The Role of Standards in Grid Integration of Renewables

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CAUTION CONCERNING FORWARD-LOOKING STATEMENTS:

This document contains "forward-looking statements" – that is, statements related to future events that by their nature address matters that are, to different degrees, uncertain. For details on the uncertainties that may cause our actual future results to be materially different than those expressed in our forward-looking statements, see http://www.ge.com/investor-relations/disclaimer-caution-concerning-forwardlooking-statements as well as our annual reports on Form 10-K and quarterly reports on Form 10-Q. We do not undertake to update our forward-looking statements. This document also includes certain forward-looking projected financial information that is based on current estimates and forecasts. Actual results could differ materially. to total risk-weighted assets.]

NON-GAAP FINANCIAL MEASURES:

In this document, we sometimes use information derived from consolidated financial data but not presented in our financial statements prepared in accordance with U.S. generally accepted accounting principles (GAAP). Certain of these data are considered "non-GAAP financial measures" under the U.S. Securities and Exchange Commission rules. These non-GAAP financial measures supplement our GAAP disclosures and should not be considered an alternative to the GAAP measure. The reasons we use these non-GAAP financial measures and the reconciliations to their most directly comparable GAAP financial measures are posted to the investor relations section of our website at www.ge.com. [We use non-GAAP financial measures including the following:

- Operating earnings and EPS, which is earnings from continuing operations excluding non-service-related pension costs of our principal pension plans.
- GE Industrial operating & Verticals earnings and EPS, which is operating earnings of our industrial businesses and the GE Capital businesses that we expect to retain.
- GE Industrial & Verticals revenues, which is revenue of our industrial businesses and the GE Capital businesses that we expect to retain.
- Industrial segment organic revenue, which is the sum of revenue from all of our industrial segments less the effects of acquisitions/dispositions and currency exchange.
- Industrial segment organic operating profit, which is the sum of segment profit from all of our industrial segments less the effects of acquisitions/dispositions and currency exchange.
- Industrial cash flows from operating activities (Industrial CFOA), which is GE's cash flow from operating activities excluding dividends received from GE Capital.
- Capital ending net investment (ENI), excluding liquidity, which is a measure we use to measure the size of our Capital segment.
- GE Capital Tier 1 Common ratio estimate is a ratio of equity

Topics

Standards development
Challenges, gaps and opportunities
Standards harmonization
Renewable generation impact

Renewable Generation Standards and Codes Development & Harmonization

Utility and Operator Perspectives

- Standards & codes have significant impact on power system reliability, operations and control
- Standards & codes affect the level of renewable energy penetration in the power system
- Standards & codes affect the ***cost*** of operation and the final ***cost*** of energy (COE) to consumers
- Individual Systems have particular requirements

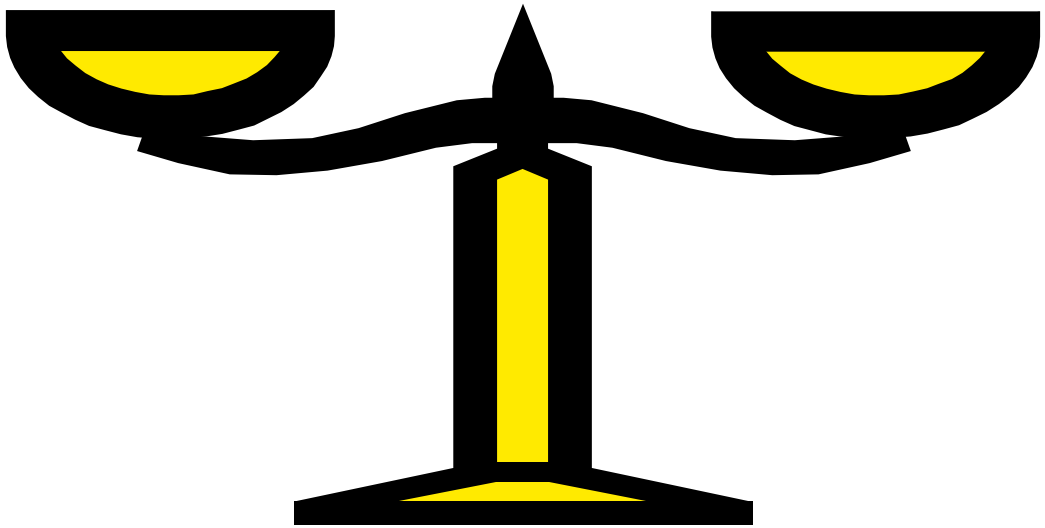
Manufacturer and Developer Perspectives

- Standards & codes affect the level of renewable energy penetration in the power system
- Standards & codes affect the ***cost*** of wind power equipment
- Transmission operators need feedback to develop realistic codes based on current and physically realizable technology
- Perceived system specific requirements may, in some circumstances, be primarily a function of past practice rather than true system needs

Development of Standards & Codes

Tight
More expensive equipment
Reduced efficiency

Loose
Compromised System Reliability



Grid Code Functional Specifications

Requirements should be no more specific than they need to be to avoid over-designed equipment and reduced efficiency, but should be specific enough for adequate system reliability.

Global Renewable Electrical Codes and Standards Development

North America

California ISO Interconnection Requirements for Variable Energy Resources, Rule 21

ISO-NE, ERCOT & PJM Technical Requirements for Wind Interconnection & Integration

Canadian Requirements for Wind Interconnection (Alberta, Ontario, HQ, BC Hydro)

FERC 661/661a Requirements, NOPR on Voltage & Reactive Power, NOI on Frequency Response

NERC Standards Drafting and Task Forces (100 regulatory standards, 130 parts, 2303 pages)

- Integration of Variable Generation Task Force **(IVGTF) 2007-2013**
- Essential Reliability Services Task Force **(ERSTF)** / Essential Reliability Services Working Group **(ERSWG) 2014+**
- Generator Verification Standards Drafting Team **(GVSDT) 2007-2014**

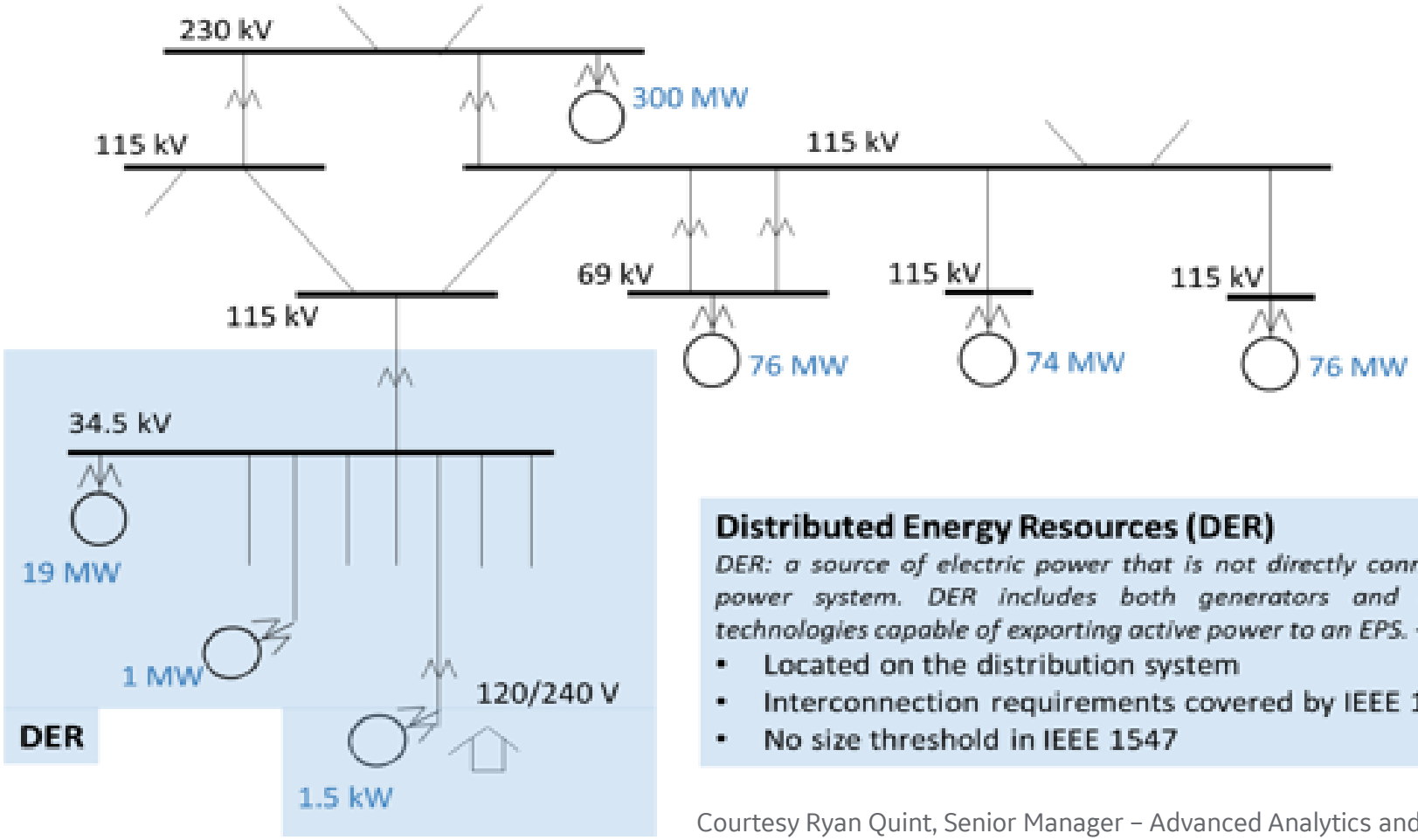
FERC mandates that all new reliability standards address all technologies

International

- IEC TC88/WG27 on Wind Models
- IEC TC8/SC8A on Wind performance, interconnection, design and forecasting
- Chinese State Power Grid Technical Code for Wind Interconnection
- Vietnamese Interconnection Requirements for Wind Generation
- Indian CERC Electricity Grid Code for Wind
- German FGH Technical Guidelines for Wind Energy
- Australian Energy Market Operator (AEMO) Guidelines for Wind Energy
- Kazakhstan Energy Ministry / KEGOK Strategic Energy Plan

BPS vs. BES

For illustration only…



Distributed Energy Resources (DER)

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. – IEEE Std. 1547

- Located on the distribution system
- Interconnection requirements covered by IEEE 1547
- No size threshold in IEEE 1547

Courtesy Ryan Quint, Senior Manager – Advanced Analytics and Modeling, NERC

RELIABILITY | ACCOUNTABILITY

BPS vs. BES

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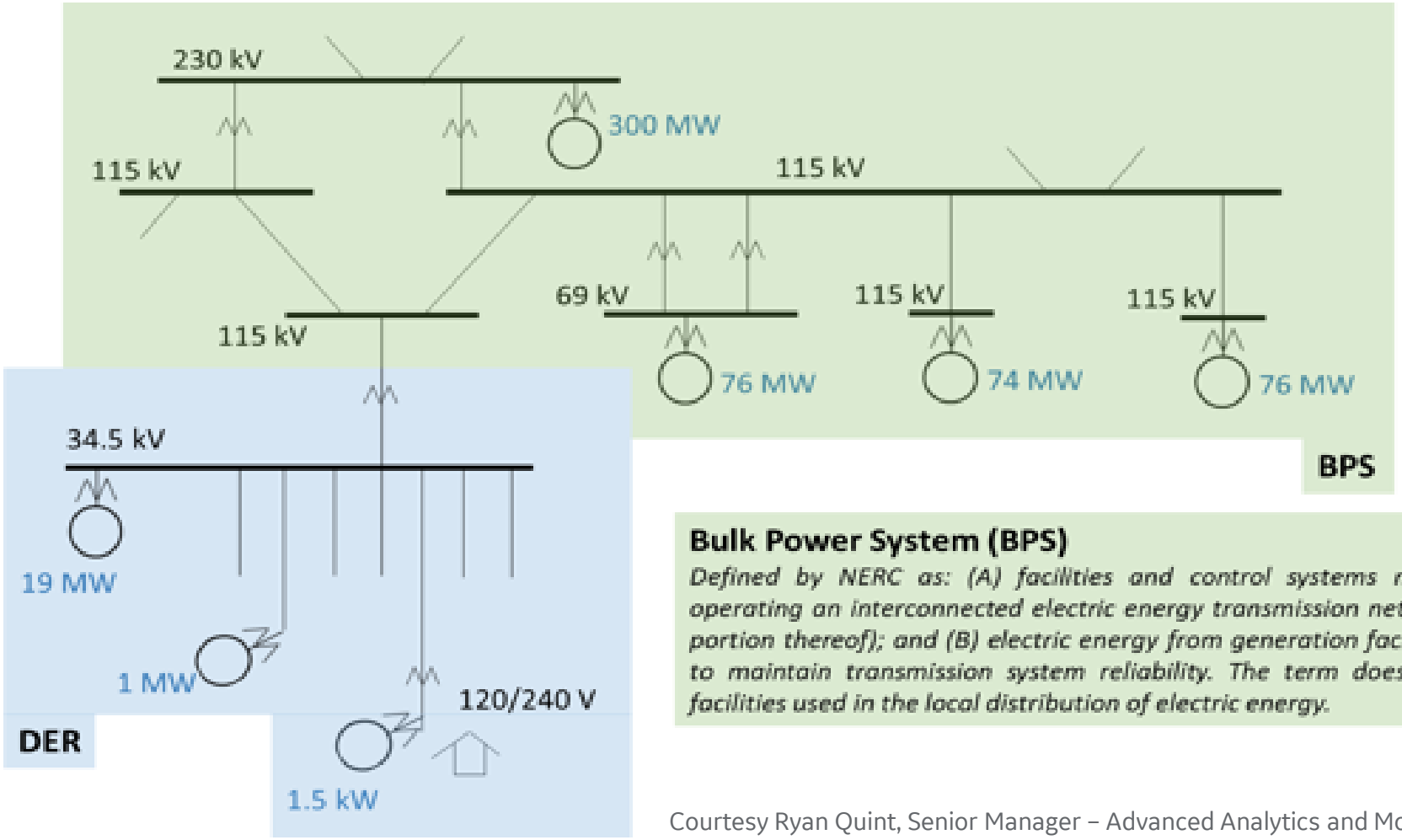

Bulk Power System (BPS)

Defined by NERC as: (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.

Courtesy Ryan Quint, Senior Manager – Advanced Analytics and Modeling, NERC

RELIABILITY | ACCOUNTABILITY

BPS vs. BES

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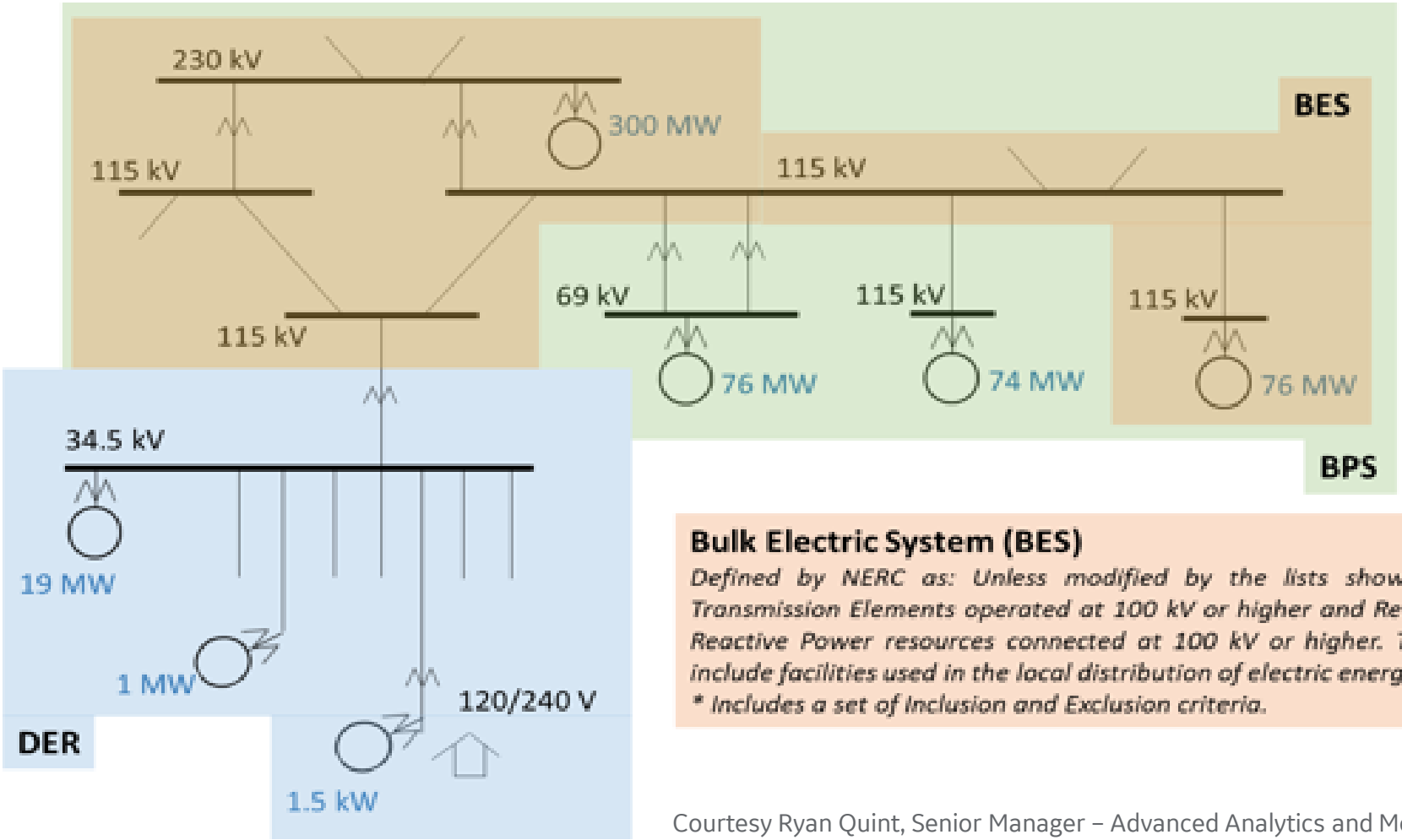

Bulk Electric System (BES)

Defined by NERC as: 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.
** Includes a set of Inclusion and Exclusion criteria.*

Courtesy Ryan Quint, Senior Manager – Advanced Analytics and Modeling, NERC

RELIABILITY | ACCOUNTABILITY

BPS vs. BES

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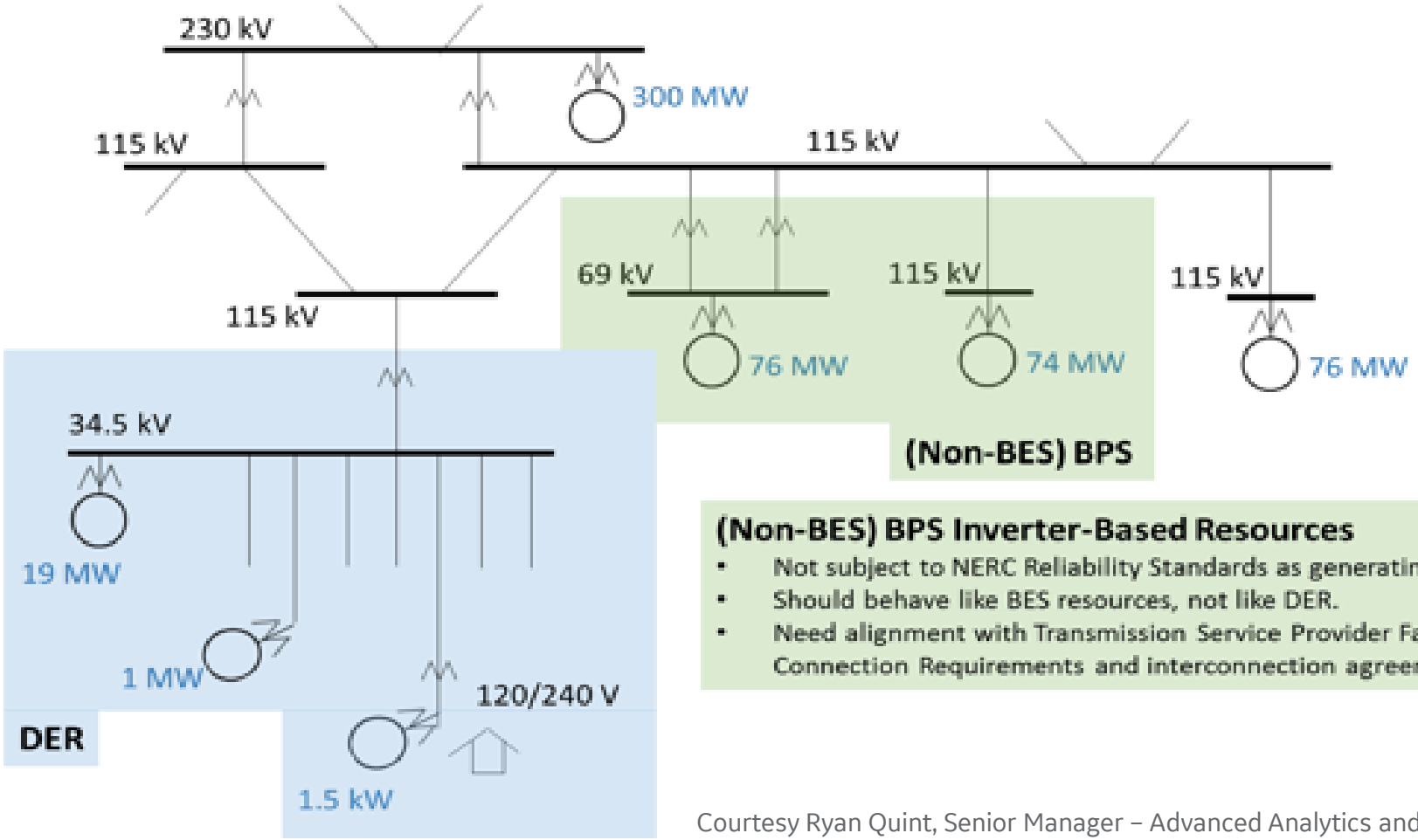

(Non-BES) BPS Inverter-Based Resources

- Not subject to NERC Reliability Standards as generating facilities.
- Should behave like BES resources, not like DER.
- Need alignment with Transmission Service Provider Facility Connection Requirements and interconnection agreements

Courtesy Ryan Quint, Senior Manager – Advanced Analytics and Modeling, NERC

RELIABILITY | ACCOUNTABILITY

DER Standards Issues

IEEE 1547 historically required a distributed generator to:

- Never regulate the feeder voltage
- Trip immediately for a grid disturbance
- Avoid islanding, by some means

Furthermore, UL 1741 historically required:

- A built-in anti-islanding detection
- Inherently excludes a direct transfer trip approach
  - DTT more suitable for a large utility scale plant

However

- IEEE standards are not reliability standards
- Utility within purview to wave requirements (sometimes)

DER Standards Issues

IEEE 1547 now *requires* a distributed generator to:

- Have the capability to regulate voltage, reactive power and pf
- Have the capability to adjust power during frequency events
- Have the capability to ride through disturbances under certain conditions and trip in other conditions

These started as EQUIPMENT STANDARDS (much like IEC) that were originally not meant to address bulk electric system reliability.

However, these EQUIPMENT STANDARDS certainly influence system reliability. The drafting team spent much effort reshaping them into PERFORMANCE standards suitable for reference in INTERCONNECTION REQUIREMENTS.

In turn, the RELIABILITY STANDARDS also influence equipment design & performance but do not always apply to DER.

HARMONIZATION AND AWARENESS IS CRITICAL!!!!

IEC TC8 SC8A
Grid Interconnection of Wind and Solar Power Plants

IEC TC8 SC8A Scope

- Development of **technical reports, technical specifications and international standards** for grid integration of variable power generation from renewables such as **PV solar and wind energy**
- SC 8A focuses on the **systemic impact of a high percentage of renewables** connected to the grid, considering that their variability and predictability

Activities and WG

- WG1 Terms and Definitions
- WG2 Renewable Energy Forecasting
- AHG3 Roadmap for Renewable Energy Integration
- JWG4 Grid code compliance assessment for RE
- JWG5 Roadmap Implementation

IEC TC8 SC8A AHG3 Roadmap

Weak Grid and Special Application Issues

5.1 Weak AC system connection and inverter control stability (performance, modeling, testing, Composite Short Circuit Ratio (CSCR) screening) and short circuit ratio (SCR) is a metric to represent the voltage stiffness of a grid

5.4 Special Application issues and analysis: Super and Sub-Synchronous Control Interaction, power system damping

Plant Level Coordination Issues

5.3 Plant-level Interaction Coordination with other plants and FACTS devices, HVDC

5.7 Coordination, utilization and performance of electrical Balance of Plant (eBOP) equipment (STATCOM, SVC, Capacitors, Reactors, storage)

5.8 Plant-level coordination of SCADA communications (for regulation, curtailment, forecasting) include TC57

5.11 Voltage/Reactive support during no wind/sun, zero active power voltage regulation

IEC TC8 SC8A AHG3 Roadmap

Voltage and Frequency Control Issues

5.5 Voltage and Frequency control and ride through regarding unbalanced operating conditions (negative sequence)

5.6 Frequency ride through (under/over, RoCoF, Performance and Testing)

5.9 Fast Fault current injection control (active and reactive)

5.10 Fast Frequency Response (i.e. Virtual Synchronous Inertia, Synthetic Inertia, Inertial response) performance, testing, modeling, coordination and monitoring

5.12 International Standard on high fidelity fault recording for all power plants

Renewables Impact

- Renewables technology is rapidly evolving to support the grid voltage and frequency under normal operation and during disturbances
  - Voltage Regulation, ZVRT/HVRT, PFR, FFR, Ramping, etc.
- Renewables is MAINSTREAM.
- As renewable gen grows, this drives the need for flexibility from non-renewable gen (gas, hydro, coal, CSP)
  - New capability, requirements and incentives for ramping/balancing from non-renewables
  - New capability, requirements and incentives for frequency support during disturbances from non-renewables
- Drives overall resiliency UP, integration costs DOWN
- Promotes higher penetration of renewables and clean flexible non-renewable generation

Standards will play a more significant role in renewable integration going forward

Summary

- Standards have a unique role to play to maintain reliability and cost effectiveness all generation technologies
- Many ongoing standards drafting activities impact the generation mix, cost of integration and operation
- More work needs to be done to tackle the jurisdictional gaps related to growing DER that are not captured by existing reliability standards
- Many parallel standards activities around the globe continue to push functional capability and harmonization of these standards
- Standards play a significant role to drive renewable system integration and it is critical to have experts contribute to drafting efforts


Thank You!