



**INTERCONNECTION  
INNOVATION e-XCHANGE**  
U.S. DEPARTMENT OF ENERGY

# Grid Engineering Practices & Standards: Defining Distribution, Sub-transmission, Transmission, and the Bulk System for Interconnection

*An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office*

**8/2/23**

**Slides at:** [https://github.com/pnnl/i2x/blob/develop/docs/assets/Definitions\\_Aug\\_2.pdf](https://github.com/pnnl/i2x/blob/develop/docs/assets/Definitions_Aug_2.pdf)

The first half of this Teams call is being recorded and may be posted on DOE's website or used internally. If you do not wish to have your voice recorded, please do not speak during the call. If you do not wish to have your image recorded, please turn off your camera or participate by phone. If you speak during the call or use a video connection, you are presumed to consent to recording and use of your voice or image.

Recording will stop after the scheduled presentations.



# Agenda

- Introduction to i2X Solution e-Xchanges (5 min)
- Review some NERC and IEEE Definitions (15 min)
- Interactive Group Discussion (45 min)
  - How important are these definitions?
  - What is the boundary between the distribution and bulk system?
  - Why are bulk electric system and bulk power system separately defined?
  - Why and how do we define the sub-transmission system?
  - What is the boundary between IEEE Standards 1547 and 2800?
  - How can distribution engineers benefit from bulk system experience?
  - What does the bulk system need from DER?
  - Extra: what grid changes should be considered for hosting capacity?
  - Extra: what else should i2X be doing in this space?
- Upcoming Events (5 min)
  - NERC/i2X Electromagnetic Transients (EMT) Bootcamp, Aug 3 & Sep 14
  - i2X Solution e-Xchange Wrap-up, August 31, 2-4 p.m. Eastern Time
  - Roadmap Highlights, RE+, September 11<sup>th</sup>, <https://www.energy.gov/eere/i2x/i2x-events>



# Interconnection Innovation e-Xchange (i2X)

**Mission:** To enable a **simpler, faster, and fairer** interconnection of clean energy resources while enhancing the **reliability, resiliency, and security** of our **distribution and bulk-power electric grids**



## Stakeholder Engagement

Nation-wide engagement platform and collaborative working groups



## Data & Analytics

Collect and analyze interconnection data to inform solutions development



## Strategic Roadmap

Create roadmap to inform interconnection process improvements



## Technical Assistance

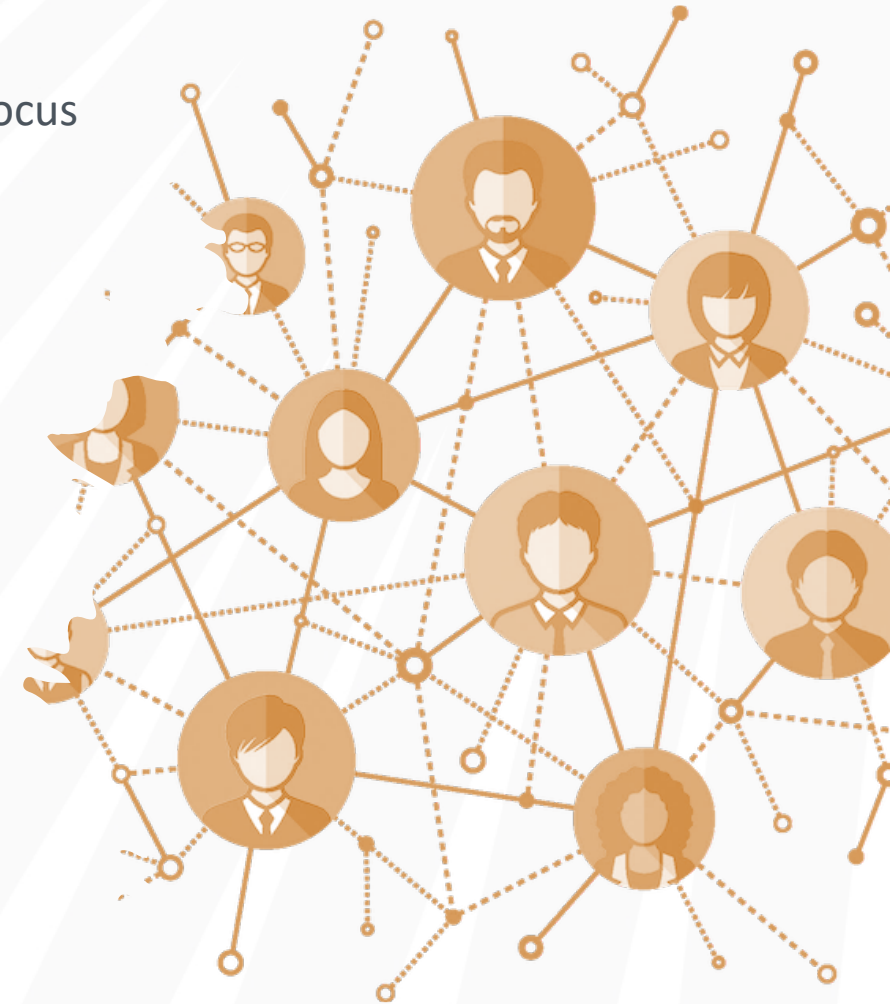
Leverage DOE laboratory expertise to support stakeholder roadmap implementation



# i2X Solution e-Xchange Topic Areas



- **Queue Management and Cost Allocation**
  - Technology, regulation, administration, and organizational change focus
  - *What* innovative interconnection solutions exist?
- **Grid Engineering Practices and Standards**
  - Engineering and technology focus
  - *How* can proposed solutions be executed?
- **Equity and Energy Justice**
  - Multidisciplinary
  - *Who* is impacted by and benefits from proposed solutions?
- **Data Transparency**
  - Multidisciplinary
  - *What* transparency concerns must be addressed?
- **Interconnection Workforce and Training**
  - Multidisciplinary
- **Special Topics**
  - Electric Vehicle Charging



# Key Outcomes from Our e-Xchange Meetings



- Inform and formulate a ***publicly available***, strategic roadmap for interconnection
  - Topical challenges and issues
  - Practical solutions to implement and scale
  - Knowledge and data gaps and new solutions to pilot
  - Success goals and measures of success
- Summary documentation for each meeting regarding ideas discussed and opportunities for targeted stakeholder action
- Provide platform for ongoing engagement before and after meetings
- **Longer term vision** → Solution e-Xchanges to continue building a national forum for all stakeholders as a community of practice, excellence, and innovation



# Upcoming Solution e-Xchanges to Consider Joining

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1. August 8<sup>th</sup>, 2-4 p.m. Eastern: Identifying Solutions to Equitably Scaling the Interconnection Workforce
2. August 11<sup>th</sup>, 1:30-3:30 p.m. Eastern: Electric Vehicle Charging Stations
3. August 15<sup>th</sup>, 2-4 p.m. Eastern: Continuing to Identify and Prioritize Solutions to Equitably Scaling the Interconnection Workforce through Hiring, Retention, and Training
4. **August 31<sup>st</sup>, 2-4 p.m. Eastern: 2023 Wrap-Up and Look Forward for Bulk and Distribution Systems**

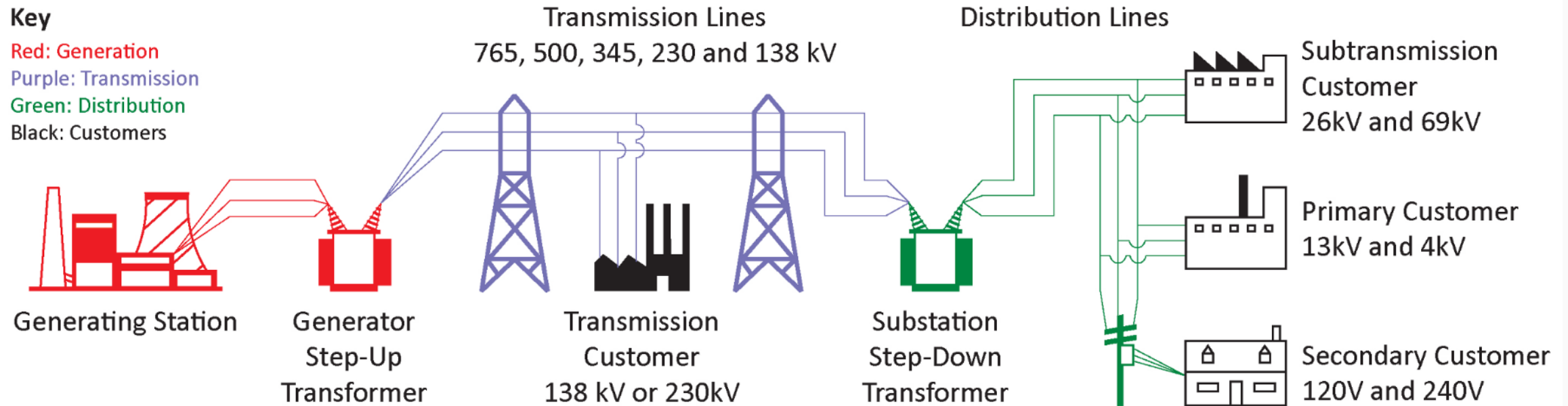
Follow the schedule of events and download materials on the i2X website.

<https://www.energy.gov/eere/i2x/i2x-solution-e-xchanges>



# The classical understanding of generation, transmission, and distribution from “Understanding the Grid”, a NERC 2-pager, March 2023.

The generation and transmission components and their associated control systems comprise the BPS.



*Note: 161 and 115 kV  
Transmission Voltages Exist*

*Note: 46, 34.5, 23 kV and other  
Distribution Voltages Exist*



**In 2003, IEEE 1547 set a DER size limit of 10 MVA, but FERC Order 2006 set a limit of 20 MVA for the Small Generator Interconnection Process.**

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## IEEE 1547-2003 (reaffirmed 2008)

**1.3 Limitations** The criteria and requirements in this document are applicable to all distributed resource technologies, with **aggregate capacity of 10 MVA or less** at the Point of Common Coupling (PCC), interconnected to Electric Power Systems (EPSs) at typical primary and/or secondary distribution voltages.

**3.1.5 distributed resources (DR):** Sources of electric power that are not directly connected to a bulk power transmission system. DR includes both generators and energy storage technologies.

*Note: distribution, transmission, sub-transmission, and bulk power system were not defined*

In 2018, IEEE 1547 left the size (and voltage) limits of DER unspecified. It also muddled the water on what a “distribution system” is.

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## IEEE 1547-2018

“This standard does not define the maximum DER capacity for a particular installation that may be interconnected to a single point of common coupling (PCC) or connected to a given feeder.”

**bulk power system (BPS):** Any electric generation resources, transmission lines, interconnections with neighboring systems, and associated equipment.

**distributed energy resource (DER):** A source of electric power that is not directly connected to a bulk power system. DER includes both generators and energy storage technologies capable of exporting active power to an EPS. An interconnection system or a supplemental DER device that is necessary for compliance with this standard is part of a DER.

*Note: distribution, transmission, and sub-transmission were not defined*

## In 2022, IEEE 2800 aimed to cover IBRs on the sub-transmission system, but it did not define sub-transmission.

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### IEEE 2800-2022 (*...Interconnection ... of IBR ... with Associated Transmission ... Systems*)

“For radial sub-transmission systems, this standard intentionally overlaps with potential application of IEEE Std 1547™, in which case it remains at the discretion of the authority governing interconnection requirements (AGIR) to decide which standard is applicable.”

**bulk power system (BPS):** Any electric generation resources, transmission lines, interconnections with neighboring systems, and associated equipment. (IEEE Std 1547™-2018) NOTE—Per NERC glossary of terms, the definition of bulk power system is: (A) facilities and control systems necessary for operating an interconnected electric energy transmission network (or any portion thereof); and (B) electric energy from generation facilities needed to maintain *transmission system* reliability. The term does not include facilities used in the local distribution of electric energy.

**sub-transmission system:** *See: transmission system (TS).*

**transmission system (TS):** The *transmission system* that is connected to an inverter-based resource (IBR). In this standard, the TS refers to both transmission and sub-*transmission systems* unless specific requirements for each are different. **Syn: sub-transmission**

# In 2014 (revised 2018), NERC published (at FERC's direction) a “bright line” threshold of 100 kV for the bulk electric system.

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Core Definition: **Bulk Electric System (BES)**: Unless modified by the lists shown below, all Transmission Elements operated at **100 kV or higher** and Real Power and Reactive Power resources connected at 100 kV or higher. This does not include facilities used in the local distribution of electric energy.

## Inclusions

1. Transformers with 2 terminals  $\geq 100$  kV
2. Generators:
  - High-side connection  $\geq 100$  kV, and
  - Unit rating  $> 20$  MVA, or
  - Aggregate rating  $> 75$  MVA.
3. Black-start resources in restoration plan
4. Dispersed resources  $> 75$  MVA, e.g., IBR plants
5. Dedicated reactive power  $\geq 100$  kV

## Exclusions

1. **Radial systems**
  - **Loops  $< 50$  kV allowed**
2. Behind the meter generation exporting  $< 75$  MVA
3. Local networks  $< 300$  kV:
  - Non-retail gen  $\leq 75$  MVA
  - Not a flowgate or transfer
4. Reactive power solely for benefit of a customer



## FERC Order 888 has been used to classify lines > 100 kV as not BES.

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Includes a seven-factor test for classifying facilities that may be local distribution. FERC has used these factors to evaluate facilities > 100 kV as local distribution (or not).

1. In close proximity to retail customers
2. Primarily radial
3. Reverse power flow is rare or non-existent
4. Incoming power is not transported to another market
5. Comparatively restricted geographical area
6. Meters at the transmission / local distribution interface
7. Reduced voltage

[https://www.nerc.com/FilingsOrders/us/FERCOrdersRules/Order\\_SCE\\_20151231\\_RC15-1.pdf](https://www.nerc.com/FilingsOrders/us/FERCOrdersRules/Order_SCE_20151231_RC15-1.pdf)

## FERC RD22-4-000 (November 2022) aims to fill gaps in IBR registration.

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NERC developed a work plan for registering IBRs that are connected to the Bulk-Power System, but not currently required to register with NERC under the BES definition.

FERC mentioned the possibility of aggregate, material impact of unregistered IBRs on the reliable operation of the Bulk-Power System. FERC mentioned a change to the BES definition as an option. NERC's planned approach is to create new registry criteria for:

- IBRs  $\geq 20$  MVA and  $\leq 75$  MVA connected at  $\geq 100$  kV.
- IBRs  $\geq 20$  MVA connected at  $< 100$  kV.

This is expected to reduce the registration gap for BPS-connected IBR from 16% to 14% of the total, resulting in 98% of BPS-connected IBRs subject to NERC Reliability Standards.

[https://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Amendment%20to%20Work%20Plan%20Filing%20RD22-4\\_final.pdf](https://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Amendment%20to%20Work%20Plan%20Filing%20RD22-4_final.pdf)

# Other IEEE and NERC groups offer various functional definitions.

## IEEE 100 (Now at <https://dictionary.ieee.org>)

**Distribution System** (1366-2022): That portion of an electric system that delivers electric energy from transformation points on the transmission system to the customer. NOTE—The distribution system is generally considered to be anything from the distribution substation fence to the customer meter. Often, the initial overcurrent protection and voltage regulators are within the substation fence and are considered part of the distribution system.

## NERC SPIDER Working Group (<https://www.nerc.com/comm/RSTC/SPIDERWG/SPIDERWG%20Terms%20and%20Definitions%20Working%20Document.pdf>)

**DER:** Any source of electric power located on the distribution system.

**Distribution System:** The electrical facilities that are located behind a transmission-distribution transformer that serves multiple end-use customers.

## NERC Glossary of Terms ([https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary\\_of\\_Terms.pdf](https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf))

**Bulk(-)Power System:** (A) facilities and control systems necessary for operating an interconnected electric energy transmission network (or any portion thereof); and (B) electric energy from generation facilities needed to maintain transmission system reliability. The term does not include facilities used in the local distribution of electric energy.

**Distribution Provider:** Provides and operates the “wires” between the transmission system and the end-use customer. For those end-use customers who are served at transmission voltages, the Transmission Owner also serves as the Distribution Provider. Thus, the Distribution Provider is not defined by a specific voltage, but rather as performing the distribution function at any voltage.

# Candidate functional definitions in an IEEE Recommended Practice that will include DER hosting capacity and dynamics analysis.

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IEEE P1729/D3.2 (2023) <https://standards.ieee.org/ieee/1729/11171/>

**Bulk electric system (BES):** is defined at the national or international level. For example, in the United States and Canada, the BES includes grid infrastructure at 100 kV or higher, including connected generation rated greater than 20 MVA for individual units, or greater than 75 MVA for aggregate generation, also including any looped circuits rated 50 kV or higher.

**Distribution system:** The electric power distribution system, for purposes of analysis, includes all equipment and controls between the Bulk Electric System (BES) and the customer meter. Transformers at the BES boundary are included, either explicitly or as part of a source equivalent. A jurisdiction or utility may define the electric power distribution system differently for other purposes.

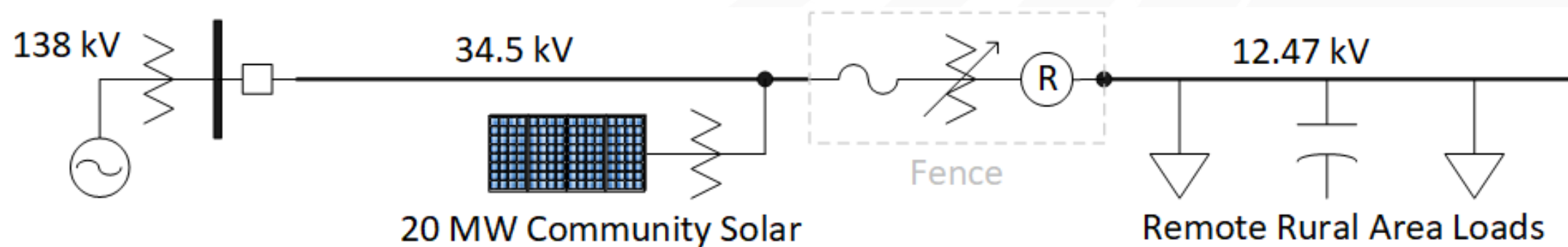
**Hosting capacity:** maximum additional capacity of distributed energy resources (DER) that an electric power distribution system (DS) can accommodate at individual locations using existing power system infrastructure, configuration, and control equipment without adversely impacting reliability, power quality, safety, or the operation of existing or approved connections.

**Sub-transmission system:** A jurisdiction or utility may define part of the electric power system, between the BES and other parts of the distribution system, as sub-transmission. The lines are typically radial and operate at less than 100 kV. For purposes of analysis, sub-transmission is part of the electric power distribution system. IEEE Std. 2800 may apply to DER connected to sub-transmission systems.

**Transmission system:** the bulk electric system (BES), excluding its connected generation.  
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## Is this DER? What difference do the size and voltages make?



# Discussion Link and Code of Conduct



1. *Assume good faith and respect differences*
2. *Listen actively and respectfully*
3. *Use "Yes and" to build on others' ideas*
4. *Please self-edit and encourage others to speak up*
5. *Seek to learn from others*

[Go to **menti.com** and enter event code **9340 9006**]

1. *Use the Meeting Chat feature to pose questions*
2. *Use the Menti pages to make comments on the current topic*
3. *Raise your hand to speak; we will call on you*



Mutual Respect . Collaboration . Openness