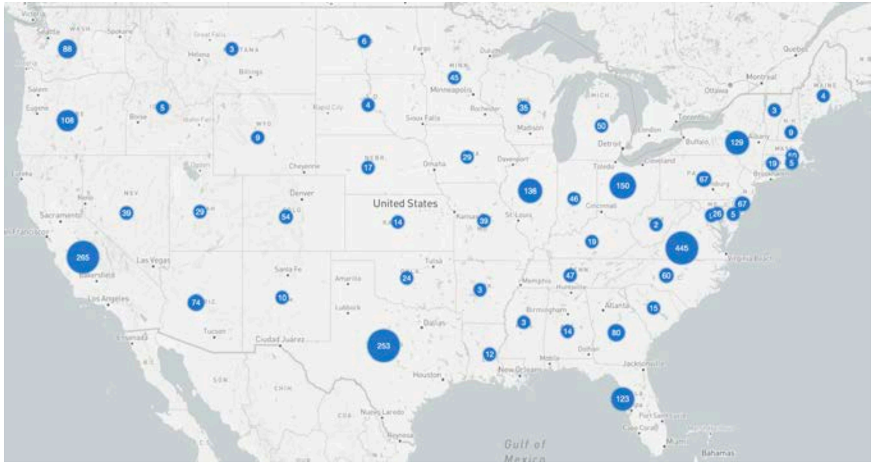
Jarrad **Wright** jarrad.wright@nrel.gov

Ram **Pandian** RamMohan.Pandian@nrel.gov

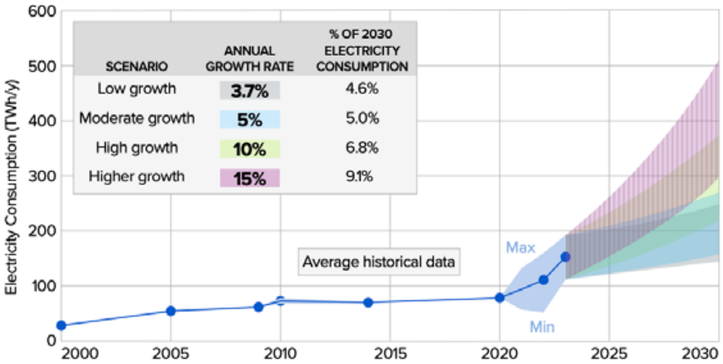
Background

Growth in data centers in the US

- **Past**
  - Demand: 90 TWh (2020)
- **Present** (2023)
  - Number: ≈5381 data centers (~50% of world)
  - Demand: 160 TWh (~4% total U.S. demand)
  - Growth: ≈78% growth (2020-2023)
  - CAGR: ≈15.5% (2020-2023)
- **Future** (2024-2030)
  - Demand: 196 - 404 TWh
  - Growth: 22.5-152%
  - CAGR 3.7-15%
  - % of U.S. demand: 4.6-9.1%



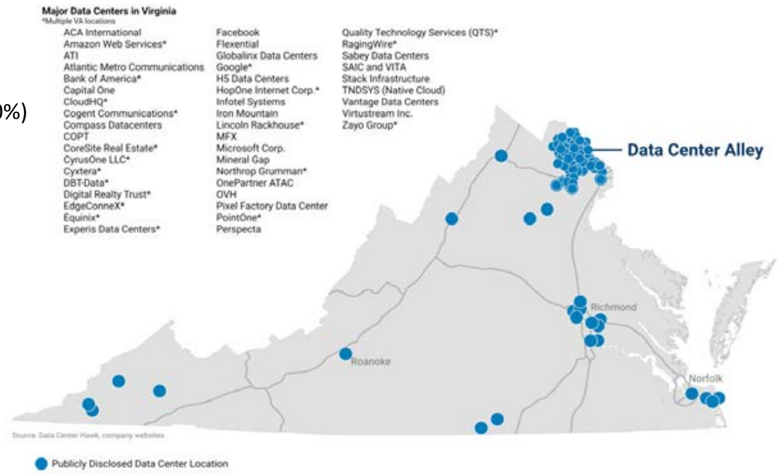
Number of data centers (by state); Source: Data Center Map



NOTES: CAGR – Compound Annual Growth Rate
Sources: VEDP; EPRI; Data Center Map

Growth in data centers in Virginia

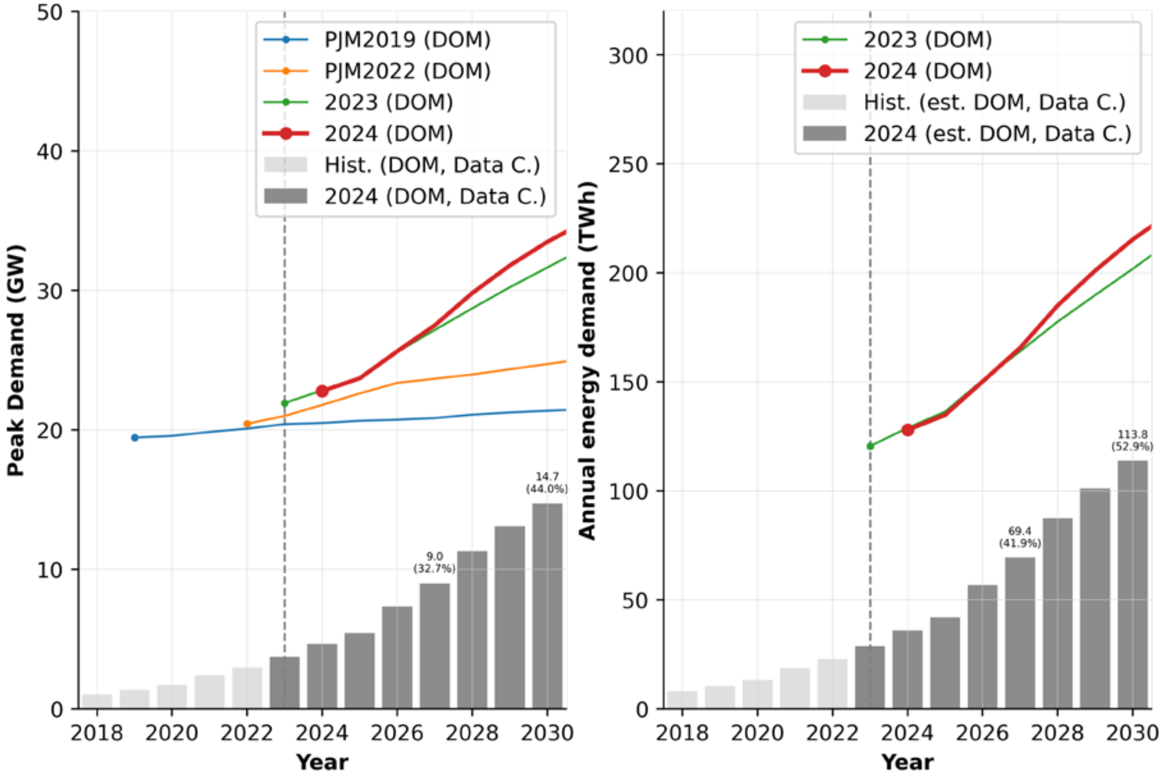
- **Past**
  - Demand: ≈13 TWh (~1.7 GW)
- **Present** (2023)
  - Number: ≈17% of U.S. data centers (Loudoun county ≈80%)
  - Demand: 33.8 TWh (≥2.8 GW)
  - Growth: ≈115% growth (2020-2023)
  - CAGR: ≈29.1% CAGR (2020-2023)
  - % of VA demand: ≈25.6% Virginia electrical demand
- **Future** (2024-2030, EPRI)
  - Demand (EPRI): 43.7 - 89.9 TWh
  - Demand (DOM): 47.3 TWh (2023), 114 TWh (2024)
  - Growth: 29.3-166% growth
  - CAGR: 3.7-15%
  - % of VA demand: 29.3-46.0%



STATE	2023 Load		Low-growth scenario (3.71%)		Moderate-growth scenario (5%)		High-growth scenario (10%)		Higher-growth scenario (15%)	
	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)
Virginia	33,851,122	25.59%	43,683,508	29.28%	47,631,928	31.10%	65,966,260	38.47%	89,880,357	46.00%

Sources: VEDP; EPRI

PJM Dominion Load Forecast



1. **Little growth** projected 4 years ago (2019 PJM forecasts)

2. **Large changes since 2022** and **uptick in 2023** PJM forecasts (notably higher in 2024)

3. Almost all growth is **data center growth** (≈300% data center growth between 2023-2030 expected, 21.8% CAGR)

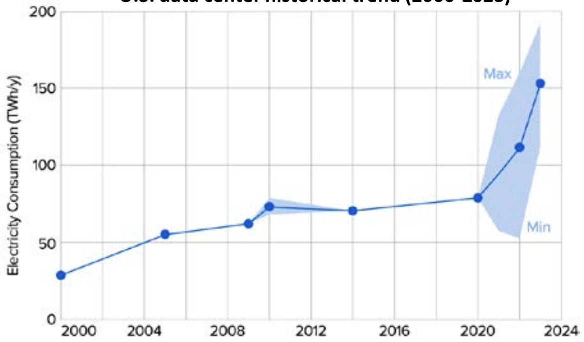
4. Data centers could compose **half of Virginia** electrical energy demand by 2030

NOTE: DOM – Dominion; Data center energy demand estimated based on typical load factor
Sources: NREL (generated based on PJM load forecast data)

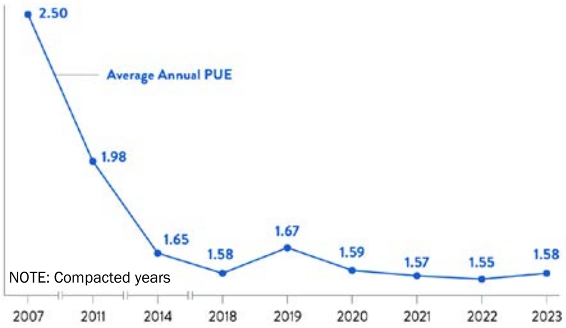
Data center demand characterization

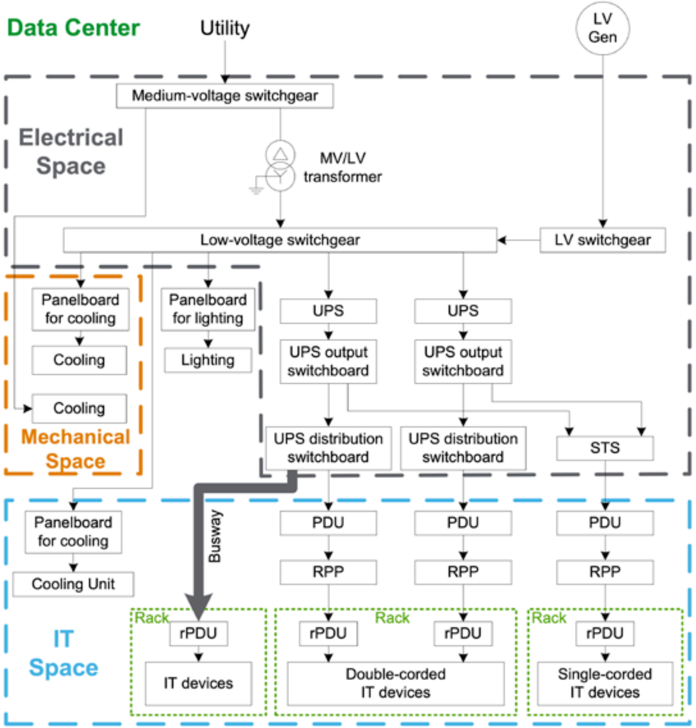
- **Small-scale** data centers. 0.5-2.0 MW each (~10% of data center demand)
- **Large-scale** commercial data centers
  - Enterprise data centers (20-30% of data center demand)
  - Co-location and Hyperscale data centers (60-70% data center demand)
- **Recently** - efficiency gains being outstripped by growing compute demand (especially co-located and hyperscale data centers)

U.S. data center historical trend (2000-2023)



Average annual PUE in data centers (2007-2023)





Data center electrical distribution system block diagram

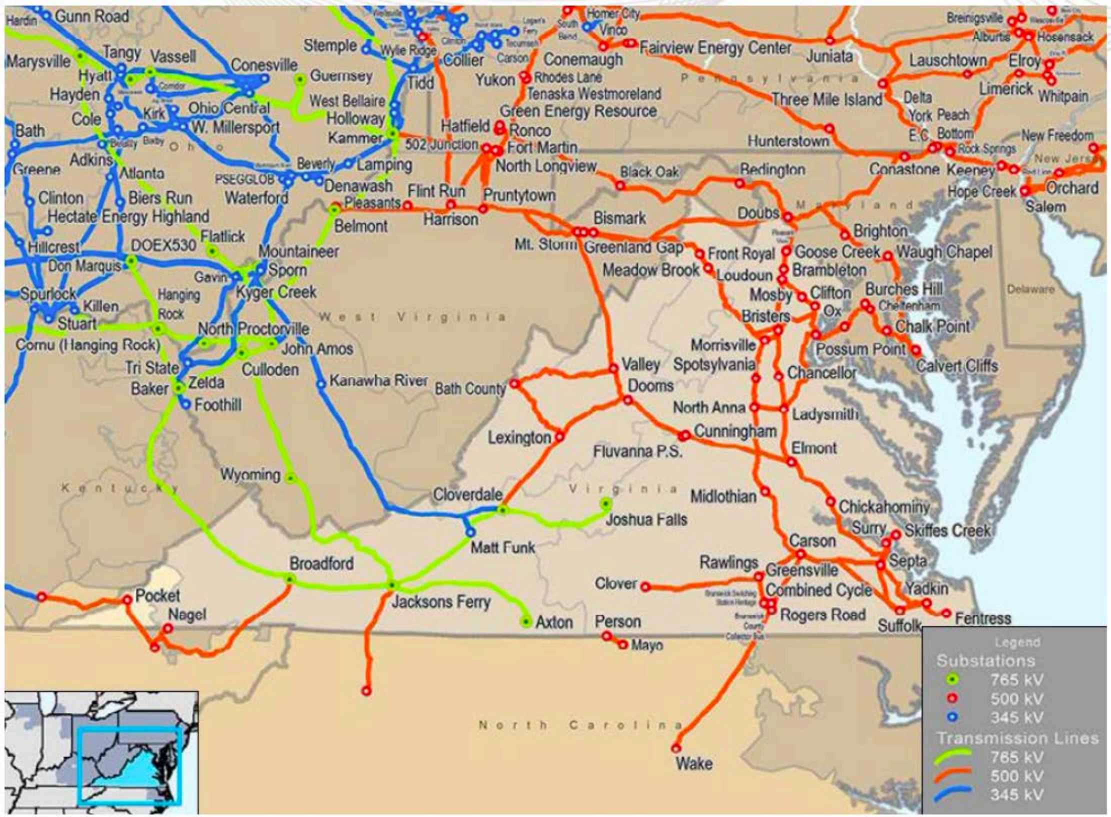
LV/MV	Low-voltage / medium-voltage
UPS	Uninterrupted Power Supply
PDU	Power Distribution Unit
RPP	Remote Power Panel

Sources: EPRI; Schneider Electric; NOTES: PUE – Power Usage Effectiveness

Current planning for growth

Dominion (Virginia) T&D Networks

- **PJM transmission (Virginia)**
  - Mostly 500 kV
  - Some 345 kV and 765 kV
- **Transmission (DOM)**
  - 6800 miles
  - 69 – 500 kV
- **Distribution (DOM)**
  - 54 000 miles
  - 400 substations
  - 4 - 46 kV



Sources: PJM RTEP 2023; Dominion IRP 2023

Dominion (Virginia) IRP 2023 expansion plans (5 options) requires substantial transmission investment

- **Current plans** in the Dominion Virginia IRP 2023 aligned with Virginia 100% clean by 2045 (Plan D and Plan E) relative to other plans (Plan A, Plan B and Plan C)
  - *"… severely challenge the ability of the transmission system to meet customers' reliability expectations"*
  - *"… would require an investment level that exceeds current transmission level expenditures and would likely exceed the future transmission level costs initially identified in the 2023 Plan"*

    NOTE: Further details not available in the public domain at this stage
- Current plans expand mostly 115 kV and 230 kV (some 500 kV) - further analysis forthcoming from Dominion in Virginia

($B)	Plan A	Plan B	Plan C	Plan D	Plan E
Total System Costs	$88.5	$100.2	$99.7	$108.8	$105.8
Grid Transformation Plan (Net of Benefits)	$(1.6)	$(1.6)	$(1.6)	$(1.6)	$(1.6)
Strategic Underground Program	$0.7	$0.7	$0.7	$0.7	$0.7
Transmission	$22.2	$28.4	$28.4	$33.1	$33.1
Total Plan NPV	**$109.7**	**$127.7**	**$127.2**	**$140.9**	**$138.0**
Plan Delta vs. Plan A	$ -	$ 18.0	$17.5	$31.2	$ 28.3

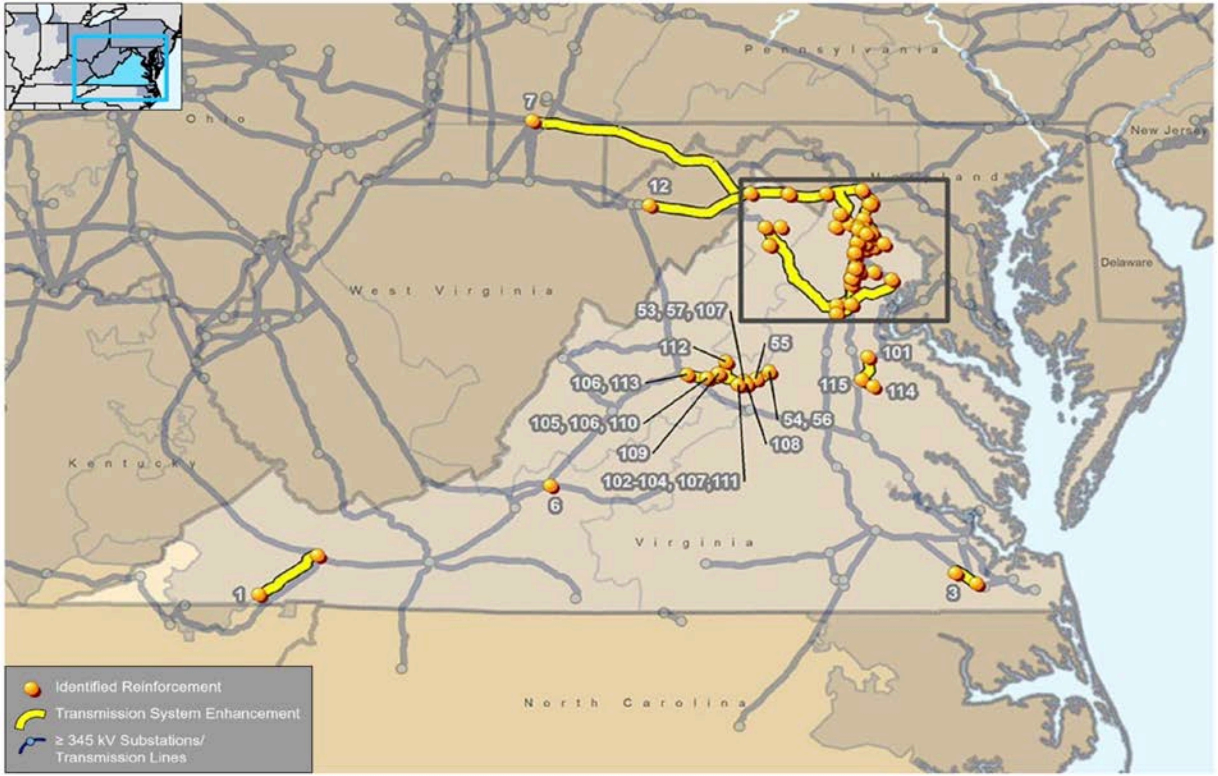
Notes: As previously ordered by the SCC, this figure includes incremental cost estimates associated with transmission and distribution investments. All costs are estimates and will vary based on the actual generation, transmission, and distribution infrastructure developed to meet customer needs. (1) Total system costs include the results from Figures 2.2.1 through 2.2.5 approved, proposed, future, and generic DSM, as applicable; costs related to environmental laws and regulations; renewable energy integration costs; and REC banking as discussed in Section 4.7.4, ***REC-Related Assumptions***. (2) All NPVs are calculated with a 6.52% discount rate. (3) Numbers may not add due to rounding.

	Plan A	Plan B	Plan C	Plan D	Plan E
NPV Total ($B)	$109.70	$127.70	$127.20	$140.90	$138.00
Approximate CO_2 Emissions from Company in 2048 (Metric Tons)	43.8 M	35.9 M	36 M	0 M	0 M
Solar (MW)	10,800 15-yr 19,800 25-yr	10,875 15-yr 19,875 25-yr	10,800 15-yr 19,800 25-yr	10,875 15-yr 23,955 25-yr	11,094 15-yr 24,294 25-yr
Wind (MW)	3,040 15-yr 3,220 25-yr	3,040 15-yr 3,220 25-yr	3,040 15-yr 3,220 25-yr	3,040 15-yr 3,220 25-yr	3,040 15-yr 3,220 25-yr
Storage (MW)	1,050 15-yr 3,960 25-yr	2,370 15-yr 5,190 25-yr	2,220 15-yr 5,220 25-yr	2,370 15-yr 9,780 25-yr	2,910 15-yr 10,350 25-yr
Nuclear (MW)	-- 15-yr -- 25-yr	804 15-yr 1,608 25-yr	804 15-yr 1,608 25-yr	1,608 15-yr 4,824 25-yr	1,072 15-yr 4,288 25-yr
Natural Gas Fired (MW)	5,905 15-yr 9,300 25-yr	2,910 15-yr 2,910 25-yr	2,910 15-yr 2,910 25-yr	970 15-yr 970 25-yr	970 15-yr 970 25-yr
Retirements (MW)	-- 15-yr -- 25-yr	-- 15-yr -- 25-yr	-- 15-yr -- 25-yr	-- 15-yr 11,399 25-yr	-- 15-yr 11,399 25-yr

Sources: Dominion IRP 2023

PJM RTEP 2023 concentrated transmission expansion in Loudoun County

PJM RTEP 2023 Baseline projects (Dec. 2023)



Sources: PJM RTEP 2023

PJM RTEP 2023 on transmission expansion and Loudoun County growth specifically

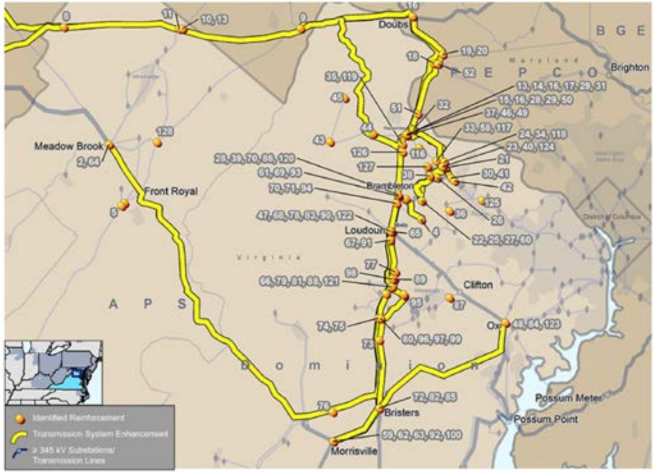
- **Many Baseline expansions in RTEP 2023**
  - – Most at 115 kV and 230 kV
  - – Some at 500 kV

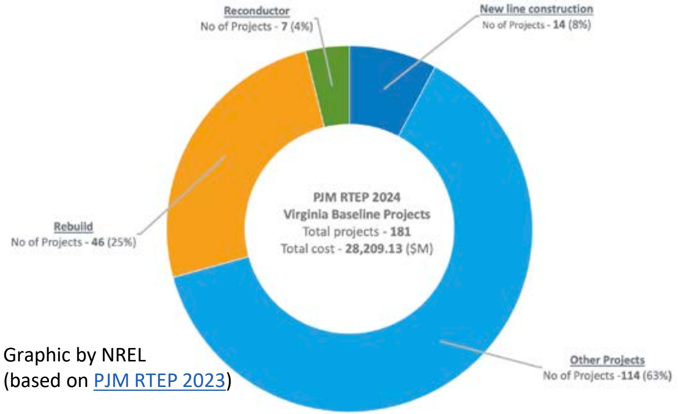
- **More specifically**, PJM continues to address "Data Center Alley" (Loudoun County, VA) demand growth

- But **growth is now higher** in 2024 forecasts than expected in RTEP 2023 (as seen in 2024 demand forecasts)

- PJM further soliciting **transmission expansion solutions** to meet this growth (amongst other areas)

Northern Virginia RTEP 2023 Baseline projects (Dec. 2023)





Graphic by NREL
(based on PJM RTEP 2023)

Sources: PJM RTEP 2023

Summary of options

GETs and Reconductoring

Summary of potential interventions

	GETs (DLR)	GETs (TTO)	GETs (APFC)	Reconductoring
Description	Dynamic Line Rating (DLR) enables increased thermal rating based on real-time temp/wind conditions	Transmission Topology optimization (TTO) are software based operational interventions that adjust power-flow to avoid congestion (re-route power-flow)[1]	Typically, power electronics based (FACTs) that are located at substations to control power flow (+address reliability), similar role to PSTs/PARs	Increases thermal rating by replacing conductors with advanced conductors (higher ampacity ratings)
Technical impact	High; 10-40% increased thermal rating	Medium; Effective congestion management (reducing binding operating periods)	Medium; Improved distribution of power flow in radial/meshed networks (potential transfer capability improvement 10-25%)	Highest; 50-100% increased thermal rating (effective on short-distance lines)
Cost / value	Low / Med	Low / Med	Med / Med	Med / High
Timeline (total)	3-12 months	<6 months	6-18 months	12-36 months
Regulatory/permitting	Low	Low	Low	Mid
Design	Mid	Low	High	Mid
Construction	Low	N/A	Mid	High

Relative timeline (qualitative)

Low Mid High N/A

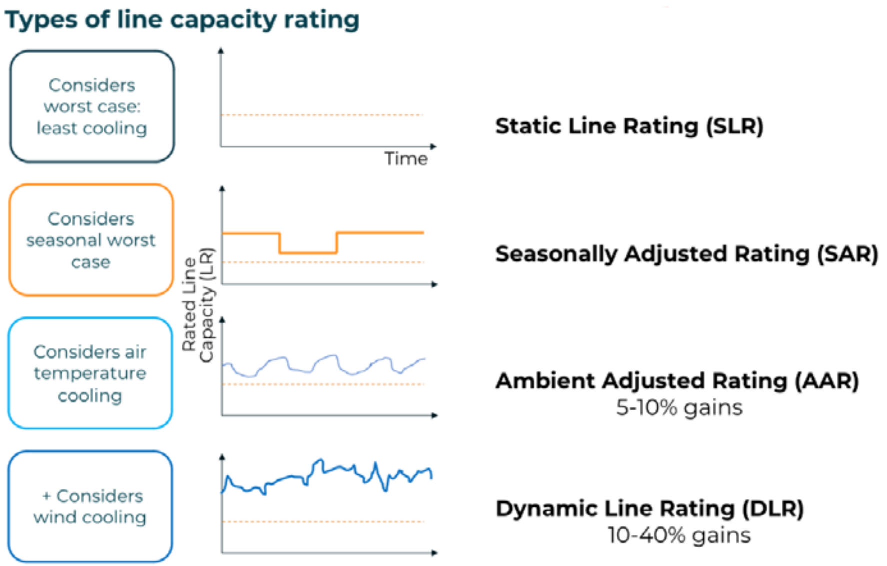
[1] Assuming the switching hardware is already in place (almost always the case);
APFC – Advanced Power Flow Controller; FACTs – Flexible AC Transmission Technologies; PAR – Phase Angle Regulator; PST – Phase-Shifting Transformer

GETs and Reconductoring

GETs: DLR

GETs (DLR)

- **Dynamic Line Rating (DLR)** is a dynamic transmission line rating based on local conditions or estimates thereof (temperature, wind speed/direction, solar irradiance)
- DLR is the most advanced manner for transmission line ratings to be established and used. Others include:
  - Static Line Rating (**SLR**) - default
  - Seasonally Adjusted Rating (**SAR**)
  - Ambient Adjusted Rating (**AAR**)
- DLR can provide for additional ampacity of a transmission line
- In principle, DLR uses the same heat-balance equations as SLR but includes more-sophisticated time-varying approaches based on real-time data or forecasts.
- Where AAR uses temperature-only, DLR also uses temperature, wind speed/direction and solar irradiance
- Field data collected along with engineering design criteria is used to calculate the maximum allowable conductor current.

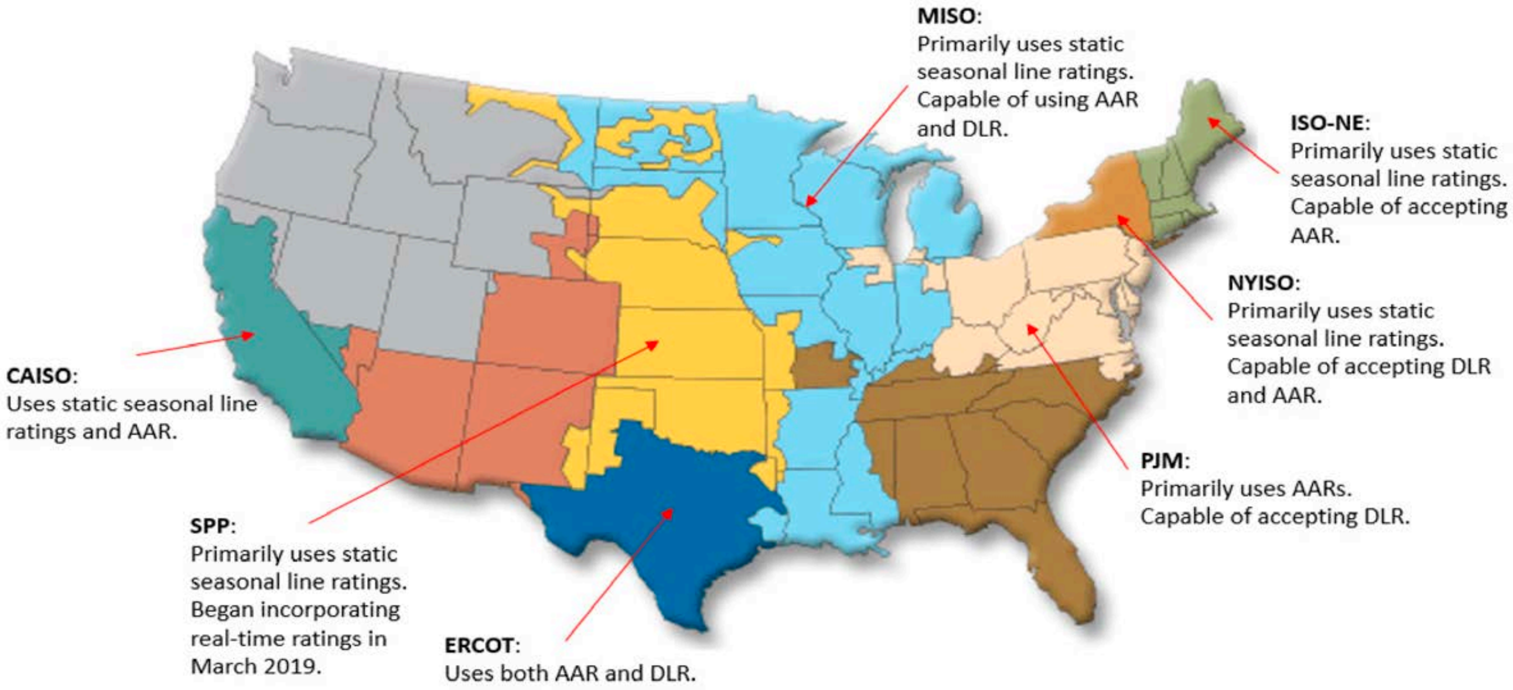


Source: B. Berry (2023) ESIG Fall Workshop

FERC Order 881 mandates transmission service providers, transmission owners, and ISOs/RTOs to establish and implement AAR for all transmission lines (at least hourly).

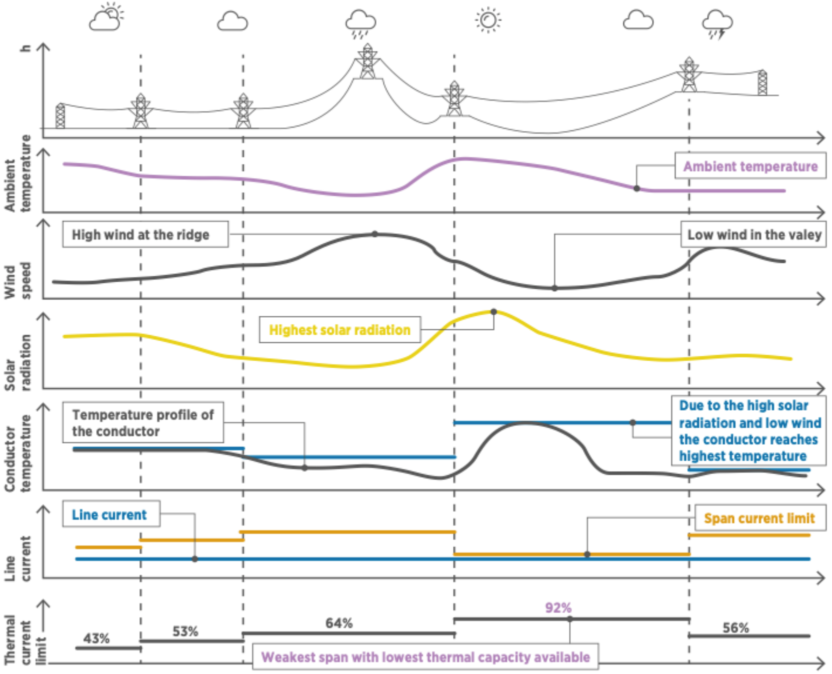
Compliance Deadline: July 12,2025

Most ISOs/RTOs use Static Line Ratings (SLRs) or Seasonally Adjusted Ratings (SARs)



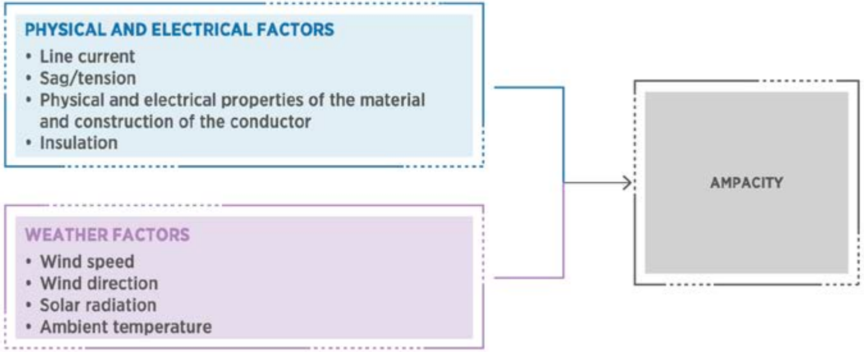
Sources: [DoE, Next-Generation Grid Technologies]

GETs (DLR)

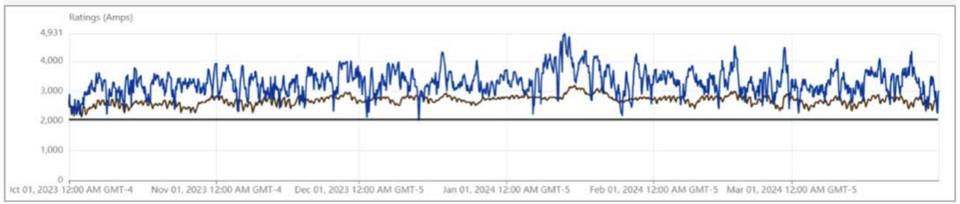


Note: Thermal current limit is the maximum current permitted to ensure no conductor material is damage and no maximum line sag is exceeded.

Sources: [Dynamic Line Rating - Innovation Landscape Brief, IRENA]



Demonstration of DLR, AAR and SLR for a 345 kV line

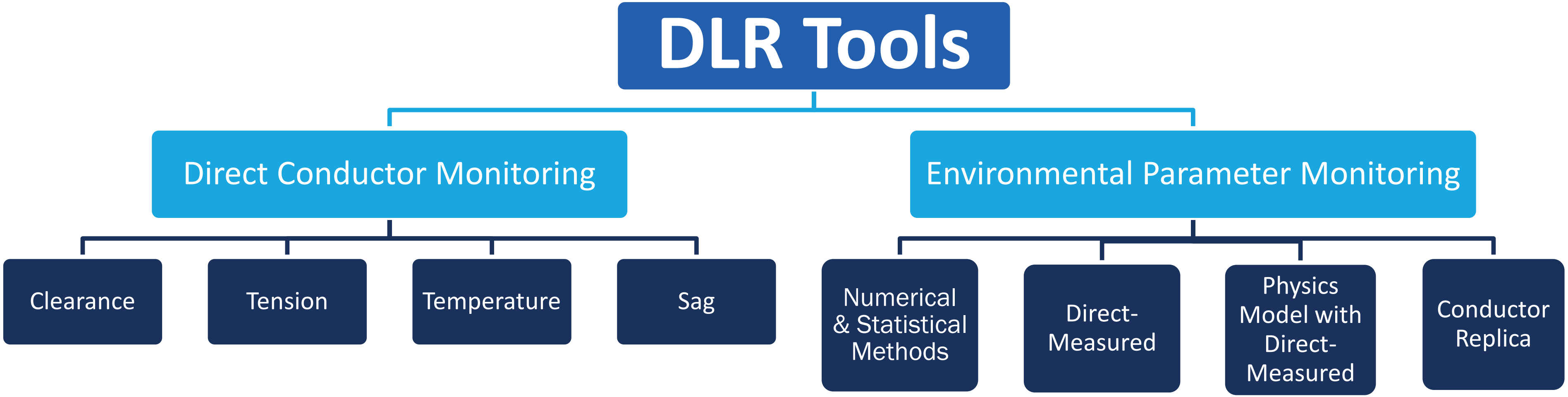


DLR is in blue, AAR is in brown, and static ratings are in black.

- DLR
- AAR
- Static ratings

Sources: [Lessons from first deployment of Dynamic Line Ratings: AES Corporation (2024)]

GETs (DLR)



Sources: Based on [DOE (2019) – Dynamic Line Rating]

GETs (DLR) – Barriers

Data Accuracy & Reliability

Volatile ratings complicate dispatch

Complex process to share dynamic ratings within ISOs

Accelerated equipment aging

Increased utility investments

Familiarity with the technology

Cyber-security risk

Lack of broadly shared technical results from pilot projects

GETs (DLR) – Case Studies

Oncor Electric Delivery Company/ERCOT
- **Year:** 2014
- **Capacity Increase:** 345 kV lines - 6-14%(above AAR); 138 kV lines – 8-12%(above AAR)

AEP
- **Year:** 2018
- **Capacity increase:** Unknown

INL/NOAA/Altalink/Idaho Power Company
- **Year:** 2019
- **Capacity Increase:** 72% (specific regions with sufficient winds)

EPRI/TVA
- **Year:** 2020
- **Capacity increase:** Unknown

National Grid
- **Year:** 2021
- **Capacity increase:** 13%

ORNL/Xcel Energy
- **Year:** 2021
- **Capacity Increase:** 9-33%(Winter), 26-36%(Summer)

PPL
- **Year:** 2021
- **Capacity increase:** 25-29%

AES Corporation
- **Year:** 2023-2024
- **Capacity increase:**
  - 345 kV: 27% (Summer), 81% (Winter)
  - 138 kV: 19% (Summer), 55% (Winter)
  - 69 kV: 23% (Summer), 9% (Winter)

Sources: Lessons from first deployment of Dynamic Line Ratings: AES Corporation – April 2024

Sources: INL (2022), A Guide to Case Studies of Grid Enhancing Technologies

GETs (DLR)

DoE Grid Resilience & Innovation Partnerships (GRIP) Program:

- Total DOE funding: $3.5 billion
- Total projects: 58 across 44 states

Analytics & Control for Driving Capital Efficiency Project:

- This project with Dominion: $67.3 million
- Grid capacity and renewable integration
- Nine (9) specific outcomes and expected benefits
- One of these: **“The world's Largest dynamic line rating project”**
- **Intended to address 200-500% load growth on specific transmission circuits in under 3 years**
- **Further coordination with Dominion (Virginia) to get status & further details (specifically – DLR components)**

GDO
GRID DEPLOYMENT OFFICE

FACT SHEET

GRID RESILIENCE AND INNOVATION PARTNERSHIPS PROGRAM

Established by the Bipartisan Infrastructure Law, the U.S. Department of Energy's Grid Deployment Office is administering a historic $10.5 billion investment via the Grid Resilience and Innovation Partnerships (GRIP) program to enhance grid flexibility, improve the resilience of the power system against growing threats of extreme weather and climate change, and ensure American communities have access to affordable, reliable, clean electricity when and where they need it.

MODERNIZING INFRASTRUCTURE TO SUPPORT GRID MANAGEMENT AND DECARBONIZATION

As clean and distributed energy resources (DERs) are deployed, grid operators will need new tools for planning, managing, and controlling them. The Analytics and Control for Driving Capital Efficiency (ACDC) project will expand the critical grid management capabilities needed to responsibly and effectively steward the energy transition. By boosting Dominion Energy Virginia's DER management capabilities, this project will increase control and improve strategic asset planning and deployment through more coordinated interconnection.

Anticipated Outcomes and Benefits

Dominion Energy Virginia anticipates a substantial investment in decarbonization infrastructure, including an approximately $10 billion investment in offshore wind. This project will adapt infrastructure to interact with technology and customers at the grid edge, enabling real-time grid visualization and advanced grid management while ensuring a variety of community benefits, including:

- Dynamic performance monitoring will reduce approximately 500 outages per year across the grid, including in **disadvantaged communities** (DACs), and enable up to $70 million of clean generation to reach the grid that would otherwise be curtailed and replaced with more costly generation.
- Deploying the world's largest dynamic line ratings project to allow Dominion Energy Virginia's operators to more effectively manage some of the growing transmission capacity constraints in PJM's service territory (which has seen a 200% to 500% load increase on certain circuits in less than three years).
- Deploying an open-source grid-forming inverter and a 2 to 4 MW BESS (Battery Energy Storage System) for a rural community. These deployments will lay the groundwork for similar projects across the utility's service territory, as well as provide insights for the PJM and Federal Energy Regulatory Commission rulemaking processes.
- Improving grid planning by collecting real-time electrical grid data.
- Increasing network capacity to account for substantial increases in electric loads.
- Controlling and preparing for voltage and frequency fluctuations caused by renewable energy resources being added to the electrical grid.
- Deploying devices and control capabilities to the remaining three-phase 34.5 kV distribution network, enabling the integration of renewable energy sources at rural customer sites in Virginia and North Carolina while equipping operators with intelligent grid devices.
- Engaging communities in the earliest stages of project development, including DACs, environmental justice communities, tribal governments, local municipalities, and local residents.
- Committing to work with academic institutions to increase the clean energy jobs pipeline and provide job training for individuals, including a deeper focus on military talent.

PROJECT DETAILS

- **Project:** Analytics and Control for Driving Capital Efficiency Project
- **Applicant/Selectee:** Virginia Electric and Power Co. (Dominion Energy Virginia)
- **GRIP Program:** Smart Grid Grants (Bipartisan Infrastructure Law, Section 40107)
- **Federal cost share:** $33,654,095
- **Recipient cost share:** $33,654,095
- **Project Location:** Virginia and North Carolina
- **Project type:** Grid Capacity and Renewables Integration

HELPFUL LINKS

- Grid Resilience and Innovation Partnerships Program
- About the Grid Deployment Office

Published October 2023. Fact sheet information is based on project applications at the time of publication and should not be considered final.

Sources: DoE GDO

GETs and Reconductoring

GETs: Transmission Topology Optimization (TTO)

GETs (TTO)

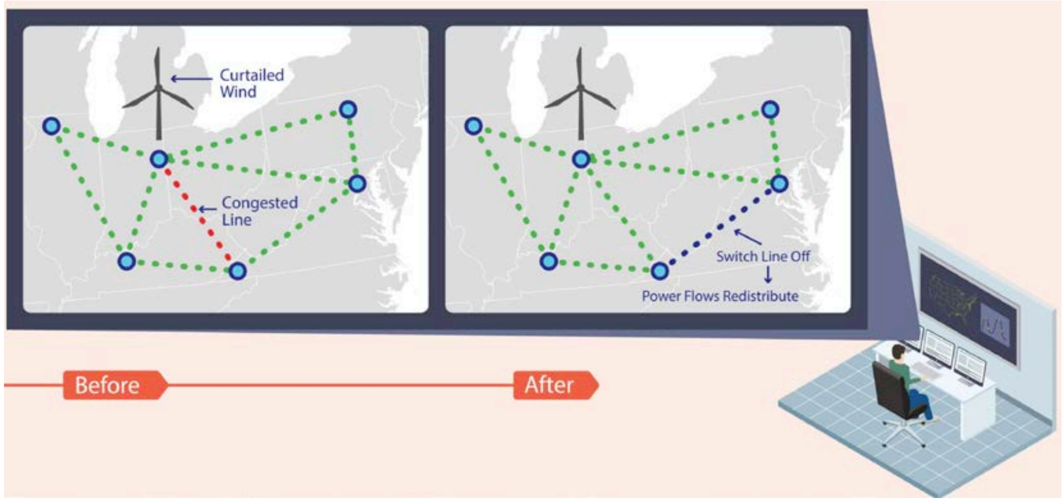
- **Transmission Topology optimization (TTO)** implements software that finds optimized reconfigurations of the network topology to reroute power around congestion (analogy – *"Waze for the transmission grid"*)

- The alternative being classical congestion management (network topology fixed and generation redispatched)

- Ensuring reliable reconfiguration is core to TO operations e.g. contingency performance, transient/voltage stability

- Typically implemented by System Operator

- Typically <1 year for implementation

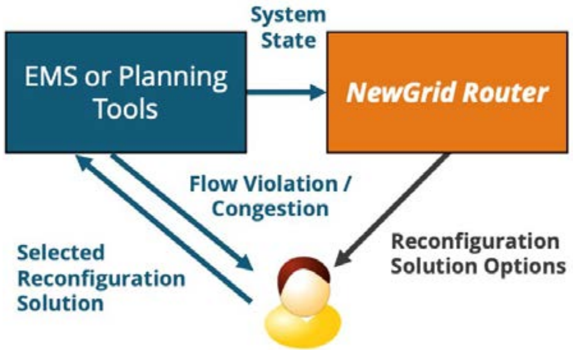


Sources: [J. Selker (2023 ESIG Fall Workshop)]

GETs (TTO)

- Has the **potential to unlock substantial value** relative to cost (software)

- Can be implemented on a **continuum** of sophistication and resulting time-scales
  - Day-ahead, intra-day, real-time: Speed of operational interventions to be effective in these timeframes
  - Weeks-ahead (operations planning): Planned outage impact minimization
  - Planning: Identify topologies for future systems, maximize value of new investments, establish important snapshots



Simplest ↕ *Highest benefits*

Process	Technology User	Application	System Integration	Timeframe
Step 1 **Reconfiguration Request Process**	**Market Participants** (RTOs, RCs and TOs have the software needed to evaluate requests)	mitigation of major expected constraints	none	days / weeks / months ahead
Step 2 **Planning and Operations Planning Support**	**RTO, RC, TOP**	operating/mitigation plan development, outage scheduling support, optimize transmission expansion	none to minimal (offline advisory tool)	days / weeks / months ahead
Step 3 **Real-Time Operations Support**	**RTO, RC, TOP**	reconfiguration options tailored to real-time conditions	EMS	days ahead to real time
Step 4 **Market Clearing**	**RTO**	continuous optimization of topology as conditions evolve	EMS and MMS	days ahead to real time

Sources: P. Ruiz (2023) ESIG Fall Workshop

GETs (TTO) - Barriers

- Unfamiliarity with the technology
- Lower returns with less capital investments
- Integration with existing operations and tools
- Market rules (congestion management - redispatch)
- Classically only applied seasonally or in emergency conditions (SPS/RPS schemes)
- Computational complexity at scale (magnified at real-time)
- Impacts on transmission elements (switching operations)
- System impacts (switching disturbances, cascading failures)

GETs (TTO) – Case Studies

PJM

- **Year:** 2014
- **Impact:** Simulated TO reduced RT congestion costs by 50%

MISO

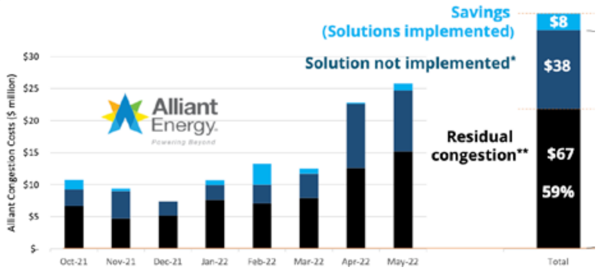
- **Year:** 2021
- **Impact:** Increased throughput by 25-60% at known 161 kV constraints (at known market seams)

Alliant

- **Year:** 2021
- **Impact:** Pilot demonstrated potential cost savings of 39%

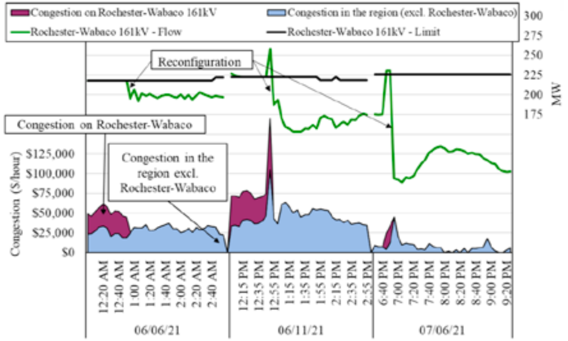
Utility (in SPP)

- **Year:** 2023
- **Impact:** Pilot estimates potential for 85% reduction in congestion costs (with consistent use of TO)



Reconfiguration impact across Alliant (pilot)

Sources: NewGrid



Reconfiguration impact of a known 161 kV constraint in MISO

Sources: Potomac Economics

Sources: P. Ruiz (2023) ESIG Fall Workshop; DoE (2020) Advance Transmission Technologies

GETs and Reconductoring

GETs: Advanced Powerflow Control (APFC)

GETs (APFC)

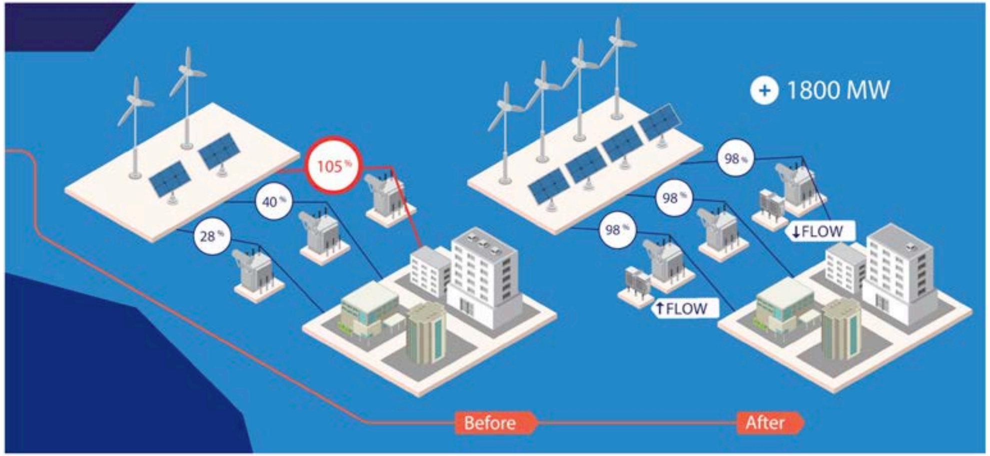
- **Advanced Power Flow Controllers (APFCs)** are hardware devices that enable the shifting of power-flow in parallel or meshed networks by adjusting the effective reactance of the network

- APFCs are **more compact**, can be **faster in response** and **more efficient** than Phase-Shifting Transformers (PSTs) / Phase-Angle Regulators (PARs)

- Typically located at existing substations

- Ability to reduce regional RE curtailment, reduce congestion (100s of hours per year) and/or improve overall transfer capability (10-25%), defer transmission investment

- Typically <1 year for construction (1-2 years for implementation)



Sources: J. Selker (2023 ESIG Fall Workshop)

GETs (APFC) - Barriers

More familiarity with PARs/PSTs and costs relative to APFC

Substation expansion (in constrained geographies)

Permitting (for new substation expansions)

Control integration with operations

Operator and maintenance staff familiarity (limited deployments)

Valuation of innovative/unique technology and incentive alignment (cost-recovery)

Need for improved planning and investment case development

Integration into planning and operations tools (security assessment, powerflow, fault, dynamics)

GETs (APFCs) – Case Studies

AEP	• **Year:** 1998 • **Impact:** Added 770 MW of capacity (reduced power losses)
NGET (UK)	• **Year:** 2019 • **Impact:** Resolve network congestion at 275 kV and 400 kV (3 substations, 2 GW of RE unlocked)
Central Hudson (US)	• **Year:** 2020 • **Impact:** Capacity increase at 345 kV (185 MW)
TransGrid (Aus)	• **Year:** 2022 • **Impact:** Increased transfer capability of 170 MW at 330 kV (2 circuits)
ISA Transelca (Colombia)	• **Year:** 2023 • **Impact:** Unlock 200 MW and resolve congestion at 220 kV for RE integration

SSSC APFC (3 substations) (UK)

Sources: SmartWires

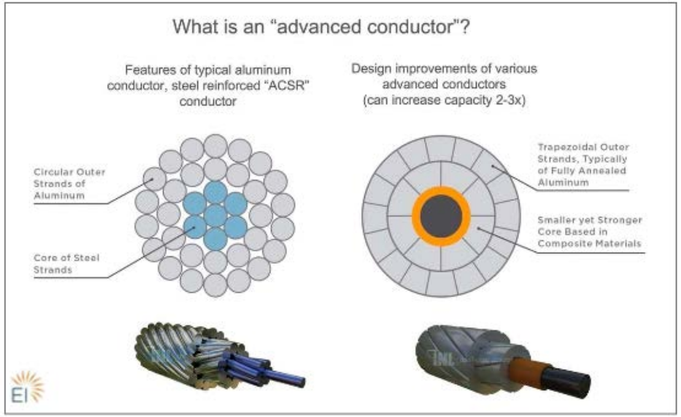
Sources: [SmartWires (various case studies)](); [DoE (2020) Advance Transmission Technologies]()

GETs and Reconductoring

Reconductoring

Reconductoring

- **Reconductoring** involves upgrading the existing transmission system's transfer capacity by reconductoring selected network lines with conductors capable of transmitting greater electrical capacity.
- **Almost always cost-effective** compared to new-build if feasibility constraints are met
- Can enable up to **double** the line capacity within an existing ROW **with advanced reconductoring** (ACCR, ACCS, ACCC, AECC)
- Helps provide **near-term interregional capacity**, providing time for new lines to be developed for long-term needs
- Distributes new transmission capacity over more transmission corridors/interfaces



Advanced conductor renderings courtesy of Idaho National Laboratory.[8]

	Name	Summary description	Provider
Advanced conductors (composite core)	**ACCR** – Aluminium Conductor Composite Reinforced	• Multi-strand Al core with Al-zirconium outer strands	3M
	ACCS - Aluminium Conductor Composite Supported (a.k.a. C^7)	• Multi-strand carbon core and trapezoidal Al outer-strands	SouthWire
	ACCC – Aluminium Conductor Composite Core	• Composite carbon & glass fiber core with annealed Al or Al-zirconium outer strands	CTC Global
	AECC – Aluminium Encapsulated Carbon Core (a.k.a. TS)	• Carbon-core (mono) with Al sheath and annealed AL trapezoidal outer strands	TS Conductor

Sources: GridLab (2023), 2035 Reconductoring Technical Report; GridLab (2024) Supporting Advanced Conductor Deployment: Barriers and Policy Solutions Companion Report; EPRI Fact sheet: Advanced Conductors

Reconductoring – Barriers

Planning Barriers
- Workforce shortage
- Increasing load/gen growth
- Non-standard planning forecast window
- Less visibility on system health

Institutional Barriers
- Slow adoption of new technologies by utilities
- Lack of proper training & tools
- Less institutional resistance to in-kind replacements
- Historical failures
- Many alternative solutions

Coordination barriers
- Siloing between TOs
- No holistic long-term regional planning

Permitting Barriers
- Limited space for construction
- New permits for reconductoring in future
- Lack of clarity for permitting reconductoring

Up-front cost barriers
- Increased conductor cost
- Existing upward rate pressure

Technical Barriers
- Age & health of existing structures
- Long lines less conducive to reconductoring (>50 mi)
- Outages during reconductoring
- Other network upgrades

Sources: GridLab (2023), 2035 Reconductoring Technical Report

Reconductoring – Successful Deployments

Lower Rio Grande Valley Reconductoring Project

- **Location:** Texas, United States
- **Re-Conductor:** ACCC
- **Voltage:** 345 kV
- **Project status:** Completed (+100% capacity increase)

Big Creek 230kV Corridor

- **Location:** Southern California, United States
- **Re-Conductor:** ACCC
- **Voltage:** 230 kV
- **Project status:** Completed

380 kV Reconductoring (Belgium)

- **Location:** Belgium
- **Re-conductor:** ACCC
- **Voltage:** 380 kV
- **Project status:** On-going (+100-150% capacity increase)

TenneT Beter Benutten Bestaande 380 kV Project

- **Location:** Netherlands
- **Re-conductor:** HTLS
- **Voltage:** 380 kV
- **Project status:** On-going (+60% capacity increase

Hot-line reconductoring with temporary support poles

Lower Rio Grande Valley Reconductoring Project
Sources: IEEE PES ESMO Conference Presentation, Glueck 2016

Sources: GridLab (2023), 2035 Reconductoring Technical Report

Conclusions and potential next steps

Summary of potential interventions

	GETs (DLR)	GETs (TTO)	GETs (APFC)	Reconductoring
Description	Dynamic Line Rating (DLR) enables increased thermal rating based on real-time temp/wind conditions	Transmission Topology optimization (TTO) are software based operational interventions that adjust power-flow to avoid congestion (re-route power-flow)[1]	Typically, power electronics based (FACTs) that are located at substations to control power flow (+address reliability), similar role to PSTs/PARs	Increases thermal rating by replacing conductors with advanced conductors (higher ampacity ratings)
Technical impact	High; 10-40% increased thermal rating	Medium; Effective congestion management (reducing binding operating periods)	Medium; Improved distribution of power flow in radial/meshed networks (potential transfer capability improvement 10-25%)	Highest; 50-100% increased thermal rating (effective on short-distance lines)
Cost / value	Low / Med	Low / Med	Med / Med	Med / High
Timeline (total)	3-12 months	<6 months	6-18 months	12-36 months
Regulatory/permitting	Low	Low	Low	Mid
Design	Mid	Low	High	Mid
Construction	Low	N/A	Mid	High

Relative timeline (qualitative)

● Low ● Mid ● High ● N/A

[1] Assuming the switching hardware is already in place (almost always the case);
APFC – Advanced Power Flow Controller; FACTs – Flexible AC Transmission Technologies; PAR – Phase Angle Regulator; PST – Phase-Shifting Transformer

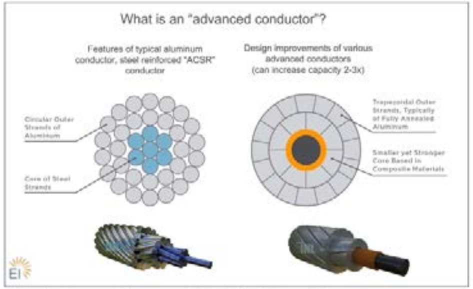
Conclusions

- **Data center demand growth** in Virginia will need to be met with many options – GETs and/or reconductoring have the potential to be part of the solution suite in the short-term and medium-term

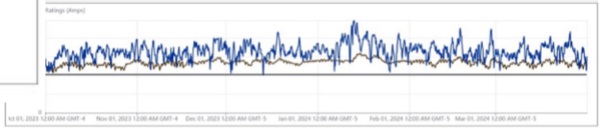
- **Almost all GETs and reconductoring technologies have more favorable economics** than transmission wires investments considering relatively **low levels of existing wide-scale deployment**

- Deployment of GETs and/or reconductoring is **not a one size fits all** – requires detailed analysis (rigorous technical assessments in reliability models and associated cost-benefit analysis)

- **Complementary nature** of GETs and/or reconductoring impacts have the potential to be **synergistic** when implemented together (more congestion relief, more transfer capability, more cost savings)



Advanced conductor renderings courtesy of Idaho National Laboratory[8]

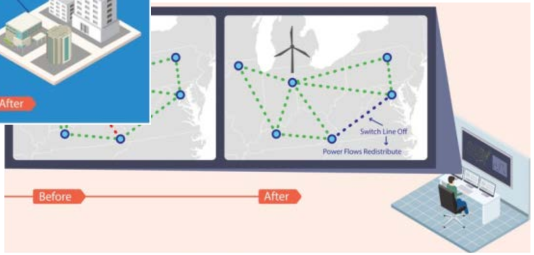


DLR is in blue, AAR is in brown, and static ratings are in black.

DLR
AAR
Static ratings

Sources: Lessons from first deployment of Dynamic Line Ratings: AES Corporation – April 2024

Sources: J. Selker (2023 ESIG Fall Workshop)



Sources: J. Selker (2023 ESIG Fall Workshop)

Potential next steps

- In addition to GETs and reconductoring, **consider the timing of all interventions** and **ordering by the most impactful** based on pre-defined criteria
  - Consider a complete taxonomy of options (in addition to GETs and/or reconductoring)
    - Demand-side management (DSM)
    - Expanded local supply options (augmented back-up power)
    - Generation expansion (within and beyond the Dominion and PJM territory)
    - Transmission expansion (localized strengthening and interregional expansion)
  - Pre-defined criteria:
    - Scale of technical impact
    - Value/cost
    - Time for implementation

- **Establish the responsible stakeholder** best positioned to address barriers e.g. regulator (State/Federal), utility, transmission owner, RTO, customer

- **Address barriers** in order of priority (considering broader scope than GETs and/or reconductoring)

- **Disseminate operational know-how** and learnings widely from pilots and commercial implementations of GETs and reconductoring

Thank you

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Jarrad **Wright** jarrad.wright@nrel.gov
Ram **Pandian** RamMohan.Pandian@nrel.gov

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