MRO 2022 Reliability Conference

Wednesday, May 18, 2022 | 8:30 a.m. to 3:45 p.m.

InterContinental Kansas City at the Plaza

Kansas City, Missouri

MIDWEST RELIABILITY ORGANIZATION

380 St. Peter St, Suite 800
Saint Paul, MN 55102
651-855-1760
www.MRO.net

LOGISTICS

WebEx Login:
Event address for attendees:
https://midwestreliability.webex.com/midwestreliability/onstage/g.php?MTID=ea482ccb0b7d1c991671ec56cb133a2cd

Event number (access code): 2555 423 6567

Audio Conference information: +1-415-655-0002 US Toll Global call-in numbers

If any help is needed logging into WebEx please reach out to Rebecca Schneider rebecca.schneider@mro.net or Lisa Stellmaker at lisa.stellmaker@mro.net.

Audio
Participants will be muted upon entry and will not be able to unmute themselves to speak.

Questions
If you have questions for a speaker, please utilize Webex's chat feature. Please submit all questions to "MRO Host". If we are unable to get all questions asked/answered during the conference, a response will be provided after the conference either directly to the requestor or through another form of outreach.

Presentations
All presentations from today's conference are available in this packet. The individual presentations and recordings from today's conference will be made available in the near future.

Feedback
Your feedback is very important to us. Please utilize the survey link, also at the end of this packet, to provide your feedback.

AGENDA

Wednesday, May 18, 2022 | 8:30 a.m. to 3:45 p.m. Central

7:30 a.m. – 8:30 a.m.	**Registration and Continental Breakfast**
8:30 a.m. – 8:50 a.m.	**Welcome and Introduction** *Bryan Clark, Director, Reliability Analysis, Midwest Reliability Organization* *Sara Patrick, President and CEO, Midwest Reliability Organization*
8:50 a.m. – 9:10 a.m.	**Conference Logistics** *Emcee: Dallas Rowley, Director System Operations, Oklahoma Gas and Electric*
9:10 a.m. – 9:55 a.m.	**Keynote Speaker – ERO Energy Availability Initiative** *Mark Lauby, Sr. Vice President and Chief Engineer, NERC* *Richard Burt, Sr. Vice President and COO, Midwest Reliability Organization*
9:55 a.m. – 10:15 a.m.	**Morning Break**
10:15 a.m. – 11:00 a.m.	**Grain Belt Express Transmission Project** *Carlos Rodriguez, Sr. Vice President, Interconnections & Grid Analysis, Invenergy*
11:00 a.m. – 11:45 a.m.	**Renewable Energy Grid Integration** *Mark Ahlstrom, VP, Renewable Energy Policy, NextEra Energy Resources*
11:45 a.m. – 12:45 p.m.	**Lunch**
12:45 p.m. – 1:30 p.m.	**MISO/SPP Joint Transmission Planning Projects** *Neil Robertson, Sr. Engineer, Interregional Relations, Southwest Power Pool* *Ben Stearney, Lead, Economic and Policy Planning, MISO*
1:30 p.m. – 2:15 p.m.	**OGE System Zonal Study for Voltage/VAR Control** *Dr. Kevin Ma, Lead Engineer, Transmission Operations Engineering, Oklahoma Gas and Electric*
2:15 p.m. – 2:35 p.m.	**Afternoon Break**
2:35 p.m. – 3:20 p.m.	**Ambient Adjusted Ratings Implementation** *David R. Ball, VP Energy Delivery Operations, American Electric Power*
3:20 p.m. – 3:45 p.m.	**Wrap up/Questions/Feedback/Adjourn** *Emcee: Dallas Rowley, Oklahoma Gas and Electric*

SPEAKER BIOGRAPHIES

Wednesday, May 18, 2022 | 8:30 a.m. to 3:45 p.m.

Bryan Clark

Director, Reliability Analysis, Midwest Reliability Organization

Bryan Clark is the Director of Reliability Analysis. This group is responsible for regional Reliability Assessments, Event Analysis, and Performance Analysis (Data Collection).

Prior to joining MRO in 2018, Bryan spent 8 years with Southwest Power Pool, as a transmission planning engineer, a market operations engineer and a Supervisor of the Day Ahead Operations department. Bryan also worked for Entergy as a Nuclear Operator where he was responsible for monitoring and operating various primary and secondary plant systems at Arkansas Nuclear One (Unit 2).

Bryan has a Bachelor of Science in Engineering from Arkansas State University, is a registered Professional Engineer in Arkansas and Minnesota, and is a member of the National Society of Professional Engineers.

Sara Patrick

President and CEO, Midwest Reliability Organization

Sara Patrick joined MRO in August 2008 as Director Regulatory Affairs and Enforcement and was promoted to Vice President Enforcement and Regulatory Affairs soon after. In 2016 she became the Vice President Compliance Monitoring and Regulatory Affairs, and in June 2018 the MRO Board of Directors named Patrick President and CEO.

Prior to joining MRO, she served as the Director of Government Affairs for Explore Information Services, LLC, a leading service provider to the property and casualty insurance industry. Patrick also served as an Assistant Attorney General for the State of Arizona under both the administration of Janet Napolitano (D) and Grant Woods (R).

Patrick is a graduate of the Lee Honors College of Western Michigan University in Kalamazoo, MI and received her doctor of jurisprudence (J.D.) from the Indiana University School of Law in Bloomington, IN. She is licensed to practice law in Minnesota and Arizona, and is a Certified Information Privacy Professional, Certified Compliance and Ethics Professional, and a member of the Energy Bar Association. Additionally, she completed the University of Idaho Utility Executive Course in June 2013.

Dallas Rowley

Director System Operations, Oklahoma Gas and Electric

Dallas Rowley is the Director System Operations for Oklahoma Gas and Electric (OG&E). Areas of responsibility include the T&D Control Centers, Substation Operations and Engineering Support, T&D Operations Engineering Support, and SCADA EMS/DMS. Previously he worked as Manager System Operations, Area Substation Operations Supervisor, and Protection and Control Technician. Dallas has 15 years of utility operations experience.

In addition, Dallas is member of the MRO RAC.

Mark Lauby

Senior Vice President and Chief Engineer, NERC

Mark G. Lauby is senior vice president and chief engineer at the North American Electric Reliability Corporation (NERC). Mr. Lauby joined NERC in January 2007 and has held a number of positions, including vice president and director of Standards and vice president and director of Reliability Assessments and Performance Analysis.

In 2012, Mr. Lauby was elected to the North American Energy Standards Board and was appointed to the Department of Energy's Electric Advisory Committee by the Secretary of Energy from 2013-2017. He has been recognized for his achievements including the 1992 IEEE Walter Fee Young Engineer of the Year Award. He was named a Fellow by IEEE in November 2011 for "leadership in the development and application of techniques for bulk power system reliability," and in 2014, Mr. Lauby was awarded the IEEE Power and Energy Society's Roy Billinton Power System Reliability Award. In 2020, the National Academy of Engineering (NAE) elected Mr. Lauby as a member.

Prior to joining NERC, Mr. Lauby worked for the Electric Power Research Institute (EPRI) for 20 years. Mr. Lauby began his electric industry career in 1979 at the Mid-Continent Area Power Pool in Minneapolis, Minnesota. Mr. Lauby is the author of more than 100 technical papers. He earned his bachelor's and master's degrees in Electrical Engineering from the University of Minnesota. In addition, Mr. Lauby attended the London Business School Accelerated Development Program, as well as the Executive Leadership Program at Harvard Business School.

Richard Burt

Senior Vice President and COO, Midwest Reliability Organization

Richard Burt joined MRO in February 2012 as a Principal Risk Assessment and Mitigation Engineer and was promoted to Vice President Risk Assessment, Mitigation and Standards in April 2015. In August 2018, he was named Senior Vice President and Chief Operating Officer.

Mr. Burt brings a diverse technical power systems and security background to the leadership team obtained through 14 years of engineering experience at Minnkota Power Cooperative in Grand Forks, ND before joining MRO. He performed project engineering associated with telecommunications, transmission planning studies, control systems, and power quality before transitioning into management roles with responsibility for both the Energy Management System and NERC Compliance Departments.

Mr. Burt attended the University of North Dakota, where he earned a Bachelor of Science degree in Electrical Engineering. Additionally, Mr. Burt completed the University of Idaho Utility Executive Course in 2020. He is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) and the IEEE Power and Energy Society, and has been inducted into both the Eta Kappa Nu and Tau Beta Pi engineering honor societies.

Carlos Rodriguez

Senior Vice President, Interconnections & Grid Analysis, Invenergy

Mr. Carlos Rodriguez is an electrical engineer with 30 years of experience in the power sector. He has been with Invenergy for 16 years, in which he has been involved in the development and electrical interconnection of over 30 GW of generation projects, including wind, solar, storage, natural gas, and high voltage direct current (HVDC). He is currently Senior Vice President of Interconnections and Grid Analysis, and his responsibilities include leading and coordinating the electrical interconnections for Invenergy at a global level, including projects in the U.S., Canada, Latin America, and other parts of the world.

Mark Ahlstrom

VP of Renewable Energy Policy, NextEra Energy Resources
Board President, Energy Systems Integration Group

Mark Ahlstrom is Vice President of Renewable Energy Policy for NextEra Energy Resources and NextEra Analytics. He is also President of the Board of Directors of the Energy Systems Integration Group, the non-profit technical collaboration association for engineers, system operators, researchers and policymakers working on our rapidly transforming energy systems. He serves on NERC's Reliability Issues Steering Committee, chairs the SPP Future Grid Strategy Advisory Group, and has worked for two decades on the reliable integration of variable generation into power systems and markets. Earlier, he was founder of two software companies, CEO of WindLogics, and served on the NERC Essential Reliability Services Working Group and the NERC Integrating Variable Generation Task Force.

Ben Stearney

Lead, Economic Policy and Planning, MISO

Ben Stearney has over 12 years of experience in the energy industry, spanning the regulatory, utility and RTO arenas. During his eight-year tenure at MISO, Ben has worked extensively in interregional planning coordination and strategy, including overseeing multiple Coordinated System Plan studies, updating Joint Operating Agreements, developing regional and interregional cost allocation policy, and, most recently, assisting in the development of the MISO-SPP Joint Targeted Interconnection Queue study. He currently serves as a Lead in MISO's economic planning group, which evaluates congestion issues through production cost analysis.

Ben received his BSEE degree from the University of Minnesota in 2010.

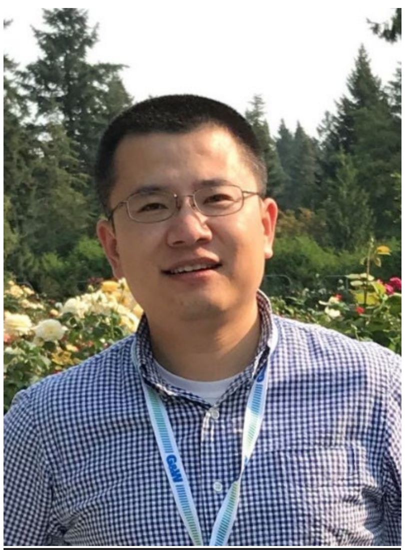
Neil Robertson

Senior Engineer, Interregional Relations, Southwest Power Pool

As a senior engineer of interregional relations, Neil Robertson primarily supports coordinated transmission planning activities between SPP and its neighboring entities.

Robertson previously served as an operations engineer at SPP from 2006 to 2019 supporting multiple operations functions including reliability coordination, balancing authority and market operations.

Robertson earned a Bachelor of Science degree in Electrical Engineering from Arkansas Tech University.



Dr. Feng (Kevin) Ma

Lead Engineer, Transmission Operations Engineering, Oklahoma Gas and Electric

Dr. Feng (Kevin) Ma is a Lead Transmission Operations Engineer with Oklahoma Gas & Electric (OG&E). He has more than 10 years of experience in the electric power industry. He received his Ph.D. degree in Electrical Engineering with a concentration on power system engineering from Arizona State University in 2011. His current role focuses on EMS modeling improvement, application development, process automation and enhancement, and engineering support to transmission system operations (e.g., ad-hoc steady state and dynamic studies).

Prior to joining OG&E, Kevin was with the Department of Business Architecture and Technology at ISO New England from 2011 through 2015, where he led the development of the online Transient Stability Assessment (TSA) system and the first of its kind cloud-based simulation platform. Kevin is a registered Professional Engineer in Oklahoma and a registered Project Management Professional. He is also a Senior Member of IEEE.

David R. Ball

VP Energy Delivery Operations, American Electric Power

David R. Ball is Vice President of Energy Delivery Operations at American Electric Power. He is responsible for Operations Centers and personnel in New Albany, Ohio; Roanoke, Virginia; Shreveport, Louisiana; Dallas, Texas; Columbus, Ohio and Corpus Christi, Texas. The AEP Transmission Operations team includes dispatching, real-time reliability, operational technology, settlements, field meter operations, compliance and operator/dispatcher training. In December 2020, David assumed responsibility of the Distribution Real Time Operations staff, the Distribution Dispatch Operational tools (D SCADA, OMS, DMS and ADMS), AEP Emergency Response and AEP Mutual Assistance.

David earned a BSEE degree in Electrical Engineering from West Virginia University Institute of Technology and an MBA degree from Marshall University. Additionally, he completed the Ohio State University Executive Leadership Program in 2008 and the University of Virginia Executive Program in 2019. David is a registered Professional Engineer in the state of Ohio.

PRESENTATIONS

All presentations for today's conference are included in order of presentation.

MRO 2022 Annual Reliability Conference

Disclaimer

Midwest Reliability Organization (MRO) is committed to providing outreach, training, and non-binding guidance to industry stakeholders on important industry topics. Subject Matter Experts (SMEs) from MRO's organizational groups and the industry may develop materials, including presentations, provided as a part of the event. The views expressed in the materials are those of the SMEs and do not necessarily express the opinions and views of MRO.

MRO 2022 Regional Risk Assessment

MIDWEST RELIABILITY ORGANIZATION

Top risks to the reliable and secure operation of the North American bulk power system in MRO's regional footprint.

Top Reliability Risks

Uncertainty of Winter Planning Reserve Margins

Analyses of recent system events indicate that actual system conditions can and have exceeded forecast winter reserve margins, particularly during cold weather conditions in the south central U.S.

Generation Availability During Severe Cold Weather

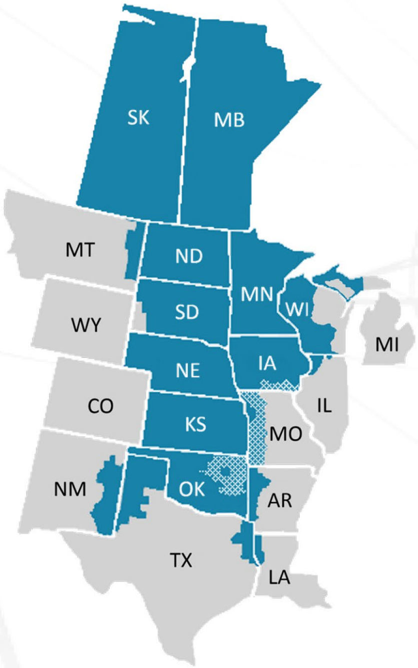
Generation availability assumed during cold weather in the southern U.S. has been shown to be unrealistically high due to a lack of generator winterization and natural gas curtailments.

Lack of Energy Assurance Assessments

The rapidly changing resource mix requires rethinking the way in which generating capacity, energy supply, and load serving needs are studied. Energy assurance will need to be accurately assessed for all hours of the year with increasing reliance on wind and solar as a fuel source.

Bulk Power System Modeling Accuracy

The rapid increase in inverter-based resources, along with the changing characteristics and magnitude of load related to distributed energy resources (DER), is challenging current bulk power models.



Top Security Risks

Supply Chain Compromise

The risk of a cybersecurity event carried out through the vendor supply chain and possibly impacting reliability of the bulk power system remains high.

Insider Threats

The threat of an employee or a contractor using authorized access, wittingly or unwittingly, to do harm to the security of the bulk power system has increased given remote connectivity during the pandemic.

Malware and/or Ransomware

Vulnerability to a malware and/or ransomware attack on the bulk power system continues to increase with modernization and the deployment of new technologies.

More information on these risks along with mitigation recommendations can be found in the full report here: www.mro.net

Electric Reliability Organization: Reliability Risk Mitigation Toolkit

Reliability Guideline

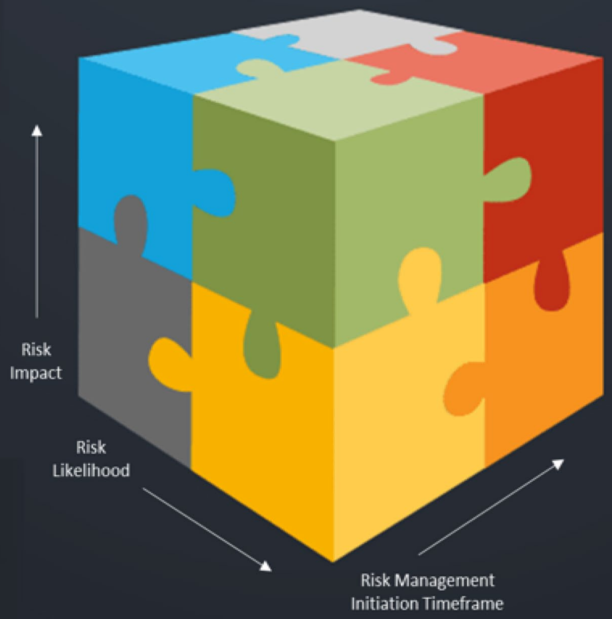
Suggested approaches or behavior in a given technical area for the purpose of improving reliability. Guidelines are not enforceable, but may be adopted by a responsible entity in accordance with its own policies, practices, and conditions.

NERC Alert: Level 2-3

NERC alerts are divided into three distinct levels, 1) Industry Advisory, 2) Recommendation to Industry, and 3) Essential Action, which identifies actions to be taken and require the industry to respond to the ERO.

Technical Engagement

Technical Engagement is a catch-all for a variety of technical activity that is conducted between the ERO and entities. This includes, technical committee activities, technical reference documents, workshops and conferences, assist visits, joint and special studies, etc.



Reliability Standards

NERC Reliability Standards define the mandatory reliability requirements for planning and operating the North American BPS and are developed using a results-based approach focusing on performance, risk management, and entity capabilities.

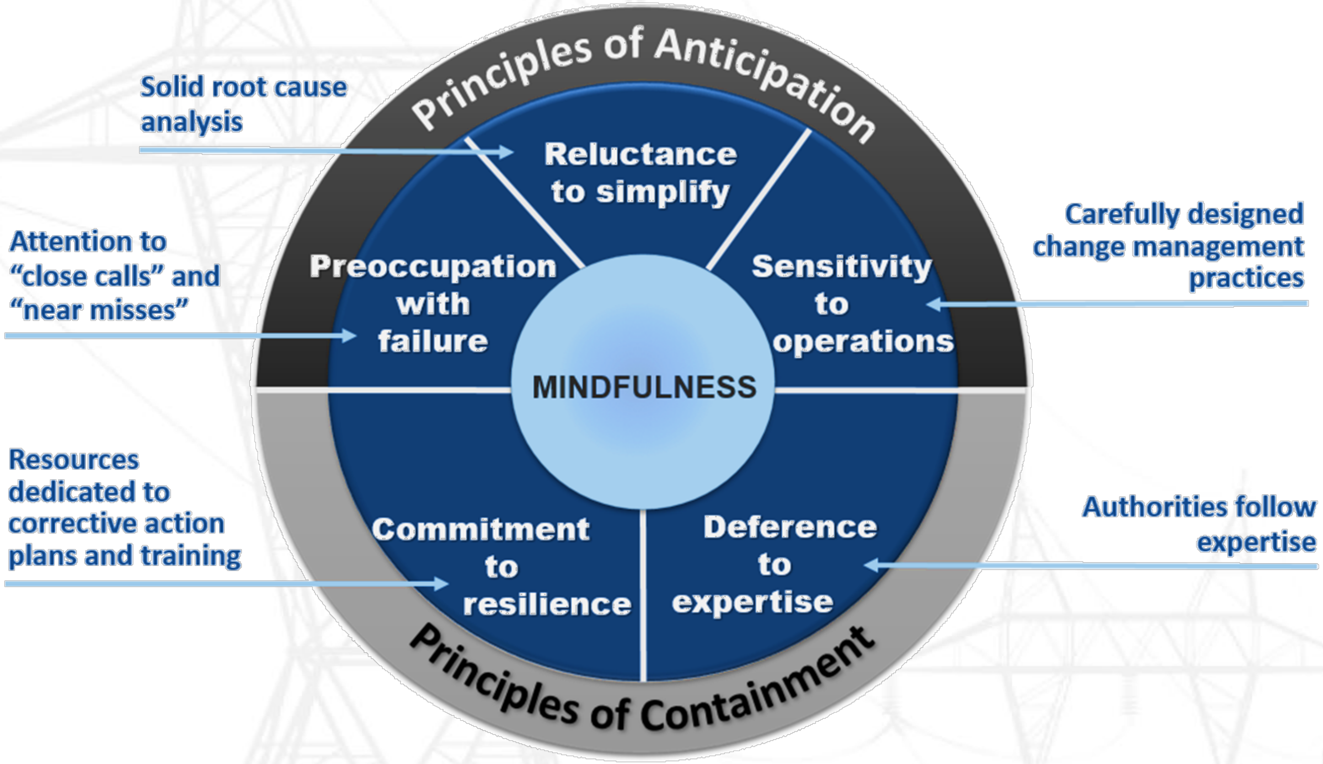
Reliability Assessment

NERC independently assesses and reports on the overall reliability, adequacy, and associated risks that could impact BPS reliability. Long-term assessments identify emerging reliability issues that support public policy input, improved planning and operations, and general public awareness.

NERC Alert: Level 1

NERC Alerts are divided into three distinct levels, 1) Industry Advisory, 2) Recommendation to Industry, and 3) Essential Action, which identifies actions to be taken and require the industry to respond to the ERO.

Key Characteristics of HEROs



RAC Support

- MRO Regional Seasonal Assessment
- Ranking of Regional Risks
- MRO Regional Risk Assessment
- Conferences and Webinars

Assessing and Mitigating Regional BPS Risk

Reliability Conference, May 18, 2022

Sara Patrick

President and CEO

Sara Patrick joined MRO in August 2008 as Director Regulatory Affairs and Enforcement and was promoted to Vice President Enforcement and Regulatory Affairs soon after. In 2016 she became the Vice President Compliance Monitoring and Regulatory Affairs, and in June 2018 the MRO Board of Directors named Patrick President and CEO.

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Patrick is a graduate of the Lee Honors College of Western Michigan University in Kalamazoo, MI and received her doctor of jurisprudence (J.D.) from the Indiana University School of Law in Bloomington, IN. She is licensed to practice law in Minnesota and Arizona, and is a Certified Information Privacy Professional, Certified Compliance and Ethics Professional, and a member of the Energy Bar Association. Additionally, she completed the University of Idaho Utility Executive Course in June 2013.

A highly reliable and secure North American bulk power system.

Our Shared Vision

The ERO Enterprise

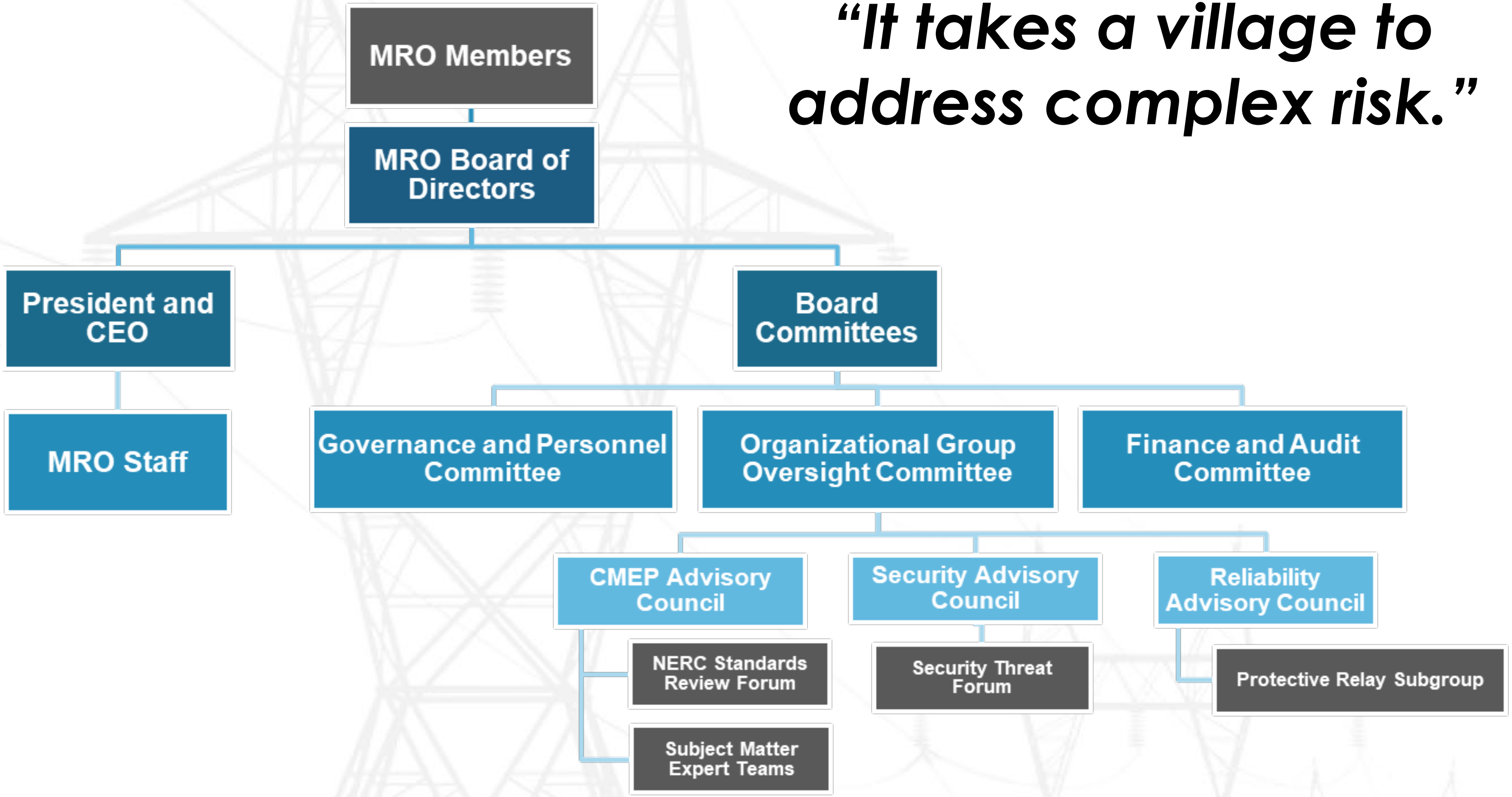
- **The ERO Enterprise offers a unique, wide-area view of risk across North America**
  - Rapidly evolving resource mix
  - Energy assurance
  - Extreme weather events
  - Cyber and physical security
  - Supply chain vulnerabilities
  - Bulk power system modeling accuracy

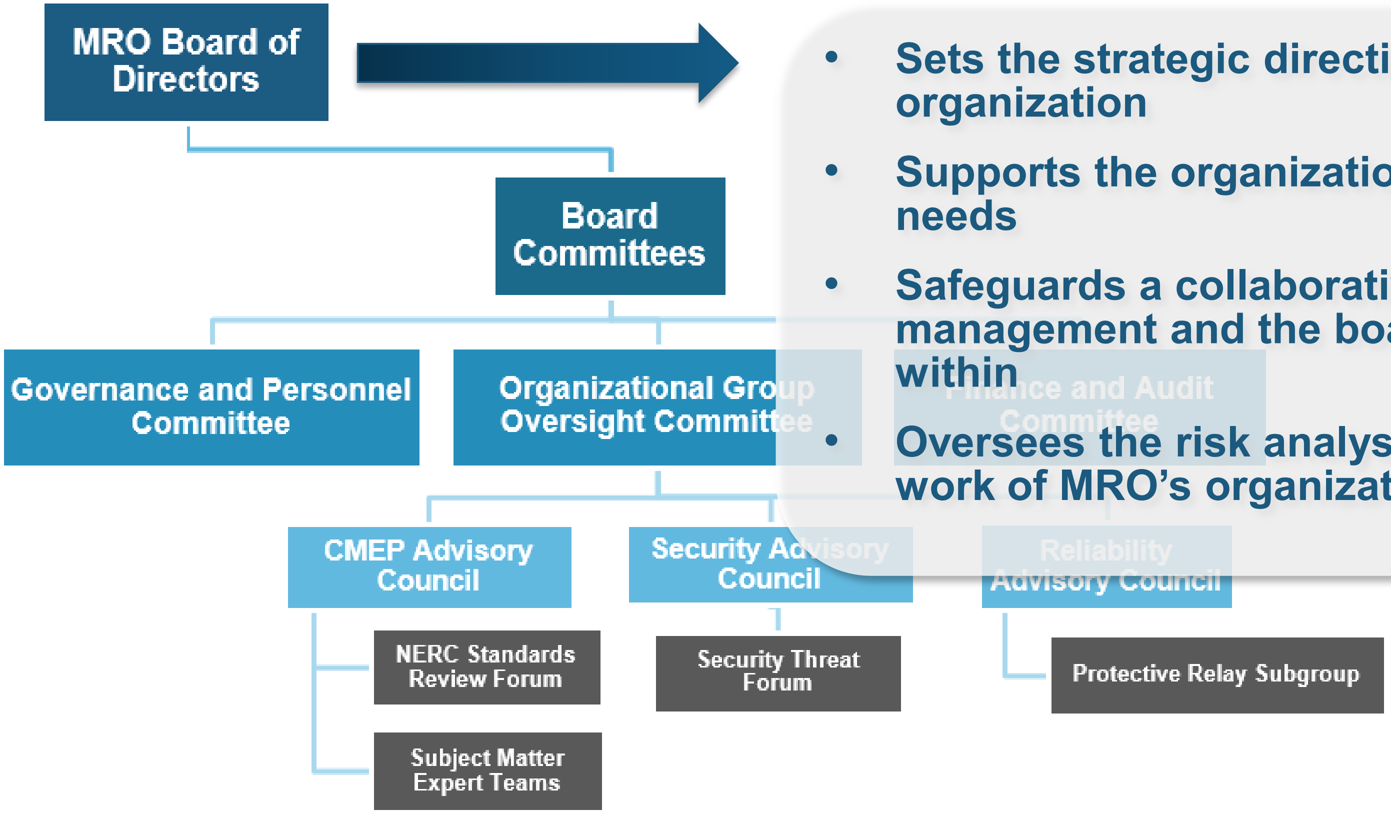
MRO's Value Proposition

- **As part of the ERO, MRO offers a targeted, regional view of risk**
  - Winter planning reserve margins
  - Generation availability during severe cold weather
  - Lack of energy assurance assessments
  - Supply chain vulnerabilities
  - Insider threats, malware and ransomware
  - Bulk power system modeling accuracy

MRO Value Proposition – Bridging the Gap

“It takes a village to address complex risk.”





- Sets the strategic direction of the organization
- Supports the organization’s mission and needs
- Safeguards a collaborative setting for management and the board to work within
- Oversees the risk analysis and mitigation work of MRO’s organizational groups

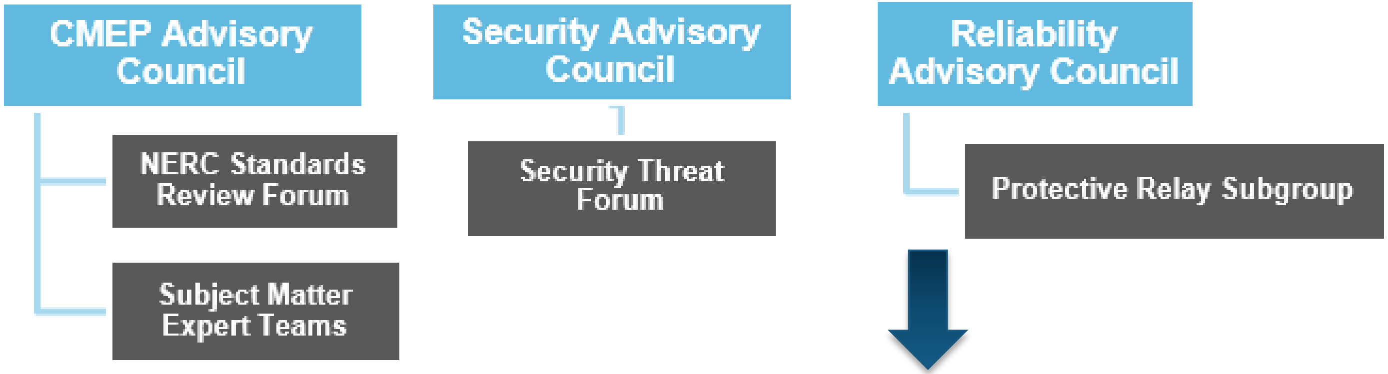
Role of the MRO Board

Role of MRO Leadership and Staff

- MRO Board of Directors
  - President and CEO
    - MRO Staff
  - Board Committees
    - Governance and Personnel Committee
    - Organizational Group Oversight Committee
    - Finance and Audit Committee

- Facilitates strategic planning process, using the RRA and current environment as primary inputs
- Ensures vision, mission and values are put into practice
- Implements strategic plan and promotes regional reliability and security perspectives
- Enables collaboration and coordination across multiple stakeholders to address regional risk
- Tracks and reports progress on strategic and business objectives to the board

Role of MRO Org Groups and the RAC



- **Helps to identify, assess and determine mitigation strategies for regional risk; provides input to the RRA**
  - Supports the preparation of special assessments and seasonal readiness plans by regional Reliability Coordinators
  - Reviews bulk power system events to identify trends and lessons learned
  - Develops guidance and promotes best practices to address reliability risks to the regional bulk power system
  - Expands outreach efforts that help registered entities become more aware of and reduce risk to their individual systems

RAC Roster

Our Future Is BRIGHT!

Name	Role	Company	Term End
Dick Pursley	Chair	Great River Energy	12/31/2022
Jason Weiers	Vice Chair	Otter Tail Power Company	12/31/2024
Andrew Witmeier	Member	MISO	12/31/2024
Binod Shrestha	Member	Saskatchewan Power Corporation	12/31/2022
CJ Brown	Member	Southwest Power Pool, Inc.	12/31/2024
Dallas Rowley	Member	Oklahoma Gas and Electric	12/31/2022
Derek Brown	Member	Evergy, Inc.	12/31/2023
Durgesh Manjure	Member	MISO	12/31/2023
Dwayne Stradford	Member	American Electric Power	12/31/2024
Gayle Nansel	Member	Western Area Power Administration	12/31/2022
Jeremy Severson	Member	Basin Electric Power Cooperative	12/31/2024
John Stephens	Member	City Utilities of Springfield, Missouri	12/31/2023
Nandaka Jayasekara	Member	Manitoba Hydro	12/31/2022
Ron Gunderson	Member	Nebraska Public Power District	12/31/2023
W. Bryn Wilson	Member	Oklahoma Gas and Electric	12/31/2023

Conference Logistics

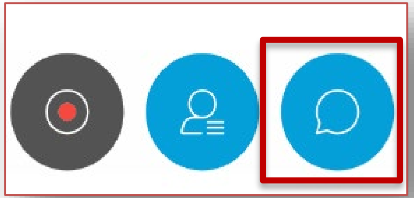
Dallas Rowley

Director of System Operations, Oklahoma Gas & Electric

MRO 2022 Reliability Conference Emcee

WebEx Chat Feature

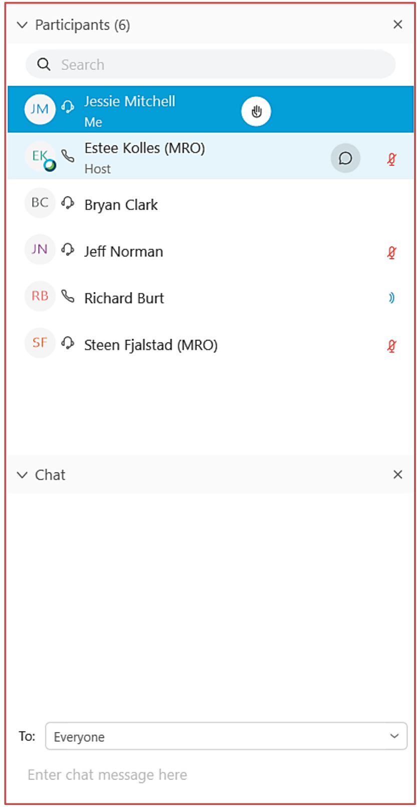
Open the Chat Feature:



The chat feature will appear to the right of the WebEx window.

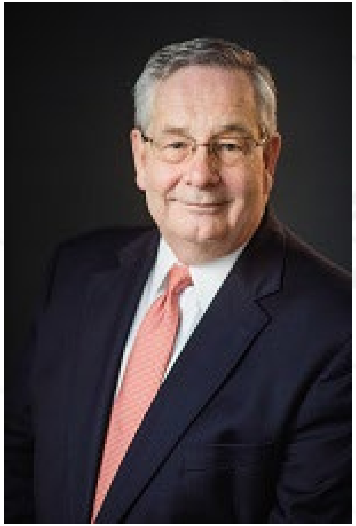
Attendees should chat their questions to: “MRO Host”.

Select MRO Host by using the drop down arrow in the “To” field.



Energy Availability

2022 MRO Reliability Conference



Mark Lauby

NERC Senior Vice President and Chief Engineer

Mr. Lauby joined NERC in January 2007 and has held a number of positions, including vice president and director of Standards and vice president and director of Reliability Assessments and Performance Analysis.

In 2012, Mr. Lauby was elected to the North American Energy Standards Board and was appointed to the Department of Energy's Electric Advisory Committee by the Secretary of Energy from 2013-2017. He has been recognized for his achievements including the 1992 IEEE Walter Fee Young Engineer of the Year Award. He was named a Fellow by IEEE in November 2011 for "leadership in the development and application of techniques for bulk power system reliability," and in 2014, Mr. Lauby was awarded the IEEE Power and Energy Society's Roy Billinton Power System Reliability Award. In 2020, the National Academy of Engineering (NAE) elected Mr. Lauby as a member.

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Richard Burt

MRO Senior Vice President and Chief Operating Officer

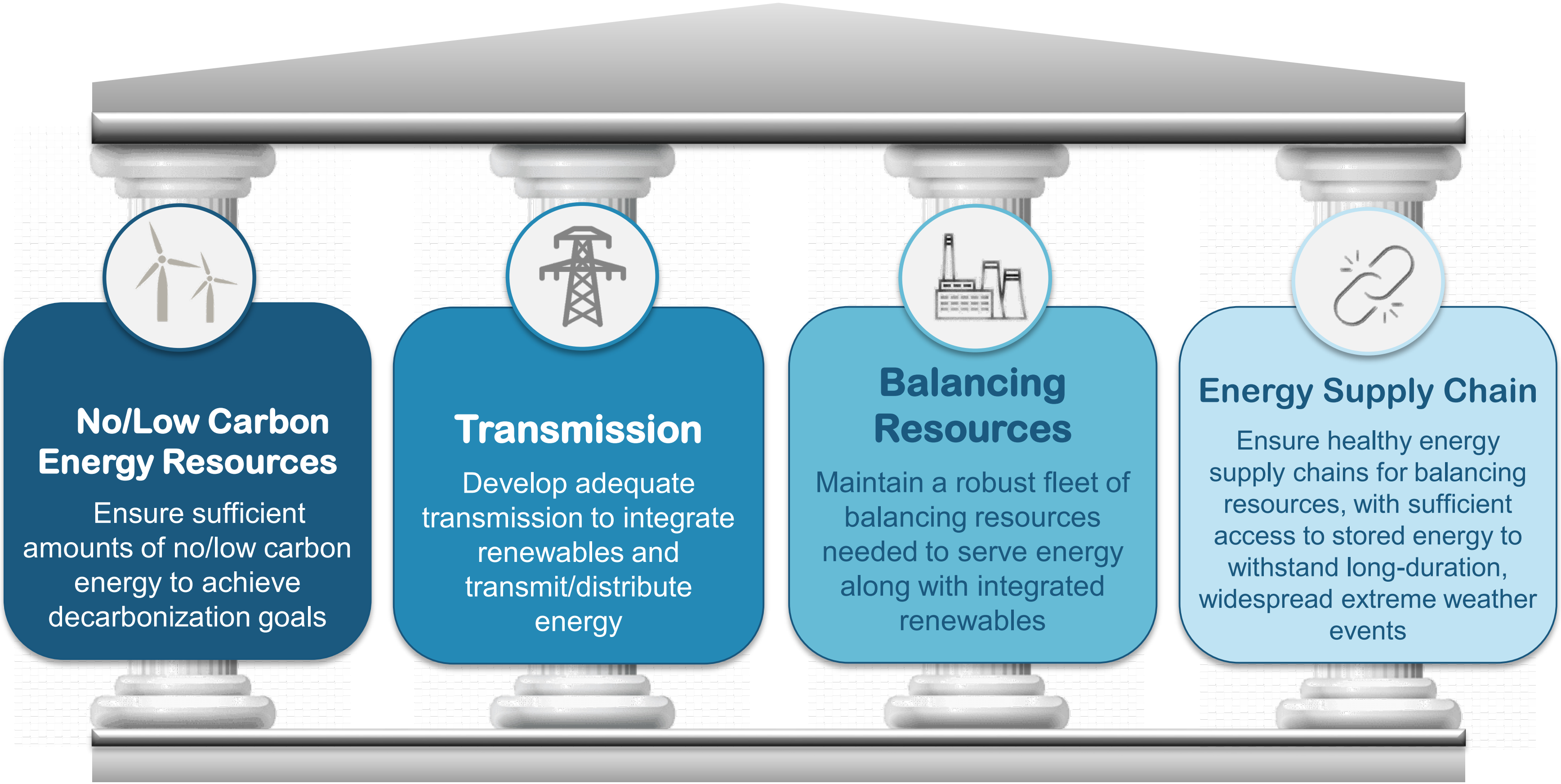
As chief operating officer, Richard Burt leads the organization’s industry-facing efforts with regard to reliability and security initiatives that strengthen the bulk power system in MRO’s regional footprint. As an engineer with technical experience in telecommunications, transmission planning studies, control systems, power quality, and security, Burt acts as liaison to the board’s Organizational Group Oversight Committee (OGOC). The OGOC is tasked with implementing the board’s vision of a stakeholder structure that effectively and efficiently supports MRO’s mission to “identify, prioritize and assure effective and efficient mitigation of risks to the reliability and security of the North American bulk power system by promoting Highly Effective Reliability Organizations (HEROs).

Burt joined MRO in February 2012 as principal risk assessment and mitigation engineer and was soon after promoted to vice president risk assessment and mitigation and standards in April 2015. In August 2018, he was named senior vice president and chief operating officer.

He brings a diverse technical power systems background to MRO’s leadership team obtained through 14 years of industry experience. Burt earned his Bachelor of Science degree in Electrical Engineering from the University of North Dakota, and has also completed the University of Idaho Utility Executive Course. He is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) and the IEEE Power and Energy Society.

Energy Transition Underway

- **The following drivers have led to rapid changes in energy resources:**
  - Governmental policies
  - Changes in resource economics
  - Consumer demand for clean energy
- **In addition to the shift in resources, an increase in extreme weather presents new challenges**
  - Fuel sources are inherently less secure



Four Pillars of the Energy Transition

The Challenge: Sufficient Energy Availability

The Challenge: Sufficient Energy Availability

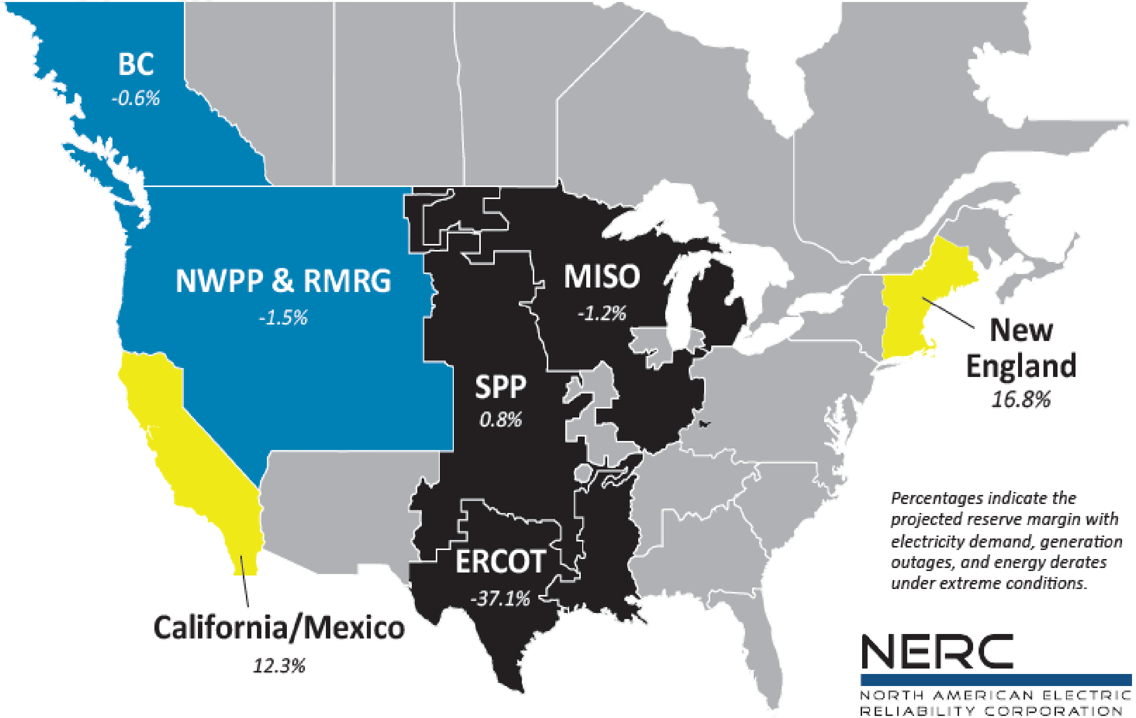
- **Power grid transition is resulting in a <u>higher level of energy uncertainty</u>, regardless of fuel type**
  - The current tools, rules of thumb, and approaches used to determine the system's ability to meet demand were not designed for today's grid
- **The focus needs not be on fuel type, but rather on *energy availability***

- Rapidly changing generation fleet
- Increasing electrification
- Widespread, long-duration, extreme weather events
- Historically, industry ensured energy through capacity and reserve margins with assurance of fuel

Considerations in Solving This Challenge

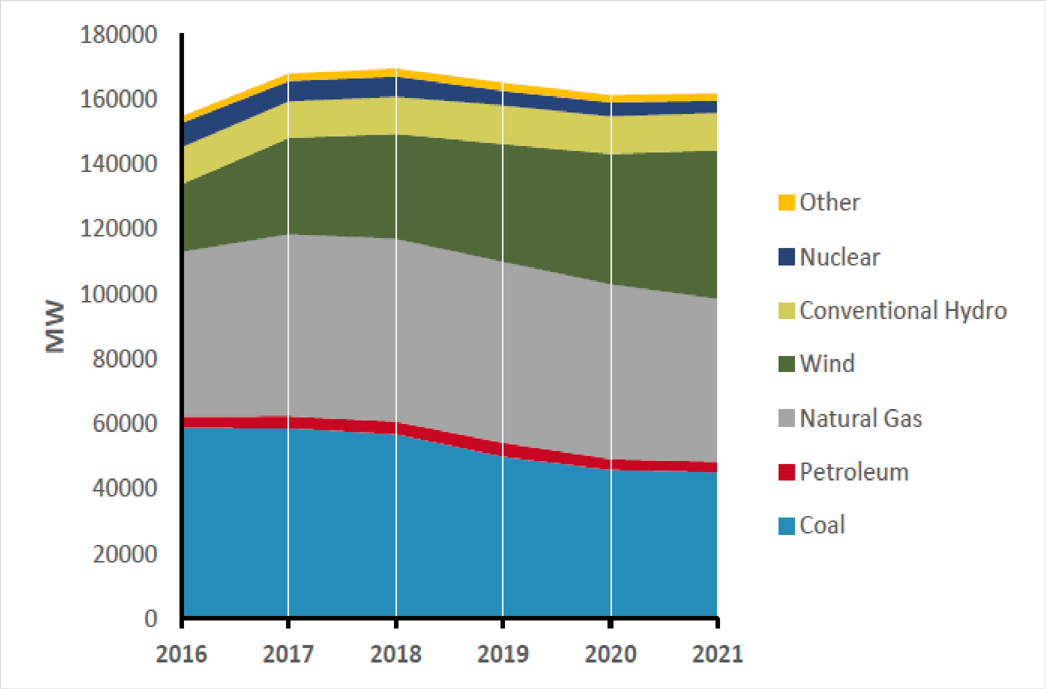
Planning Reserve Margins

Forecasted 2021/2022 Winter PRMs	
MISO	SPP
49%	56%

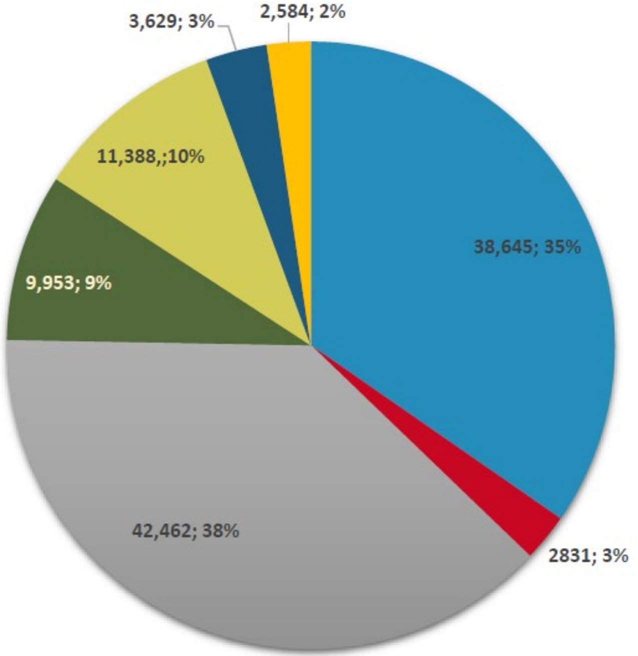


Regional Generation Changes

MRO Nameplate vs. Capacity



Nameplate



Capacity

ERO Capacity vs. Load

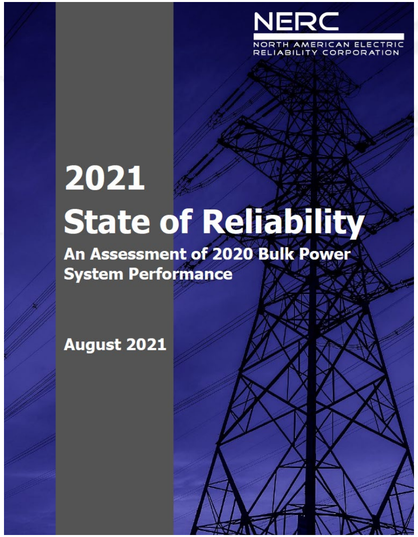


Table 5.1: Generation Resource Capacity by Fuel Type

Generation Fuel Type	2010 On-Peak		2020 On-Peak	
	GW	Percent	GW	Percent
Coal	294.9	27.7%	235.9	22.6%
Natural Gas	417.7	39.2%	447.2	42.9%
Hydro	165.6	15.5%	140.7	13.5%
Nuclear	114.0	10.7%	110.1	10.6%
Oil	27.8	2.6%	40.2	3.9%
Wind	17.0	1.6%	24.7	2.4%
Solar	0.0	0.0%	21.4	2.1%
Other	28.9	2.7%	22.2	2.1%
Total:	1,065.8	100.0%	1,042.5	100.0%

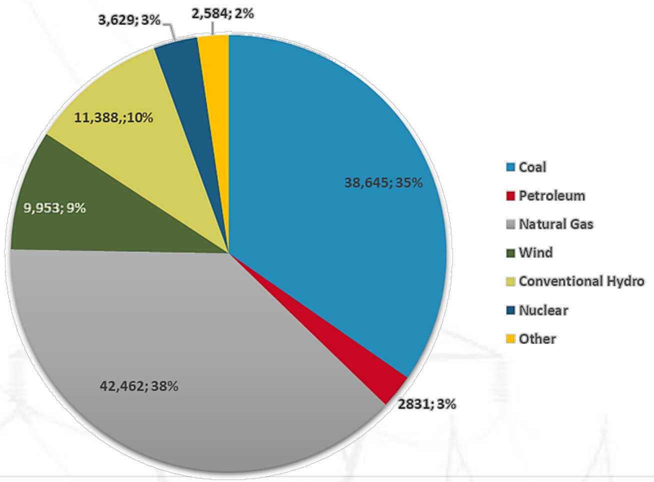
Installed wind nameplate = 122 GW in 2020, yet accredited wind capacity at peak load is 24.7 GW (or 2.4% of total resource capacity).

Total capacity has dropped by 23 GW from 2010 to 2020, however total load has increased by about 85 GW in the same 10 years.

Capacity ≠ Energy

- **Across North America, from 2010-2020:**
  - Load has grown 85 GW while CAPACITY has dropped by 23 GW
  - 2020 Wind Capacity was 2.4% of total (9% in wind-heavy MRO)

Area	2020-21 Winter Nameplate (MW)	2021-22 Winter Nameplate (MW)	2021-22 Winter Peak Capacity (MW)
MH	259	259	52
MISO (MRO)	26,064	28,447	4,561
SPC	241	627	85
SPP	23,546	27,535	6,334



Influx of Solar is Coming to MRO

Solar and Wind Nameplate Capacity, Existing and Planned Additions through 2031										
Assessment Area	Nameplate MW of Solar					Nameplate MW of Wind				
	Existing	Tier 1	Tier 2	Tier 3	Total	Existing	Tier 1	Tier 2	Tier 3	Total
MISO	728	10,989	53,756	4,907	**70,380**	22,854	5,593	14,649	730	**43,826**
MH	0	0	0	0	**0**	259	0	0	0	**259**
SPC	2	10	10	57	**79**	242	385	200	100	**927**
SPP	278	444	32,170	149	**33,041**	27,535	4,604	16,892	0	**49,031**
Total	1,008	11,443	85,936	5,113	**103,500**	50,890	10,582	31,741	830	**94,043**

Existing Solar
1,008 MW

Queued Solar: 102,492 MW

Existing Wind
50,890 MW

Future Wind: 43,153

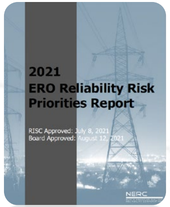
Assessing Regional Risk

- **MRO staff and the three MRO advisory councils collaborate to:**
  - Identify risks that may have a higher probability of occurrence and/or impact within the MRO region
  - Assess the resulting risks in terms of impact and likelihood, using the MRO Reliability Risk Matrix

Reliability Risk Matrix						
Consequence/Impact (C)		Likelihood (L)				
		L1	L2	L3	L4	L5
		Very Unlikely	Unlikely	Possible	Likely	Almost Certain
C5	Severe	Medium	High	High	Extreme	Extreme
C4	Major	Medium	Medium	High	High	Extreme
C3	Moderate	Low	Medium	High	High	High
C2	Minor	Low	Low	Medium	Medium	High
C1	Negligible	Low	Low	Low	Medium	Medium

Consequence/Impact –How could a typical event due to this risk effect BPS Reliability?	
Severe (C5)	Impacts may have widespread effects to the BPS across North America.
Major (C4)	Impacts may have widespread effects to the RC area.
Moderate (C3)	Impacts may have widespread effects to portions of the RC area.
Minor (C2)	Impacts may have effects on the local entity.
Negligible (C1)	Impacts may have small or non-existent effects to the BPS.
Likelihood – What is the reasonable probability that consequences will occur?	
Almost Certain (L5)	Mandatory Controls – No NERC reliability standards in place for mitigation. Emerging Trends – Increasing trends have been identified. Event History – Documented events or widely publicized exploits have been recorded.
Likely (L4)	Mandatory Controls – No NERC reliability standards in place for mitigation. Emerging Trends – Some trends have been identified. Event History – Documented events or generally publicized exploits have been recorded.
Possible (L3)	Mandatory Controls – NERC reliability standards in place for limited mitigation. Emerging Trends – Some trends have been identified. Event History – No documented events, or moderately publicized exploits have been recorded.
Unlikely (L2)	Mandatory Controls – NERC reliability standards are in place for mitigation. Emerging Trends – Some trends have been identified. Event History – No documented events, or minimally publicized exploits have been recorded.
Very Unlikely (L1)	Mandatory Controls – NERC reliability standards are in place for mitigation. Emerging Trends – No known trends identified. Event History – No documented events or publicized exploits have been recorded.

Correlation Between MRO and Continent-Wide Risks



Changing Resource Mix	Resource Adequacy and Interdependencies	Extreme Natural Events	Bulk Power System Planning	Protection System Complexity and Human Performance
Bulk Power Modeling Accuracy	Generation Availability During Cold Weather	Uncertainty of Winter Reserve Margins	Bulk Power Modeling Accuracy	Misoperations Due to Commissioning Errors
Reactive Resource Adequacy	Reactive Resource Adequacy	Cold Weather Operation of SF6 Breakers	Reactive Resource Adequacy	
Lack of Energy Assurance Assessments	Lack of Energy Assurance Assessments	Generation Availability During Cold Weather	Lack of Energy Assurance Assessments	
	Inverter Based Resource Capabilities	Transmission Line Ratings During Cold Weather		

2022 Prioritized Regional Risks

Security

- Supply Chain Compromise
- Insider Threat
- Ransomware/Malware

Reliability

- Lack of Energy Assurance Assessments
- Generation Availability During Cold Weather
- Uncertainty of Winter Planning Reserve Margins
- BPS Modelling Accuracy

Mid-to-Long Term (1-5 years)

- Ensure that resources are planned that can provide options to obtain sufficient and flexible energy resources
- Review tools, rules-of-thumb and processes to support the need for these energy resources

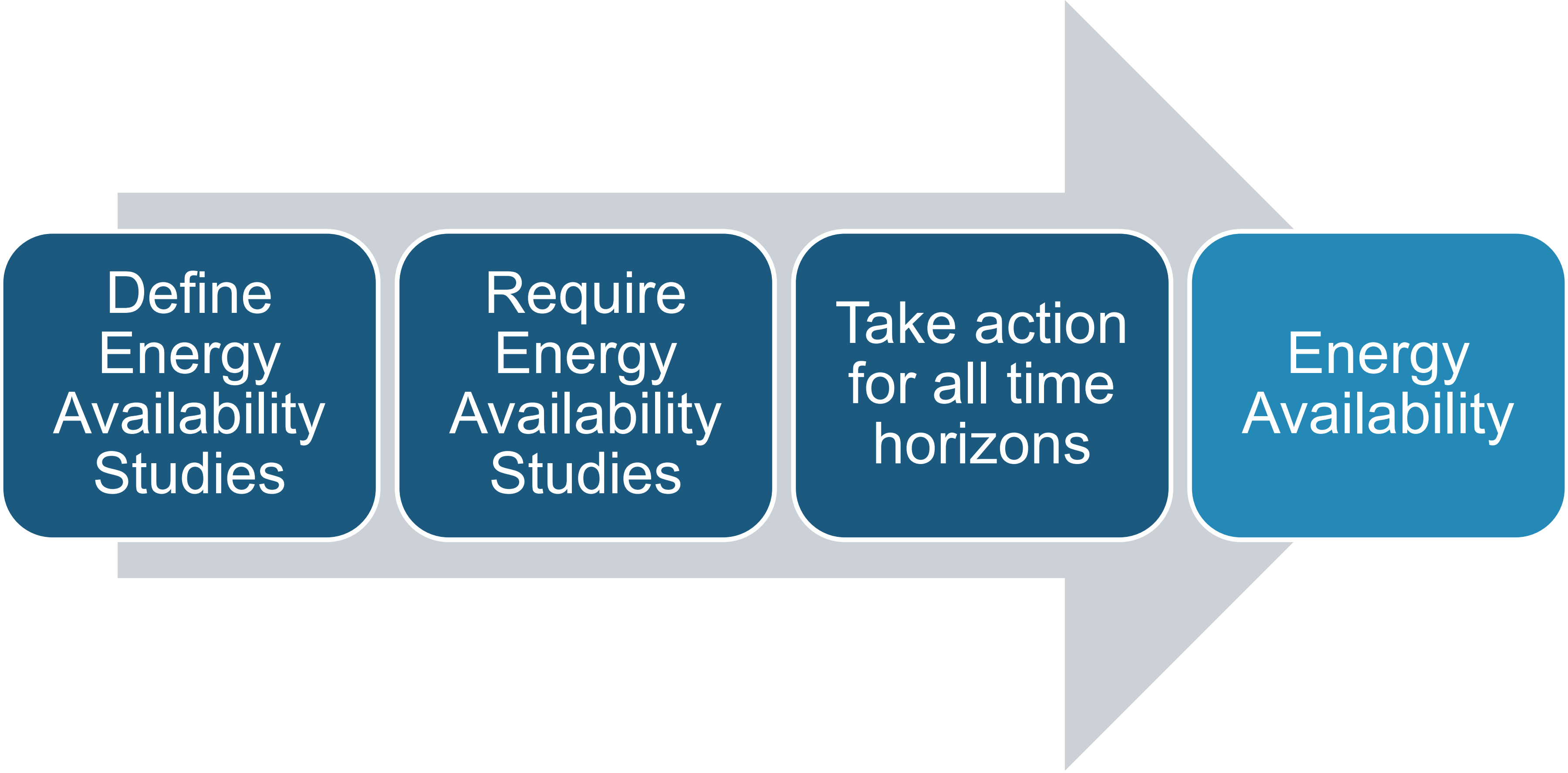
Operational Planning (1 day – 1 year)

- Ensure sufficient resources are available and able to provide energy to meet demand and off-set ramping requirements
- Electrical energy production needs to reflect status of energy availability given the uncertainties

Real-Time (0-1 day)

- Ensure sufficient amounts of capacity, energy, and ramp flexibility are available from available resources

Energy Availability in 3 Timeframes



What MUST Be Done?

Electric Reliability Organization: Reliability Risk Mitigation Toolkit

Reliability Guideline

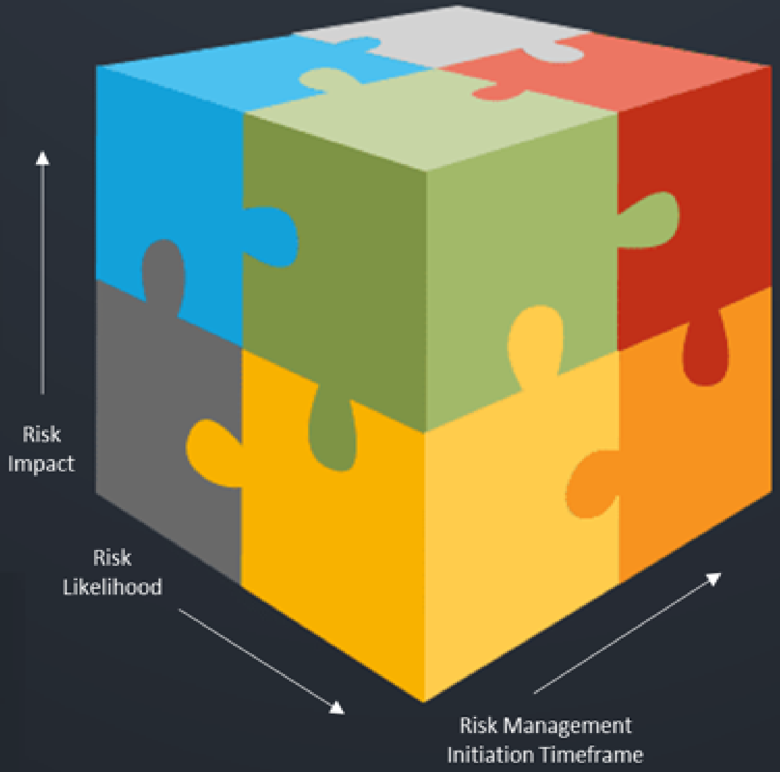
Suggested approaches or behavior in a given technical area for the purpose of improving reliability. Guidelines are not enforceable, but may be adopted by a responsible entity in accordance with its own policies, practices, and conditions.

NERC Alert: Level 2-3

NERC alerts are divided into three distinct levels, 1) Industry Advisory, 2) Recommendation to Industry, and 3) Essential Action, which identifies actions to be taken and require the industry to respond to the ERO.

Technical Engagement

Technical Engagement is a catch-all for a variety of technical activity that is conducted between the ERO and entities. This includes, technical committee activities, technical reference documents, workshops and conferences, assist visits, joint and special studies, etc.



Reliability Standards

NERC Reliability Standards define the mandatory reliability requirements for planning and operating the North American BPS and are developed using a results-based approach focusing on performance, risk management, and entity capabilities.

Reliability Assessment

NERC independently assesses and reports on the overall reliability, adequacy, and associated risks that could impact BPS reliability. Long-term assessments identify emerging reliability issues that support public policy input, improved planning and operations, and general public awareness.

NERC Alert: Level 1

NERC Alerts are divided into three distinct levels, 1) Industry Advisory, 2) Recommendation to Industry, and 3) Essential Action, which identifies actions to be taken and require the industry to respond to the ERO.

Electric Industry

Energy Planning

- Metric and Scenario Development
- Climatology Data
- Fuel Assessment
- Power System Research

Energy Assessment

- Metric Evaluation
- Probabilistic Energy Analysis
- Criteria Determination

Regulatory and Policy

- Independent Assessment
- Reliability Standards
- Power Supply Authority

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Reliability and Security Technical Committee

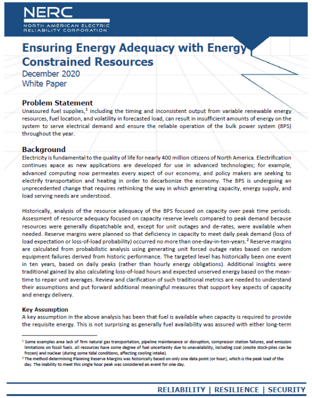
Reliability Issues Steering Committee

Partners to Get Us There

New NERC Industry Group

Energy Reliability Assessments Task Force (ERATF)

Utilities	ISOs/RTOs	EPRI	Manufacturers	ERO


NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Ensuring Energy Adequacy with Energy Constrained Resources
December 2020
White Paper

Problem Statement
Unassured fuel supplies,[1] including the timing and inconsistent output from variable renewable energy resources, fuel location, and volatility in forecasted load, can result in insufficient amounts of energy on the system to serve electrical demand and ensure the reliable operation of the bulk power system (BPS) throughout the year.

Background
Electricity is fundamental to the quality of life for nearly 400 million citizens of North America. Electrification continues apace as new applications are developed for use in advanced technologies; for example, advanced computing now permeates every aspect of our economy, and policy makers are seeking to electrify transportation and heating in order to decarbonize the economy. The BPS is undergoing an unprecedented change that requires rethinking the way in which generating capacity, energy supply, and load serving needs are understood.

Historically, analysis of the resource adequacy of the BPS focused on capacity over peak time periods. Assessment of resource adequacy focused on capacity reserve levels compared to peak demand because resources were generally dispatchable and, except for unit outages and de-rates, were available when needed. Reserve margins were planned so that deficiency in capacity to meet daily peak demand (loss of load expectation or loss-of-load probability) occurred no more than one-day-in-ten-years.[2] Reserve margins are calculated from probabilistic analysis using generating unit forced outage rates based on random equipment failures derived from historic performance. The targeted level has historically been one event in ten years, based on daily peaks (rather than hourly energy obligations). Additional insights were traditional gained by also calculating loss-of-load hours and expected unserved energy based on the mean-time to repair unit averages. Review and clarification of such traditional metrics are needed to understand their assumptions and put forward additional meaningful measures that support key aspects of capacity and energy delivery.

Key Assumption
A key assumption in the above analysis has been that fuel is available when capacity is required to provide the requisite energy. This is not surprising as generally fuel availability was assured with either long-term

[1] Some examples area lack of firm natural gas transportation, pipeline maintenance or disruption, compressor station failures, and emission limitations on fossil fuels. All resources have some degree of fuel uncertainty due to unavailability, including coal (onsite stock-piles can be frozen) and nuclear (during some tidal conditions, affecting cooling intake).
[2] The method determining Planning Reserve Margins was historically based on only one data point (or hour), which is the peak load of the day. The inability to meet this single hour peak was considered an event for one day.

RELIABILITY | RESILIENCE | SECURITY

Industry Input Received

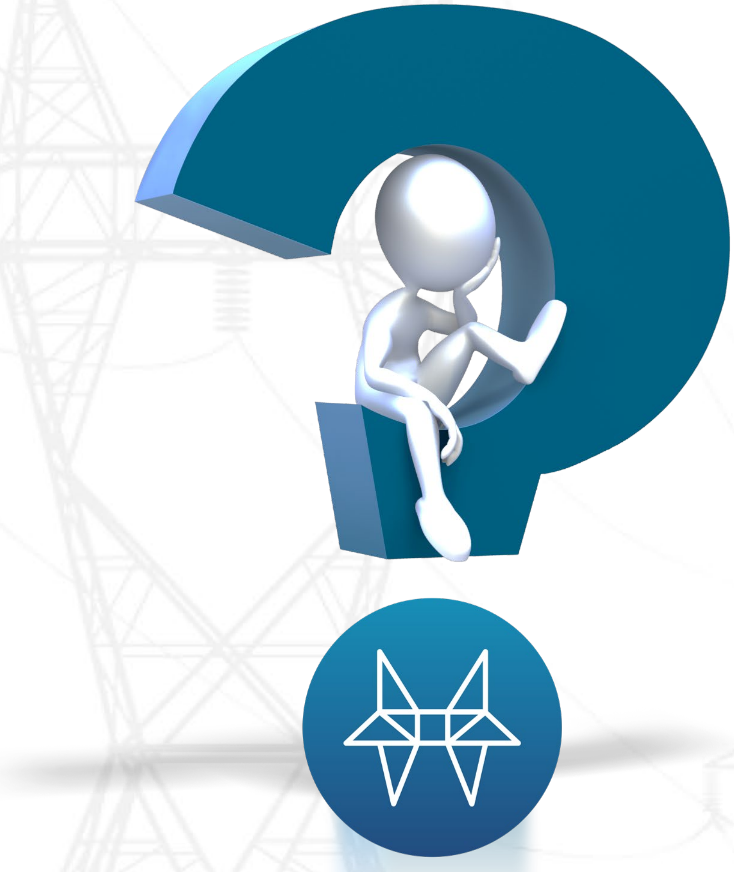
- What do we do with high impact, low likelihood energy assessments?
- Energy assessments need to be performed throughout the year, not just for peak cases
- Geographical nuances to reliability issues related to energy availability
- Dependency on other critical infrastructure is a key aspect of this risk, and there is a likely need to model fuel infrastructure
- Need to create metrics and criteria for energy assessments
- Assumptions used in studies must be a focus, and various scenarios considered including extreme events
- Assessments need to be considered in the operational timeframe as well, not just long-term planning

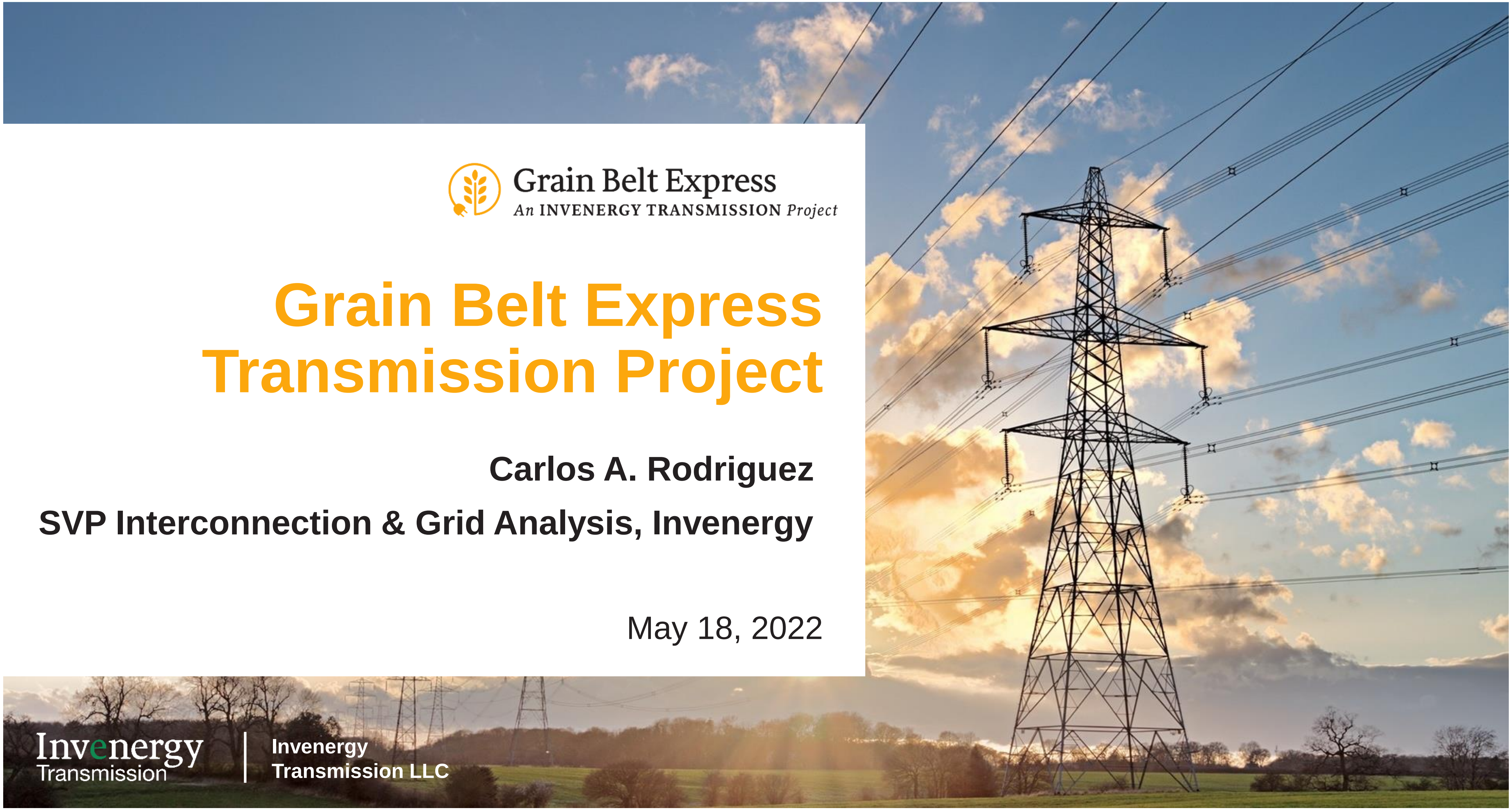
Actions Taken

- **Industry workshop held to discuss feedback and survey results**
- **Reviewed current NERC Standards against this risk**
  - Determined need for new Standards related to both real-time operations and planning

Next Steps

- May 2022 – Review industry comments and proposed responses at NERC MRC (Members Representative Committee)
- May 2022 – Hold an outreach conference on the proposed responses to industry comments and update the SAR (Standard Authorization Request)
- June 2022 – NERC RSTC (Reliability and Security Technical Committee) SAR endorsement
- June or July 2022 – NERC Standards Committee SAR acceptance
- July 2022 – Solicit industry volunteers for Standard Drafting Teams





Grain Belt Express
An INVENERGY TRANSMISSION Project

Grain Belt Express Transmission Project

Carlos A. Rodriguez

SVP Interconnection & Grid Analysis, Invenergy

May 18, 2022

Table of Contents

Project Specifics:

- Approximately 800 miles
- 600kV High Voltage Direct Current (HVDC)
- 4,000 megawatts (MW)
- Low-cost sustainable power

- **Power Source:** Western Kansas and surrounding area
- **Customers:** Missouri and other states in the region

Grain Belt Express is a transformational energy infrastructure project that will connect millions of Americans with clean energy.

$10 Billion
Capex investment in transmission line and the new generation it will enable

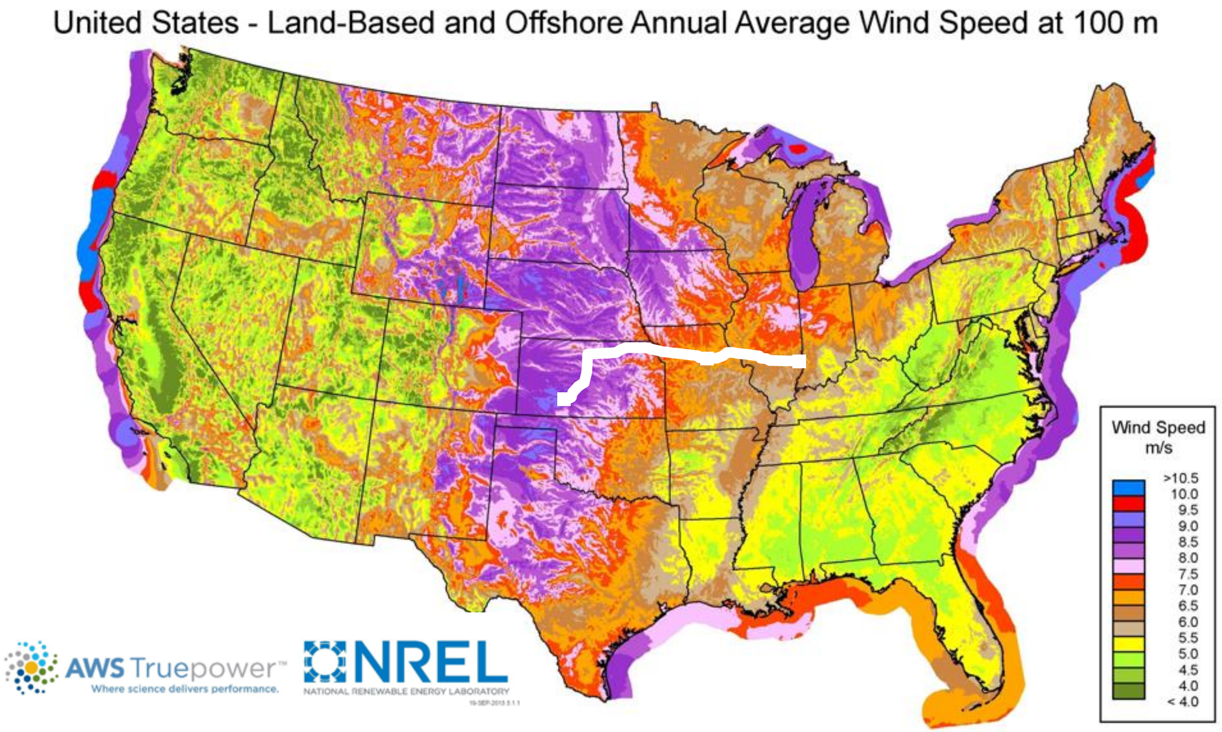
4 Gigawatts
Capacity for wind and solar harvested from western Kansas

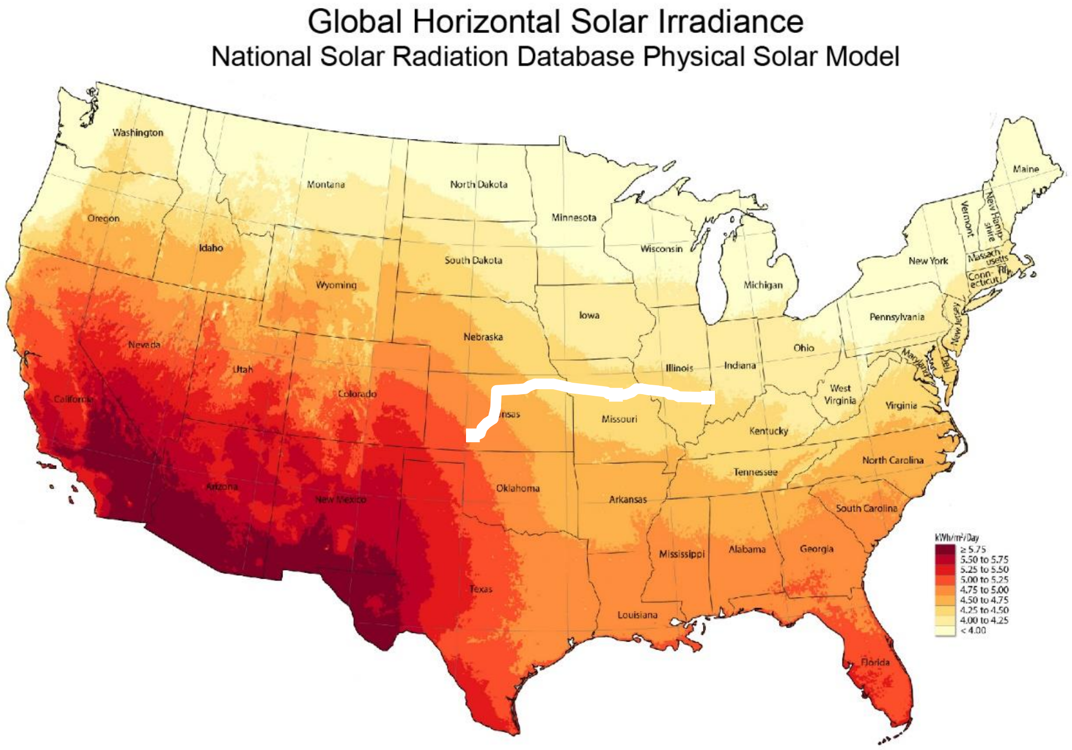
12,000 construction jobs
supported per-year for 3 years in KS, MO & IL for line and generation

1.6M Homes Powered
with 4,000 megawatts of affordable renewable energy

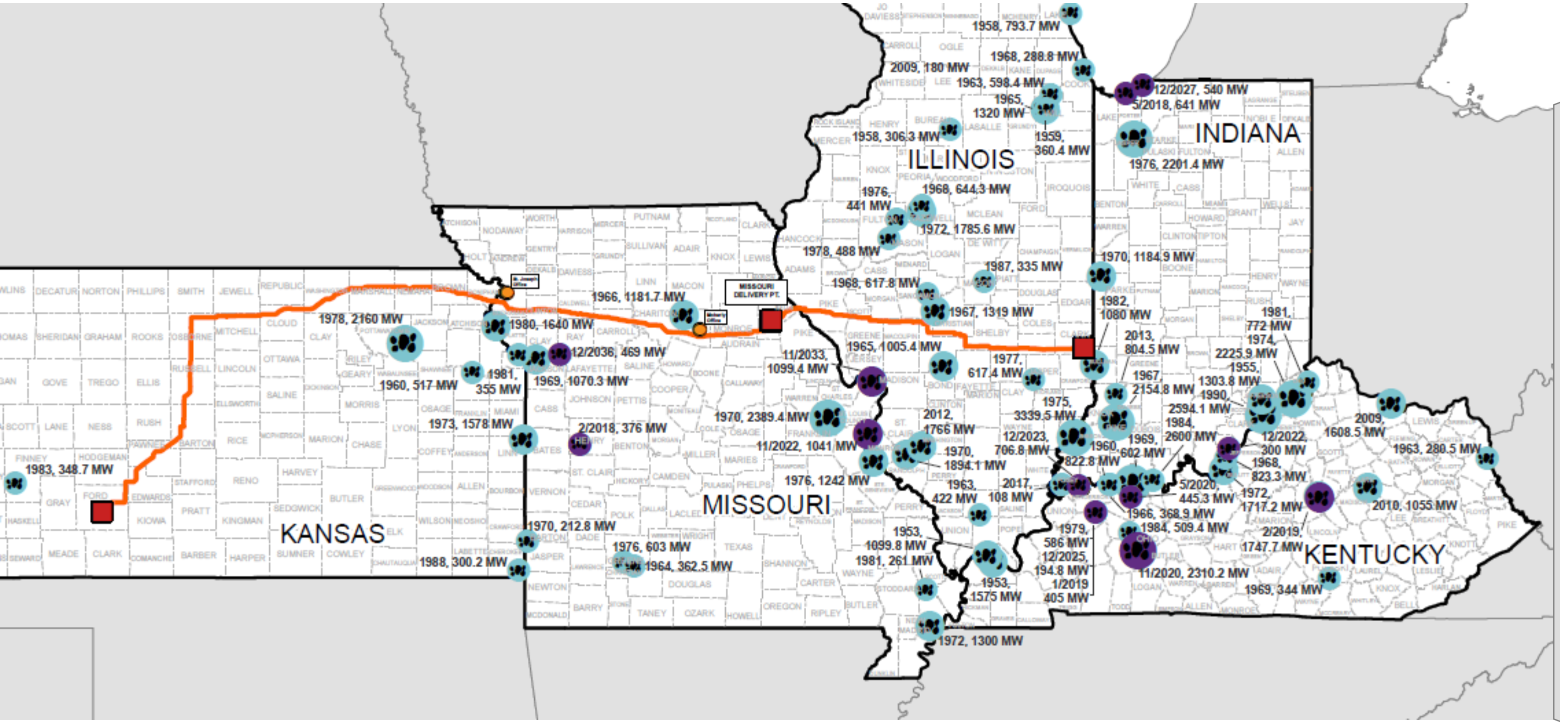
15M tons/year CO2
annual carbon pollution emissions avoided (US tons)

Grain Belt will unlock access to one of the strongest combined wind and solar energy resources in the United States.





Coal plants across the Midwest have already announced retirements. Grain Belt will help fill the power gap with zero-carbon generation.



Total Generation Today
72,500 MW

Coal Plant Retirements
8,400 MW

Legend

- Coal Power Plants (Year Online)
- Announced Coal Plant Retirements (Retirement Date)

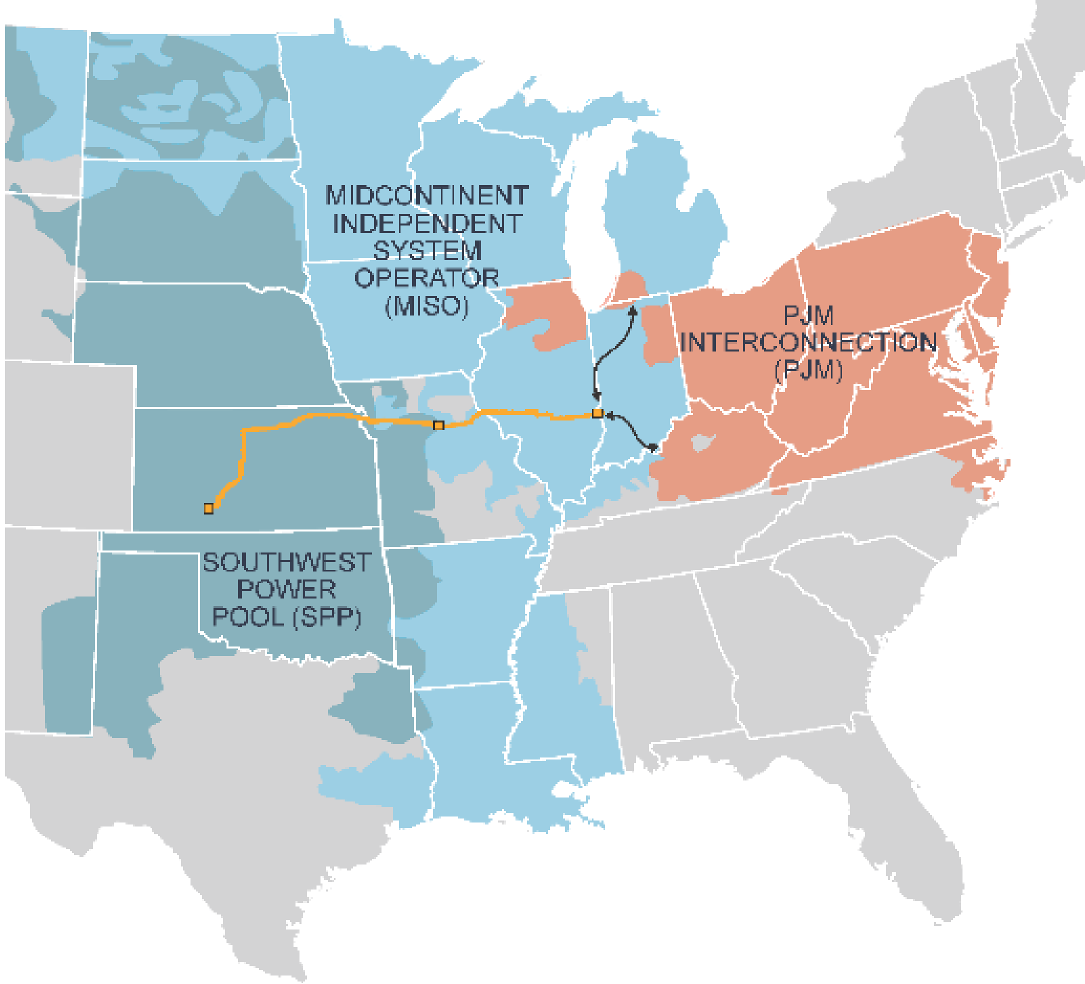
Plant Operating Capacity (MW)

< 1000 | 1000 - 2000 | > 2000

Grain Belt Express will be a reliability and resilience backbone for the U.S.

By directly linking three of the largest U.S. power markets—SPP, MISO and PJM—Grain Belt Express will increase electric system reliability for each region including through:

- **Emergency two-way power flow between regions**
- **Black start capability (ability to "jump start" outage-affected regions using power from another region)**
- **Greater geographic diversity of renewables**



THE KANSAS CITY STAR. MEDIA COMPANY

"Grain Belt Express promises stronger electric grid…" (4/12/21)

"While the $2 billion overhead transmission line aims at exporting wind energy from Kansas, it will also be capable of moving electricity both directions, which could have helped mitigate the electricity crisis that hit the United States earlier this year. "Lines like Grain Belt Express could have been the savior," said Jay Caspary, a transmission expert who worked at the Southwest Power Pool for nearly 20 years. "The value of transmission becomes really apparent when you don't have it. Because you're stuck with local resources."

Selected Final Route

Grain Belt Express Regulatory Overview

In 2020, Invenergy Transmission closed its acquisition of the Grain Belt Express project from Clean Line Energy Partners.

Grain Belt Express has received final regulatory approval in MO, KS and IN

- **Kansas:** KCC granted Grain Belt Siting Certificate in May 2013 and extended Certificate in September 2019
- **Missouri:** MPSC granted Grain Belt CCN in March 2019
- **Indiana:** IURC granted Grain Belt CCN in May 2013 and January 2020

Grain Belt Express in Illinois:

- Project granted a CPCN by the ICC in 2015
- CPCN appealed in 2018
- In September 2021, Governor Pritzker signed into law the Climate and Equitable Jobs Act, which allows a “qualified direct current project” that does not currently own, control, operate or manage within Illinois any equipment or property used or to be used for the transmission of electricity, to apply for a CPCN for the project at the ICC, prior to December 31, 2023.

DECEMBER 2011
Grain Belt Express certified a public utility by Kansas Corporation Commission

MAY 2013
Indiana Utility Regulatory Commission grants Grain Belt Express Certificate of Convenience and Necessity

MAY 2013
KCC grants Grain Belt Express Siting Certificate

MAY 2014
Grain Belt Express obtains negotiated rate authority from the Federal Energy Regulatory Commission

NOVEMBER 2018
Invenergy Transmission LLC announces intent to acquire Grain Belt Express from Clean Line Energy Partners LLC

MARCH 2019
Missouri Public Service Commission votes unanimously to grant Grain Belt Express a Certificate of Convenience and Necessity

JUNE 2019
Missouri Public Service Commission and Kansas Corporation Commission unanimously approve Invenergy Transmission LLC’s acquisition of the project

SEPTEMBER 2019
Kansas Corporation Commission unanimously approves Grain Belt Express’ Siting Certificate Extension

JANUARY 2020
Indiana Utility Regulatory Commission unamiously confirms Grain Belt Express Certificate of Convenience and Necessity and Invenergy Transmission LLC’s acquisition of the project

2021
Illinois Commerce Commission approvals to be pursued as soon as this year

Project Schedule

2026 COD Target Phase 1 (2,500 MW to Missouri)

2029 COD Target Phase 2 (additional 1,500 MW to Indiana)

2022
- Continue easement acquisition
- Complete lattice tower testing
- HVDC vendor selected

2023
- HVDC converter and T-line engineering and procurement
- Award T-line EPC

2024
- Construction start for HVDC and transmission line

2025
- Construction

2026
- Construction
- Testing
- COD (Q4)

HVDC Technology Overview

Why use HVDC (High Voltage Direct Current) instead of HVAC (High Voltage Alternating Current) for the transmission of power for Grain Belt?

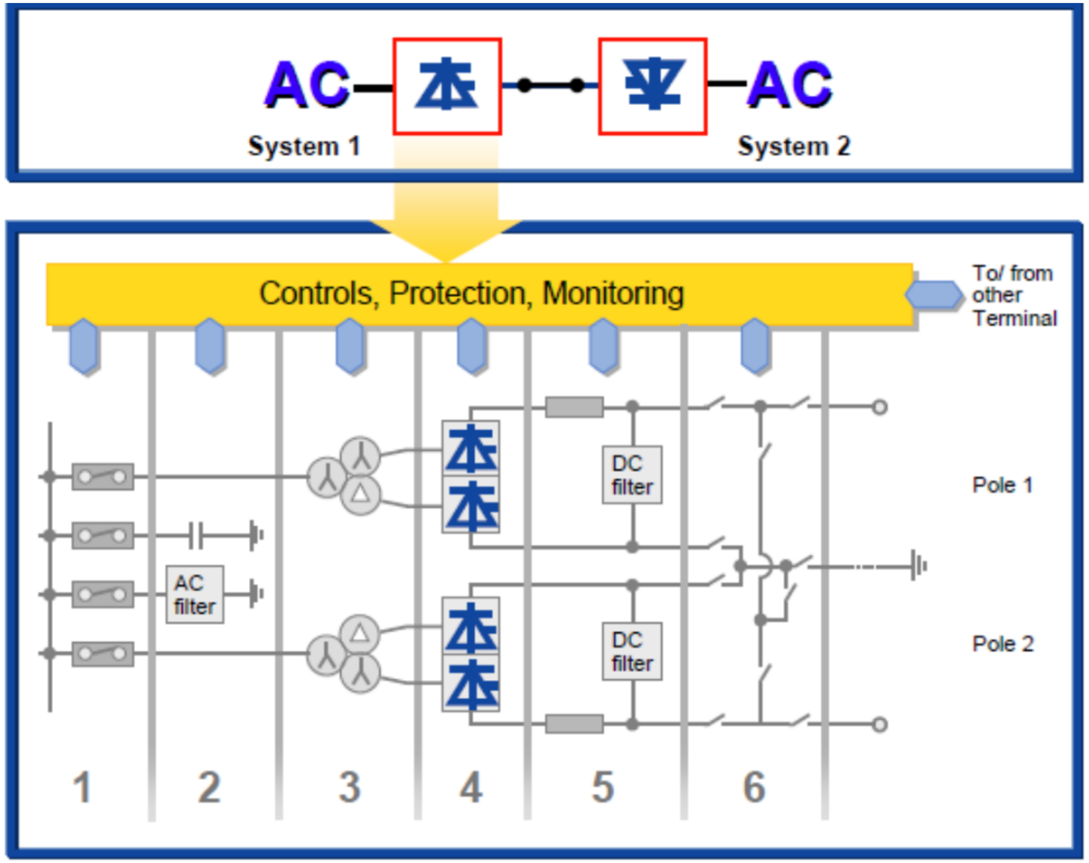
- The main reason is that transmitting power with HVAC over a distance of about 350-400 miles or more gets very complicated and costly.

- Therefore, HVDC should be considered for distances longer than about 350-400 miles.

- The Grain Belt project has a segment from SPP to MISO of more than 500 miles. Transferring power with HVAC is very complicated and costly over this long distance, due to voltage collapse, voltage stability, expensive reactive compensation equipment, and other issues

- In addition, an HVDC line's investment cost is lower than an HVAC line beyond the critical distance of about 350-400 miles, it has a smaller right of way requirement (due to one less conductor), lower losses, no stability issues, and high controllability

HVDC Technology Overview, LCC



1 AC Switchyard

2 AC Filters, Capacitor Banks

3 Converter Transformers

4 Thyristor Valves

5 Smoothing Reactors and DC Filters

6 DC Switchyard

CONVERTER STATION SIMPLIFIED SINGLE LINE DIAGRAM EXAMPLE FOR LINE CONMUTATED CONVERTER (LCC)

Note the use of thyristors and reactive compensation on the AC side

HVDC Technology Overview, VSC

CONVERTER STATION SIMPLIFIED SINGLE LINE DIAGRAM EXAMPLE VOLTAGE SOURCED CONVERTER (VSC)

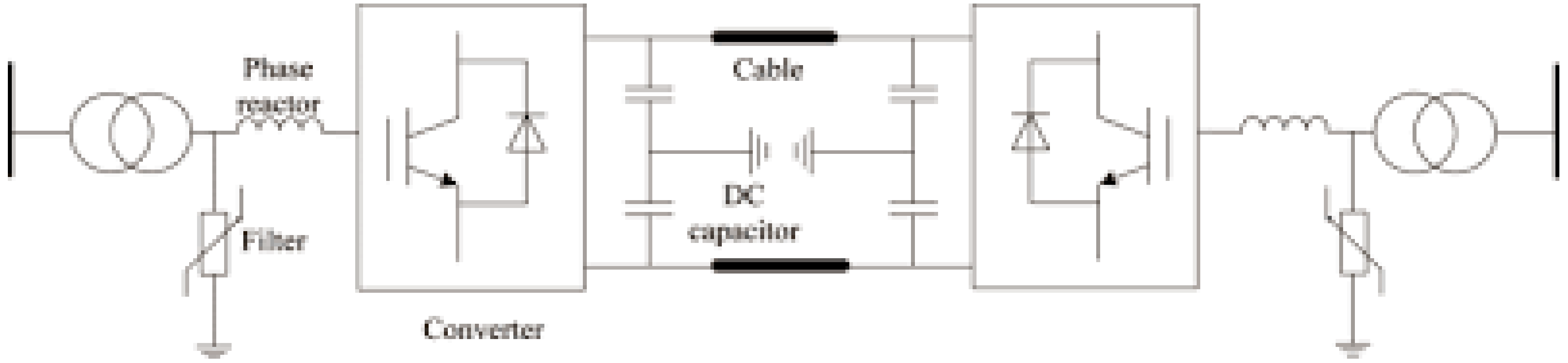


Figure 1. typical VSC-HVDC scheme structure

Note the use of transistors and diodes and absence of reactive compensation on the AC side

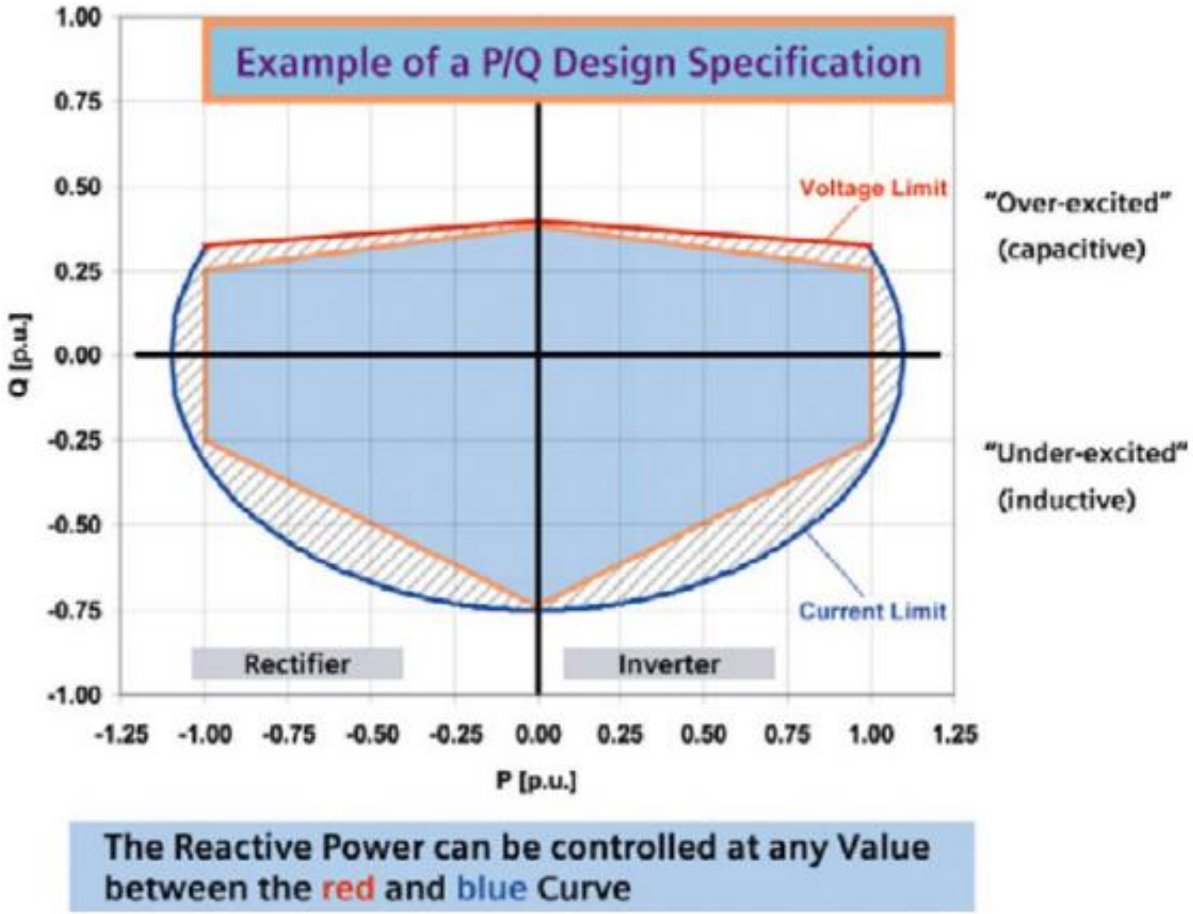
HVDC Overview

	LCC	VSC
Application	Point to Point, Back to Back, Multi-terminal	Point to Point, Back to Back, Multi-terminal, HVDC Grid
Ratings	High DC Voltages (up to 1000KV) and Power	Lower (compared to LCC) DC voltage and Power
Semi-conductor	Thyristors – can withstand voltage in either polarity Only controlled turn-on	IGBT – can pass current in either direction Controlled turn-on/turn-off
Voltage	Output voltage can be either polarity to change power direction	Output voltage remains fixed, current direction changes to change power direction
Overload	High Inherent Overload	No overload unless specified
AC system	Requires a stronger ac system	Can work in a weak or even "dead" ac system
Black start	Theoretically possible	No issue
Reactive Power	Consume ~50%-60% reactive power (based on real power rating), typically operate a unity power factor	No Reactive power Requirements, can meet a +/-0.95PF condition
Harmonics	Produces significant AC and DC harmonics which require ac/dc filters to be installed	Very little harmonics generated, require no ac filters (typically)
Footprint	Large site area (dominated by filters)	Compact site areas (50%-60% of LCC area)
DC Line Fault Performance	Can clear and restart from a DC fault ~250msec inherently (does not require ac breakers to be opened)	Normal design requires ac breakers to be opened which results in a 700msec-900msec dc line fault clearing. Can use a full-bridge converter or DC breaker, but newer technology and increase cost and losses
Losses	~0.6%-0.7% rating of converter	~0.8%-0.9% rating of converter

LCC vs VSC Comparison

- Two of the main advantages of VSC over LCC is its capability of providing/absorbing significant amounts of reactive power and being able to operate isolated from a strong AC system.
- However, LCC can achieve higher ratings than VSC and has lower converter losses

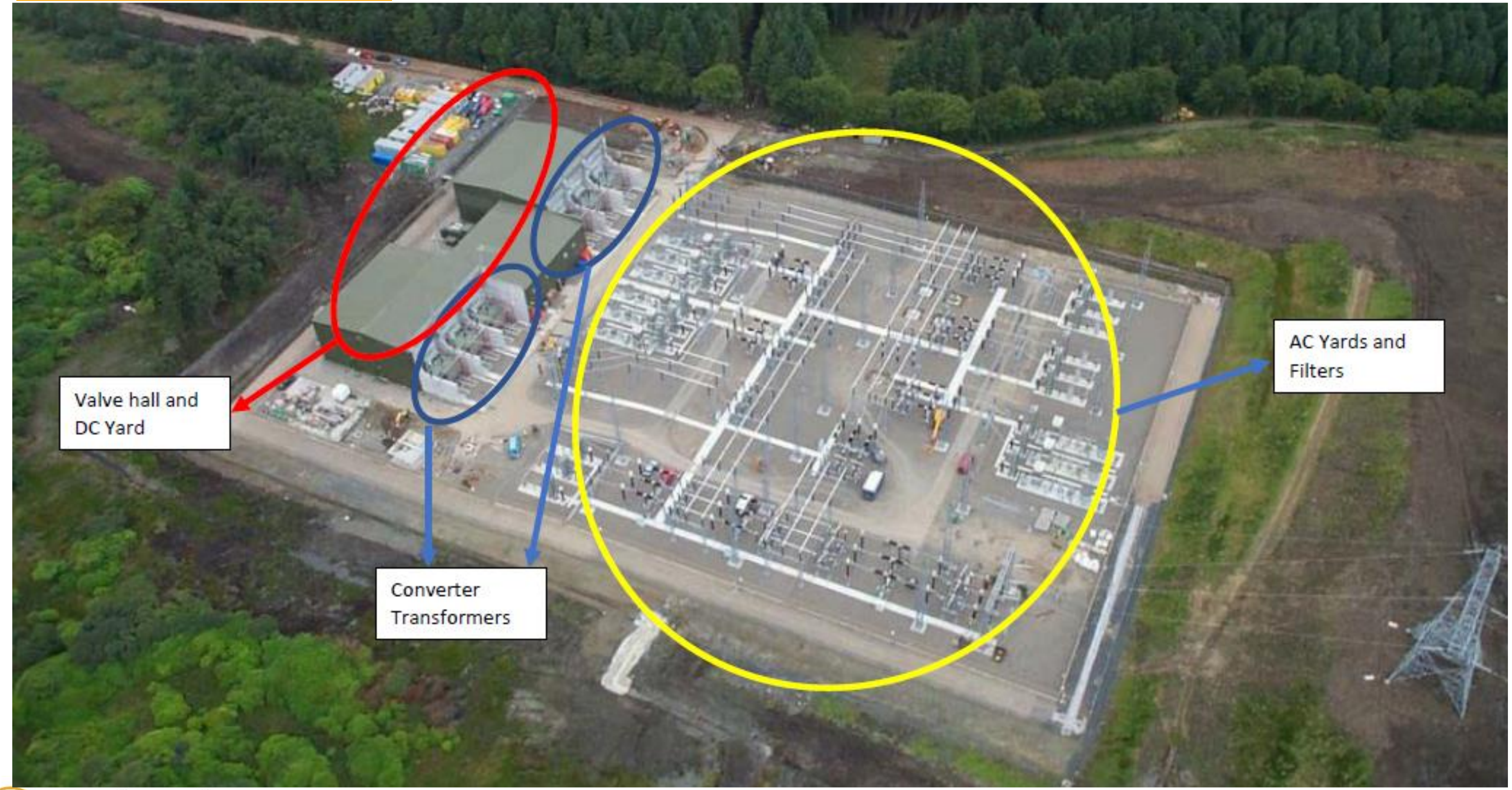
HVDC Overview



VSC Reactive Capability (provide/absorb VARS)

(LCC converters cannot provide reactive power, they just consume it)

HVDC Overview



LCC Typical layout

HVDC Overview

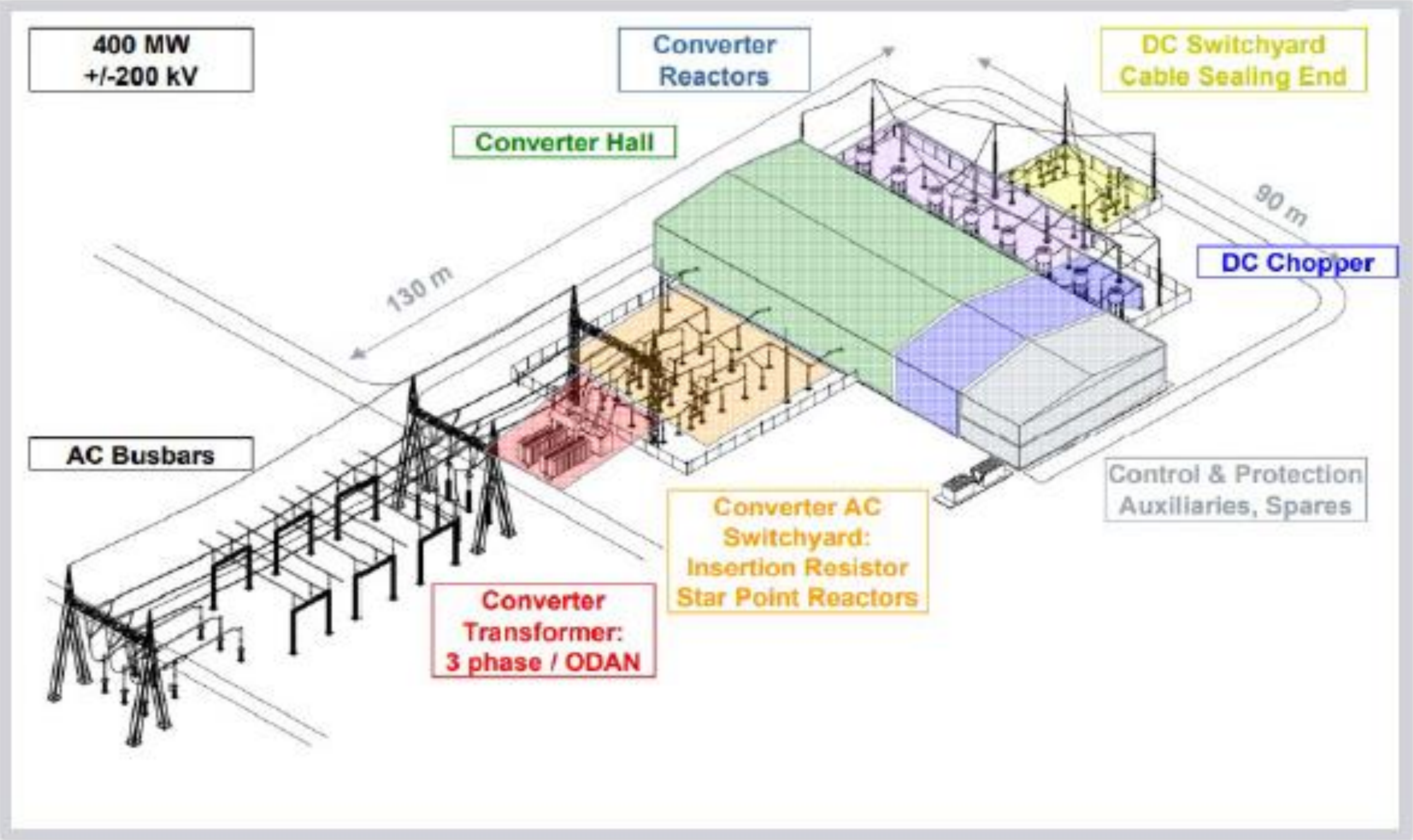
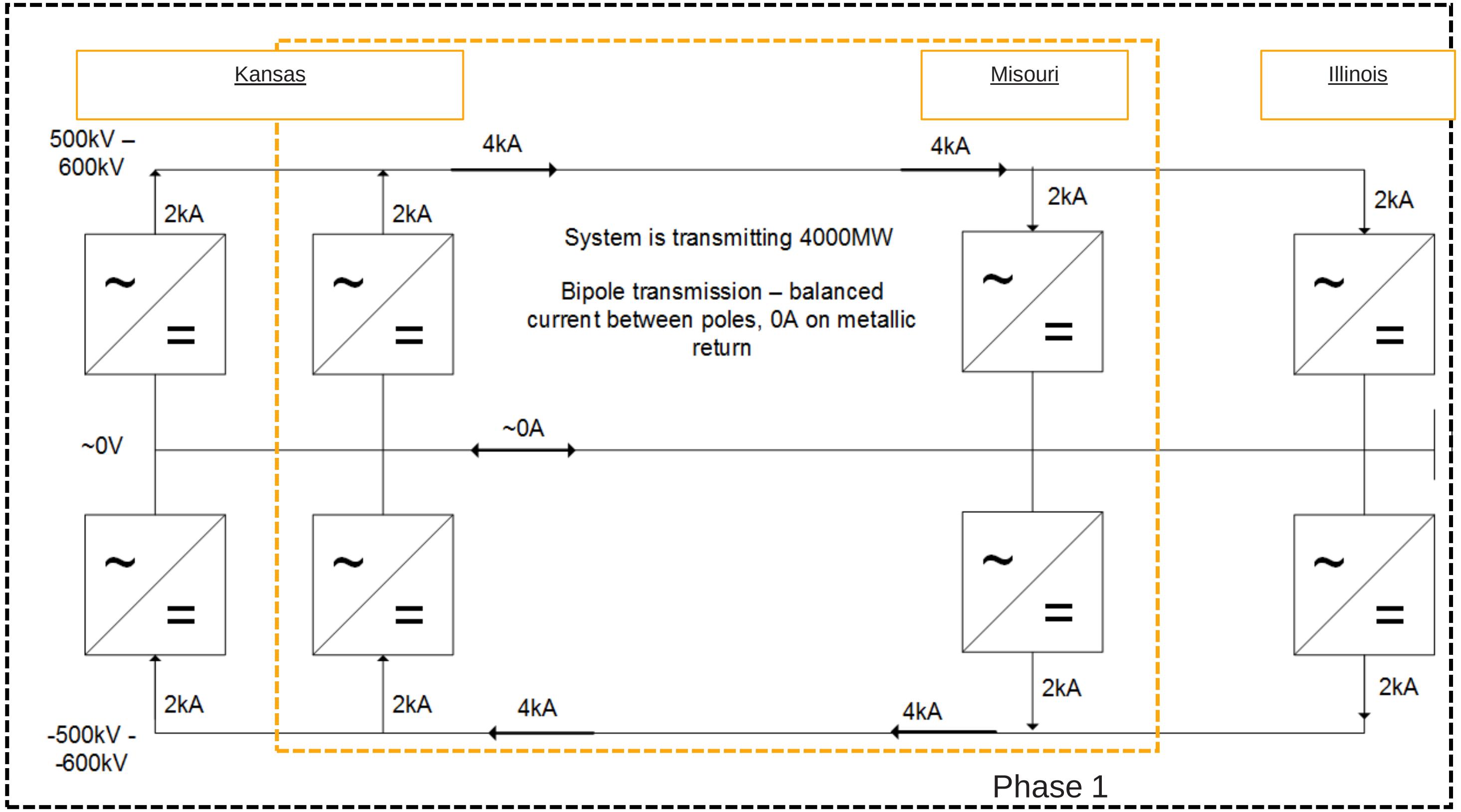


Figure 9: HVDC Plus with Braking Resistor Layout

VSC Typical layout

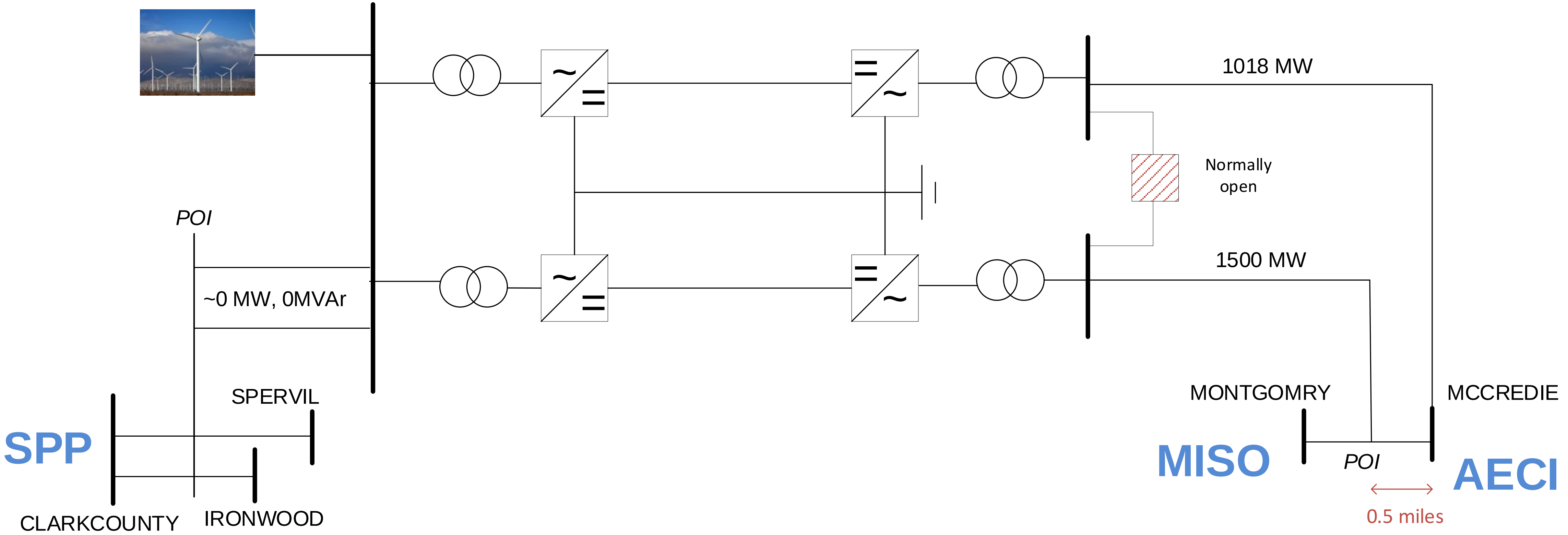
HVDC Overview

- Voltage-Source Converter
- Bipolar configuration with metallic return conductor
- Multi-terminal
- Similar projects:
  - Maritime Link – Canada (500MW)
  - Nordlink - Norway/Germany (1400MW)
- VSC-HVDC can supply/absorb dynamically ≈0.4pu in Mvar
- Main vendors: ABB, GE, Siemens

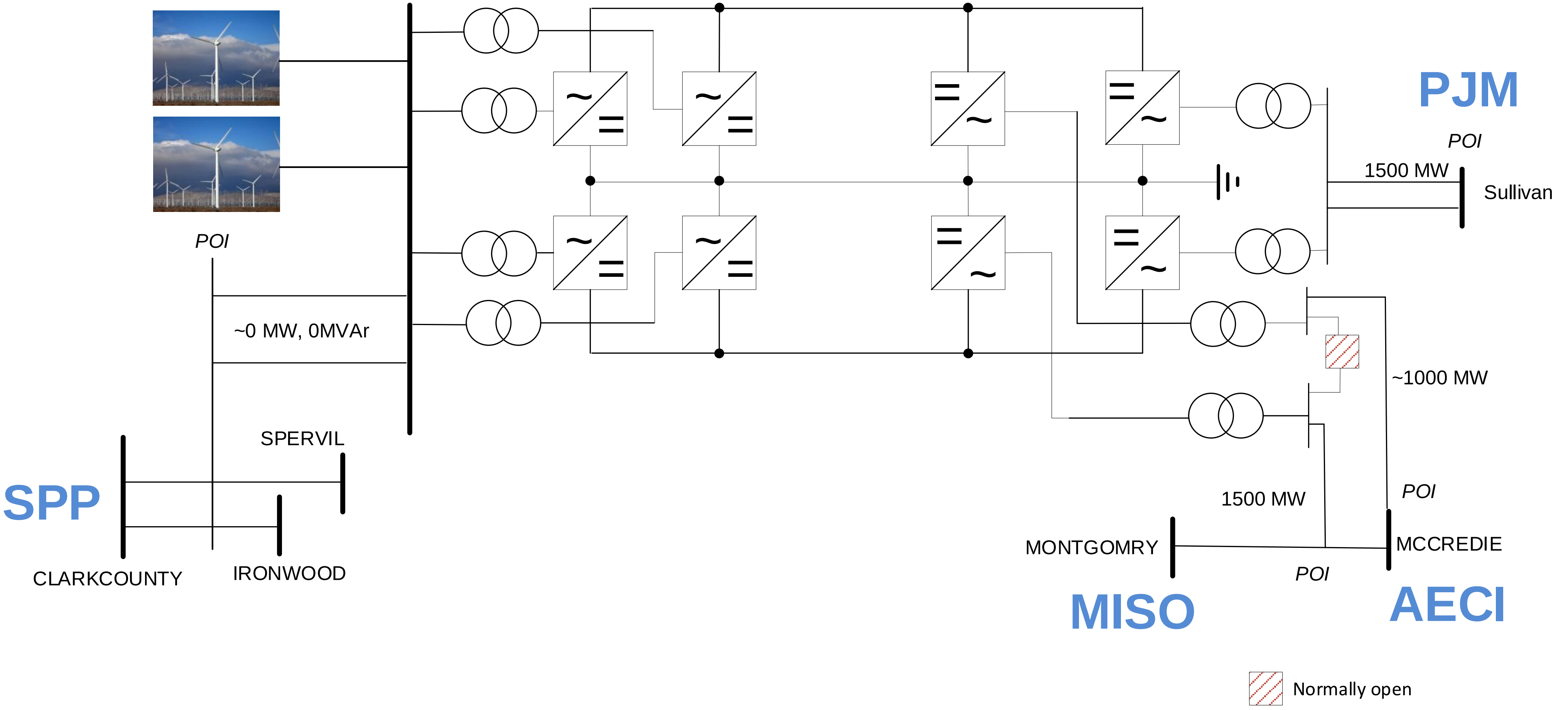


Phase 2

Grain Belt Express: Simplified One Line Diagram of potential Configuration for Phase 1



Grain Belt Express: Simplified One Line Diagram of potential Configuration for Phase 1 + Phase 2



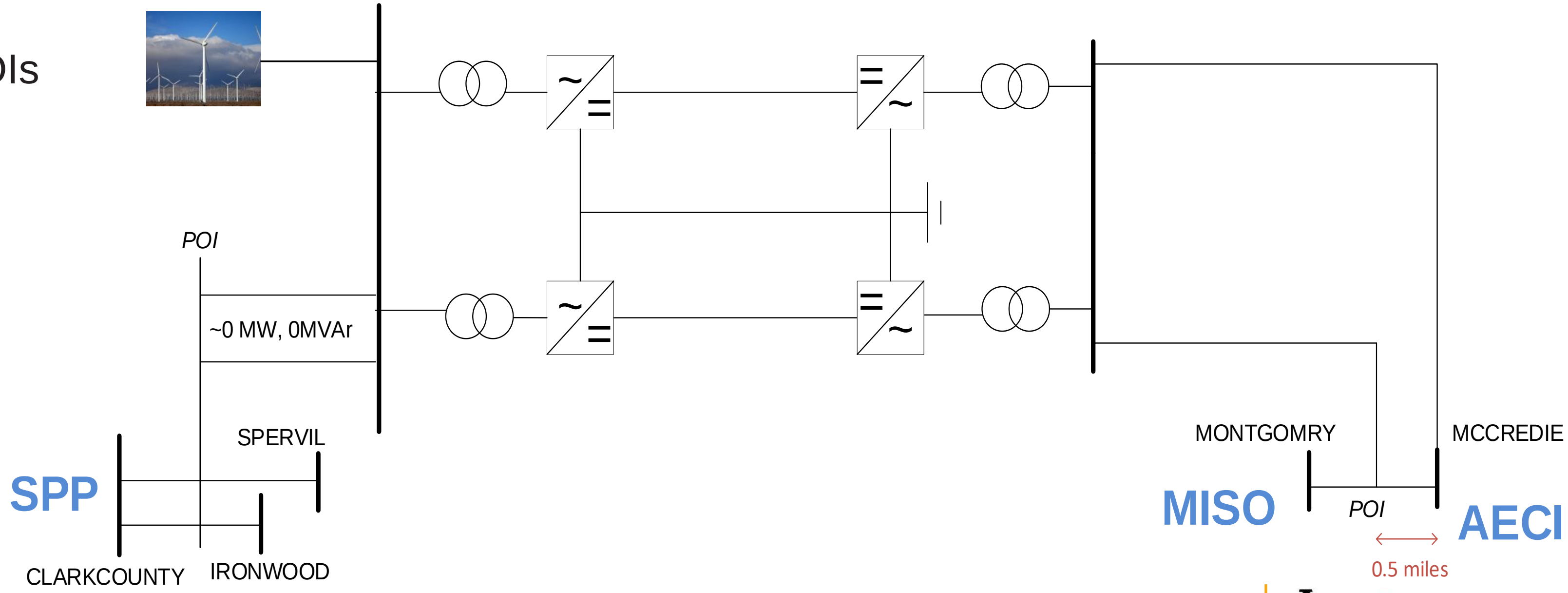
Applicable Interconnection Processes

- **SPP Planning Criteria Section 5.5 and section 14,** subject to review and approval of the Transmission Working Group (TWG)
- **MISO Attachment X**, Generator Interconnection Procedures (GIP)
- **MISO Attachment GGG**, Merchant HVDC Transmission Connection Procedures (MHCP)
- **AECI**, Generator Interconnection Procedures (GIP)
- **PJM,** Merchant Transmission Interconnection

Interconnection to two separate BAs in Missouri

MISO has indicated the following concerns with the interconnection of the Grain Belt Express project:

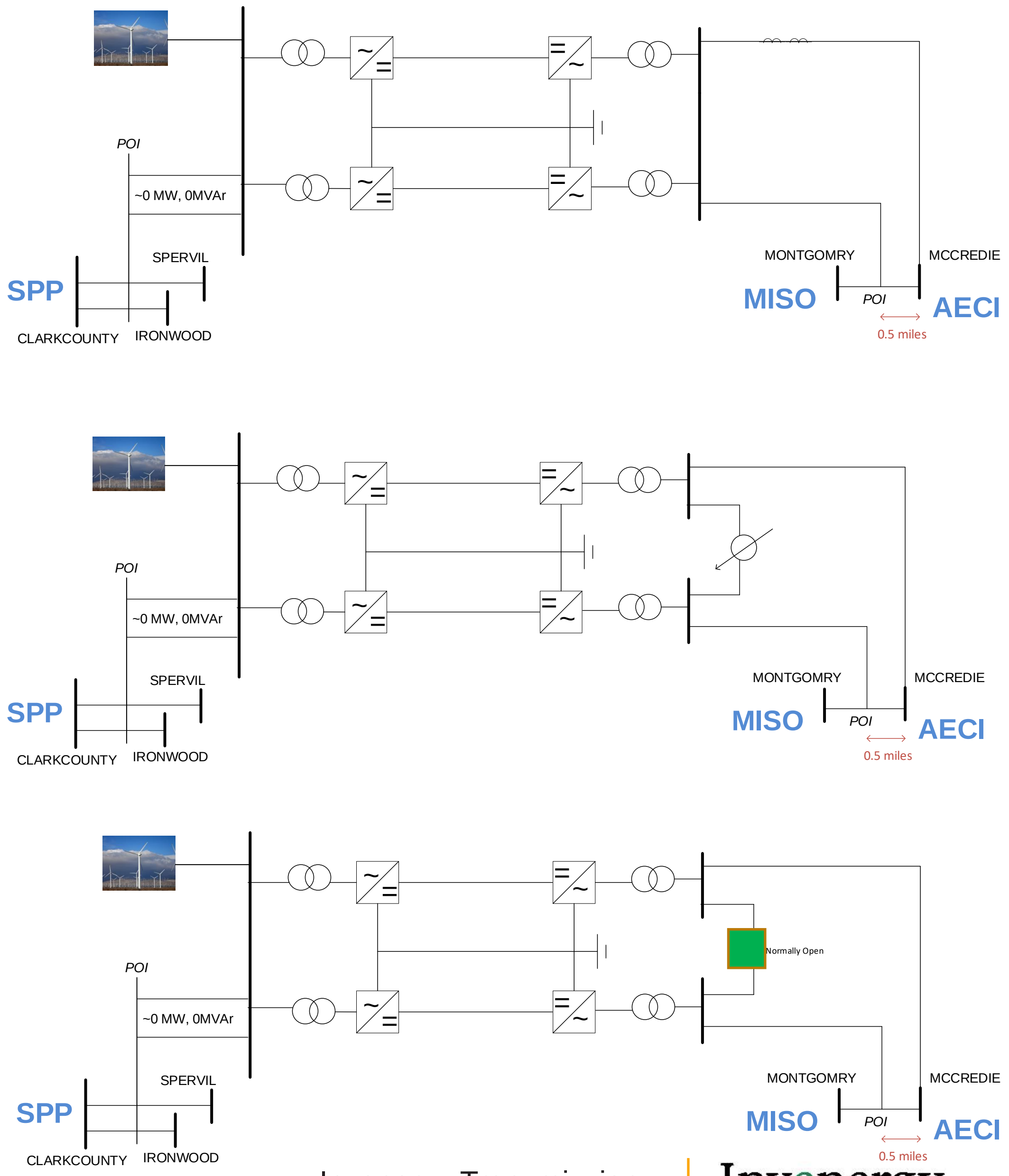
- Inability to precisely schedule power to each point of interconnection (POI)
- The application of an HVDC runback to control the flow to the specific POI, after a loss of one of the two lines from the converter station to the POIs
- Potential violation of NERC rule Section 500 Part 1.4 whereas a BES facility can only be controlled by one and only one entity/device.
- Loop power flow between POIs



Solutions

Invenergy looked at various options

- Series reactor on the McCredie to GBX line
- Phase shifting transformer between the two poles
- <u>**Split bus operation of the HVDC system**</u>



Split Bus Operation

This configuration mitigates the MISO concerns:

- Controls flow accurately over the full range of the pole
- Well within the design capabilities of the HVDC link
- Each pole connected via a radial line from the converter station to its respective POI
- Overcomes the NERC Section 500 Part 1.4 potential issue
- No need for a converter runback after the loss of one of the lines

Some drawbacks:

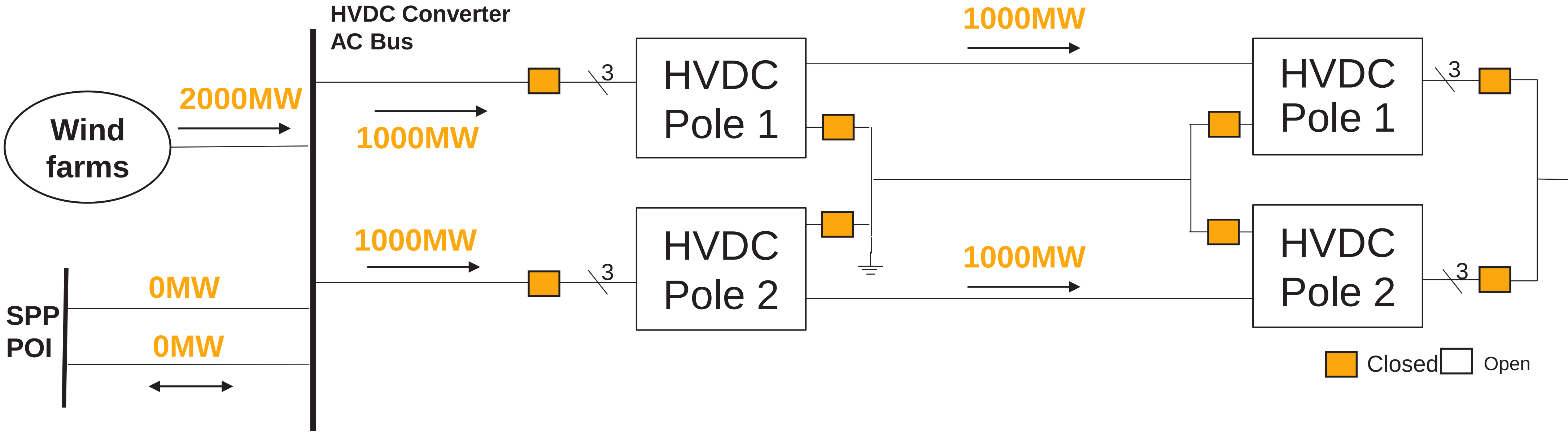
- Slightly increased losses
- Some loss of bipole functionality (picking up power on redundant pole)

System Studies - DC Fault – Example

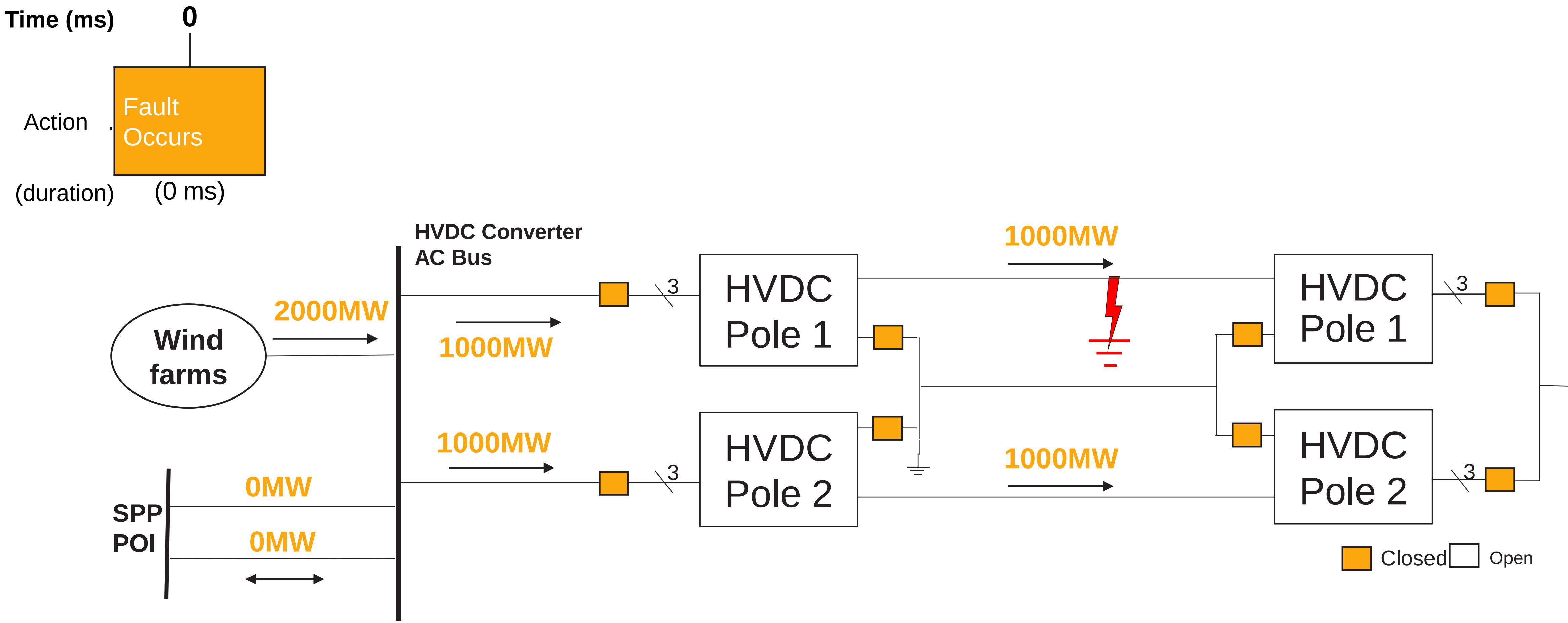
Time (ms)

Action .

(duration)

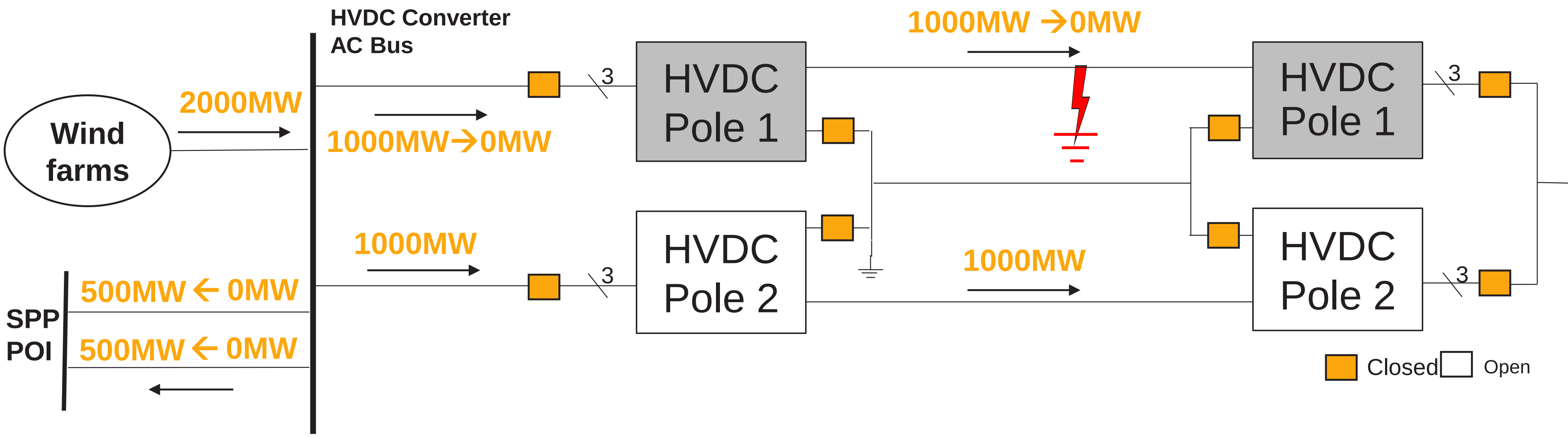


DC Fault – Example



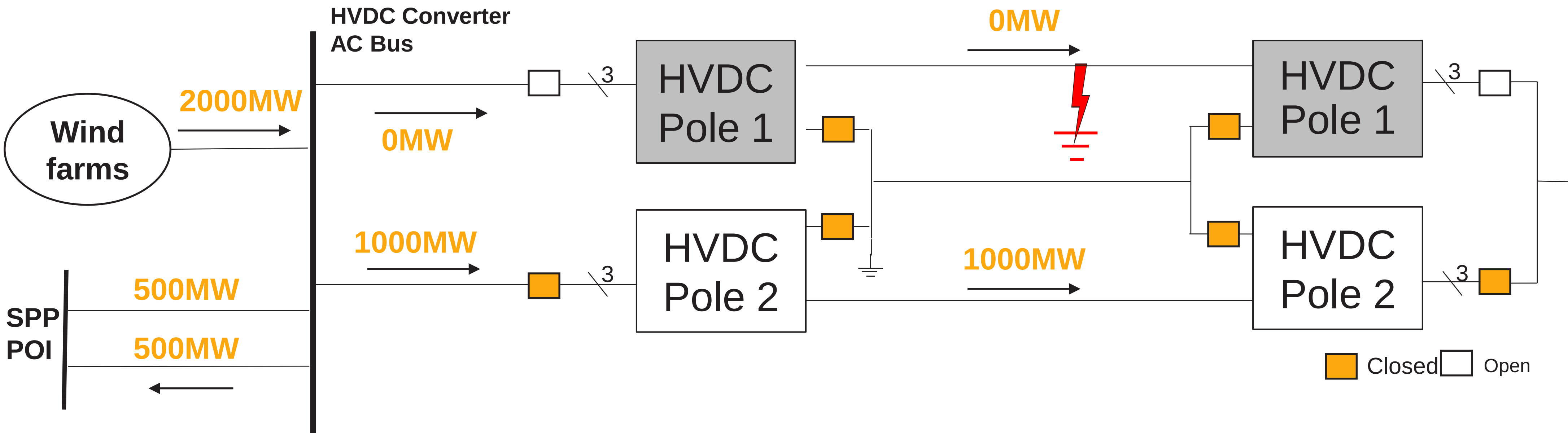
DC Fault – Example

Time (ms)	0	40
Action	Fault Occurs	Detection + Converter Block
(duration)	(0 ms)	(40 ms)



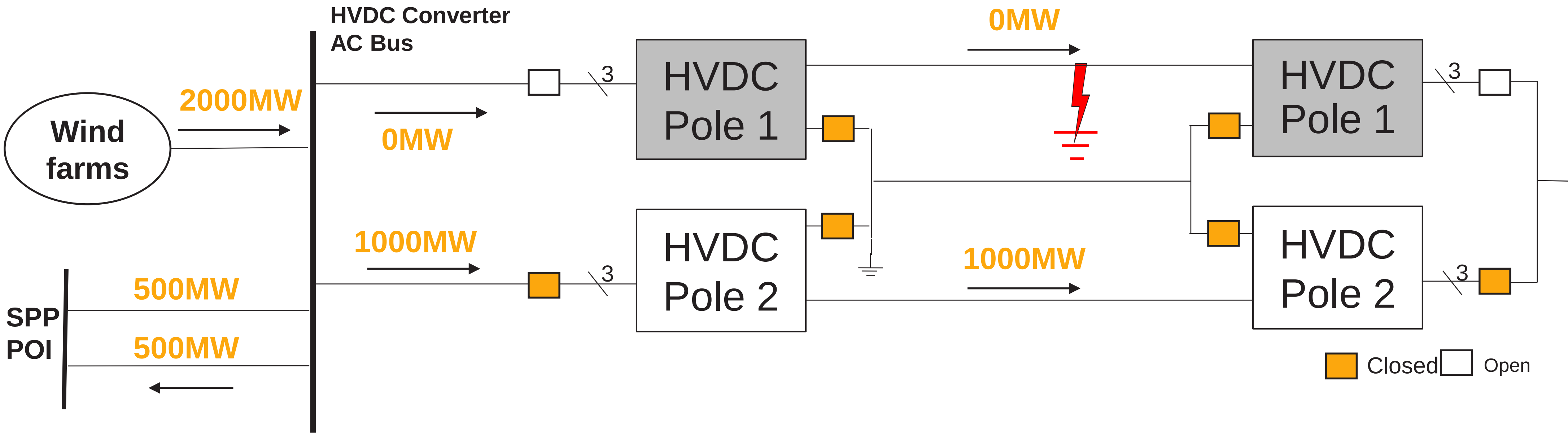
DC Fault – Example

Time (ms)	0	40	70
Action	Fault Occurs	Detection + Converter Block	AC Breakers Open
(duration)	(0 ms)	(40 ms)	(30 ms)



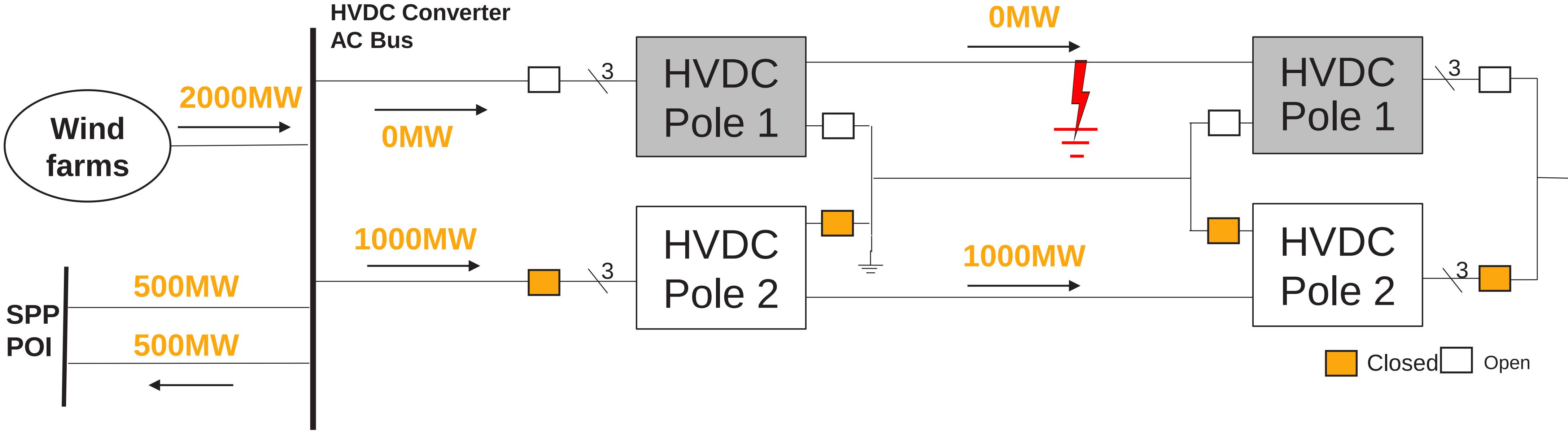
DC Fault – Example

Time (ms)	0	40	70	400
Action	Fault Occurs	Detection + Converter Block	AC Breakers Open	DC Line Deionization
(duration)	(0 ms)	(40 ms)	(30 ms)	(300-350 ms)



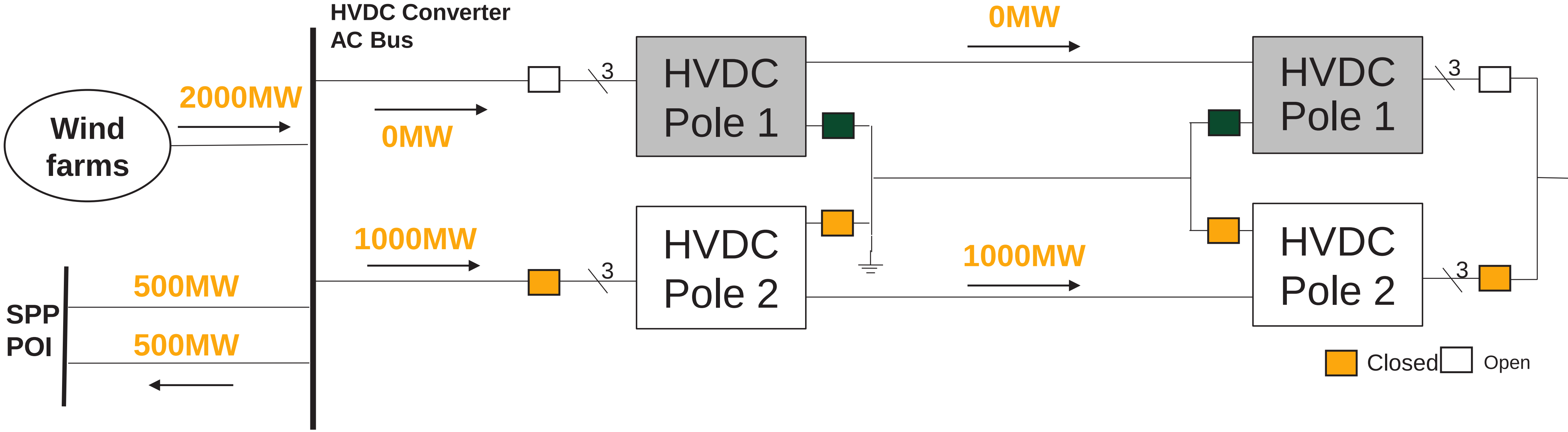
DC Fault – Example

Time (ms)	0	40	70	400	420
Action	Fault Occurs	Detection + Converter Block	AC Breakers Open	DC Line Deionization	NBS Switch Open
(duration)	(0 ms)	(40 ms)	(30 ms)	(300-350 ms)	(20 ms)



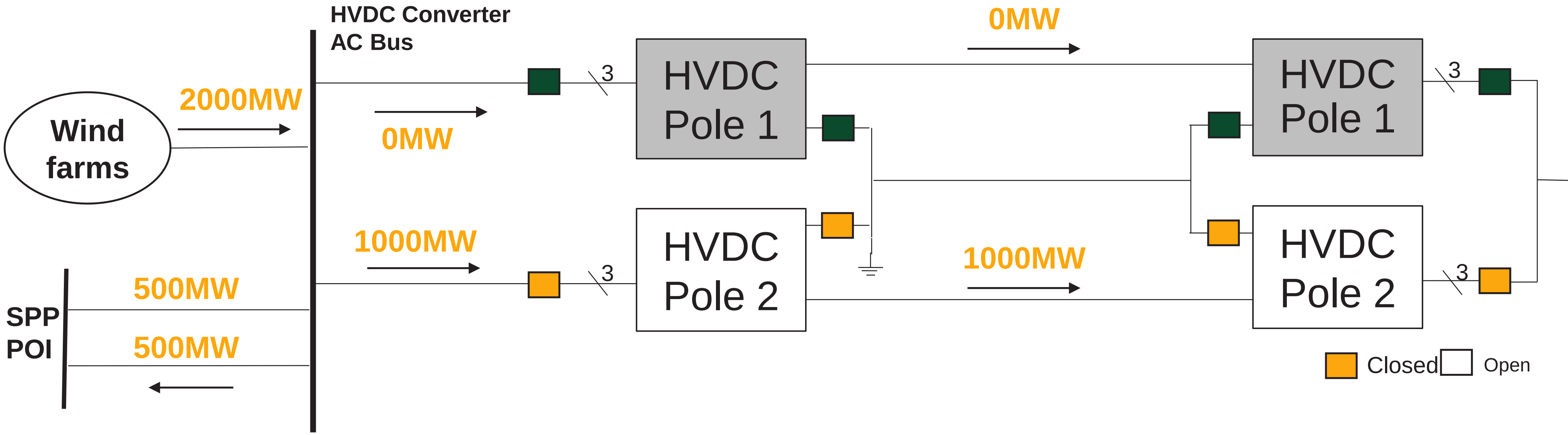
DC Fault – Example

Time (ms)	0	40	70	400	420	520
Action	Fault Occurs	Detection + Converter Block	AC Breakers Open	DC Line Deionizatio n	NBS Switch Open	NBS Switch Close
(duration)	(0 ms)	(40 ms)	(30 ms)	(300-350 ms)	(20 ms)	(100 ms)



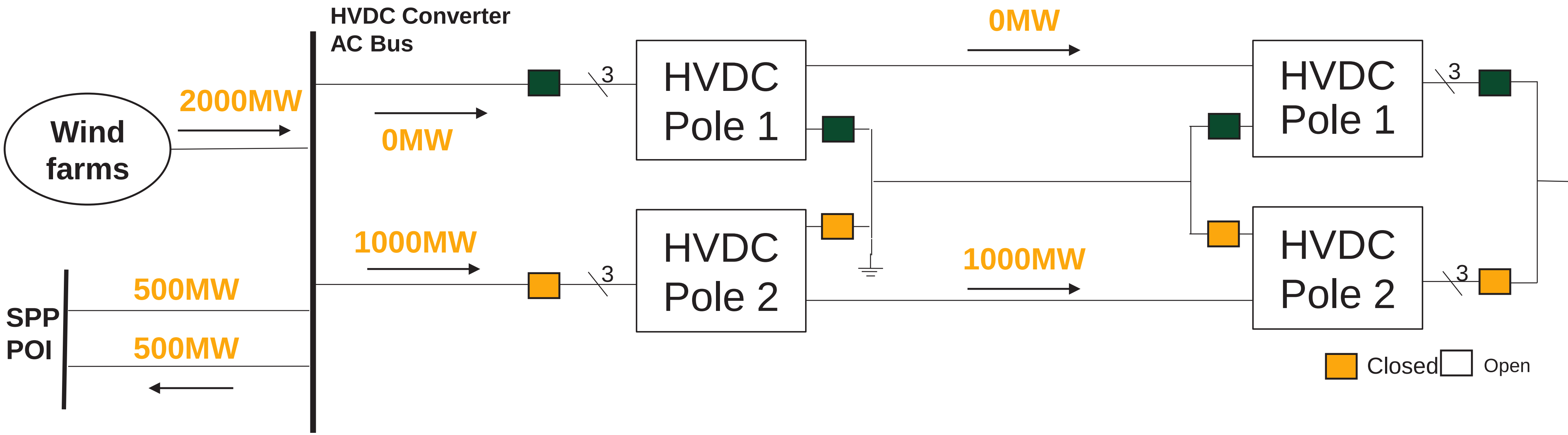
DC Fault – Example

Time (ms)	0	40	70	400	420	520	590
Action	Fault Occurs	Detection + Converter Block	AC Breakers Open	DC Line Deionizatio n	NBS Switch Open	NBS Switch Close	AC Breakers Close
(duration)	(0 ms)	(40 ms)	(30 ms)	(300-350 ms)	(20 ms)	(100 ms)	(70 ms)



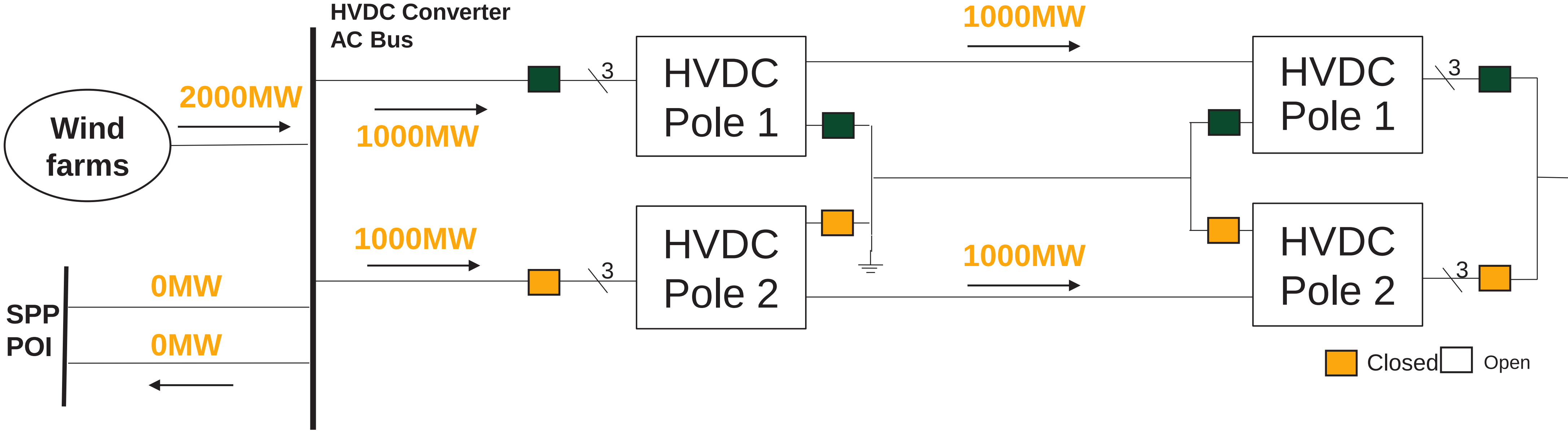
DC Fault – Example

Time (ms)	0	40	70	400	420	520	590	630
Action	Fault Occurs	Detection + Converter Block	AC Breakers Open	DC Line Deionization	NBS Switch Open	NBS Switch Close	AC Breakers Close	Converter De-block
(duration)	(0 ms)	(40 ms)	(30 ms)	(300-350 ms)	(20 ms)	(100 ms)	(70 ms)	(40 ms)



DC Fault – Example

Time (ms)	0	40	70	400	420	520	590	630	780 ms
Action	Fault Occurs	Detection + Converter Block	AC Breakers Open	DC Line Deionizatio n	NBS Switch Open	NBS Switch Close	AC Breakers Close	Converter De-block	**Power Ramp-up**
(duration)	(0 ms)	(40 ms)	(30 ms)	(300-350 ms)	(20 ms)	(100 ms)	(70 ms)	(40 ms)	(150 ms)

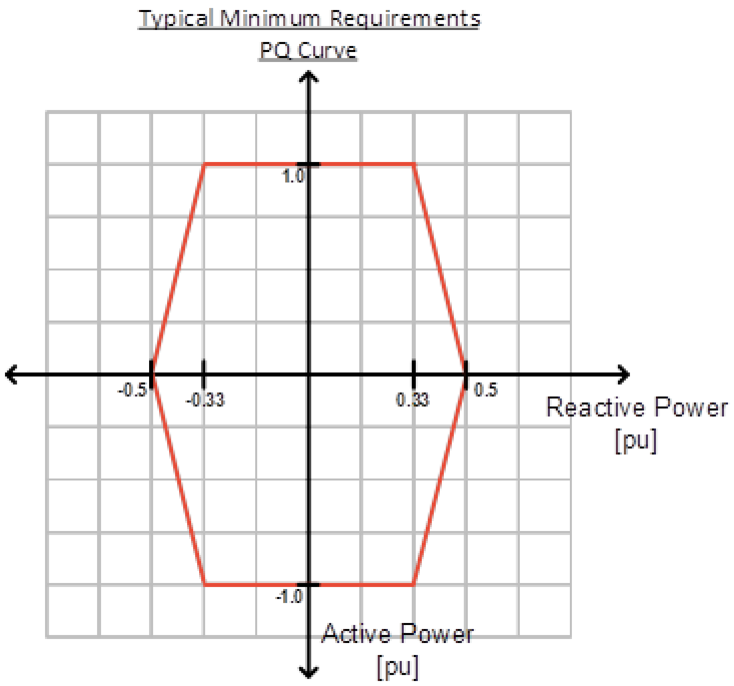


Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

- The Grain Belt Project will have unique reliability benefits and efficiencies as an interregional merchant HVDC transmission project.
- HVDC projects can operate bidirectionally and act as generation at the delivery point, avoiding the same transmission losses, loop flows and other issues associated with AC transmission
- Grain Belt can have a significant diverse mix of renewable generation (solar, wind and battery) that can be directed to the region in greatest need
- Whenever an emergency is declared by any of the three RTOs, Grain Belt and its partners can cause scheduled deliveries to be interrupted and re-routed meet the emergency need
- The fact that Grain Belt and its interconnected renewable projects will be built on a merchant basis means that customers will not be allocated the bulk of the costs of Grain Belt and yet will be the beneficiaries of the reliability services that this project will deliver

Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

- **Frequency Control**: able to provide both dynamic and steady-state frequency control through fast modulation of the HVDC power.
- **Voltage/Reactive and Power Factor Control**: A VSC HVDC system has full 4-quadrant control at each POI as shown below. This versatility allows the HVDC system to accurately control the reactive power out of the VSC within its design limits. This control of the reactive power allows for the HVDC system at POI to either set or follow a specific Voltage, Power Factor or Q schedule. Furthermore, at lower levels of real power, up to 50% of the converter rating could be used for reactive power control/support.



Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

- **Island mode operation:** A VSC-HVDC system is able to operate in an islanded mode, by operating in a grid-forming mode, providing the synchronizing voltage required for system. It is in this way that VSC-HVDC is being used to connect large amount of isolated renewable energy. As generation increases or decreases, the HVDC system will automatically adjust to ensure HVDC power order matches the generation for a balanced power flow

- **Black Start:** Using the same functionality as the islanded mode operation, the HVDC system can be used to black start a system. The fast voltage control of the converter manages the voltage dips during energization, and as the grid is gradually expanded during the restoration process.

- **Reversing power:** Using the precise controllability of the HVDC system and the inherent capability of the VSC HVDC converters, the HVDC system can reverse power almost instantaneous, this transition occurs bumpless and it is especially useful to supply power under emergencies

- **Power modulation:** Using the inherent capabilities of the VSC HVDC system, specific points can be monitored (bus voltage, frequency, power flow on adjacent lines) and the system can provide power modulation features to enhance grid stability. In fact the VSC can actual emulate the PSS functionalities of a standard generator

Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

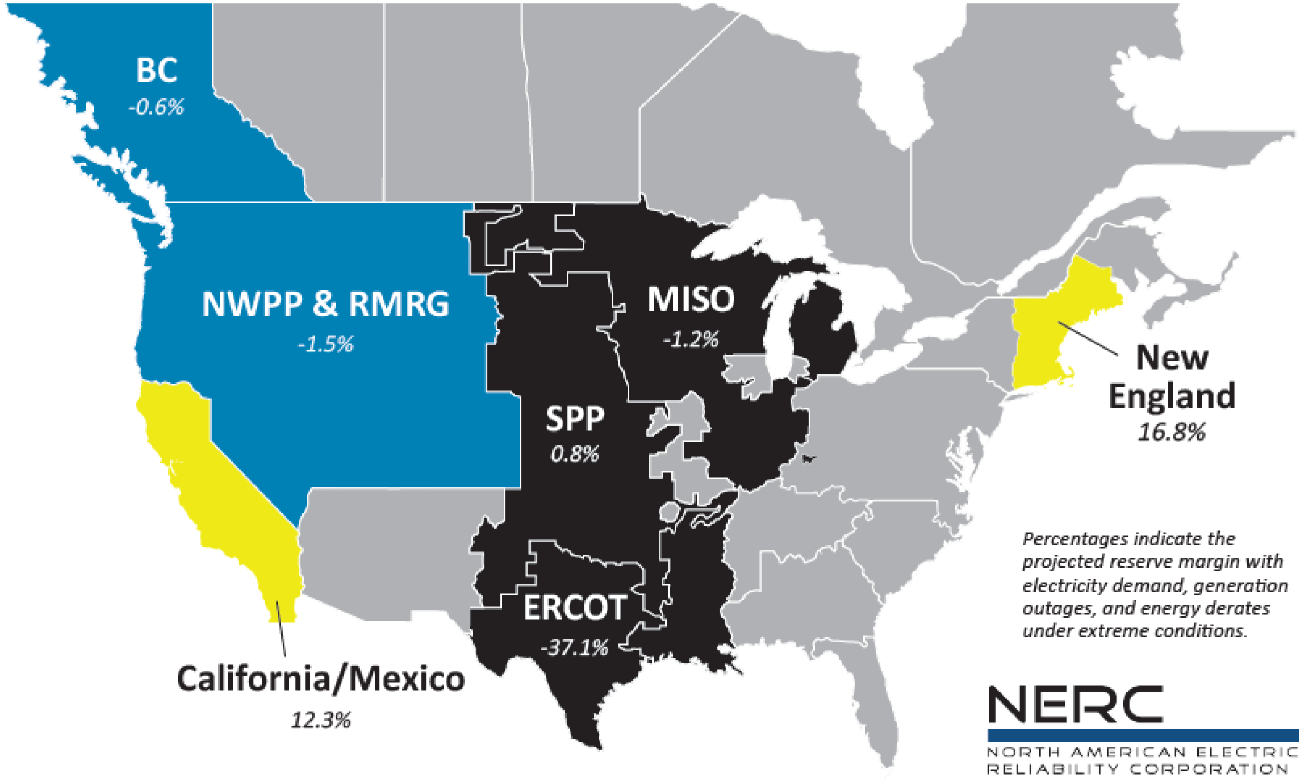
- **Low voltage ride through:** the HVDC system can provide HVRT and LVRT
- **Harmonics**: VSC HVDC generate very little harmonics to the AC systems and in most cases can meet the grid requirements without the use of an AC filter
- **Fault clearing and restart:** In the event of a DC line fault, an HVDC system will temporarily stop power transmission on the faulted pole (the unfaulted pole will continue power transmission) for ~800msec after which time it will recover to full power
- **Interconnection to weak systems and system stability:** VSC-HVDC systems are perfectly suited for systems with very low SCR and in fact can operate in an islanded system only connected to renewable generation. They can provide a wide range of system stability functions and can provide transient, small signal and voltage stability
- **Inertia**: A VSC-HVDC system does not inherently provide inertia, but can be designed to provide synthetic inertia which will functionally act like inertia by responding to system changes

Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

- **Primary Frequency Response:** HVDC can provide this functionality and can occur instantaneously
- **Reserve/ramping:** Able to increase/decrease output very quickly.
- **Regulation:** Through the frequency controller, the HVDC system can provide ACE functionality
- **Flexibility:** Flexibility is a reliability attribute that measures the ability of a unit to turn on and off quickly and frequently in a single operating day. Three characteristics that commonly determine a resource's flexibility are cycling capability, quick start time and low minimum run times. An HVDC system can be scheduled anywhere within it's rating (0-1pu), it can emulate the functionality of quickly turning on/off a unit
- **Fuel assurance:** Fuel assurance considers the ability of a balancing authority to withstand disruptions to fuel supply chains and delivery mechanisms that hinder generator performance. The HVDC is not fuel dependent
- **Extreme weather performance:** the HVDC system can perform under extreme weather conditions such as extreme heat, extreme cold, high wind, icing, etc.

Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

- In the 2022 MRO Regional Risk Assessment, a list of reliability risks have been identified. The Grain Belt Project can help deliver the necessary energy to reduce these reliability risks.
- **Uncertainty of Winter Planning Reserve Margins**



- The Grain Belt Project will be designed to perform under extreme weather conditions such as extreme heat, extreme cold, high wind, icing, etc.

- Whenever an emergency is declared by any of the three RTOs (SPP, MISO, PJM), Grain Belt and its partners can cause scheduled deliveries to be interrupted and re-routed to meet the emergency need

Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

Increasing reliability during severe weather events

- **February 2021 Winter Storm Uri —** Each additional 1 GigaWatt (GW) of transmission ties between the Texas power grid (ERCOT) and the Southeastern U.S. **could have saved nearly $1 billion, while keeping the heat on for hundreds of thousands of Texans**. *
- With stronger transmission ties, other parts of the Central U.S. also could have avoided power outages while saving consumers hundreds of millions of dollars. In particular, consumers in the Great Plains, served by the Southwest Power Pool (SPP), and those in the Gulf Coast states, served by the southern part of the Midcontinent Independent System Operator (MISO), **each could have saved in excess of $100 million** with an additional 1 GW of transmission ties to power systems to the east. *
- **The Grain Belt Project could have provided up to 4 GW of power to SPP during winter storm Uri, via a combination of local generation and transfers of power from the other RTOs.**

** Source: “Transmission makes the Power System Resilient to Extreme Weather”, Grid Strategies July 2021*

Grain Belt Project Technical Capabilities and Impact on Reliability as an Interregional Line

TABLE 1. *Value of 1 GW of additional transmission by region for each event*

Receiving region – delivering region	Savings per GW of additional transmission capacity (millions of $)
WINTER STORM URI, FEBRUARY 2021	
ERCOT – TVA	$993
SPP South – PJM	$129
SPP South – MISO IL	$122
SPP South – TVA	$120
SPP S – MISO S (Entergy Texas)	$110
MISO S-N (Entergy Texas - IL)	$85
MISO S (Entergy Texas) – TVA	$82

The Grain Belt Project could have enabled direct power transfers between PJM - SPP South, MISO IL – SPP South, saving hundreds of millions of dollars during winter storm Uri

Source: "Transmission makes the Power System Resilient to Extreme Weather", Grid Strategies July 2021

Interconnection and Market Design Policy Should Encourage and Properly Value Interregional MHVDC

1. FERC must establish **compensable products or services** to capture **interregional MHVDC reliability and resilience benefits** and develop specific methodologies to place a value on these services;
2. FERC should confirm that transmission systems will be allowed to **operate the system flexibly** with respect to injection limits, to maximize the potential for deliveries from interregional merchant transmission lines **during system emergency conditions**;
3. FERC must direct RTOs to **acknowledge, account for and adequately value** reliability benefits of interregional merchant transmission in **transmission planning efforts**; and
4. When accounting for interregional merchant transmission in planning, FERC should direct RTOs to **properly allocate network upgrades required for integration and interconnection**, consistent with existing FERC beneficiary pays cost allocation principles

Example of Potential Emergency Reliability Product

- **Product**: Bundled firm generation and transmission that can be interrupted by any RTO whenever an emergency is declared, which will cause Grain Belt, the generator and the offtaker to agree to interrupt those deliveries and re-route the generation and transmission to the region with the greatest emergency need
- **Charge**: Combined monthly demand charge ($/kw/mo) and emergency energy charge ($/MWH).
- **Contractual Mechanisms:** Once the products are developed, the RTOs can develop a joint agreement with their neighbors and the interregional project for the joint operation of the interregional project that can specify operational protocols, including whether and when to declare an emergency and how interruptions and re-routing of energy to meet the emergency would be accomplished. That would be a FERC-filed rate schedule. There would also be a rate schedule for the transmission company, and generation companies to provide the stand-by capacity and energy in exchange for the demand charge and energy charge. The transmission project, generation projects and offtakers would have contractual mechanisms that would permit the RTOs to declare an emergency and effectuate interruption and re-routing consistent with the operational protocols in that joint operating agreement.

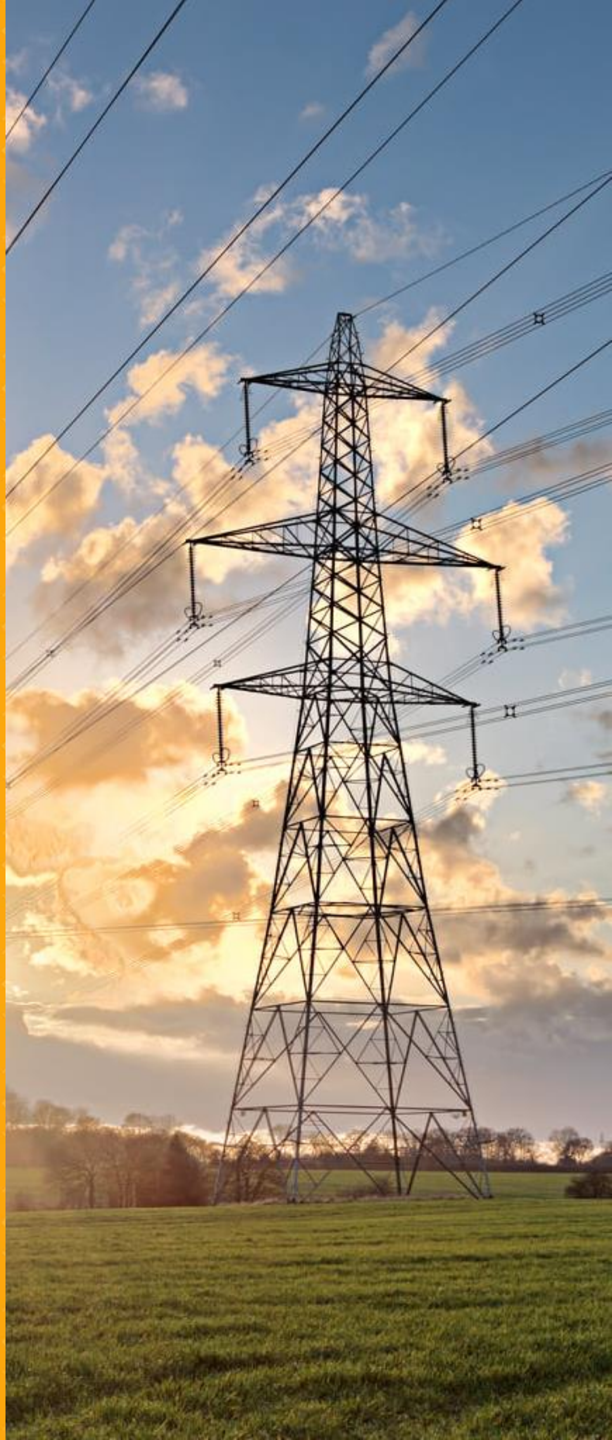
Summary and Conclusions

1. Grain Belt Express is a transformational energy infrastructure project that will connect millions of Americans with clean energy
2. Grain Belt will unlock access to one of the strongest combined wind and solar energy resources in the United States
3. Coal plants across the Midwest have already announced retirements. Grain Belt will help fill the power gap with zero-carbon generation
4. Grain Belt Express will be a reliability and resilience backbone for the U.S.
5. Grain Belt will increase reliability under severe weather events, enabling direct power transfers between three different RTOs
6. Grain Belt is in a very advanced stage of development with an expected late-2026 in-service date

Grain Belt Express
An INVENERGY TRANSMISSION Project

Grain Belt Express:
An Energy Connection for America's Heartland

Thank You



Invenergy Transmission | Invenergy Transmission LLC

Renewable Energy Grid Integration – Opportunities and Challenges

May 2022

NextEra Energy is comprised of strong businesses supported by a common platform

- ~$140 B market capitalization[(1)]
- ~59 GW in operation[(2)]
- ~$139 B in total assets[(3)]

Largest vertically integrated electric utility in the United States by retail MWh sales

The world leader in electricity generated from the wind and sun

Engineering & Construction

Supply Chain

Wind, Solar, and Fossil Generation

Nuclear Generation

1) As of May 3, 2022; Source: FactSet
2) Megawatts shown includes assets operated by Energy Resources owned by NextEra Energy Partners as of September 30, 2021; all other assets are included at ownership share
3) As of September 30, 2021

NextEra Energy's strategic focus remains on investing for the benefit of customers, shareholders, and the environment

NextEra Energy Strategic Focus

- **FPL's continued smart investments further enhance its best-in-class value proposition**
  - FPL residential customer bills remain well below the national average and are 40% below the average of the top 20 investor-owned utilities[1]
  - Industry leading profile includes high reliability, excellent customer service, and clean energy
- **Energy Resources continues to capitalize on the outstanding renewables development environment**
  - Expect to build ~23 – 30 GW from 2021 - 2024
  - Total addressable market has substantially increased with the combination of low-cost renewables and low-cost storage
- **NextEra Energy's balance sheet strength and access to capital remain a core strategic focus**

No company is better equipped to take advantage of the broad decarbonization of the U.S. economy than NextEra Energy

NEXTera ENERGY

1) Top 20 investor-owned utilities determined by reported customers

Our core strategy has focused on the importance of ESG impacts for more than 25 years

- Vision to be largest, most profitable clean energy provider in the world
- Vision informed by our values:
  - We are committed to excellence
  - We do the right thing
  - We treat people with respect

FPL

Gulf Power

- Aim to be the most reliable and best operating utilities in the country
- Keep costs low
- Rapidly grow clean energy

NextEra Energy Resources

- Build a diversified clean energy company
- Grow the world's leading wind, solar and storage portfolio

Deliver outstanding value for our customers

Support our communities and empower our teams

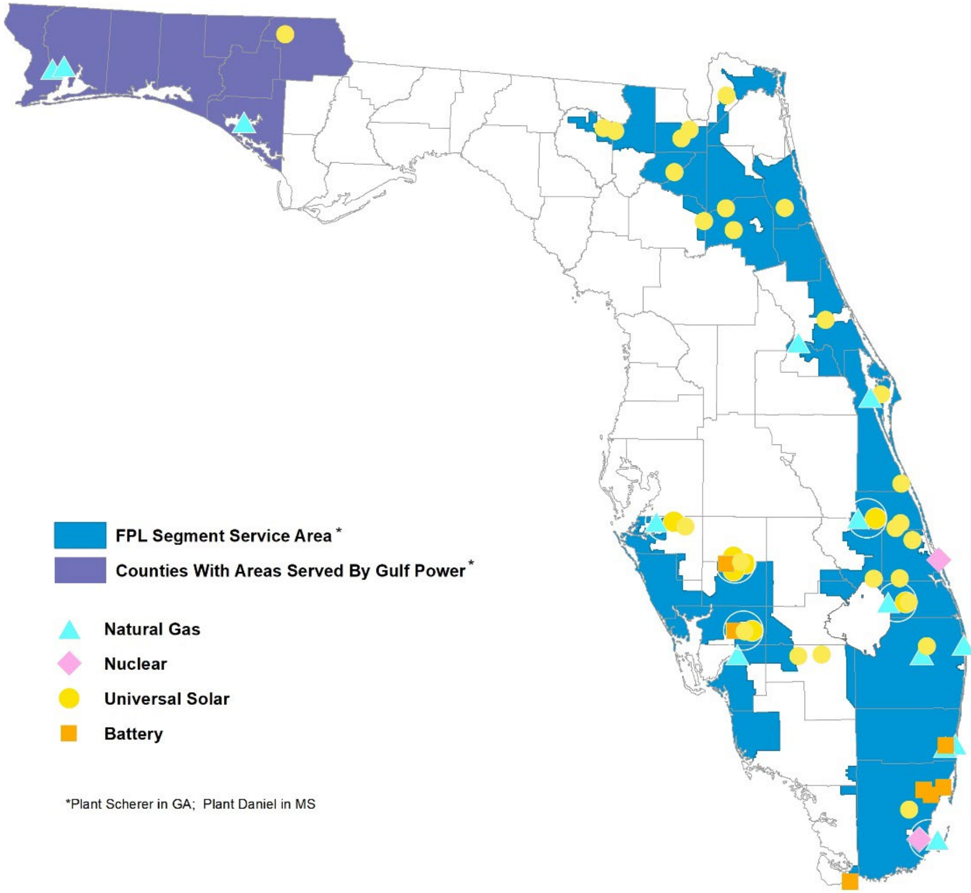
Do good for the environment

Generate significant shareholder value

Florida Power & Light is recognized as one of the best utility franchises in the U.S.

Florida Power & Light Company(1)

- One of the largest electric utilities in the U.S.
- Vertically integrated, retail rate-regulated
- ~5.7 MM customer accounts
- ~32 GW in operation
- Operating revenues
  - FPL: ~$12 B
  - Gulf Power: ~$1.4 B
- Total assets:
  - FPL: ~$66 B
  - Gulf Power: ~$7 B



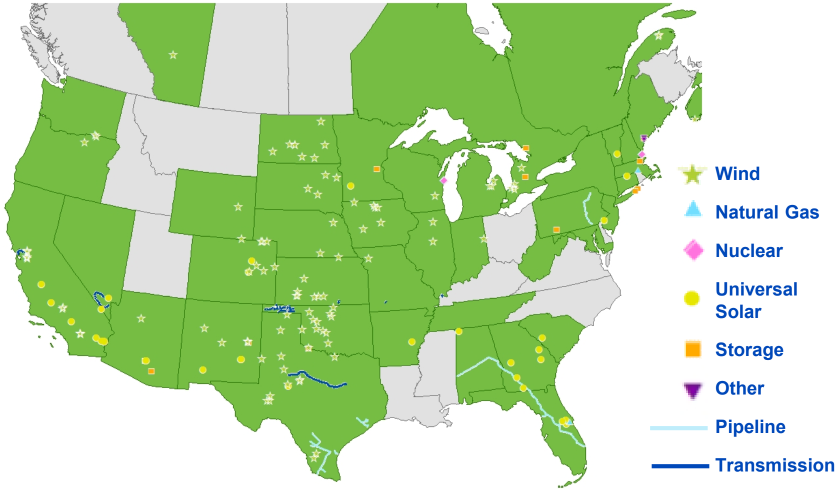
1) Gulf Power legally merged into FPL on 1/1/2021; FPL & Gulf Power operate under separate rate agreements; customer account and GW data is FPL and Gulf Power combined

Note: All financial data is as of September 30, 2021, except operating revenues which are for full-year 2020

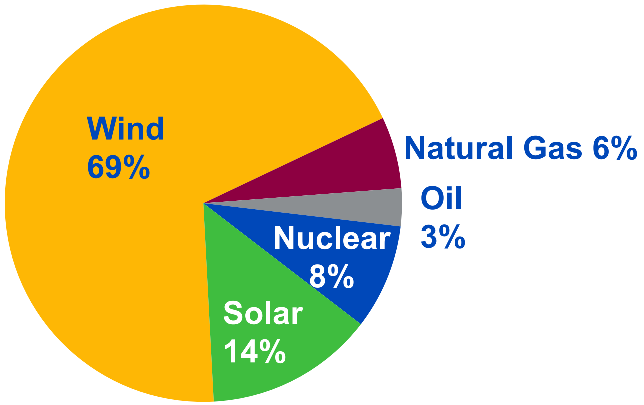
NextEra Energy Resources is the leading North American clean energy company

NextEra Energy Resources

- **World leader in electricity generated from the wind and sun**
- **~26 GW[1] of generation in operation**
  - ~18 GW wind
  - ~4 GW solar
  - ~2 GW nuclear
  - ~2 GW natural gas/oil
- **~15 GW wind and solar in backlog[2]**
- **~3 GW battery storage, including backlog**
- **~$63 B in total assets**



Generation Capacity[1]

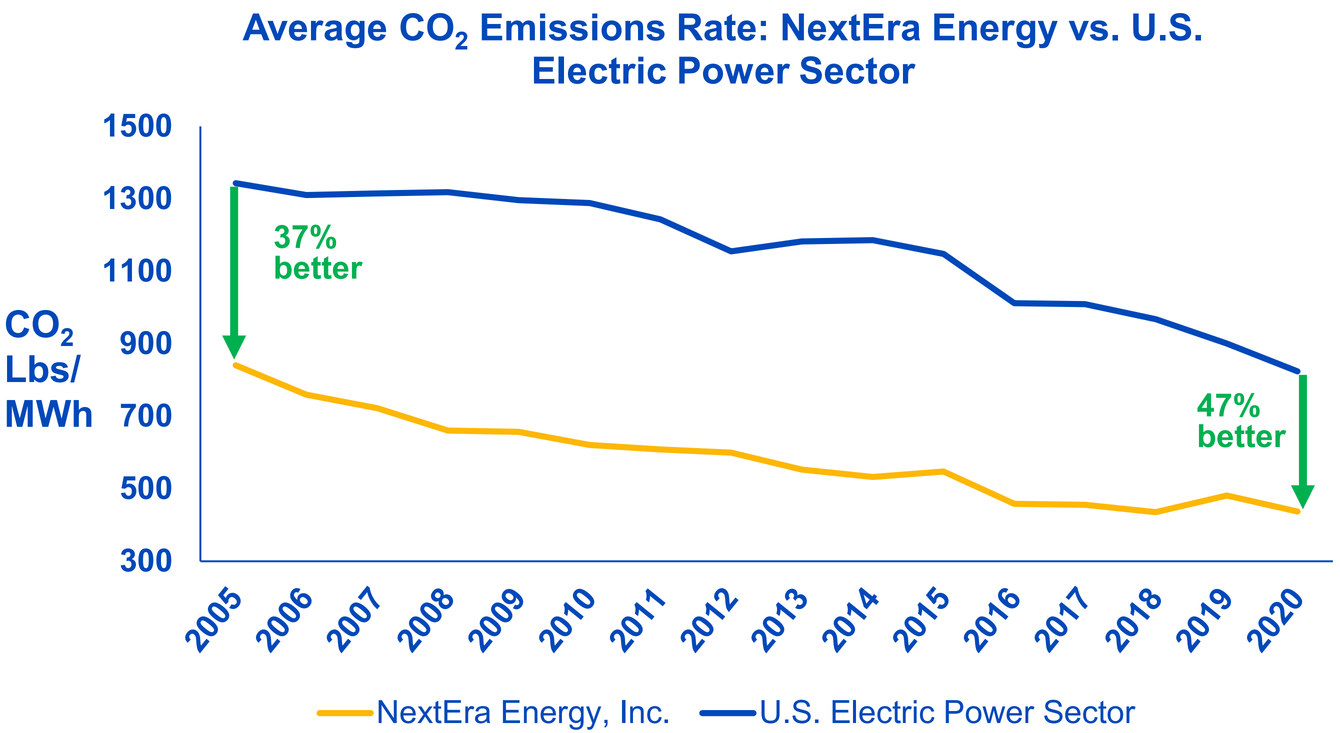


1) Megawatts shown includes assets operated by Energy Resources owned by NextEra Energy Partners as of September 30, 2021; all other assets are included at ownership share
2) Includes signed contracts as of October 20, 2021; excludes battery storage

Note: All other data as of September 30, 2021

We have one of the lowest emissions profiles of any utility in North America

Reducing Carbon Emissions[1,2]



75% increase in clean electricity generation[3]

~57 MM tons of avoided CO_2 emissions in 2020

Our rate has improved more than the industry's

NextEra Energy's CO_2 emissions rate ~15 years ago was better than the industry average in 2020

1) Sources: NextEra Energy: historic internal; U.S. Electric Power Sector: DOE data
2) Please see the Definitional Information slide in the Appendix for additional information related to our emissions reduction rate
3) As of year-end 2020 since 2005

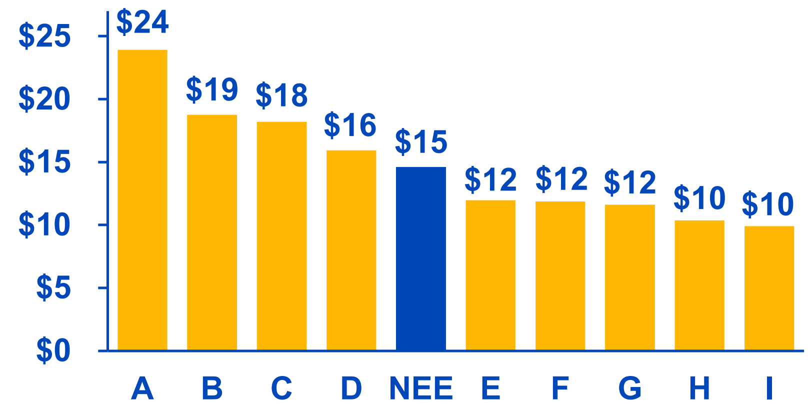
NEXTera ENERGY

Energy Resources is well positioned to benefit as the US pursues electrification to deliver economic carbon reductions

Competitive Advantages

- **Scale advantage enabling us to buy, build and operate cheaper**
  - 5th largest capital spender in U.S.(1)
  - Best-in-class supply chain relationships
- **Cost of capital advantages**
  - Investment-grade balance sheet
- **Development expertise**
  - >20 year history of renewables execution
  - Customer relationships and interconnection queue positioning
- **Data analytics developed in-house**
  - Proprietary algorithms to manage our fleet efficiently and achieve top decile O&M performance in the industry
  - Tremendous data only available through our scale and decades of experience
  - Using data and algorithms to enhance development capabilities

2020 Top 10 US Capital Investors(1)



NextEra Analytics

~39 B
Operating Data Points per Day

1) NextEra Energy in total; estimates based on publicly available data

Energy Resources' competitive advantages position us to continue to capitalize on what we believe is the best renewables development environment in our history

Energy Resources Development Program[1]

(Signed Contracts as of October 20, 2021)

	2021 – 2022 Signed Contracts	2021 – 2022 Expectations	2023 – 2024 Signed Contracts	2023 – 2024 Expectations	2021 – 2024 Expectations
Wind[2]	5,093	3,700 – 4,400	1,010	2,250 – 3,500	5,950 – 7,900
Solar	4,321	4,800 – 5,600	5,164	7,000 – 8,800	11,800 – 14,400
Energy Storage	1,639	1,650 – 2,000	1,514	2,700 – 4,300	4,350 – 6,300
Wind Repowering	549	375 – 700		200 – 700	575 – 1,400
Total	11,602	10,525 – 12,700	7,688	12,150 – 17,300	22,675 – 30,000
Build-Own-Transfer	110		690		

Energy Resources now has ~18,100 MW in its backlog of signed contracts, supporting our industry-leading long-term growth expectations

1) MW capacity expected to be owned and/or operated by Energy Resources; includes build-own-transfer projects with long-term O&M agreements
2) Includes ~280 MW for Energy Resources' share of both NextEra Energy Partners' ~100 MW announced acquisition and 391 MW wind portfolio acquisition closed in Q3 2021

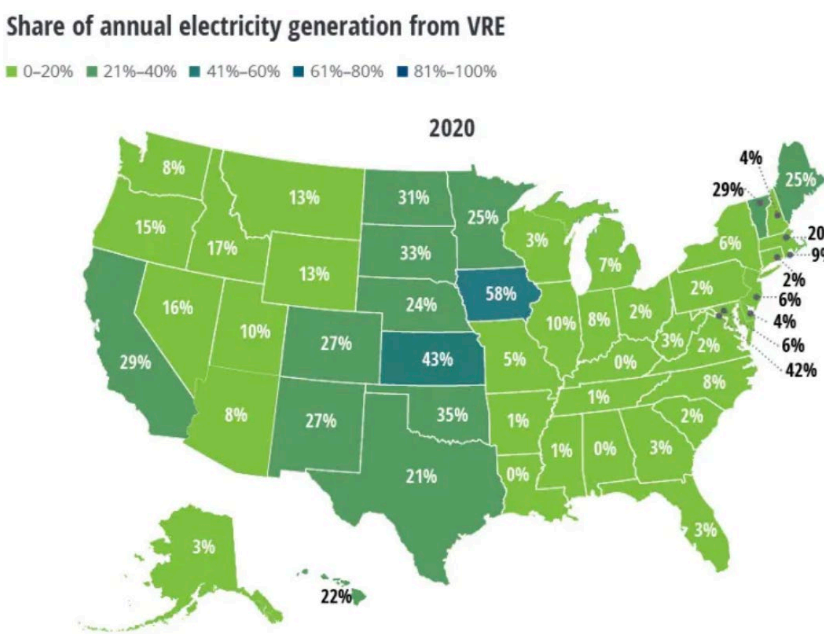
NEXTera ENERGY

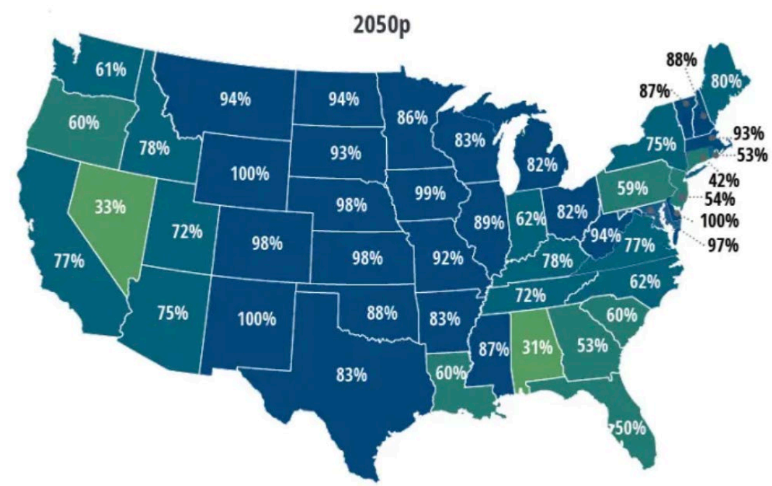
The United States electric grid is transitioning to clean energy

US Electric Grid Transition

How do you go from this level of renewable energy in 2020[1]…

…To this level of renewable energy in 2050



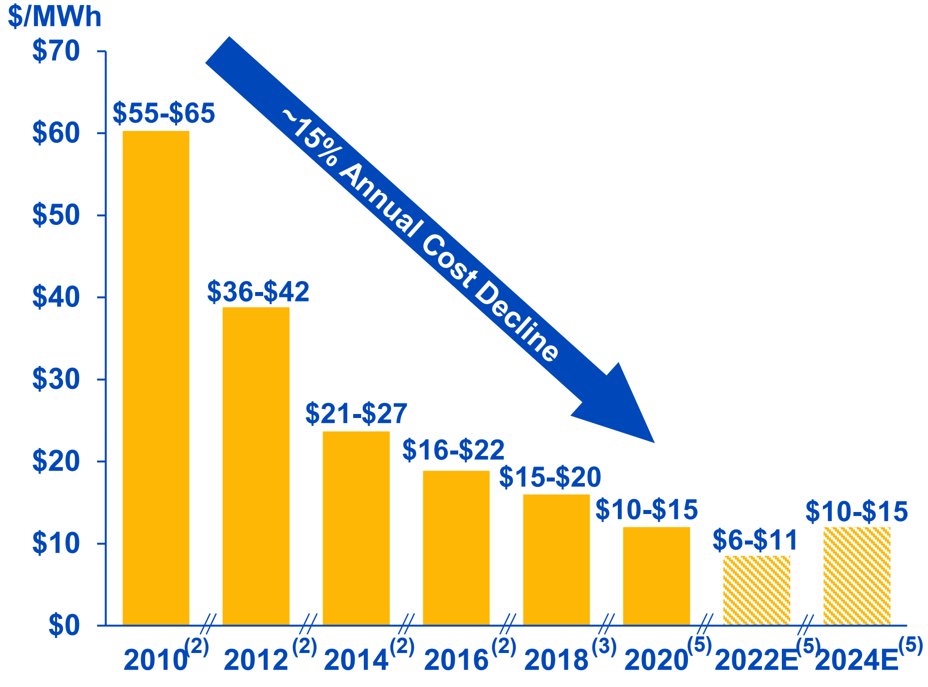


1) Deloitte Renewable Energy Transition Article – September 21, 2021 (https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/us-renewable-energy-transition.html)

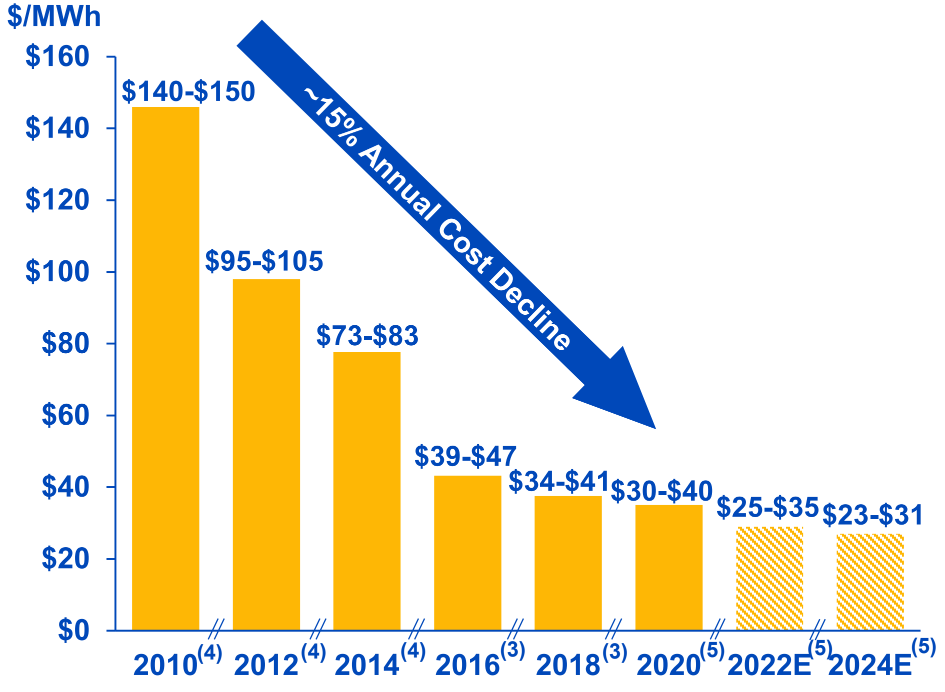
Technology improvements and capital cost declines have significantly improved wind and solar economics

Wind & Solar Technology

Levelized Cost of Electricity from Wind
(Including Production Tax Credits[1])



Levelized Cost of Electricity from Solar
(Including Investment Tax Credits)



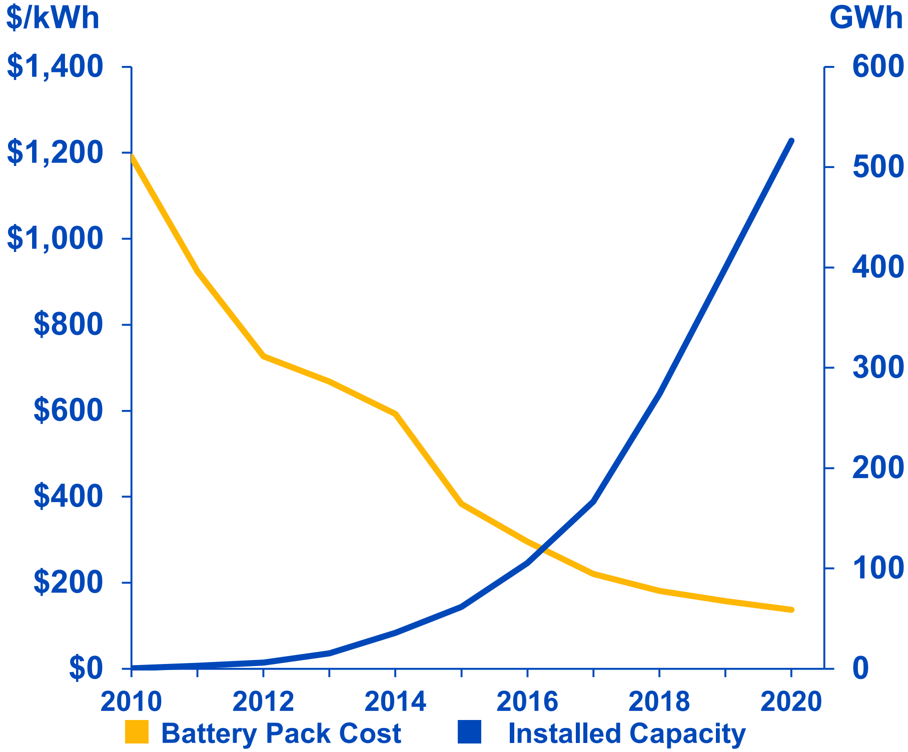
1) 2010-2022: 100% PTC, 2024: 60% PTC
2) Source: U.S. Department of Energy, Wind Technologies Market Report
3) Source: Bloomberg New Energy Finance
4) Source: IHS Markit. The use of this content was authorized in advance. Any further use or redistribution of this content is strictly prohibited without written permission by IHS Markit. All rights reserved
5) Energy Resources' estimate

NEXTera ENERGY

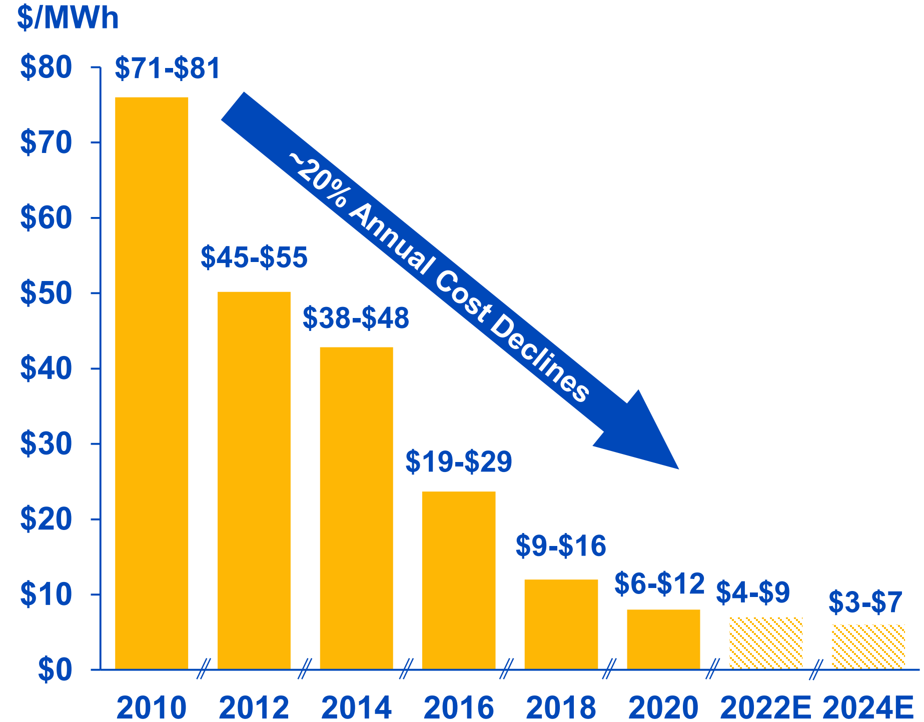
Increased manufacturing capacity and technology improvements have resulted in energy storage cost declines and the ability to create low-cost near-firm wind and solar

Energy Storage Costs

Battery Pack Cost Relative to Capacity[1]



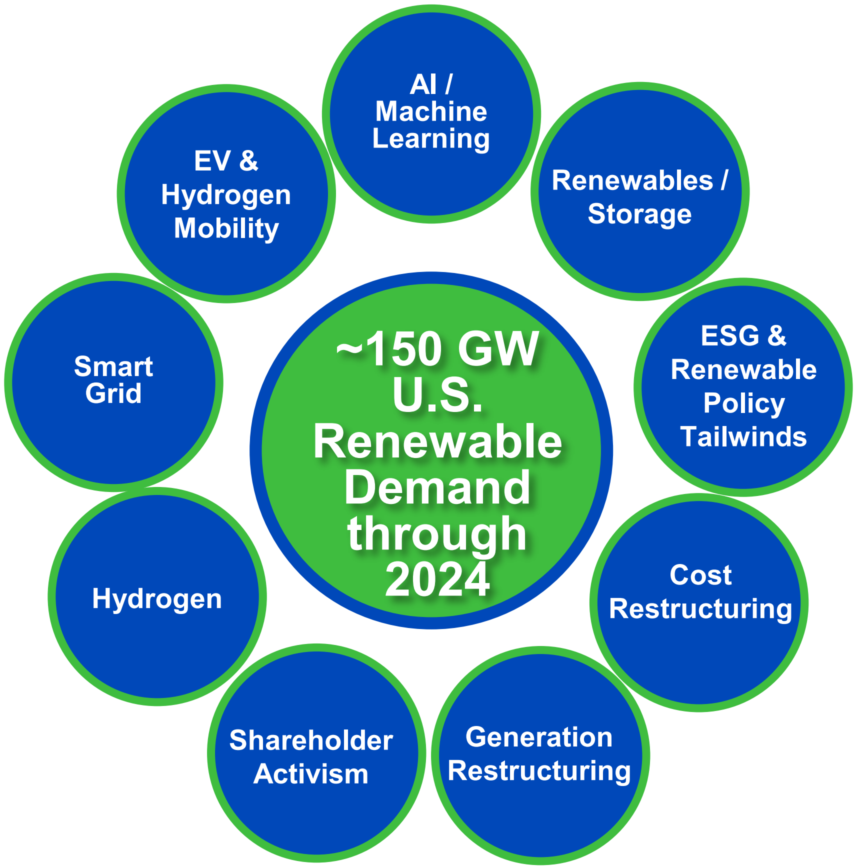
4-Hour Battery Storage Adder[2]



1) Source: Bloomberg New Energy Finance – Lithium-Ion Battery Price Survey Dec 2020
2) Energy Resources' estimate; assumes: 4-hour battery storage at 25% of nameplate solar capacity; total battery system costs calculated as two times Bloomberg New Energy Finance battery pack cost

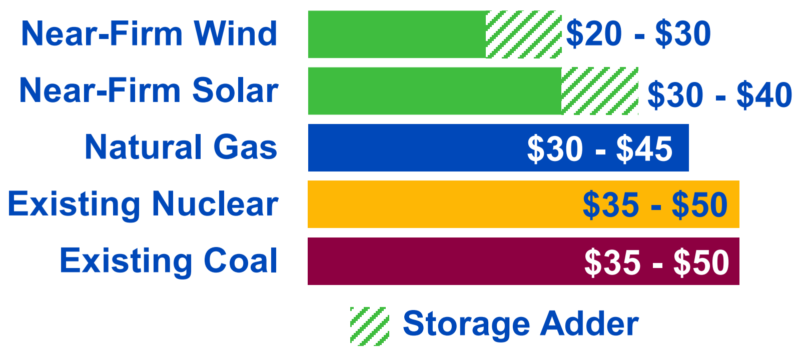
We expect the industry's clean energy transformation will further expand and accelerate over the coming years

Disruptive Industry Changes Today

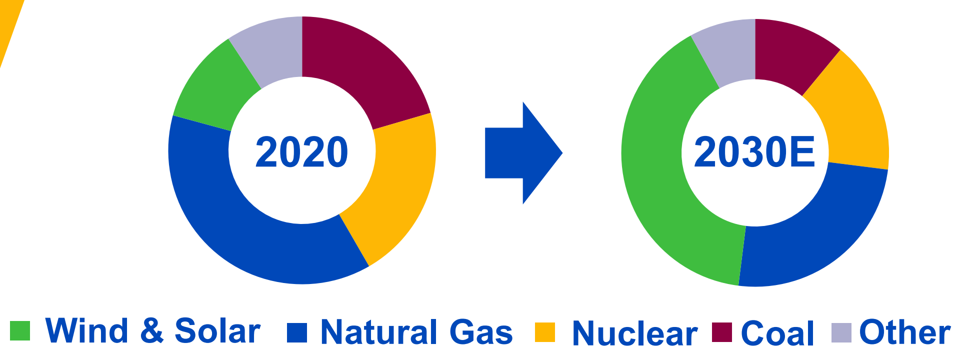


Potential Cost per MWh Mid-2020s(1)

($/MWh)



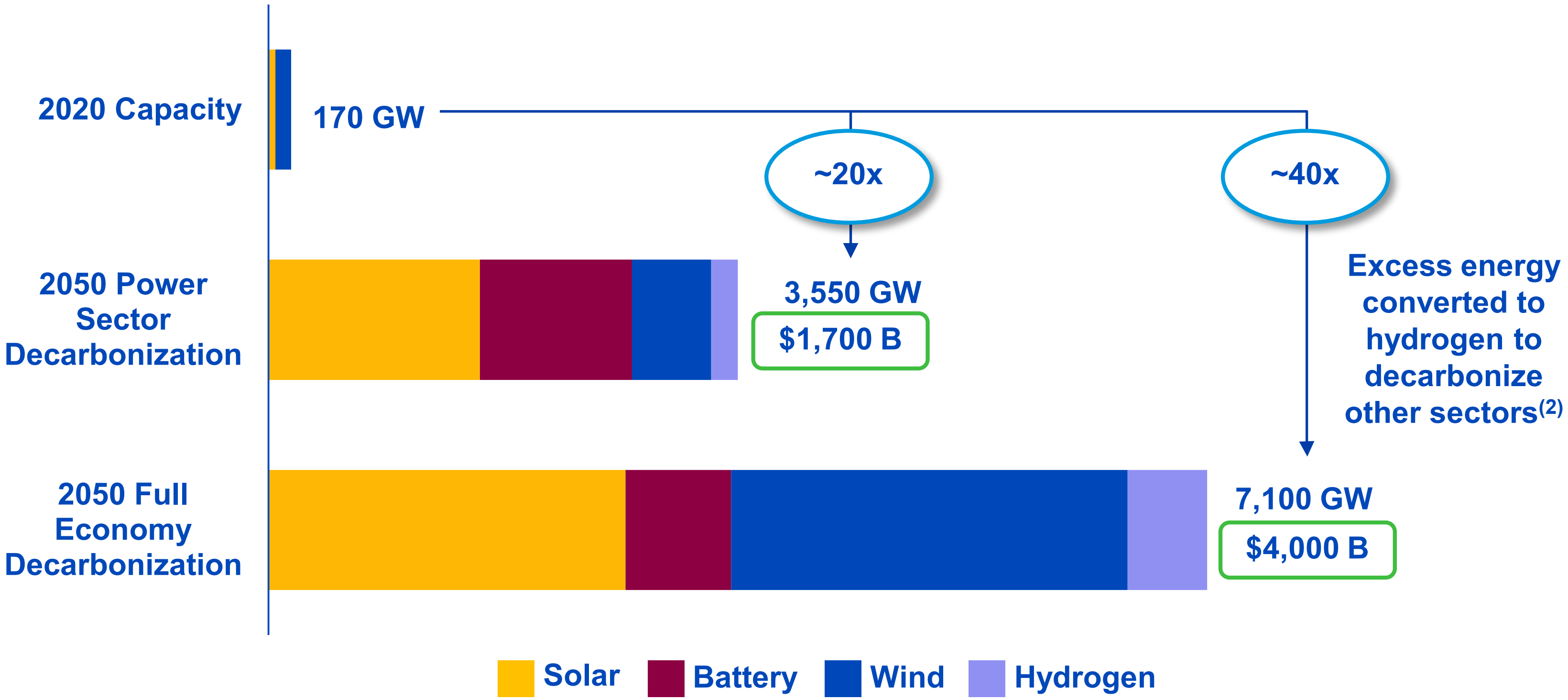
U.S. Electricity Production by Fuel Type(2)



1) Represents projected cost per MWh for new build wind, solar, and natural gas; excludes PTC for wind and assumes 10% ITC for solar; projected per MWh operating cost including fuel for existing nuclear and coal; based on NextEra Energy internal estimates
2) 2020 source: U.S. EIA Annual Anergy Outlook 2021 Reference Case: 2030 estimate source: National Renewable Energy Laboratory (NREL) 2020 Low Renewable & Low Battery Cost Scenario

Decarbonization of the entire U.S. economy could create ~$4 trillion investment opportunity through 2050

2050 Decarbonized U.S. Economy: Growth in Renewables and Storage Opportunity[1]



Customer costs may be net neutral to achieve a decarbonized electric grid by 2050

1) NextEra Energy internal analysis, with uncertainties in assumptions including transmission and land costs, future cost declines for certain technologies, and treatment of stranded costs for certain existing generation assets; Princeton Net-Zero America Report for Full Economy Decarbonization
2) High renewable penetration to decarbonize the electricity sector results in ~25-30% excess renewable generation in 2050, which could be used to make hydrogen to decarbonize other sectors of the economy

Interconnection study process is lengthy and inconsistent yet is the only way for generation developers to gain access to grid interconnection

Challenges with interconnection study process

- 5-6 year study process leads to increased number of projects in queue to "reserve" a place in line
- Need for automation and use of technology
- Standardization of study assumptions, fuel-based dispatch and other key study criteria
- Consistency between regions, RTOs, utilities, etc.
- Need for consistency and certainty for developers and transmission owners related to cost and schedule
- Stated and enforceable timelines for affected system studies needed to fix on-going delays in study completion

NEXTera ENERGY

Interconnection of low-cost clean energy project provides mutli-value benefits to multiple customers

Why it matters?

- **Goal of developers is to provide the lowest cost and cleanest energy projects for its customers**
  - These projects not only provide benefits to customers but also lower costs for all customers where the project interconnects
- **Customers of renewable developer projects provide states where they do business with jobs, tax revenues and clean, low-cost power in the area of interconnection**
- **Buildout of transmission provides various benefits including reliability and resiliency (e.g., 2021 winter weather events – transmission between PJM, MISO and SPP)**
- **Reasonable inputs needed in transmission planning process to build out "backbone" facilities required for customer reliability**

Solution to the broken interconnection process includes changes that fundamentally alter the current process and recognize the differences between the grid of 30 years ago and today

What's The Solution

- **Cost Allocation**
  - Reform of participant funding rules to align costs with the benefits provided to all parties so that generation developers are not stuck with 100% of the costs
    - -- Included in potential reforms at the Federal Energy Regulatory Commission (FERC)
- **Technology**
  - Use of cloud computing and automation to shorten the interconnection study process
    - -- NextEra and Amazon partnering on project to significantly improve the completion timeframes for interconnection studies
  - Standardization of study methodologies and study completion timeframes
- **Regulatory**
  - Improved transmission planning to incorporate clean energy goals into long-range planning process and ensure right facilities are being built to accommodate clean energy future
    - -- Included in April Notice of Proposed Rulemaking from FERC

Energy Systems Integration Group is a non-profit educational association that provides workshops, resources and education on the evolving electricity and energy systems.

ESIG supports engineers, researchers, technologists, policymakers and the public with the transformation of energy systems in a way that is economic, reliable, sustainable, thoughtful and collaborative.

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ENERGY SYSTEMS
INTEGRATION GROUP

MISO/SPP Joint Transmission Planning Projects

MRO Reliability Conference

May 18, 2022

SPP Southwest Power Pool

MISO

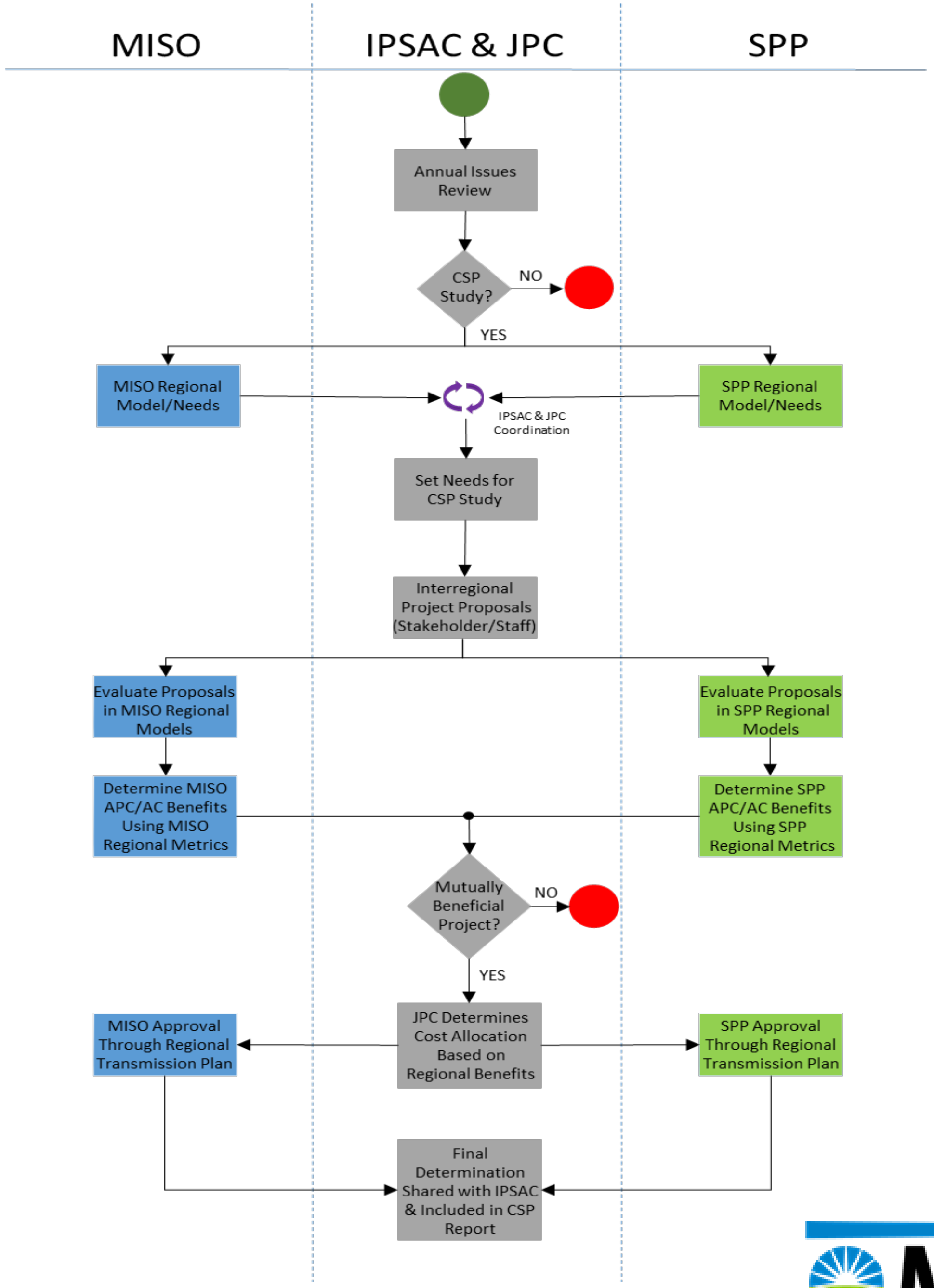
Current Interregional Planning Efforts

- MISO-SPP Coordinated System Plan (CSP)
  - Standing process through which MISO and SPP coordinate interregional planning activities
  - 2022 effort focuses on the development of a Targeted Market Efficiency Projects (TMEPs) process
    - Uses day-ahead and real-time market congestion data to indicate potential interregional transmission upgrade opportunities
    - Process focuses on quick-hit upgrades that are low cost and can be constructed in a relatively short amount of time (e.g. brownfield)
- MISO-SPP Joint Targeted Interconnection Queue (JTIQ) Study
  - Special study intended to address issues along the MISO-SPP seam frequently identified in the generator interconnection process

MISO-SPP Coordinated System Plan (CSP) Overview

Coordinated System Plan study process

- MISO and SPP enhanced the CSP study process in 2019 through Joint Operating Agreement (JOA) changes
  - New process takes advantage of each RTO's respective regional process
- Study scope is determined as a part of an annual issues review with stakeholders
  - Scope may include reliability, economic or public policy issues
- RTOs coordinate on model development, issues identification, and technical analysis throughout the evaluation process



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Recent MISO-SPP Coordinated System Plan (CSP) study efforts

- MISO and SPP performed CSP studies in 2019 and 2020
  - Both studies focused on economic congestion issues in the 10+ year planning horizon
  - No projects met the required B/C ratios in both organizations for recommendation
- Although no projects were recommended, studies provided valuable insight into the challenges and limitations of the existing JOA process
- Results prompted MISO and SPP to explore other study concepts that focused on prominent seams issues

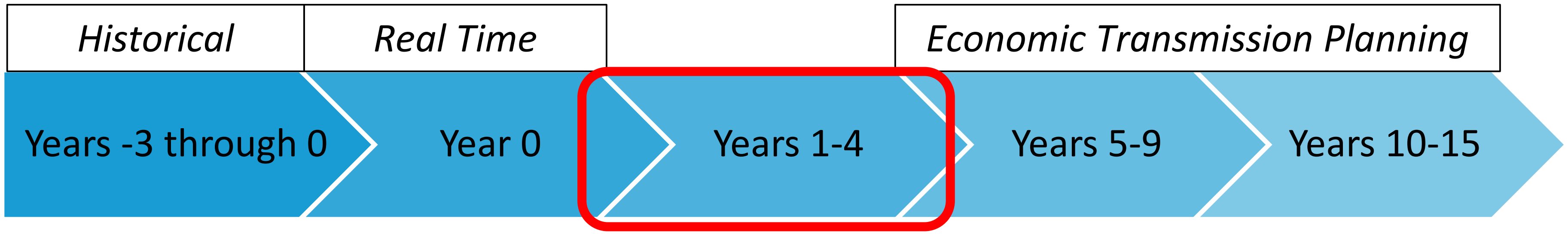
MISO-SPP Targeted Market Efficiency Project (TMEP) Study

MISO-SPP Targeted Market Efficiency Projects (TMEP) study background

- MISO and PJM originally developed the TMEP concept in 2015 as way to relieve known market-to-market (M2M) congestion issues through valuable 'quick-hit' projects
  - Since inception, MISO and PJM have performed TMEP studies in 2016 and 2018 resulting in a total of seven new upgrades
- MISO and SPP began exploring a way to build on the successful MISO-PJM process to meet the needs of the MISO-SPP seam
- RTOs formally kicked off the study effort as a part of the 2022 CSP planning cycle
  - Study will cover both identification of potential upgrades and process development for the MISO-SPP JOA
  - Draft study scope is posted with the May 6 IPSAC materials

Objective: Help bridge the gap between real-time and longer-term planning horizons

- Economic Transmission Planning typically focuses on years 5 and beyond
- Future economic planning models do not always capture the actual congestion showing up repeatedly in Day Ahead (DA) and Real-Time (RT) markets



The TMEP concept complements longer term market efficiency planning

Targeted Market Efficiency Project

- Driver is historical M2M congestion
- Limited scope and cost
- Straight-forward benefit determination

Longer Term Market Efficiency Project

- Driver is future congestion identified in regional planning processes
- Candidate projects go through project solicitation (as applicable)
- Longer model development and more complex analysis process

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TMEP Process Overview

1. Identify scope of potential flowgates by comparing market data in each RTO (e.g. M2M Settlements and DA/RT market data)
   - Data analysis to identify targeted flowgates for study
   - Coordinate with operators and stakeholders to ensure congestion is expected to persist
2. Solution development: Look for potential projects to address historical congestion
   - Outreach to facility owners to identify limiting elements and upgrade costs
   - Benchmark projects using reliability and economic models
   - Verify solution passes criteria (benefit > cost; in-service time etc.)
3. Cost allocation calculations and regional approval processes

MISO and SPP Stakeholders are considering appropriate criteria for TMEP eligibility

Description	Current MISO-PJM Criteria (To be refined with MISO-SPP Stakeholders)
Flowgates eligible for TMEP study evaluation	Limited to M2M only
M2M historical data sample size	2 years
Minimum historical M2M congestion cost used for screening potential flowgates	$1M
Perform in conjunction with a CSP study	Yes
Cost threshold for projects	$20M
In service timeframe	3 years (3rd summer peak)
"Payback" period	4 years of avoided congestion
Project benefit determination	Average of M2M data sample period

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2022 CSP Study Timeline and Milestones

	May	June	July	Aug	Sept	Oct	Nov	Beyond…
CSP scope devlopment								
Data gathering and determine final candidate flowgate list								
Develop initial criteria through IPSAC								
Asset owner outreach								
Solution development								
Process and criteria refinement as needed								
Finalize intial project recommendations and process								
Document Process and Recommended Projects in CSP Report								
JOA/Tariff process language development								Q4 2022 -Q1 2023
Regional cost allocation development								2023
FERC filings								2023

- Planned IPSAC dates:
  - July 22 10:00 AM – 12:00 PM CT
  - September 23 10:00 AM – 12:00 PM CT
- Additional IPSAC meetings will be scheduled as needed as study progresses

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MISO-SPP Joint Targeted Interconnection Queue (JTIQ) Study

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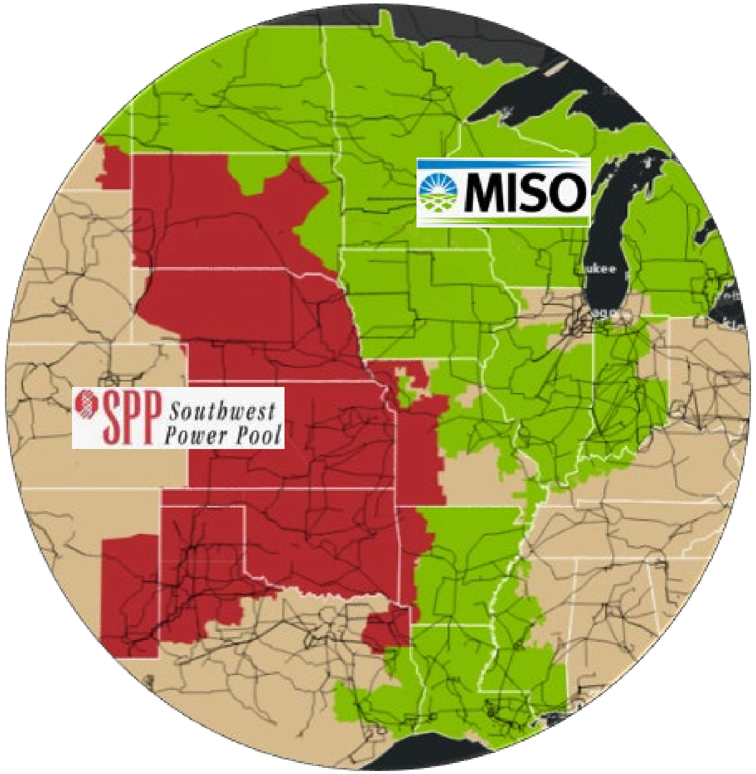
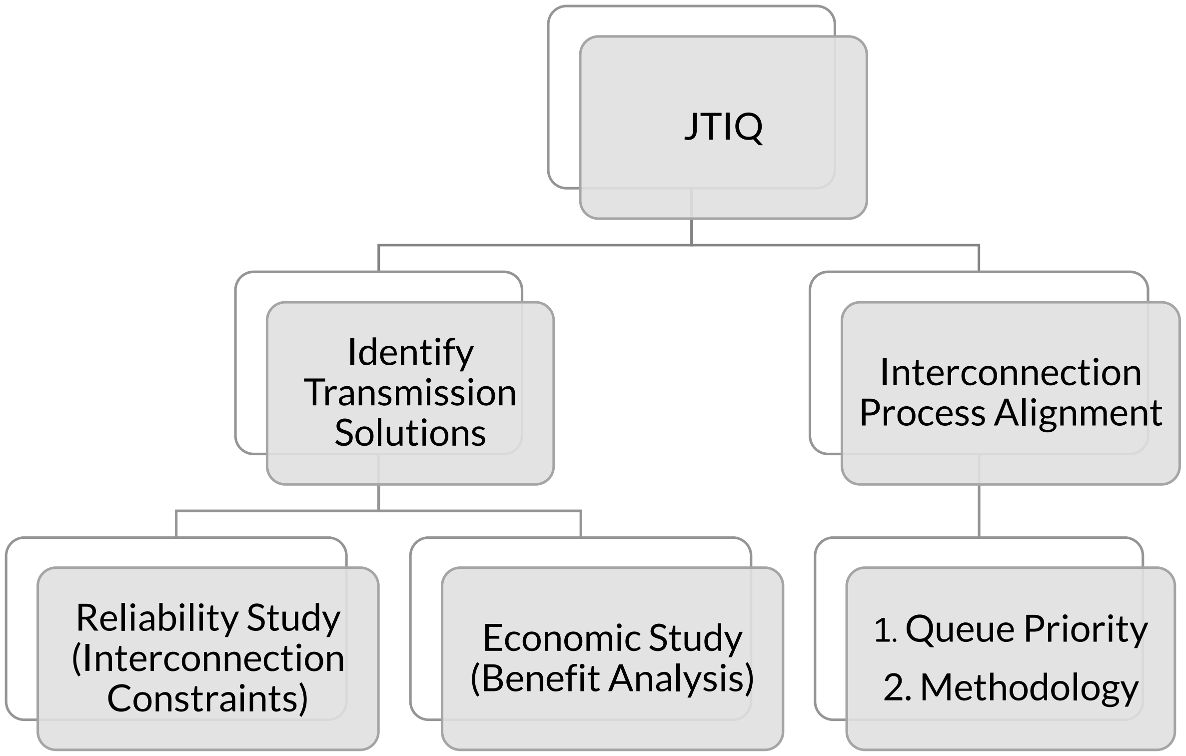
The SPP-MISO JTIQ Study focuses on optimizing transmission needed for interconnection across the seams and for the evolving resource mix



- SPP and MISO are experiencing similar resource mix shifts
- The transmission system is at capacity along the SPP-MISO seam
- Upgrades are too costly for small groups of interconnection customers, contributing to churn in the queue

JTIQ Study Assumptions and Process

- Models
  - MISO MTEP21 5 and 10 year out models
    - 2025 summer shoulder and peak
    - 2030 summer shoulder and peak
  - SPP ITP 2 and 5 year out models
    - 2023 summer peak
    - 2026 light load
    - 2026 summer and winter peak
  - Models include generation additions based on GI queues and MTEP/ITP futures
- Constraints Identification
  - Performed contingency analysis and applied DFAX criteria to filter constraints
    - 5% DF of at least one study unit in one RTO
    - 3% DF of at least one study unit in neighboring RTO
  - Resulted in 52 selected constraints
- Mitigation Plan Development
  - Approximately 60 projects analyzed with 16 different portfolio combinations to determine the optimized solution to address constraints



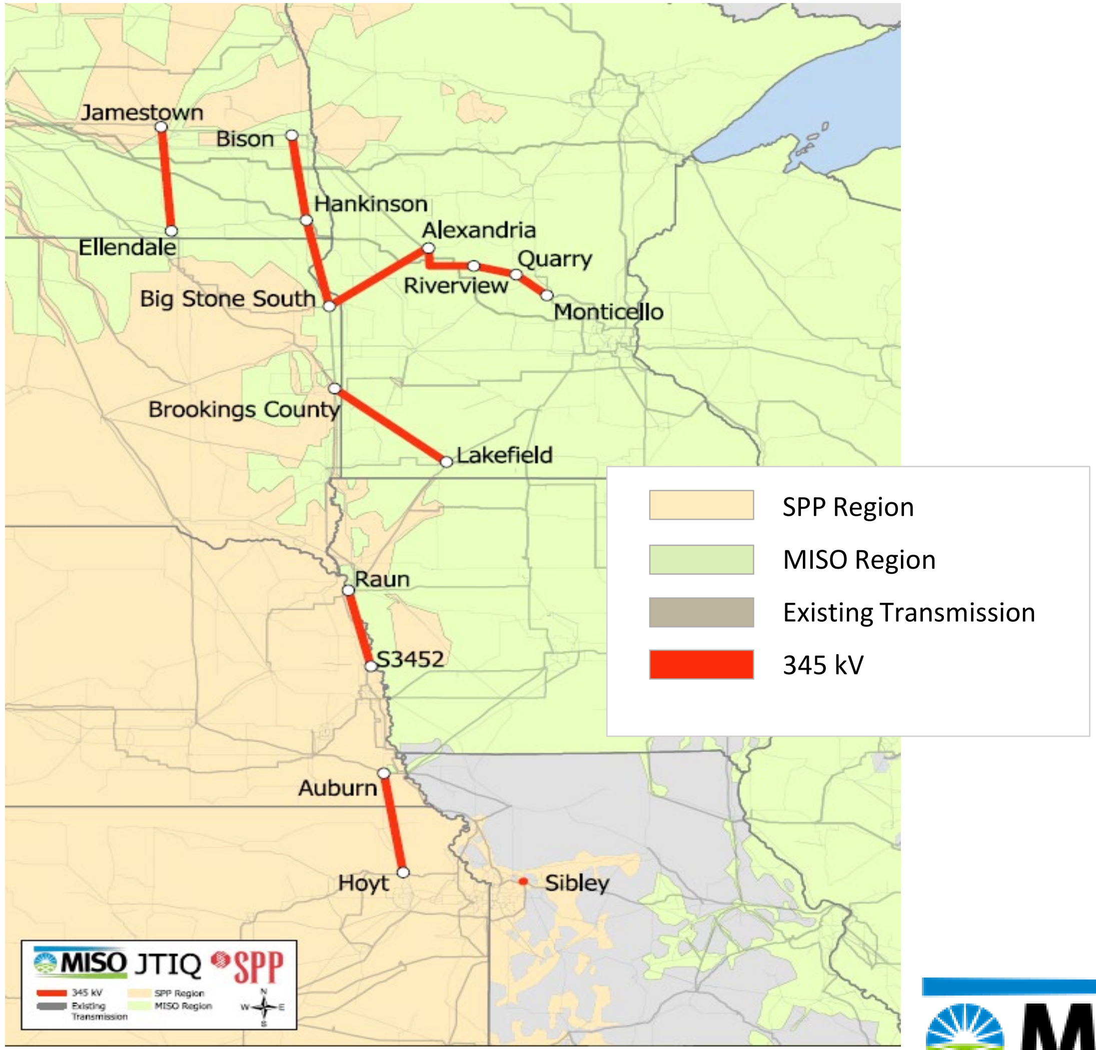
SPP and MISO finalized a portfolio to mitigate most constraints along multiple MISO-SPP state boundaries

This portfolio provides a range of benefits:

- **Improves reliability** by mitigates existing constraints

- **Increase interregional transfer capability,** and

- **Provides economic Adjusted Production Cost (APC) benefits**



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JTIQ Portfolio – List of Projects

JTIQ Portfolio	Location by RTO	Cost ($M)
*Bigstone – Alexandria – Riverview – Quarry – Monticello 345 kV**	*MISO*	*424.5*
*Jamestown – Ellendale 345 kV**	*MISO*	*165*
Bison – Hankinson – Big Stone South 345 kV	MISO	476
Brookings Co – Lakefield 345 kV	MISO	331
Raun – S3452 345 kV	MISO - SPP	144.4
Auburn – Hoyt 345 kV	SPP	90.5
Sibley 345 Bus Reconfiguration	SPP	18.8
Total Cost of Portfolio of Projects	MISO - SPP	1650.2

**Projects included in MISO's Long Range Transmission Plan (LRTP) Tranche 1*

Project Name	Cost in $M	MISO PV Benefit ($M)	SPP F2 20Y Benefit ($M)	SPP-MISO Combined B/C
JTIQ Portfolio	1,650.2	724.23	246.74	0.60

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The JTIQ Portfolio will enable the ability to interconnect new capacity along the MISO-SPP seam

- JTIQ Portfolio could enable new generation capacity along the combined MISO and SPP seam
  - Power flow models estimated 28 GW of combined new enablement
- Capacity Enabled Calculations include
  - Generation enabled by constraints mitigated by JTIQ projects in both RTOs
  - Additional Generation at existing resources by utilizing unused capacity on mitigated constraints and JTIQ portfolio projects
- SPP performed analysis on the impact of including the JTIQ portfolio in a previous SPP Affected System Study for a MISO DPP Cycle and a SPP DISIS Cycle
  - JTIQ Portfolio alleviates 60% of the constraints previously identified in AFS Study
  - JTIQ Portfolio alleviates 44% of the constraints previously identified in DISIS study
  - No adverse impacts observed (no additional constraints) in DISIS or DPP Affected System study in the region of interest

JTIQ Portfolio - Next Steps

- The JTIQ final study report was published in March 2022
- Timeline
  - MISO and SPP are working with stakeholders to develop a cost allocation framework in Q2 and Q3 of 2022
  - FERC filings for cost allocation are targeted for the end of 2022
  - Formal MISO and SPP approvals of JTIQ transmission projects targeted for Q1/Q2 2023

MISO-SPP Interregional Planning – conclusions and expected future challenges

- Both TMEPs and JTIQ present excellent opportunities to build valuable transmission upgrades that:
  - Enhance robustness of the transmission system
  - Address constraints currently observed in real-time operations
- Cost allocation will continue to be a challenge to interregional transmission development
- Recent policy developments will play a large role in future interregional project development efforts
  - FERC Notice of Proposed Rulemaking (NOPR) on transmission planning
  - SPP's Consolidated Planning Process (CPP)
  - Expected Generator Interconnection NOPR

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MISO

Contact Information

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OGE System Zonal Study for Voltage/Var Control

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May 18, 2022

Outline

- About OGE
- Background
- Methodology
- Study Case
- Applications

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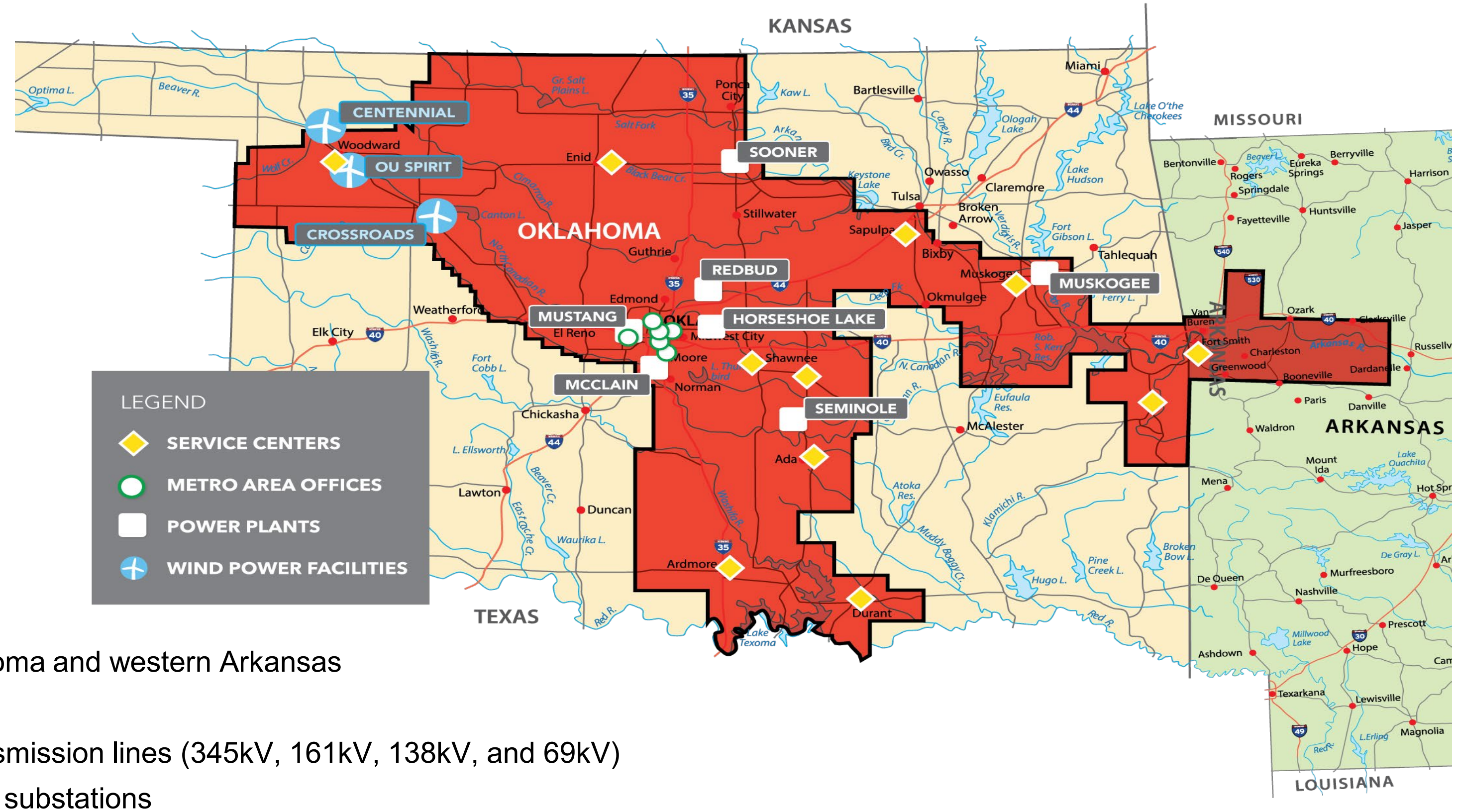
Oklahoma Gas & Electric (OGE)



- Founded in 1902
- Service territory: Oklahoma and western Arkansas
- 840k+ customers
- 4k+ circuit miles of transmission lines (345kV, 161kV, 138kV, and 69kV)
- 160+ BES transmission substations
- Total interconnected generation capacity: ~16,000 MW (Wind: ~7,600 MW)
- 7,057 MW peak load (2011)

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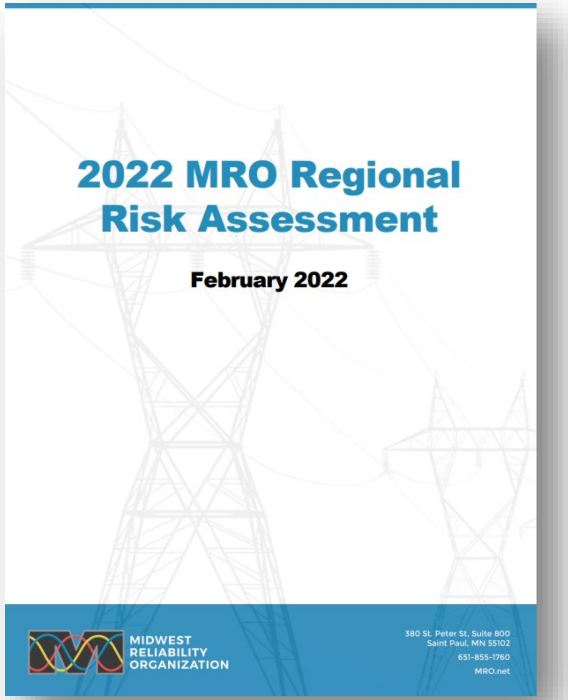
Background

- Transmission Operators operate transmission system per the established System Operating Limit (SOL) to maintain system reliability.

- Related NERC Reliability Standards
  - VAR-001-5 Voltage and Reactive Control
  - VAR-002-4.1 Generator Operations for Maintaining Network Voltage Schedules
  - TOP-001-5 Transmission Operations

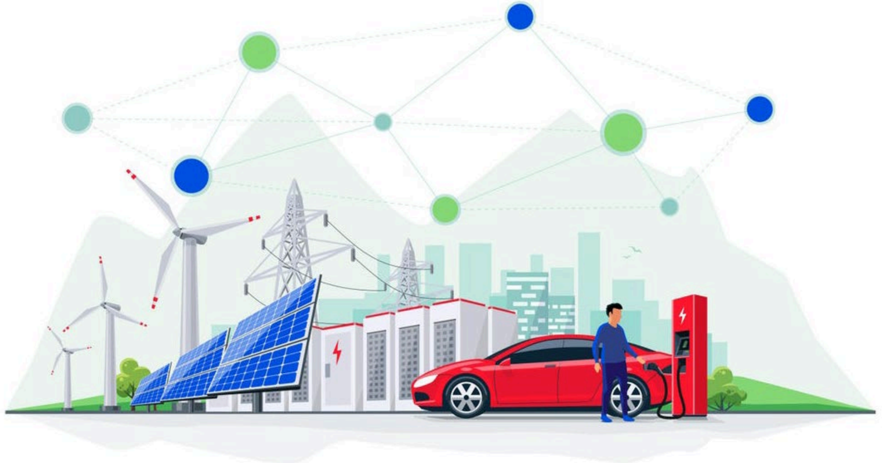


Operations and Planning Risks

- *Reactive Capability of IBRs and Reactive Resource Adequacy*
- *Inverter Based Resource Modeling and Ride Through Capabilities*

Background (Cont'd)

- Controlling power system voltage is typically a local issue
- Dividing a given system into several zones is of practical value
- Evolving system conditions (renewable energy, DERs, etc.)
- Zonal assignment needs to account for those changes and be evaluated in a systematic way



https://www.forbes.com/sites/jeanmarcollagnier/2019/01/14/renewable-energy-boom-is-pushing-the-grid-to-its-limits-prompting-operators-to-reinvent-themselves/?sh=3e8e713d5b33

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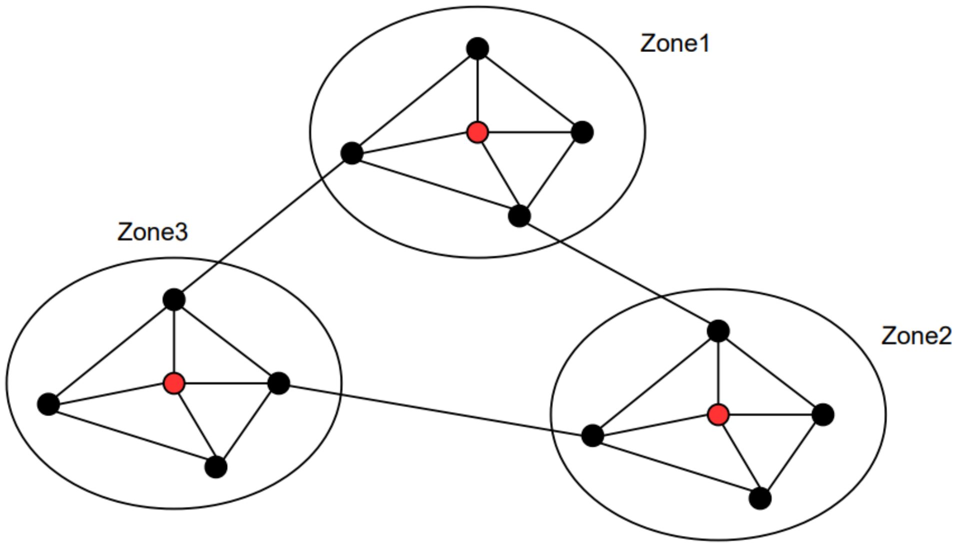
Voltage Control Zone

Buses have similar voltage responses to system perturbations

A pilot bus has a good representation of all buses in the same zone

Each zone is sufficiently de-coupled from its neighboring zones



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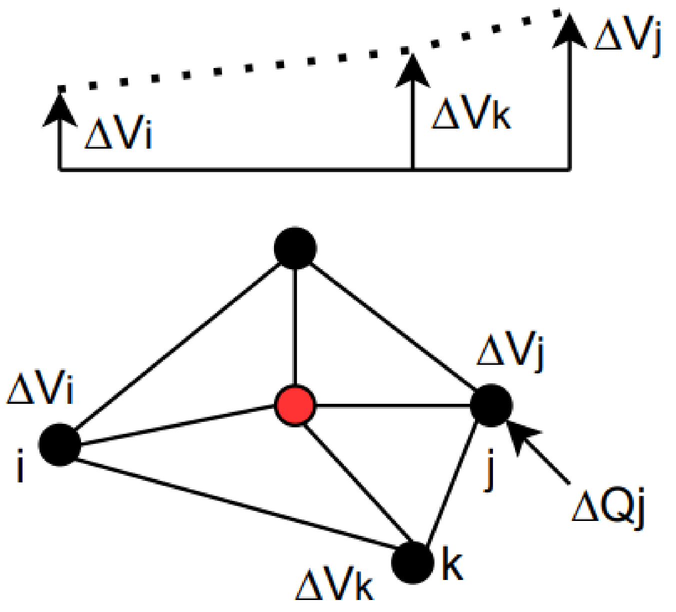
Methodology

Bus Voltage Attenuation



Bus Attenuation Index

$$a_{ij} = \frac{\Delta V_i}{\Delta V_j} = \left(\frac{\partial V_i}{\partial Q_j}\right) / \left(\frac{\partial V_j}{\partial Q_j}\right)$$

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Methodology (Cont'd)

Bus Attenuation Index $a_{ij} = \frac{\Delta V_i}{\Delta V_j} = \left(\frac{\partial V_i}{\partial Q_j}\right) / \left(\frac{\partial V_j}{\partial Q_j}\right)$

System Jacobian Matrix

$$\begin{bmatrix} \Delta \boldsymbol{P} \\ \Delta \boldsymbol{Q} \end{bmatrix} = \begin{bmatrix} \frac{\partial \boldsymbol{P}}{\partial \boldsymbol{\theta}} & \frac{\partial \boldsymbol{P}}{\partial \boldsymbol{V}} \\ \frac{\partial \boldsymbol{Q}}{\partial \boldsymbol{\theta}} & \boxed{\frac{\partial \boldsymbol{Q}}{\partial \boldsymbol{V}}} \end{bmatrix} \begin{bmatrix} \Delta \boldsymbol{\theta} \\ \Delta \boldsymbol{V} \end{bmatrix}$$

$$[\Delta \boldsymbol{Q}] = \left[\frac{\partial \boldsymbol{Q}}{\partial \boldsymbol{V}}\right] [\Delta \boldsymbol{V}]$$

$$[\Delta \boldsymbol{V}] = \left[\frac{\partial \boldsymbol{Q}}{\partial \boldsymbol{V}}\right]^{-1} [\Delta \boldsymbol{Q}]$$

Bus Voltage Sensitivity

$$\begin{bmatrix} \vdots \\ \Delta V_i \\ \vdots \\ \Delta V_j \\ \vdots \end{bmatrix} = \begin{bmatrix} \vdots \\ \partial V_i / \partial Q_j \\ \vdots \\ \partial V_j / \partial Q_j \\ \vdots \end{bmatrix} [\Delta Q_j]$$

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Methodology (Cont'd)

Bus Attenuation Matrix

$$\begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} & \ddots & a_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}$$

$$a_{ij} = \left(\frac{\partial V_i}{\partial Q_j}\right) \Big/ \left(\frac{\partial V_j}{\partial Q_j}\right)$$

Electrical Distance Matrix

$$\begin{bmatrix} 0 & \cdots & D_{1j} & \cdots & D_{1n} \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ D_{i1} & \cdots & 0 & \ddots & D_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ D_{n1} & \cdots & D_{nj} & \cdots & 0 \end{bmatrix}$$

$$D_{ij} = D_{ji} = -\log(a_{ij} \cdot a_{ji})$$

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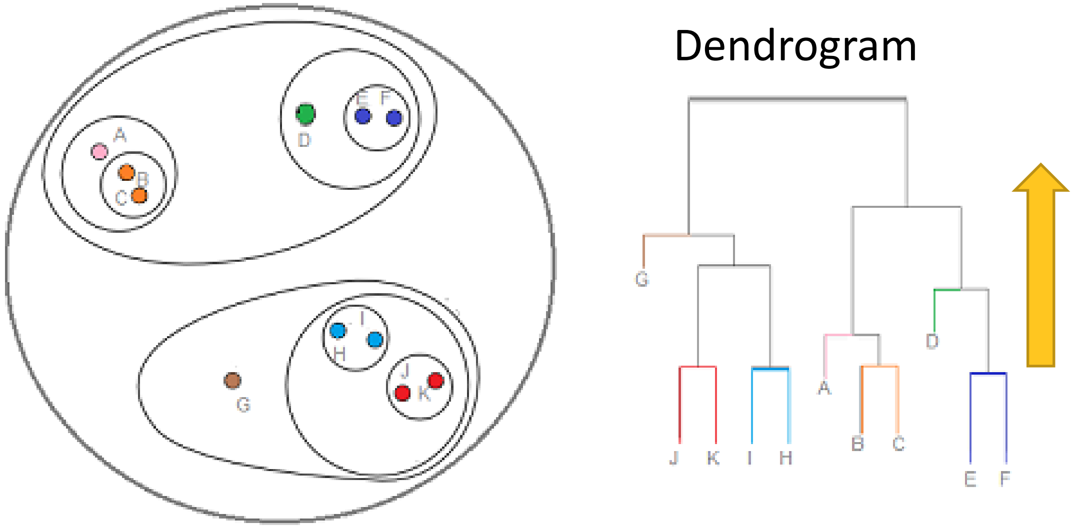
Methodology (Cont'd)

Hierarchical Clustering

- Starts by treating each observation as a separate cluster
- Repeatedly executes the following steps:
  - Identify the two clusters that are closest together
  - Merge the two most similar clusters
- Ends until all the clusters are merged into one



https://www.statisticshowto.com/hierarchical-clustering/

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Study Procedure

- Number of OGE buses: 655
- Excluded buses: wind farm collector buses, bus-tie transformer tertiary buses, etc.

Step 1. Study Case (2020 MDWG-20S)

Step 2. Calculate the Jacobian matrix and obtain the submatrix

Step 3. Invert submatrix to build voltage sensitivity matrix

Step 4. Calculate bus attenuation indices for all bus pairs

Step 5. Calculate electrical distance for all bus pairs

Step 6. Cluster buses based on calculated electric distance

Fine tune the number of groups

scipy.cluster

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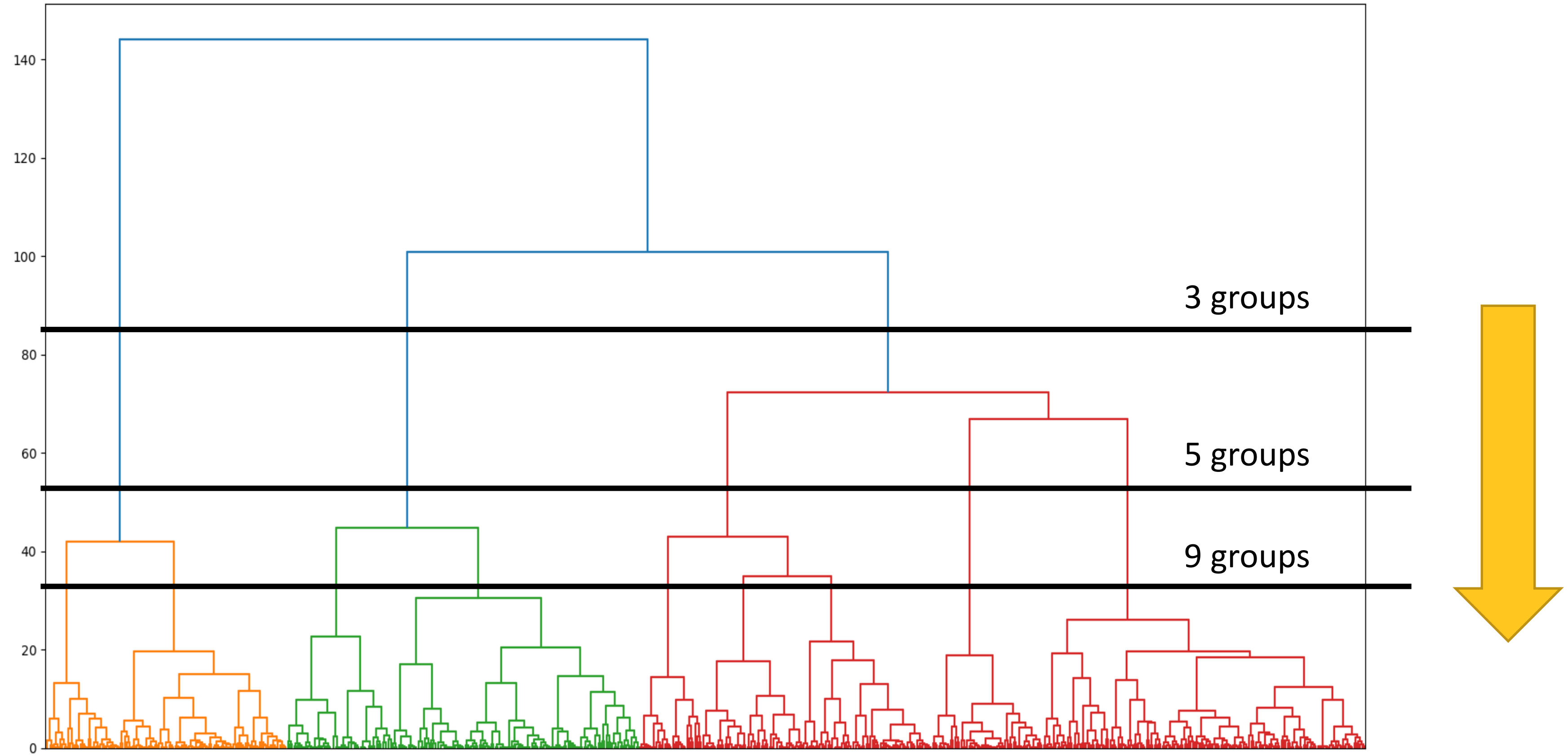
Results – Bus Hierarchy



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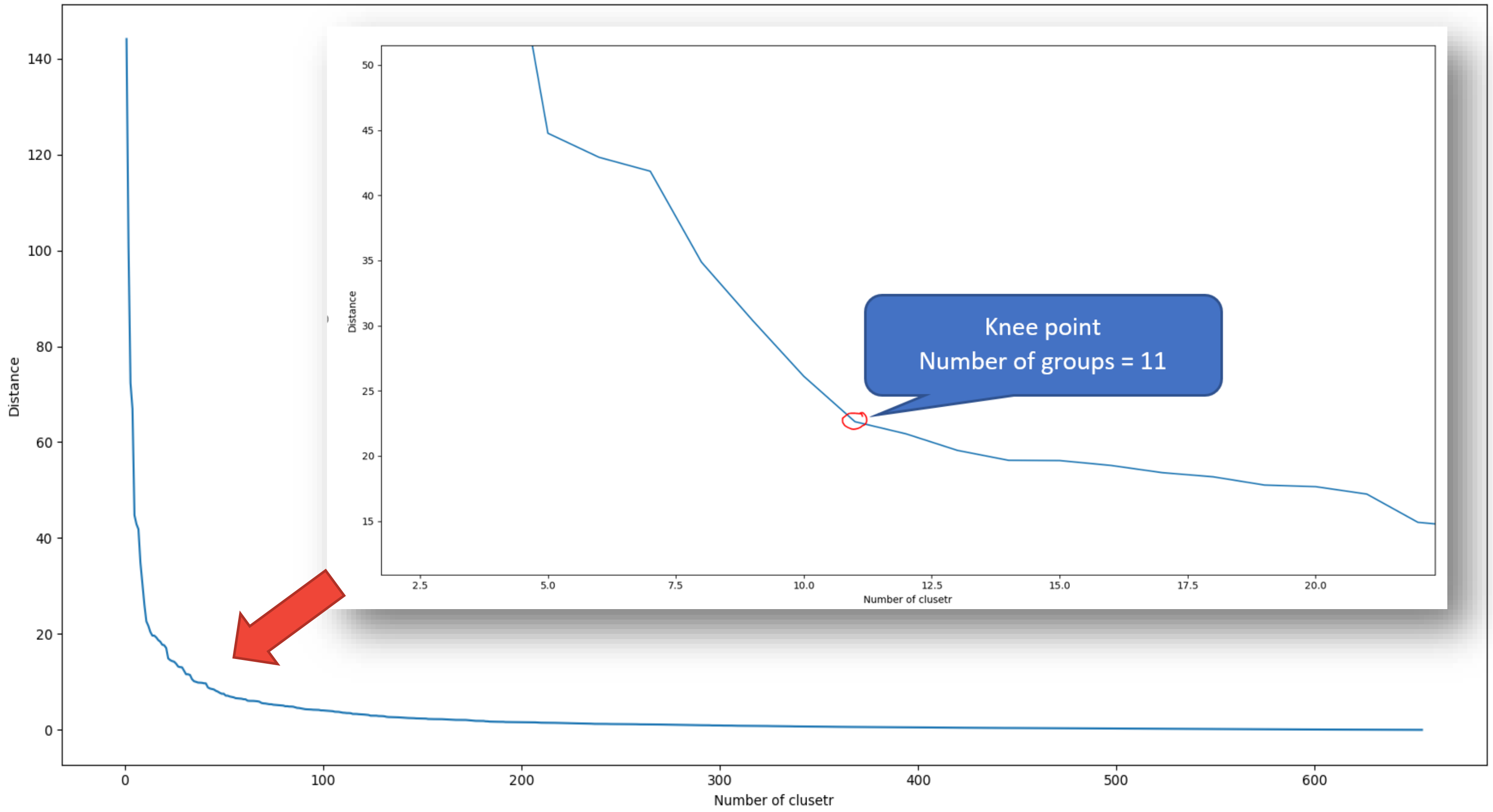
Results – Bus Clusters



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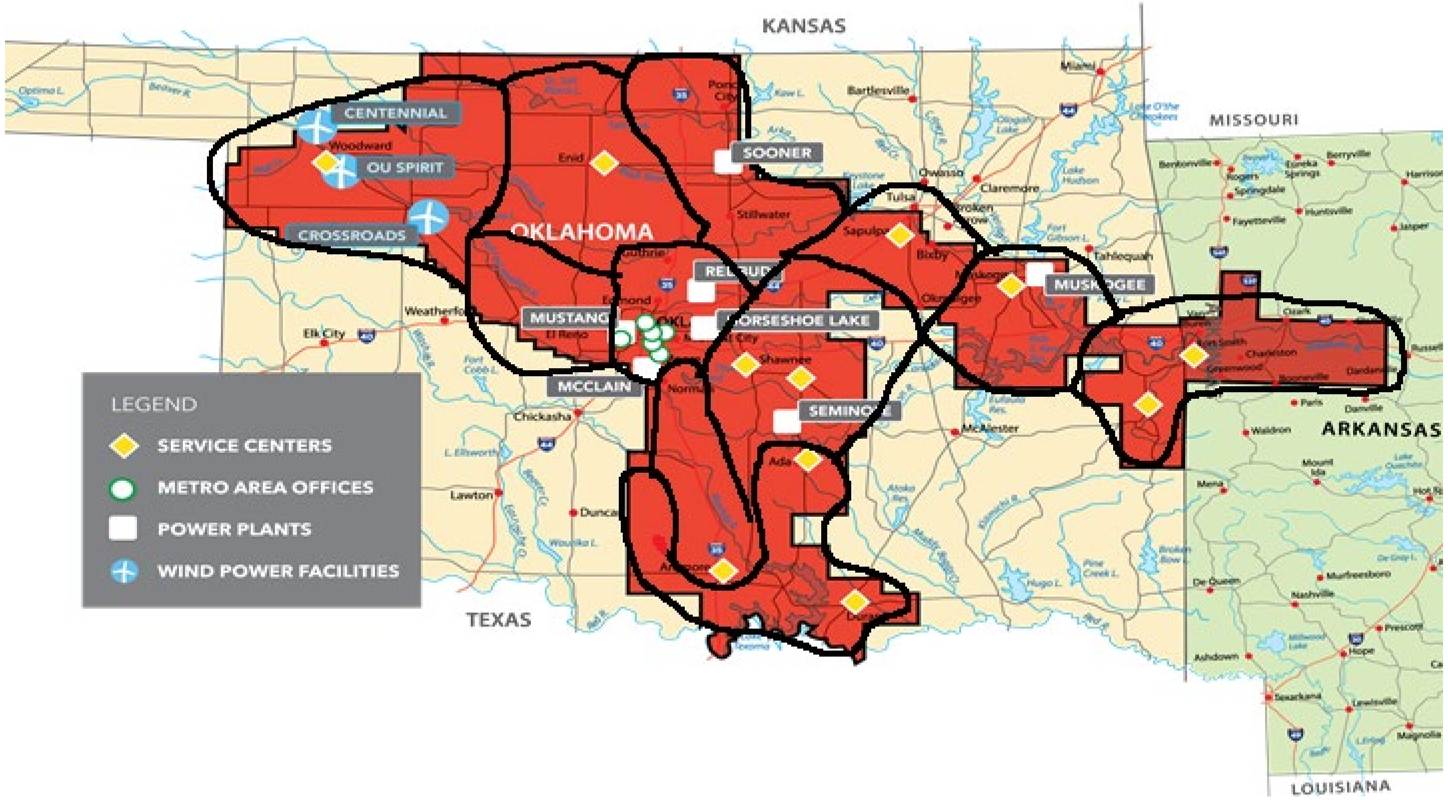
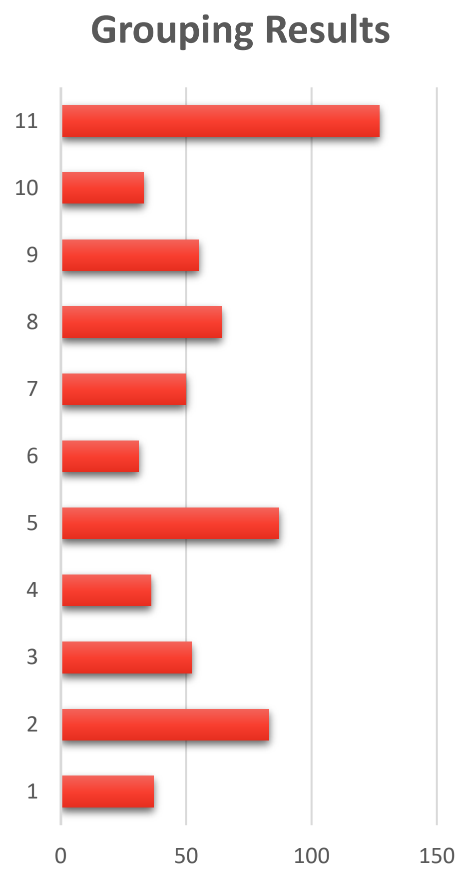
Results – Zonal Assignment





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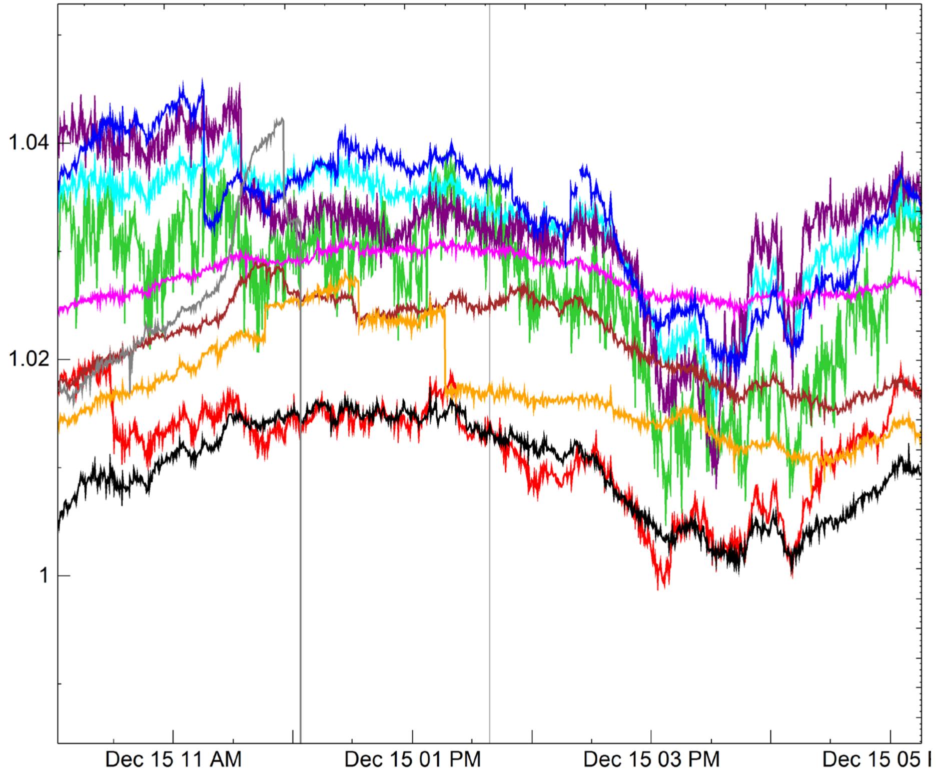
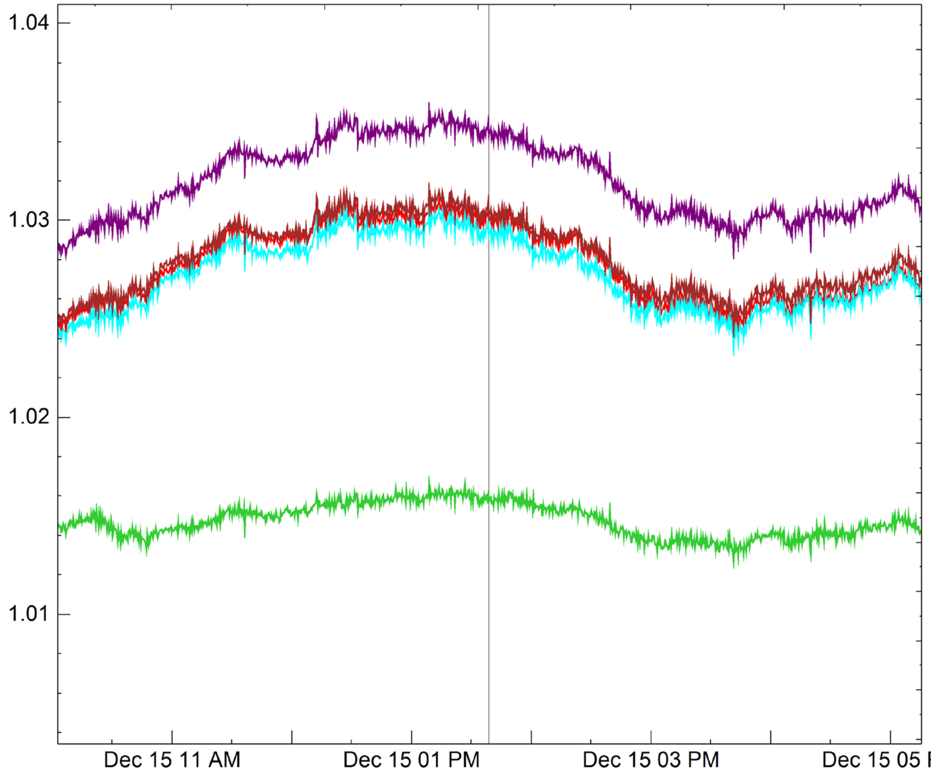
System Event Response

Voltage magnitude at pilot buses



Voltage magnitude at selected buses in a zone



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Applications

- **Re-grouped the elements in regional voltage summary page in SCADA display**
  - Buses monitored
  - Shunt devices
- **Future work**
  - Define zonal VAR reserve metrics considering both dynamic and static reactive power resources
  - Validate the zonal assignment regularly and update the boundaries when deemed necessary

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Questions?

References

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- Zhong, J., Nobile, E., Bose, A., & Bhattacharya, K. (2004). Localized reactive power markets using the concept of voltage control areas. *IEEE Transactions on power systems*, *19*(3), 1555-1561.

Dynamic Line Ratings (DLR)

Vision into Ambient Adjusted Rating (AARs)

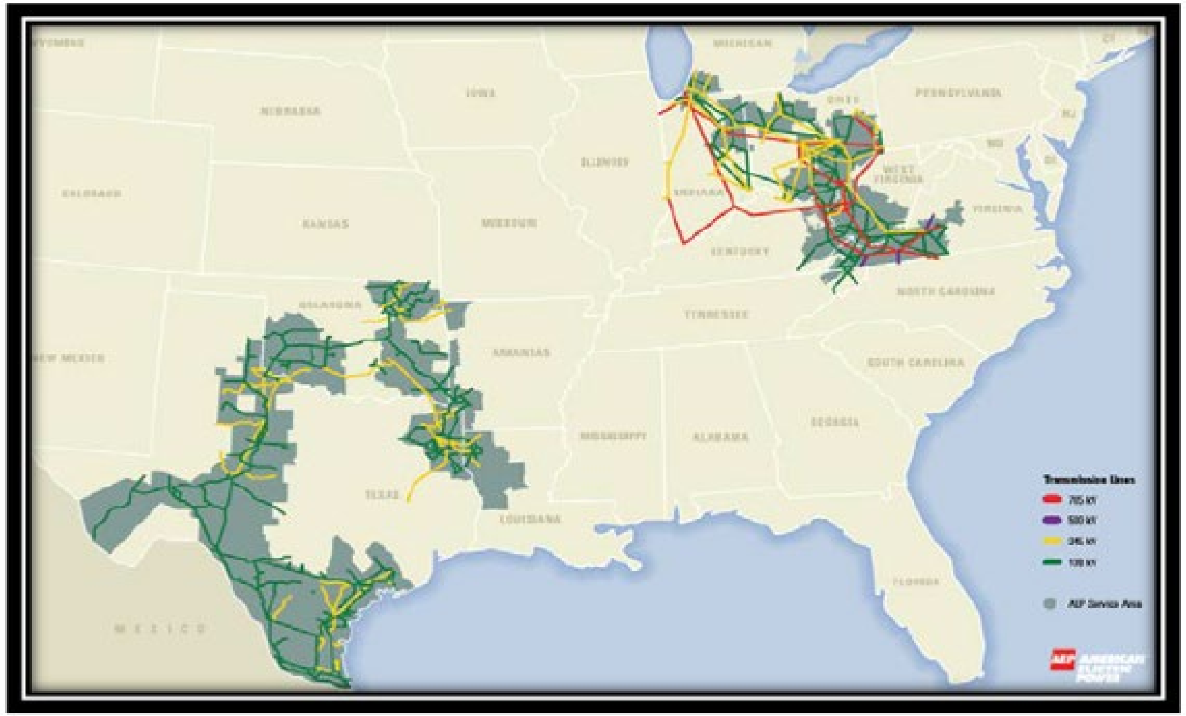
David R. Ball
VP, Energy Delivery Operations
American Electric Power

AMERICAN ELECTRIC POWER

BOUNDLESS ENERGY℠

Energy Delivery Operations

- Operate in 11 states
- Across Texas RE, RF & MRO
- ~5.5 million regulated customers
- ~16,800 employees
- ~30,000 MW Generation
- ~40k miles Transmission line
- ~223k miles Distribution line
- Over 6000 substations

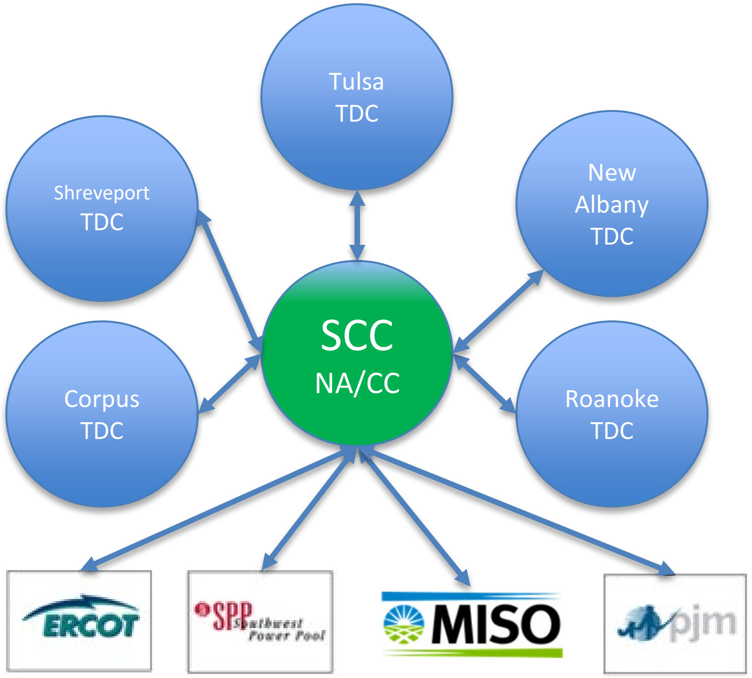


AEP Transmission and Service Area Map

Energy Delivery Operations

- AEP Energy Delivery Operations has **five** active control centers responsible for the operation of AEP's Transmission System
- AEP functions as TOP in

PJM, MISO, SPP, and ERCOT



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AEP State Estimator
Ambient Adjusted Ratings

- 3rd Party Vendor used for Temperature Data
  - Contract includes data security and encryption
- AEP created a diverse and redundant application which queries 3rd party's Web API
  - Application runs on a protected but non-CIP network
  - Front end processors then poll the application to update SCADA (CIP) with temperature data

AEP State Estimator
Ambient Adjusted Ratings

AMERICAN ELECTRIC POWER
BOUNDLESS ENERGY

- AEP State Estimator Temp Zones & Monitoring
  - Real-time temperature data retrieved every 5 minutes and refreshed with every SE process run

AEP SE Temperature Zone Monitoring		
PJM-MISO	**SPP**	**ERCOT**
IM – Indiana & Michigan	PSO – Tulsa	TNN – Childress
OOC – Ohio (OPCO)	SWEP – Shreveport	TNC – Abilene
RO – Roanoke	SYSTEM – AEP System Average	TNW – San Angelo
AB – Abingdon		TCC – Corpus Christi
TR – Tristate		TCS – Harlinen & Mcallen
SYSTEM – AEP System Average		TCW – Del Rio & Laredo
		TCN – Victoria

AEP State Estimator
Ambient Adjusted Ratings

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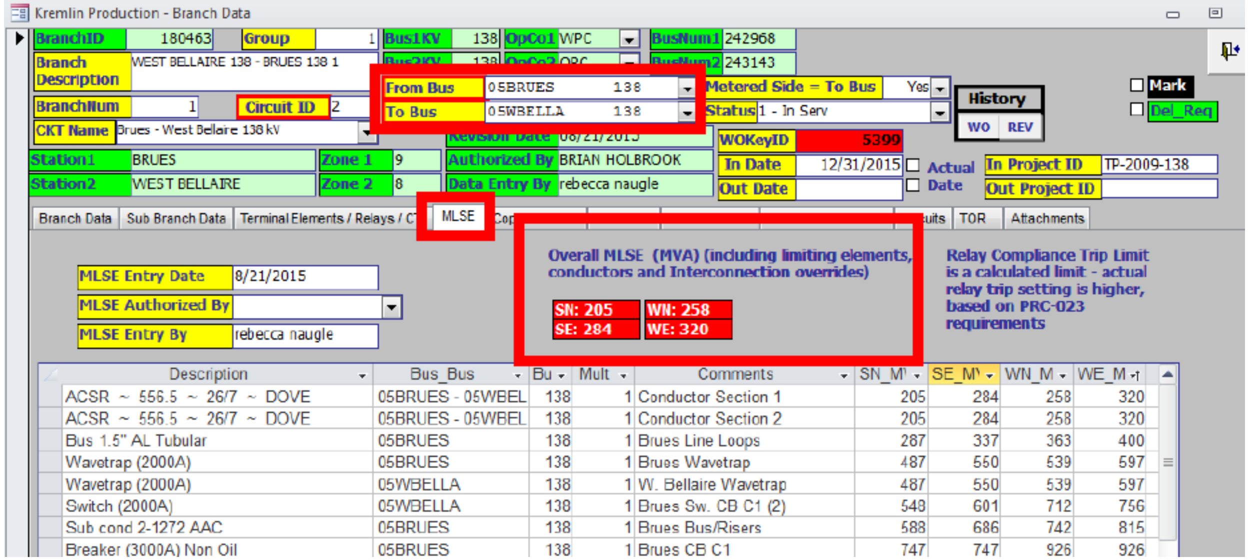
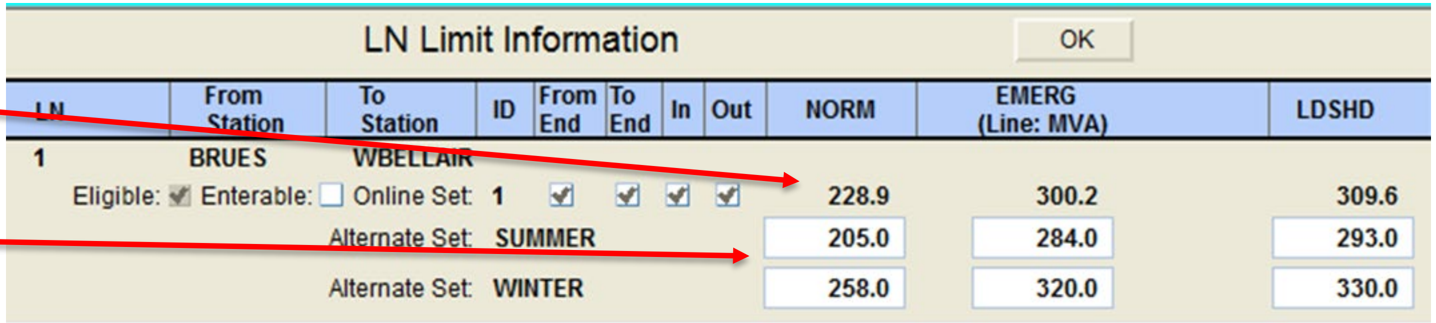


- Engineering ensures core/seasonal ratings from TPLAN database match in the SE and are submitted to RTOs

- Ambient Adjusted Ratings
- Core/Seasonal Ratings



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AEP State Estimator Ambient Adjusted Ratings

- The AEP State Estimator calculates ambient adjusted ratings based on real-time temperature data
  - AAR algorithm performs calculation via interpolation between the core summer/winter facility ratings (normal and emergency)
  - All facilities are assigned to a zone and temperature data is applied to each zone for use in the state estimator AAR algorithm

AAR

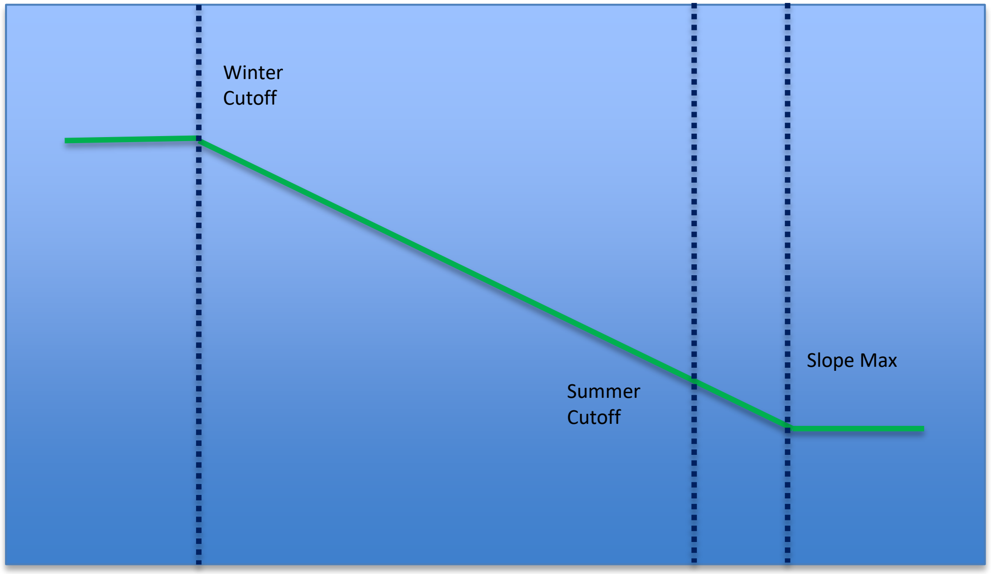
STUDY CA BRANCH SUMMARY

CTVL: 13 Items

KV	Monitored Elements	Emergency Limit (MVA)	Pre CTG (MVA)	Post CTG (MVA)	% Over Limit	CTG Description	NEW Viol	Time Since	CTG ID
138	MALISZEW-HYATTCS-0138-1 @MALISZEW	254	170	299	117	HYATT - MALISZEWSKI 138-2	☑	29-May-2014 10:56:06	CCT00253
345	AMOS TRANSF 3/X___8	800	354	797	100	AMOS T7 345/138/34.5	☐	29-May-2014 06:14:28	XFMR2048
138	AMOS TRANSF 1/X___8	800	351	796	99	AMOS T7 345/138/34.5	☐	29-May-2014 06:14:28	XFMR2048
138	NCROWNCI-THIVENER-0138-1@NCROWNCI	108	55	98	91	SPORN TB 3/1 MOAB	☑	29-May-2014 10:56:06	XFMR2264
138	NEWCOMER TRANSF 1/X___1	72	40	64	88	MUSKING - ENEWCON - WCAMBRID 138	☐	29-May-2014 09:26:06	CCT02357

AEP State Estimator
Ambient Adjusted Ratings

- Regional differences in AAR calculations based on planning criteria / RTO recommendations



Ambient Temperature

SE	Equipment	Cutoff Summer Temp	Cutoff Winter Temp	Slope_Max Temp	Slope_Min Temp
PJM-MISO	Lines	95°F	35°F	104°F	35°F
SPP	Lines	104°F	68°F	115°F	68°F
ERCOT	Lines	104°F	68°F	115°F	68°F

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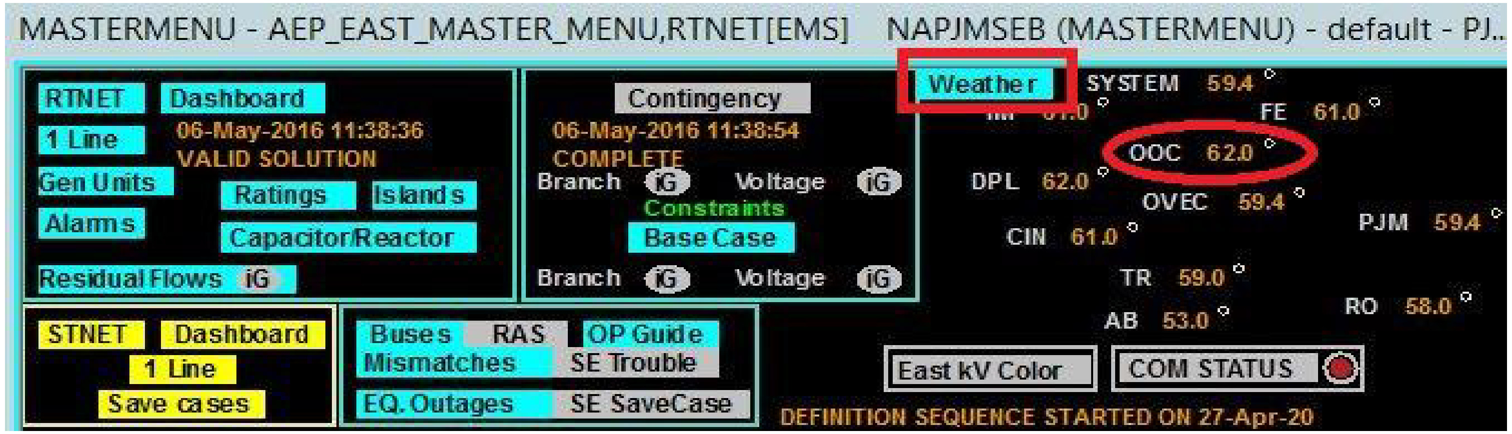
RTCA operates on N-1 criteria

AEP State Estimator
Ambient Adjusted Ratings

- Operators monitor weather parameter status through visual indicators on dashboards and supplemental PI displays



RTCA operates on N-1 criteria

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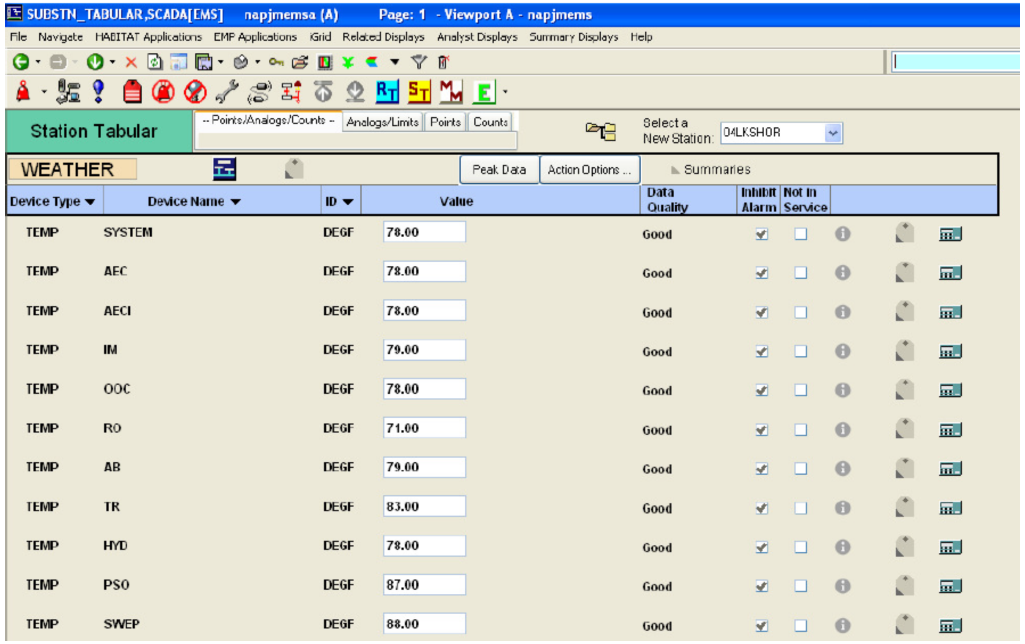
AEP State Estimator Ambient Adjusted Ratings

- SYSTEM temperature zone values are used as the default backup for individual point failures
- Operational procedures established to manually override Temperature zone values for failed / unreasonable data
- Temperature data may also be adjusted for Operational study purposes



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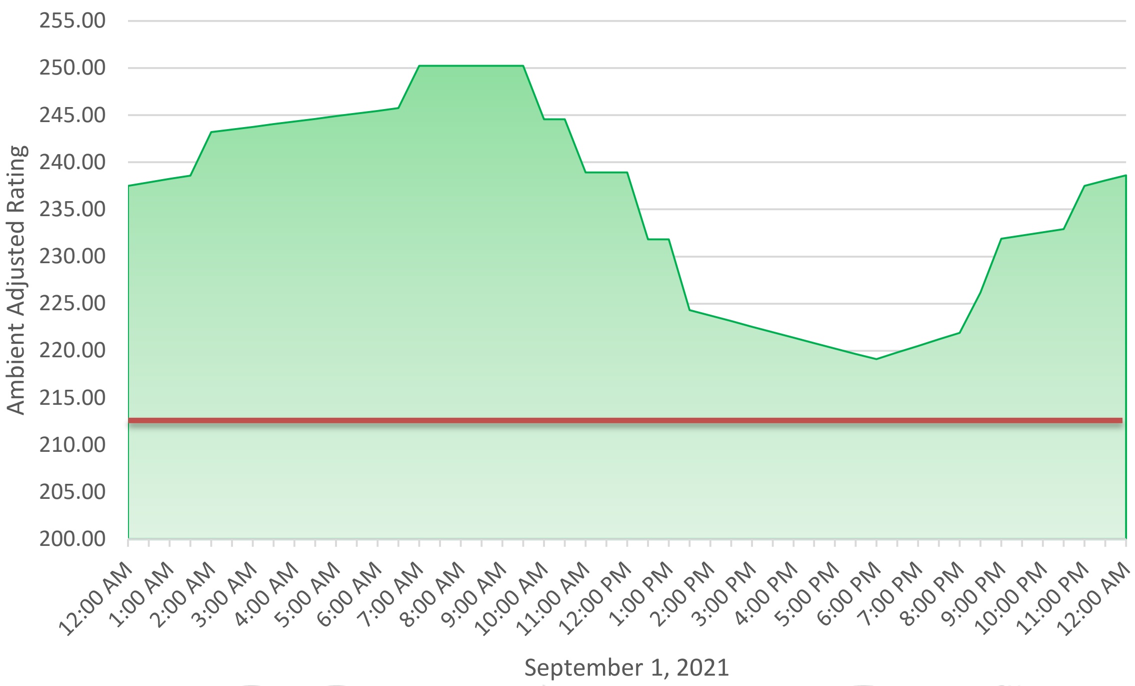
AEP State Estimator
Ambient Adjusted Ratings

- Sample AARs for Sept 1 on one AEP facility
  – With no AAR, would be limited to Summer static limit only

LN Limit Information

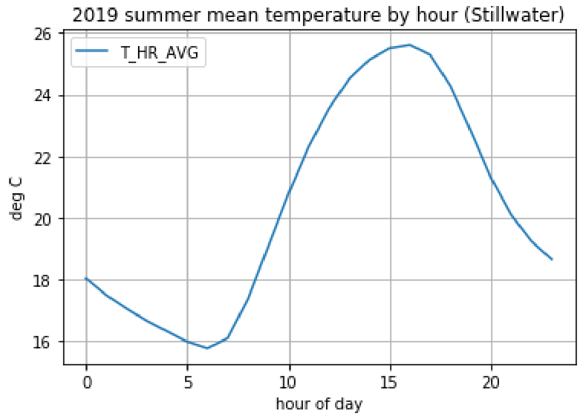
LN	From Station	To Station	ID	From End	To End	In	Out	NORM
1	21STTAP	TULSA_SE						
Eligible: ☑	Enterable: ☐	Online Set:	1	☑	☑	☑	☑	229.0
		Alternate Set:	SUMMER					212.0
		Alternate Set:	WINTER					263.0

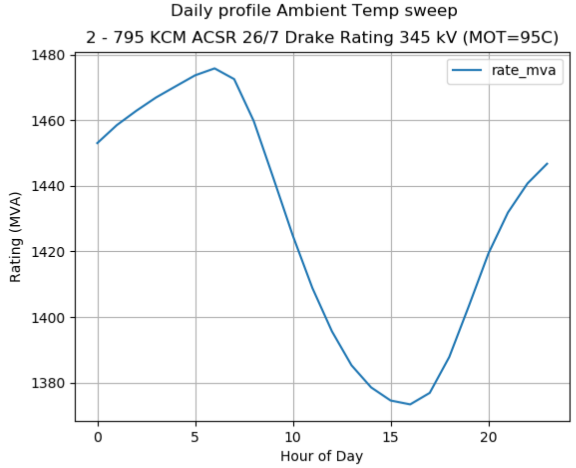
AAR example for 21STTAP_TULSE1 138 kV



AEP State Estimator Ambient Adjusted Ratings

- Example AAR for a typical daily temperature profile for a 345 kV line in the AEP footprint





RTO Coordination
Ambient Adjusted Ratings

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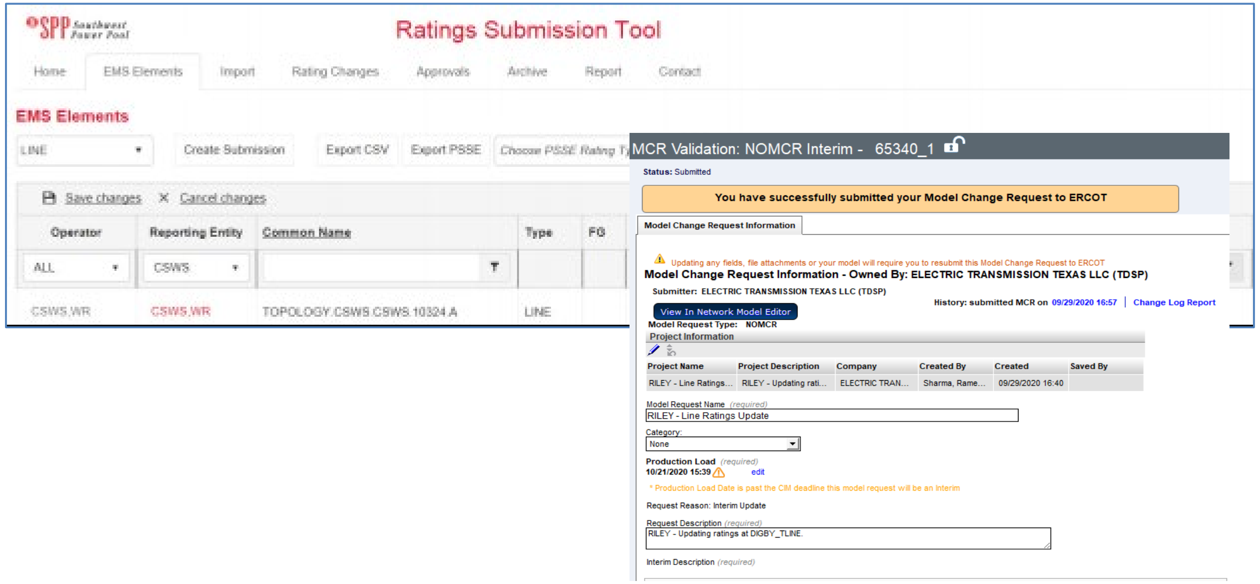
- PJM TERM Tickets
  - AEP AARs closely match PJM 8 temperature sets
- SPP Rating Submission Tool
  - Subset of AEP AARs sent via ICCP
- MISO seasonal rating provided via email
  - AARs for AEP only facilities sent via ICCP
- ERCOT NOMCR rating submittals
  - AEP AARs closely match ERCOT temperature sets (btw 20-115 degrees) for select facilities

	Normal		Long Term		Short Term		Load Dump	
Temp	Day	Night	Day	Night	Day	Night	Day	Night
95	1108	1108	1108	1108	1108	1108	1142	1142
86	1175	1175	1175	1175	1175	1175	1211	1211
77	1242	1242	1242	1242	1242	1242	1280	1280
68	1309	1309	1309	1309	1309	1309	1349	1349
59	1377	1377	1377	1377	1377	1377	1419	1419
50	1444	1444	1444	1444	1444	1444	1488	1488
41	1511	1511	1511	1511	1511	1511	1557	1557
32	1578	1578	1578	1578	1578	1578	1626	1626



RTO Coordination
Ambient Adjusted Ratings

- Upon recognition of a constraint, the SCC engages in a constraint verification process with the RC
- Any rating discrepancy between the RTO and AEP is logged and the most conservative limits is used until the discrepancy is resolved
- If necessary, AAR can be overridden with manually entered values
  - May be necessary for tieline coordination or field identified equipment issues
- AAR coordination via ICCP could increase significantly
  - Presently providing to SPP and MISO on select facilities
  - Pending Order 881 implementation

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AEP DLR Technology Assessment

- The DLR technology was found to be beneficial in assessing the real time rating of the line conductor
  - The line conductor is one element used in developing the overall rating for a facility
  - DLR technology only provides benefit when the most limiting series element is the line conductor
- DLR technology presents real time operational challenges
  - How to manage frequently changing conductor ratings in real-time system operations
  - How to incorporate the ratings changes into the real time monitoring and real time assessment tools and maintain system reliability
- DLR technology may require monitoring multiple spans on lines where the conductor type or conditions change across the line topology

FERC Order 881

- AEP formed a task force to review potential gaps for adherence to Order 881
  - Legal
  - Regulatory
  - Compliance
  - Operations
  - Planning
  - Engineering

- AEP has a good start on AARs but additional process changes likely needed to meet all requirements of Order 881

Summary

- AEP supportive of AARs to reliably optimize use of the AEP system as temperature varies while operating within FAC-008 SOL methodologies
  - Maximize transmission capability during cooler temps
  - Operate more conservatively during hotter temps
- Imperative operators can trust the situational awareness tools and processes must be in place to resolve discrepancies
- Internal FERC Order 881 team developed to review potential process changes
- Consistency in implementation, coordination and data management of AARs will be critical moving forward

AEP Comment Summary

1. **AEP supports the targeted and voluntary implementation of DLRs by transmission providers to address congestion for market purposes and suggests that the Commission should encourage, but not *require* implementation of DLRs.**
   - DLRs are appropriate only for consideration in real-time operations, when very specific facility rating criteria are met or system configurations in a specific area are identified, and not for system planning purposes.
   - AEPs use of AARs across the AEP footprint, which limits the use cases where DLR provides cost effective System Operating Limit (SOL) mitigation.
   - AEP suggests that the Commission consider requiring transmission providers to evaluate the benefits of DLR above current real time ratings practices on their top 10 historically congested facilities each year based on the cost of congestion and submit an informational report to the Commission on their findings.
   - DLRs only provide benefit when the most limiting series element is the line conductor and significant margin exists between the line conductor and the next most limiting element.
2. **DLRs pose a variety of implementation risks that must be considered.**
   - AEP recommends that the Commission assess the reliability impacts of any potential widespread requirements for DLR, particularly with respect to physical and cybersecurity. This will require a comprehensive evaluation of current NERC Reliability Standards to ensure the integrity and confidentiality of DLR systems and data.
   - DLRs present real-time operational challenges. Verification and integration into the real time operational tools used by the System Operators to perform Real Time Monitoring / Control and Real Time Assessments is one of the most challenging steps in implementing DLR because of the highly complex nature of work performed by the System Operators.
   - There may be significant upgrades required to communication infrastructure in order to integrate DLRs into real time operational tools.
3. **AEP suggests that the Commission not consider requirements related to DLRs until after the implementation of AARs, and that the Commission should remain technology-neutral.**
   - Implementation of the requirements adopted in Order No. 881 are expected to change congestion patterns. Therefore, it would be premature to adopt DLR requirements at this time.
   - The Commission should remain technology-neutral, particularly given the rapid changes and advancements in technology. A requirement to install one particular technology could unintentionally stifle innovation with respect to alternative methodologies.

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Wrap up / Questions
Feedback
Adjourn

Upcoming Event Dates

Meeting & Webinar Dates:

- MRO 2022 Regional Summer Assessment (RSA) Webinar – June 30, 2022
- MRO CMEP Conference – July 26, 2022

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Thank you all for attending this event!

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