July 30, 2024

2024 Power Electronics & Energy Conversion Workshop
Session: Regional Electric Grid Needs

HVDC and EHV AC As Part of a Wholistic Grid Solution

Presented by Dan Sullivan
Tech Support by: Jeff Varness, Chris Postma, Joe Warner

Albuquerque, New Mexico

POWER ENGINEERS

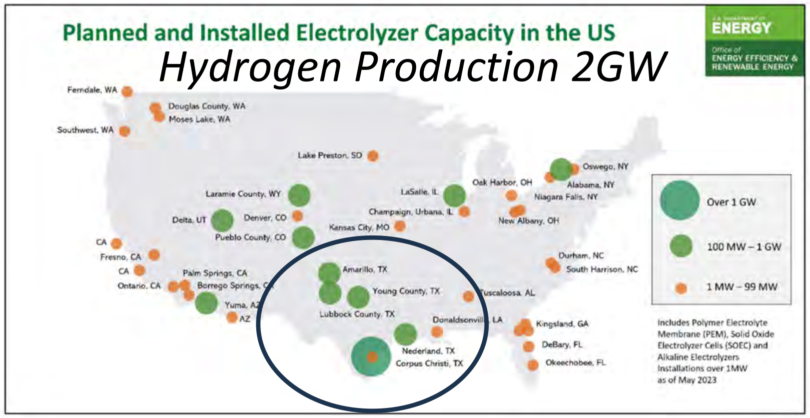
Agenda

- ERCOT and Texas Region Issues
- Today's Transmission System and Issues at Hand
- HVDC
- EHV AC & HVDC
- Grid Resilience
- Examples of Resilience Improvement
- Macrogrid using EHV and HVDC as a wholistic integrated solution
- Panel and Questions

Dan Sullivan
Director of Advisory Services

Dan.Sullivan@powereng.com

Figure 1. Current or Planned Installations of Electrolyzers (PEM, SOEC, Alkaline) over 1 MW in the U.S. as of May 2023[2]

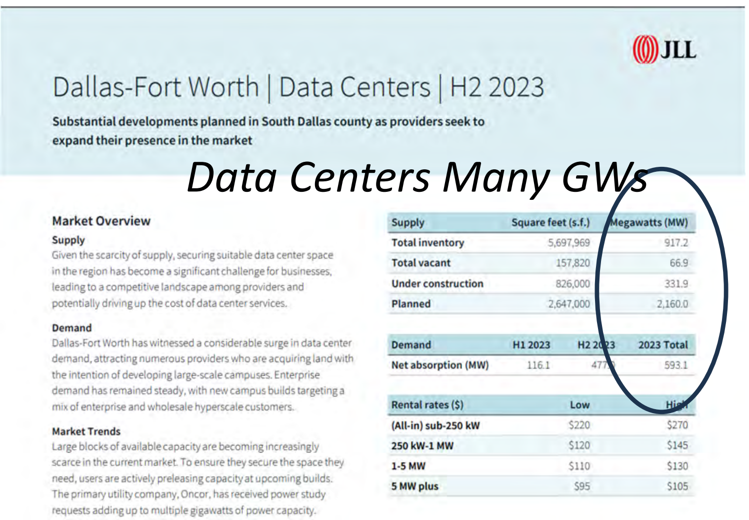


Source: DOE Hydrogen Program Record dtd 6/2/2023

Issue at Hand

ERCOT forecasts very large load increases, and 345 kV transmission may be insufficient to serve these demands

Exploring alternative transmission solutions in the form of higher Extra High Voltage (EHV) AC transmission voltages and High Voltage Direct Current (HVDC)



JLL

Dallas-Fort Worth | Data Centers | H2 2023

Substantial developments planned in South Dallas county as providers seek to expand their presence in the market

Data Centers Many GWs

Market Overview

Supply

Given the scarcity of supply, securing suitable data center space in the region has become a significant challenge for businesses, leading to a competitive landscape among providers and potentially driving up the cost of data center services.

Demand

Dallas-Fort Worth has witnessed a considerable surge in data center demand, attracting numerous providers who are acquiring land with the intention of developing large-scale campuses. Enterprise demand has remained steady, with new campus builds targeting a mix of enterprise and wholesale hyperscale customers.

Market Trends

Large blocks of available capacity are becoming increasingly scarce in the current market. To ensure they secure the space they need, users are actively preleasing capacity at upcoming builds. The primary utility company, Oncor, has received power study requests adding up to multiple gigawatts of power capacity.

Supply	Square feet (s.f.)	Megawatts (MW)
Total inventory	5,697,969	917.2
Total vacant	157,820	66.9
Under construction	826,000	331.9
Planned	2,647,000	2,160.0

Demand	H1 2023	H2 2023	2023 Total
Net absorption (MW)	116.1	477.[illegible]	593.1

Rental rates ($)	Low	High
(All-in) sub-250 kW	$220	$270
250 kW-1 MW	$120	$145
1-5 MW	$110	$130
5 MW plus	$95	$105

Source: JLL North American Data Center Report H2 dtd 2023

Project Loads

Data Centers >> est 2+ GW

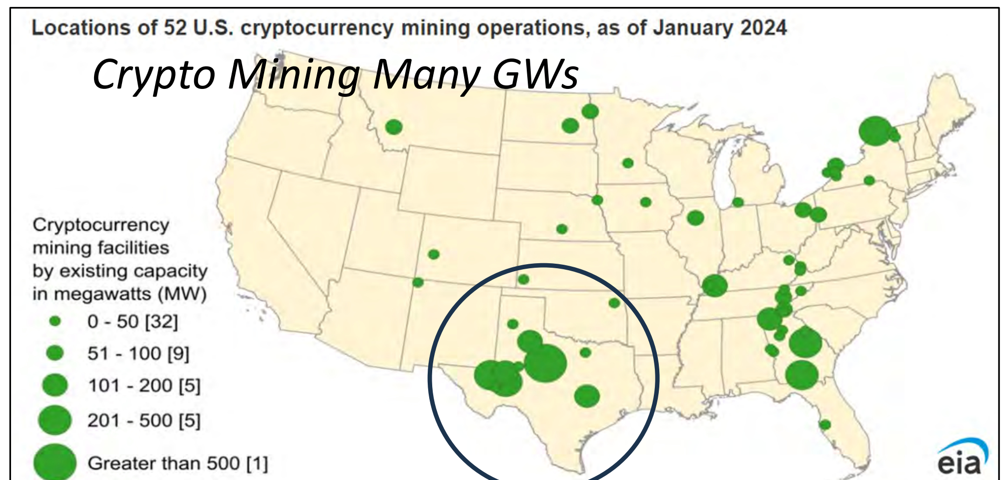
Crypto Mining >> est 2 GW

Hydrogen Production >> 2GW

Permian Basin >> 18 GW

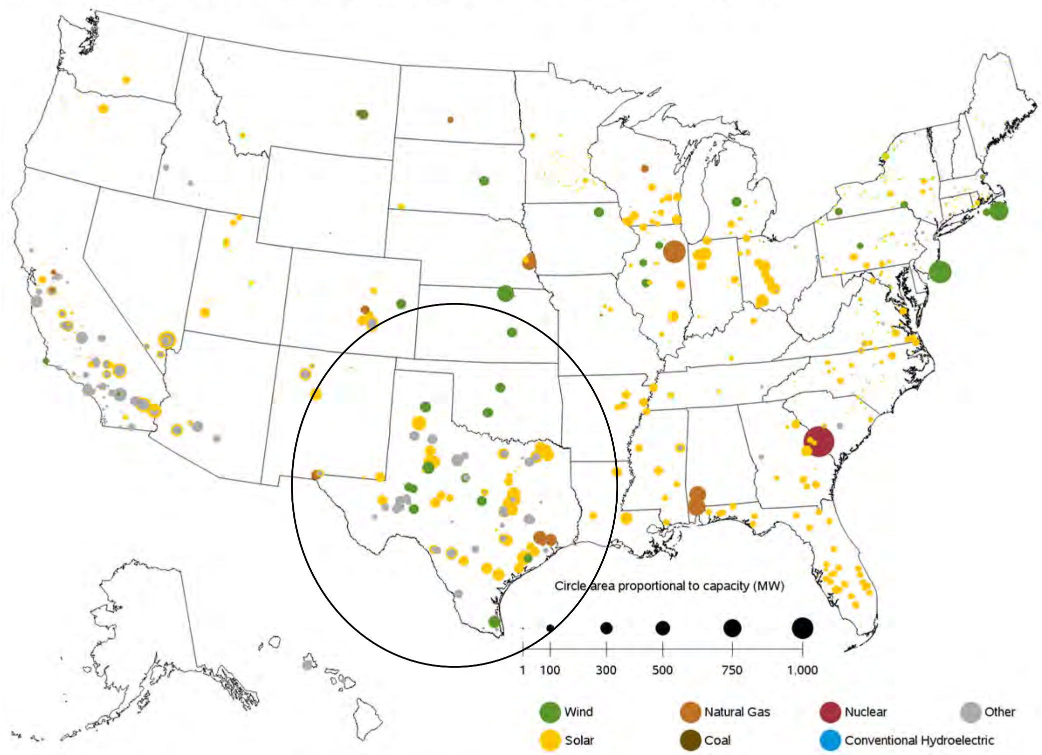
Electrification

Extreme weather / Resilience



Texas and Renewables

Figure 6.1.C. Utility-Scale Generating Units Planned to Come Online from June 2023 to May 2024

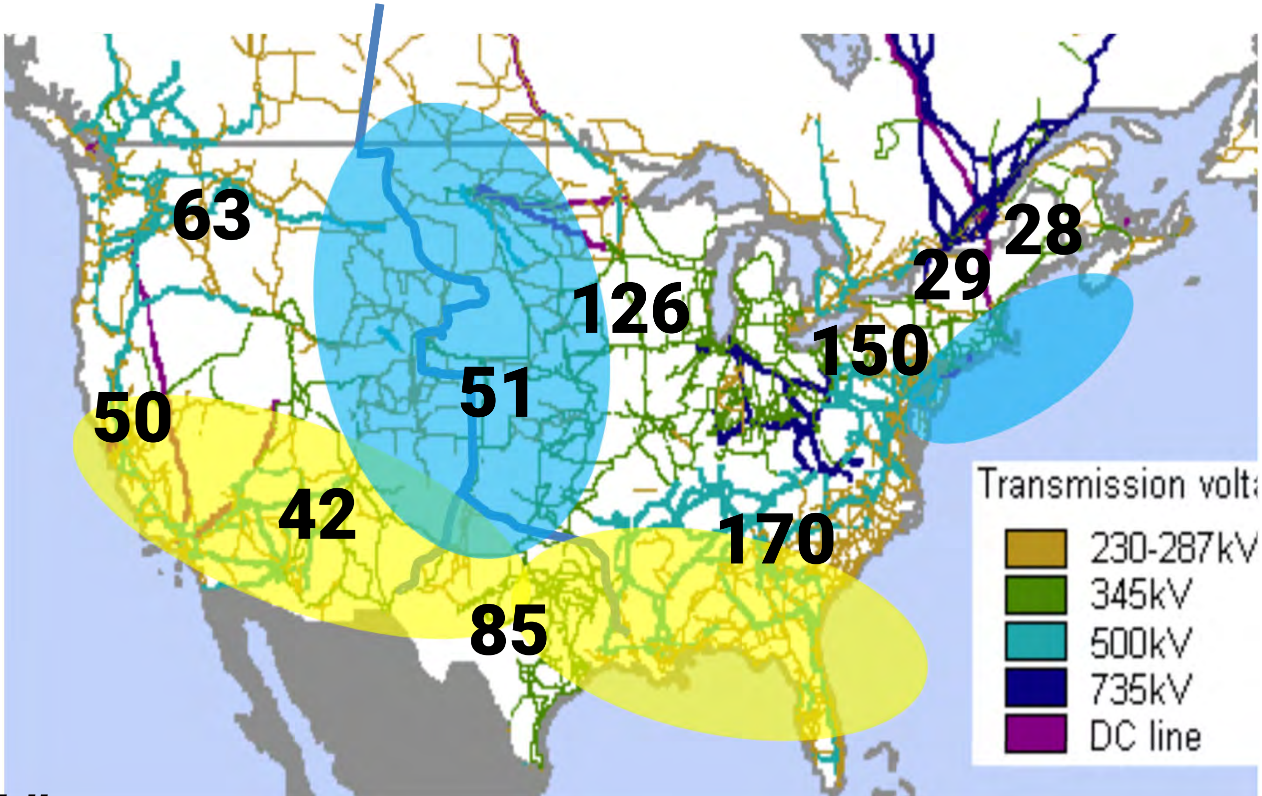


Sources: U.S. Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report' and Form EIA-860M, 'Monthly Update to the Annual Electric Generator Report.'

- » "In 2023, the most new solar capacity, by far, will be in Texas (7.7 GW) and California (4.2 GW), together accounting for 41% of planned new solar capacity."
- » "The most wind capacity will be added in Texas in 2023, at 2.0 GW"

Source: eia article, "More than half of new U.S. electric-generating capacity in 2023 will be solar" dated 2/6/23

Snapshot of Today's Transmission Grid



= estimated historical peak demand in a given region

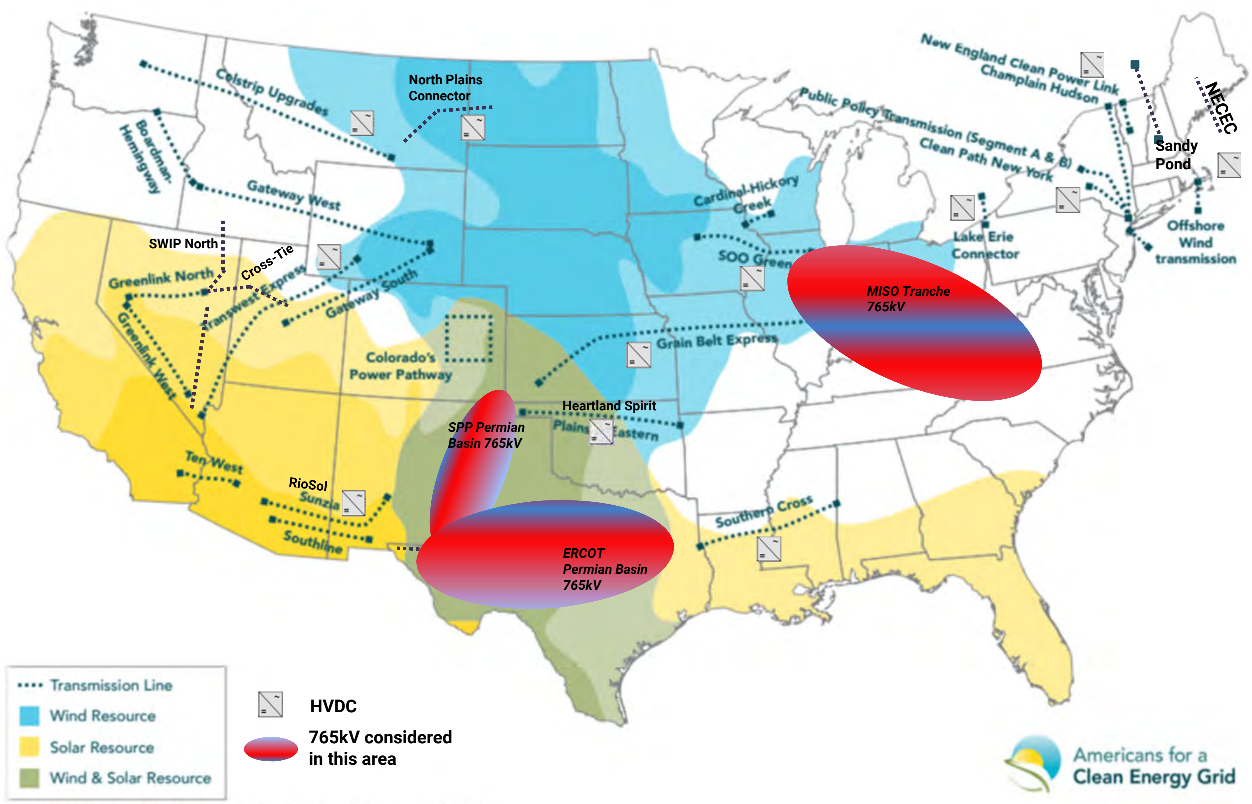
Grid Snapshot

- Deploy diverse renewables
- Retire coal fired plants
- Strategically deploy thermal units
- Significant load growth
- Weak system challenges
- OSW deployment stalled
- Developing transmission
- Regional severe weather challenges

Transmission

- 345 kV AC (>67,000 miles)
- 550 kV AC (>29,000 miles)
- 765 kV AC (2,400 miles)
- HVDC (4,000 miles)

Advancement of Recent MegaProjects



Source: As indicated with annotated by POWER Engineers

EHV AC, HVDC

Most projects driven by renewable integration, with some upgrades

Most HVDC projects are > 3,000MW bipole, with off-shore wind projects at 1,000–1,200MW AC or HVDC symmetrical monopole

Most terrestrial projects are overhead transmission with a couple exceptions

Project owners are primarily project developers with a few electric utilities

Increasing number of entities applying for DOE grant(s)

Getting Most From Existing Grid

- Flexible AC transmission systems
  - STATCOM, SSSC, TCSC
- Fixed series compensation
- Grid-enhancing technologies (GETS)
  - DLR, advanced conductoring
  - Power flow control, sensors, metering
- Energy storage
- Demand response

HVDC


Source: Siemens Energy

Trends

- Not available for new projects until >2030+
- Suppliers control project schedule and scope
- Insufficient planning experience & models
- Lack of standardization, and inoperability btw OEMs
- Project execution timeline is 5-7 years

Common Ratings and Configuration

- 320 or 400 kV DC (Symmetrical Monopole)
  - ~ 5-8 acre site
- +/- 525 or 625 kV DC (Bipole OH)
  - ~ 15 acre site
  - $900M-$1.2B installed cost of both converter stations

HVDC vs EHV AC

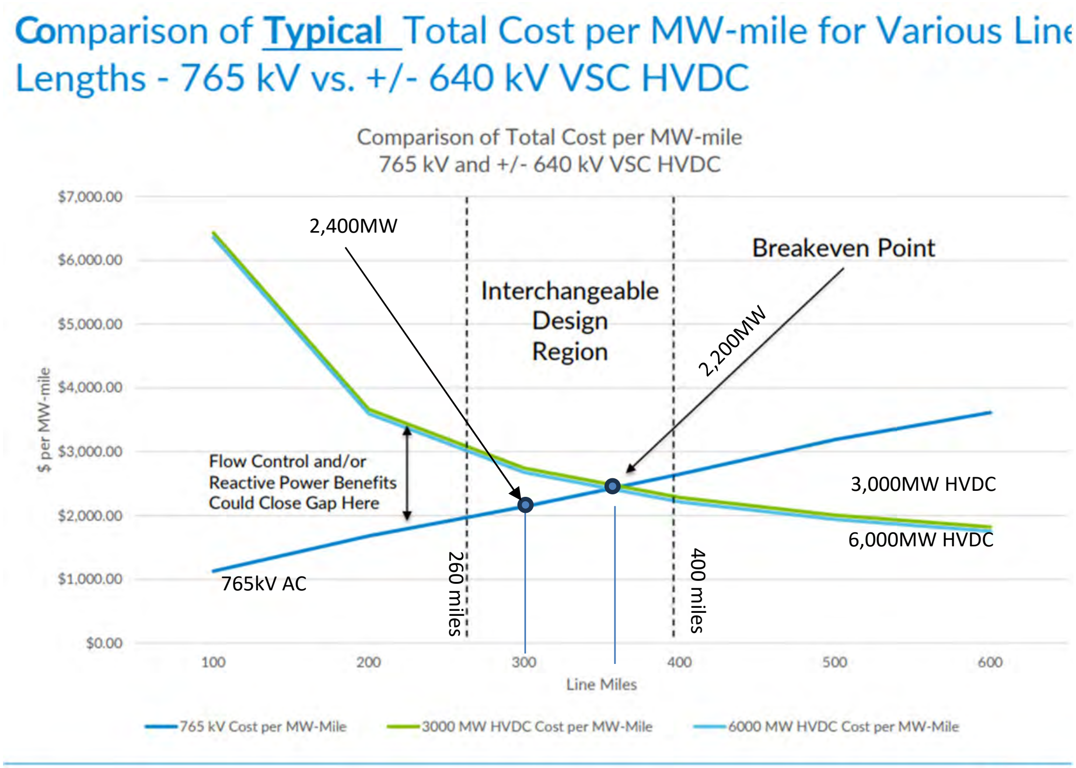


Figure 4

- EHV AC does facilitate easier interconnection while HVDC is a bit difficult to tap (with current day technology)
- AC is cost effective for distances up to ~250–300 miles
- 765 larger ROW than HVDC
- HVDC provides powerflow controllability
- VSC HVDC can provide blackstart support
- HVDC allows asynchronous connections
- VSC HVDC minimizes potential for interaction issues with IBRs

Source: MISO, Discussion of Legacy, 765 kV, and HVDC Bulk Transmission, ERCOT EHV & HVDC Workshop, June 26, 2023

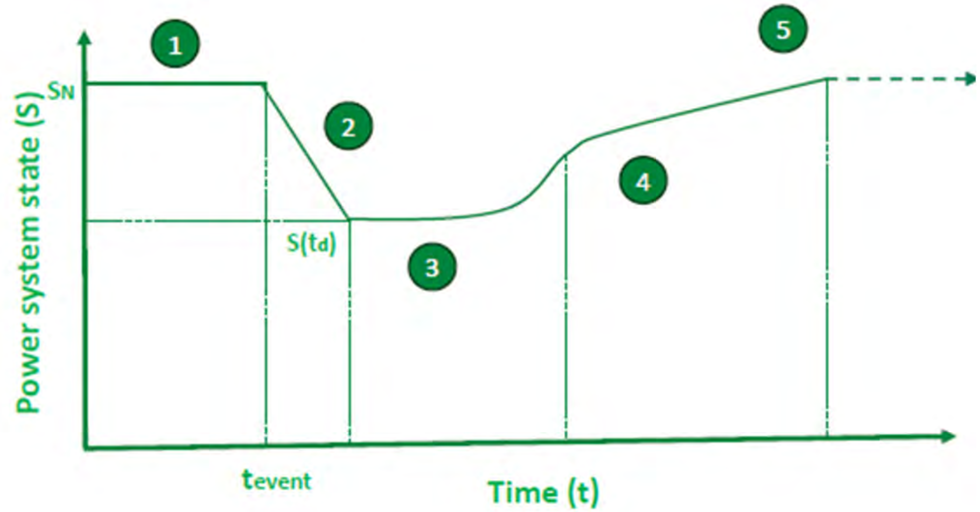
Grid Resilience

IEEE

» The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event

CIGRE

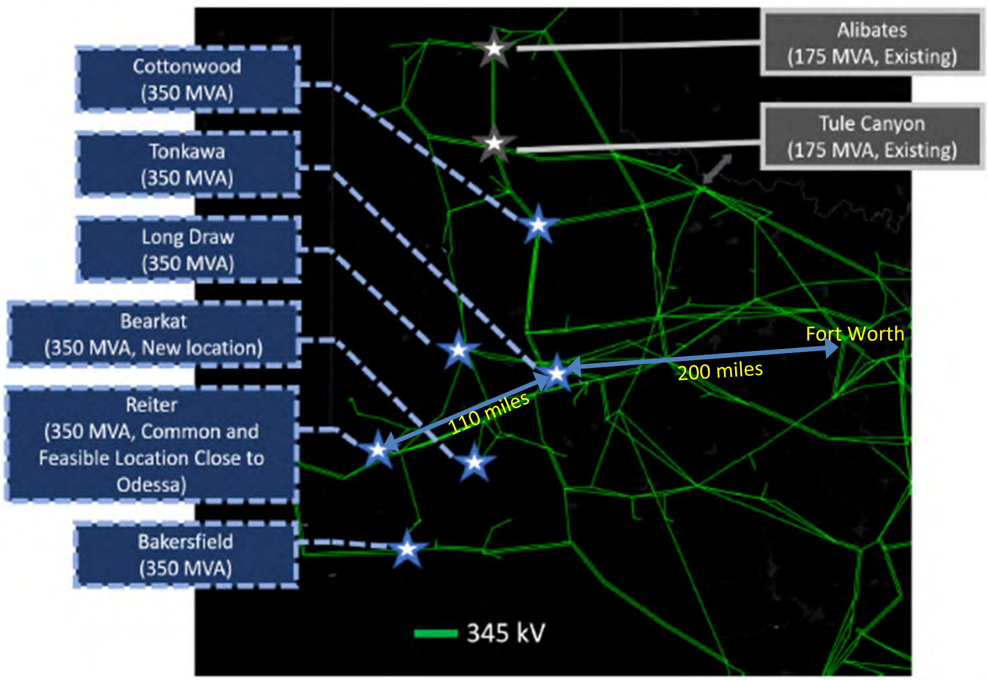
» The ability to limit the extent, severity and duration of system degradation following an extreme event.



1. Steady state
2. Disturbance or event
3. Response
4. Recover
5. Restore

Source: Reynaldo Nuqui, PhD, Hitachi Energy, "Improving Grid Resilience with HVDC & FACTS," IEEE/PES Panel, May 8, 2024

ERCOT : Improve System Strength & Resilience



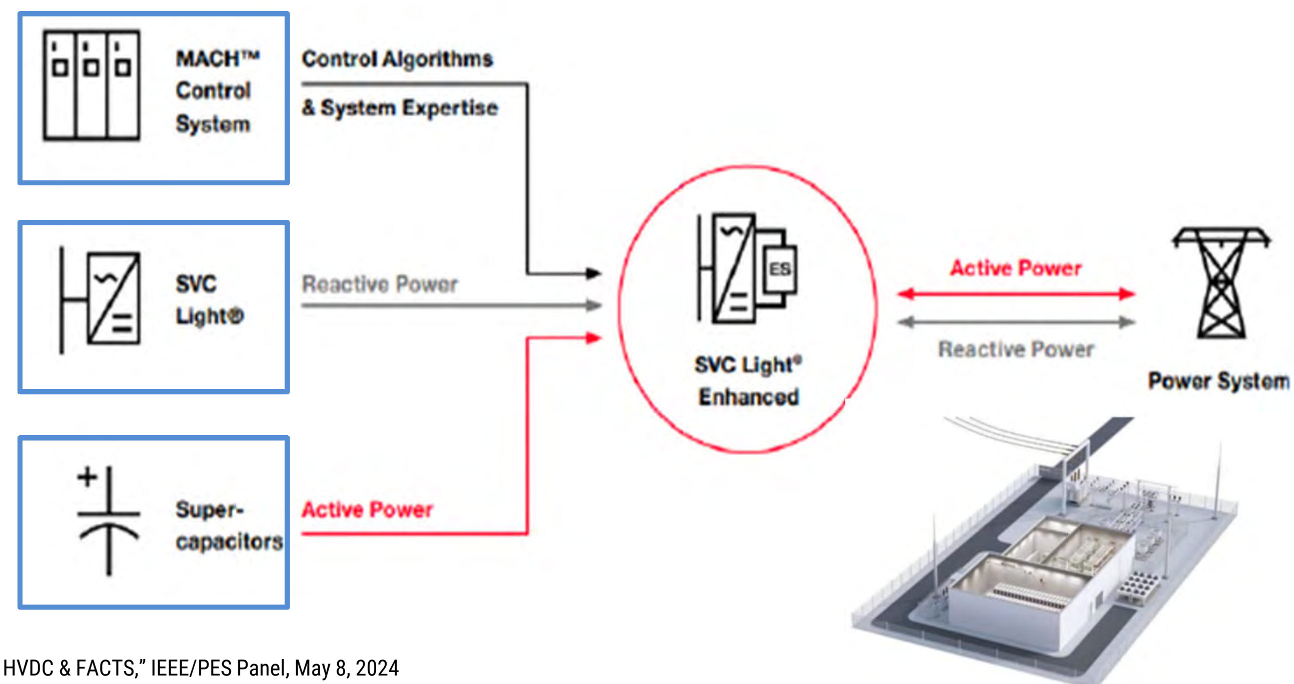
- Six 350 Mva synchronous condensers (2,100 MVA)
  - were identified to provide effective improvement to West Texas
- Added system strength and resilience
  - to addresses operational challenges during unexpected disturbance conditions.
- Significant improvement in system responses
  - for critical faults even under stressed system conditions (e.g., reduction in potential generation tripping, improved voltage recovery).
- Requirements of each Sync Condenser
  - 350 MVA rating
  - 3,600 A fault current contribution to 345 kV POI
  - 2,000 MW-s inertia

Source: ERCOT, C. Danielson, “Final Update –Assessment of Synchronous Condensers to Strengthen West Texas System,” Regional Planning Group Meeting, June 13, 2023

STATCOM Enhancements to Improve Grid Resilience

System Issues	STATCOM Enhancement	Solution

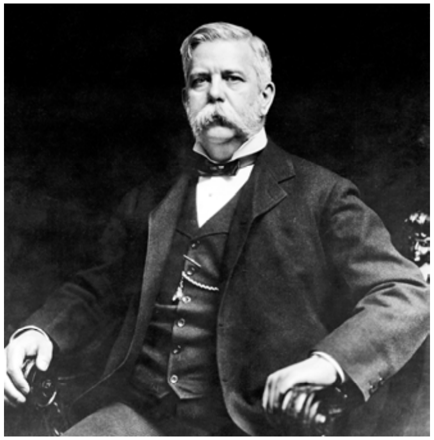
- Voltage Regulation
- Inertia
- Short Circuit Contribution
- System Strength Support
- Negative Sequence Support



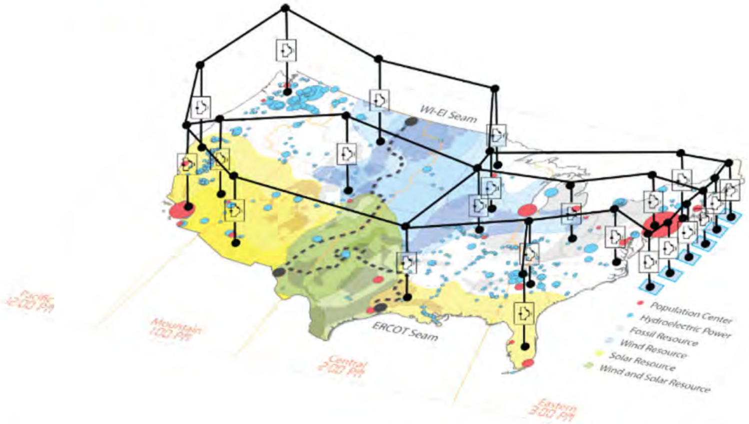
Source: Reynaldo Nuqui, PhD, Hitachi Energy, "Improving Grid Resilience with HVDC & FACTS," IEEE/PES Panel, May 8, 2024

Source Siemens Energy

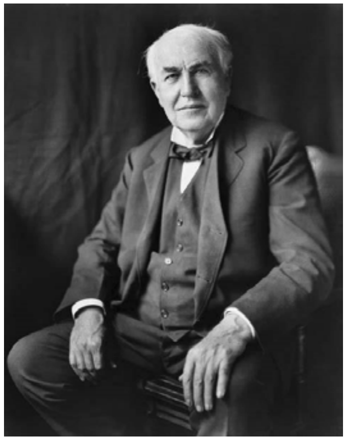
Bringing Enemies Together



Mr. Westinghouse



Mr. Edison



Thank You