Concentrated DER: How an Oxymoron is Causing Power Quality Concerns on the Grid

Brant Werts, November 29, 2016

DUKE ENERGY®

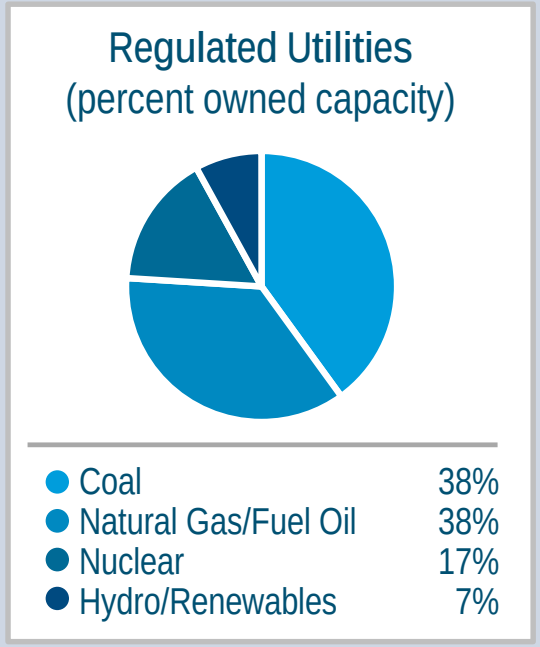
Business Segments

Regulated Utilities

- Regulated generation, electric and gas transmission distribution systems
- Duke Energy Carolinas
- Duke Energy Progress
- Duke Energy Indiana
- Duke Energy Ohio/Kentucky
- Duke Energy Florida

Commercial Portfolio

- Duke Energy Renewables



Duke Energy's Distributed Energy Resource Objectives

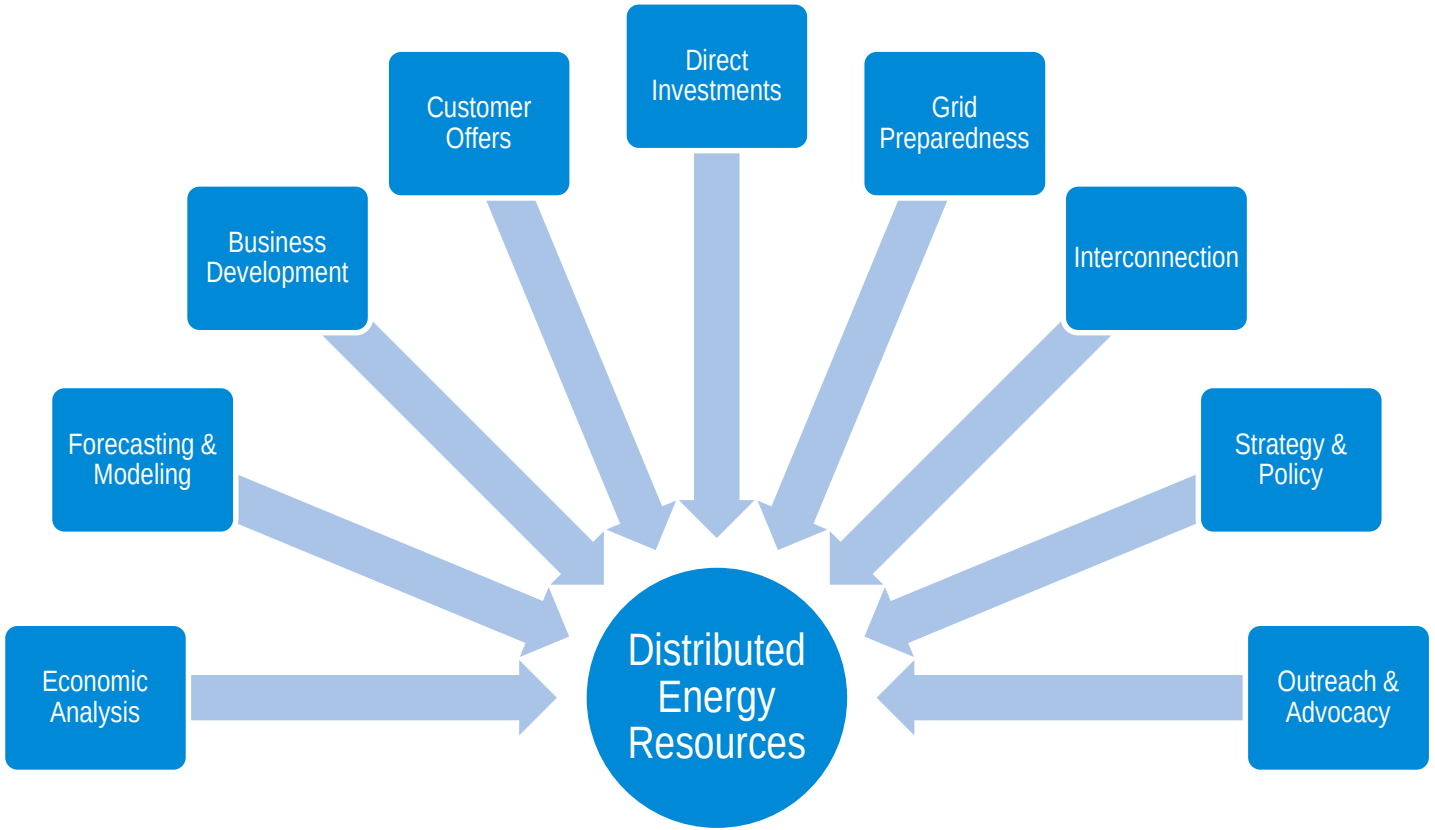
Develop customer products and offers

Advance policies and investment opportunities

Integrate DER technologies for grid and customer

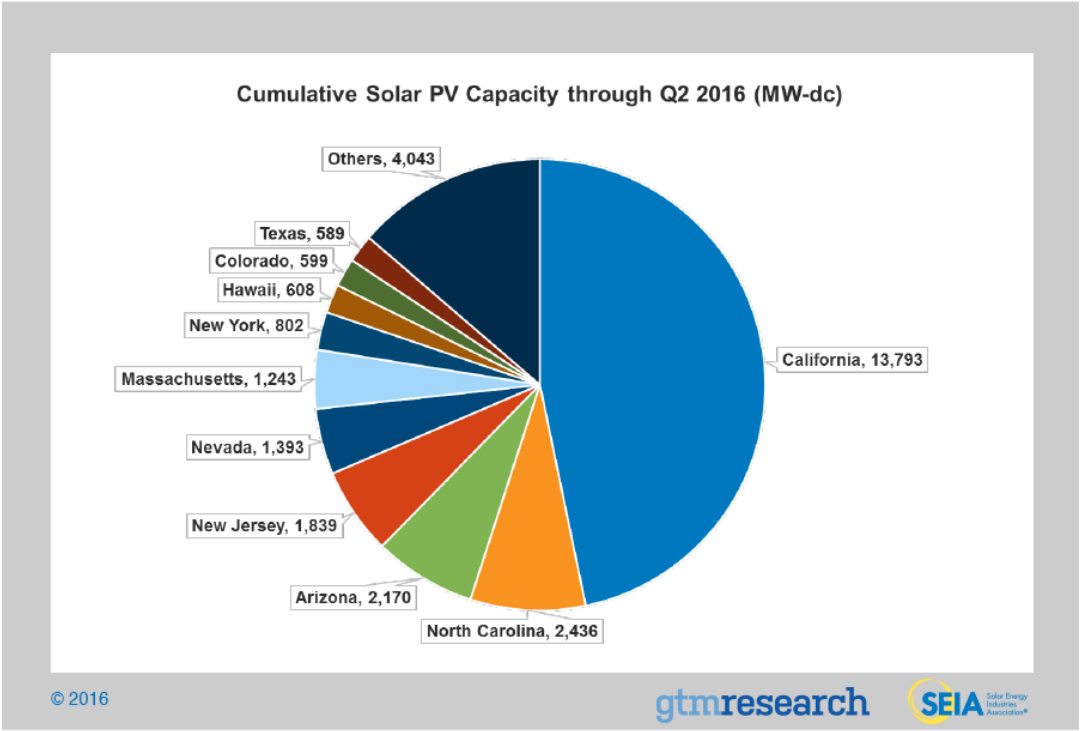
Align generation planning with DER technology trends

Distributed Energy Resources: *What We Do*



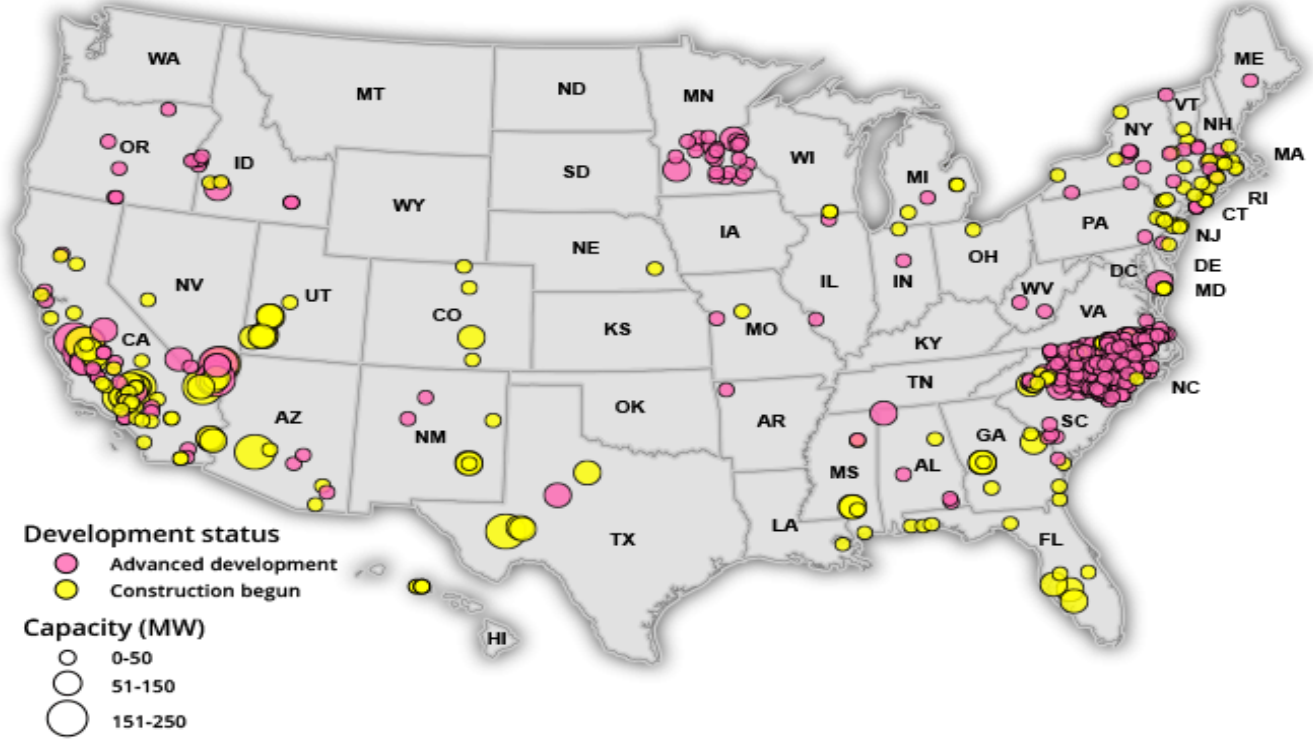
Facts about Solar in NC

- North Carolina is 2nd in the nation for total installed solar capacity and 2nd for growth.
- 97% of the solar is utility scale.
- Around 3% is net metered.
- The utilities own about 10%.



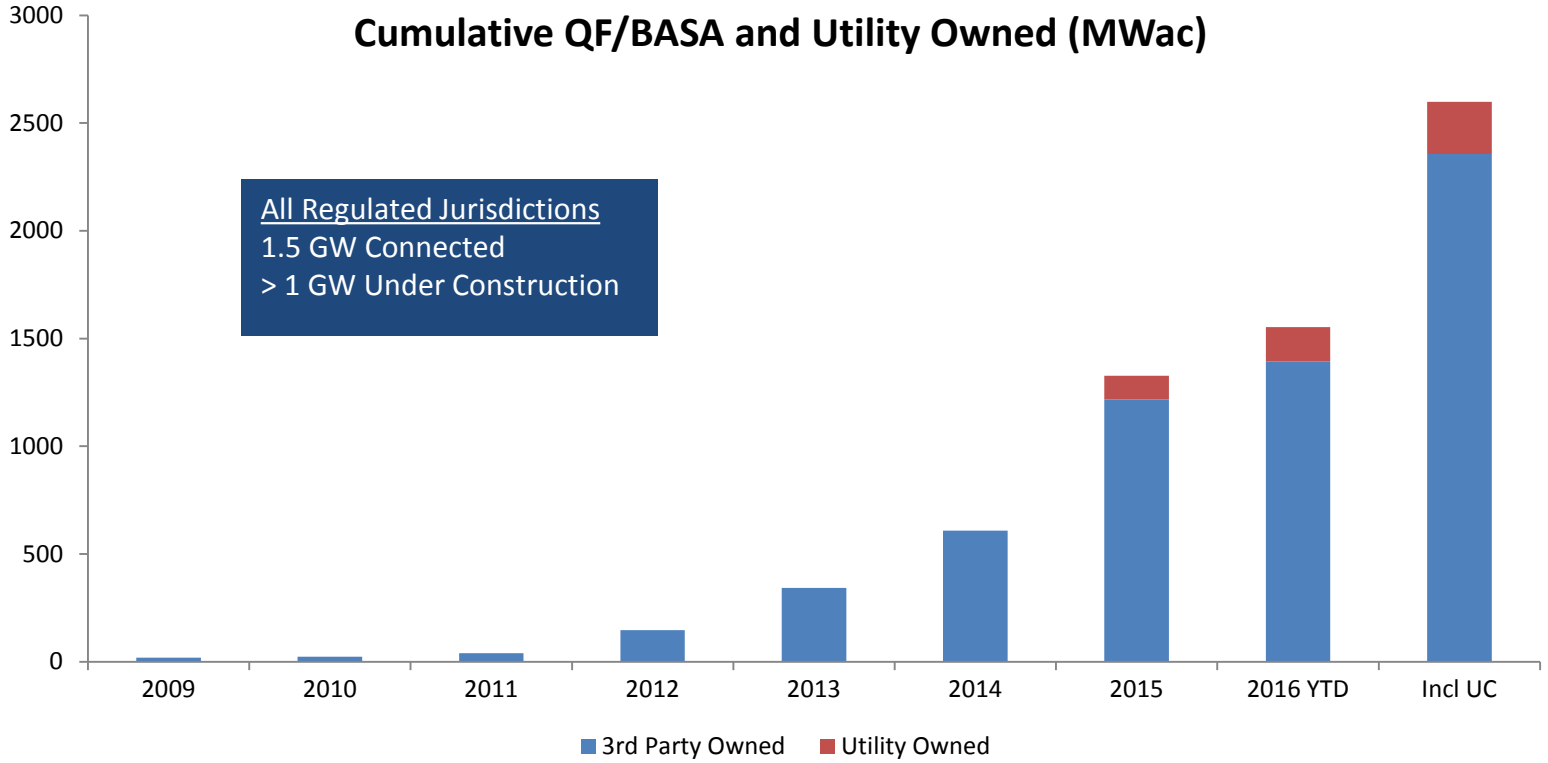
Solar Development Not Driven by Irradiance

US planned utility-scale solar projects in advanced development or under construction



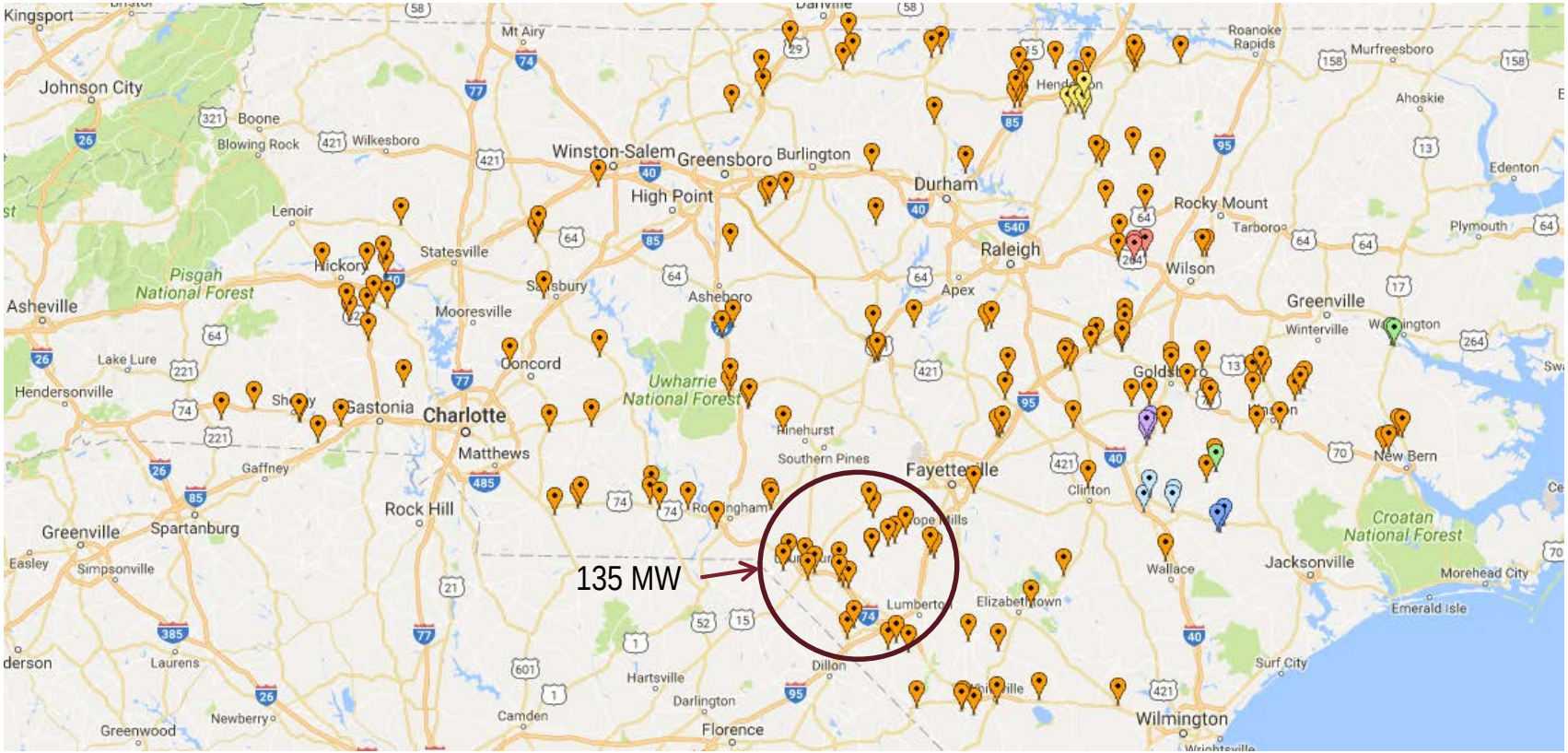
As of May 26, 2016.
Source: SNL Energy, an offering of S&P Global Market Intelligence
Map credit: Alip Artates

Integrating Solar on Our System



Note: Cumulative 2009-2016 Connected and Under Construction (UC) are based on status in the Interconnection Queue

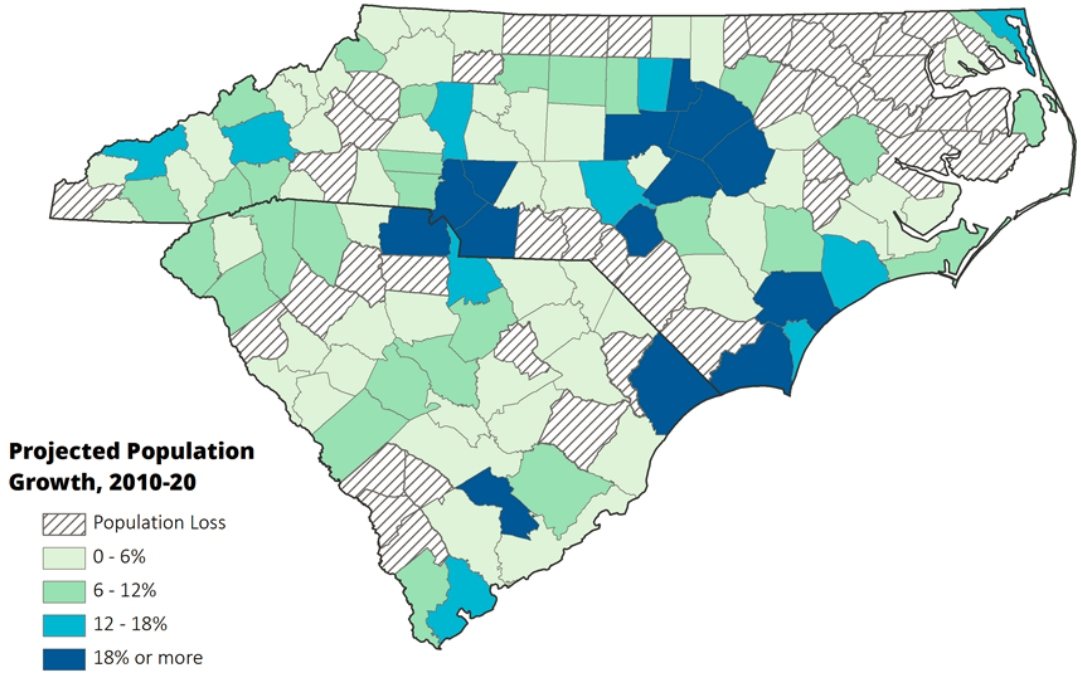
Carolinas – Concentrations of Solar in Rural Areas



Load Growth expected in Urban Areas

Population growth will be uneven across the Carolinas

Projected population growth, 2010-2020



Sources: NC OSBM, SC Revenue & Fiscal Affairs Office

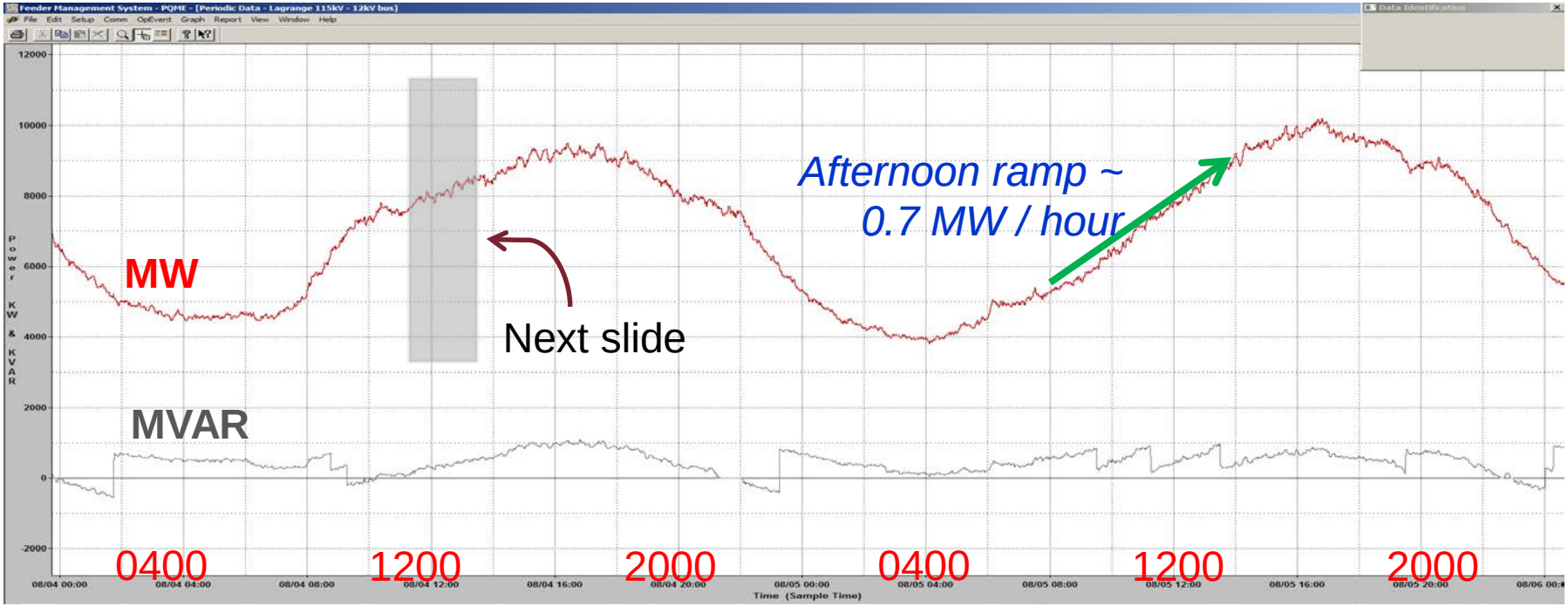
UNC Carolina Population Center | Carolina Demography

DER Concerns during the Interconnection Study Process

- Legacy systems were designed to:
  - Serve radial load and regulate voltage from a single source
  - Progressively smaller conductors down circuit (lower cost).
  - Voltage regulated to +/- 5% of nominal voltage in the radial direction to provide proper voltage automatically from zero load to full load to distribution customer equipment.
  - Not designed for bi-directional flow associated with generation.
  - Not designed for frequent large power fluctuations that may occur with intermittent sources such as PV.

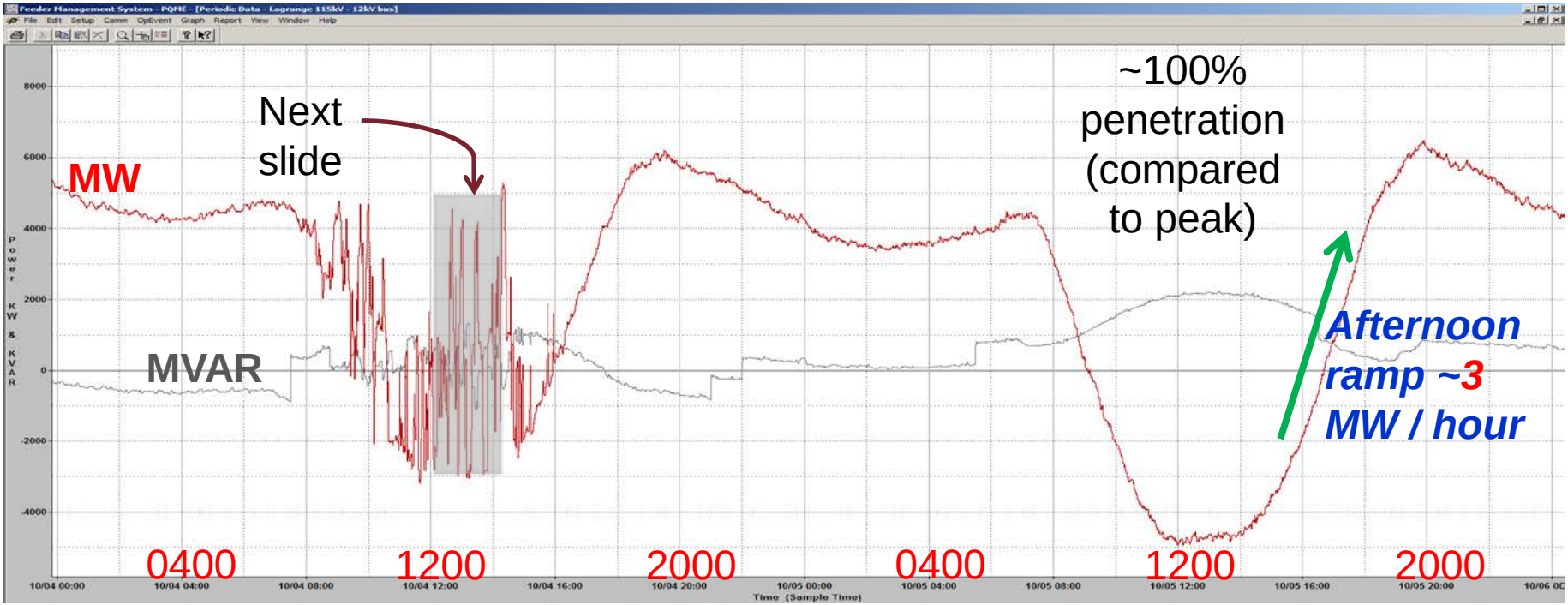
- Possible Impacts
  - High and Low Voltage deviations
  - Increased operations of voltage regulation equipment
  - Delayed protection tripping

Duke Energy Progress – Substation before Solar



One-minute real & reactive power flow measured at distribution bus,
48 hour period

Duke Energy Progress – Substation with 10 MW of Solar



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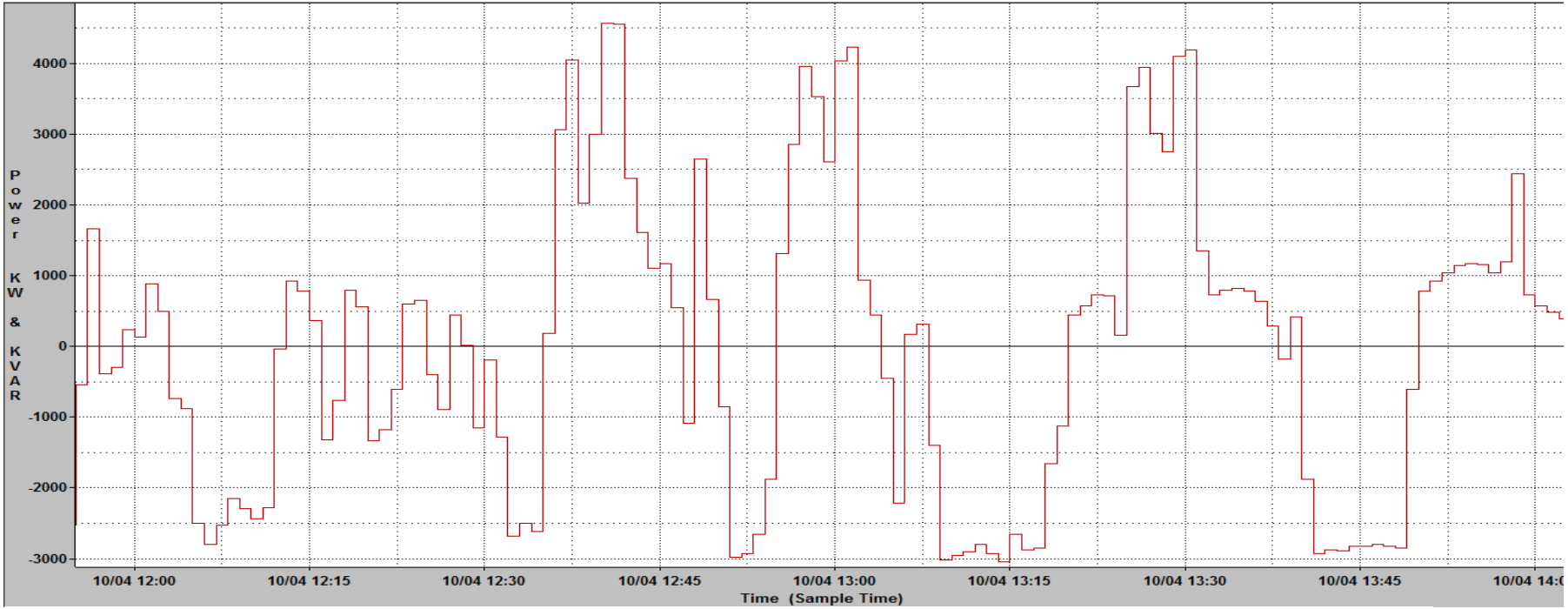
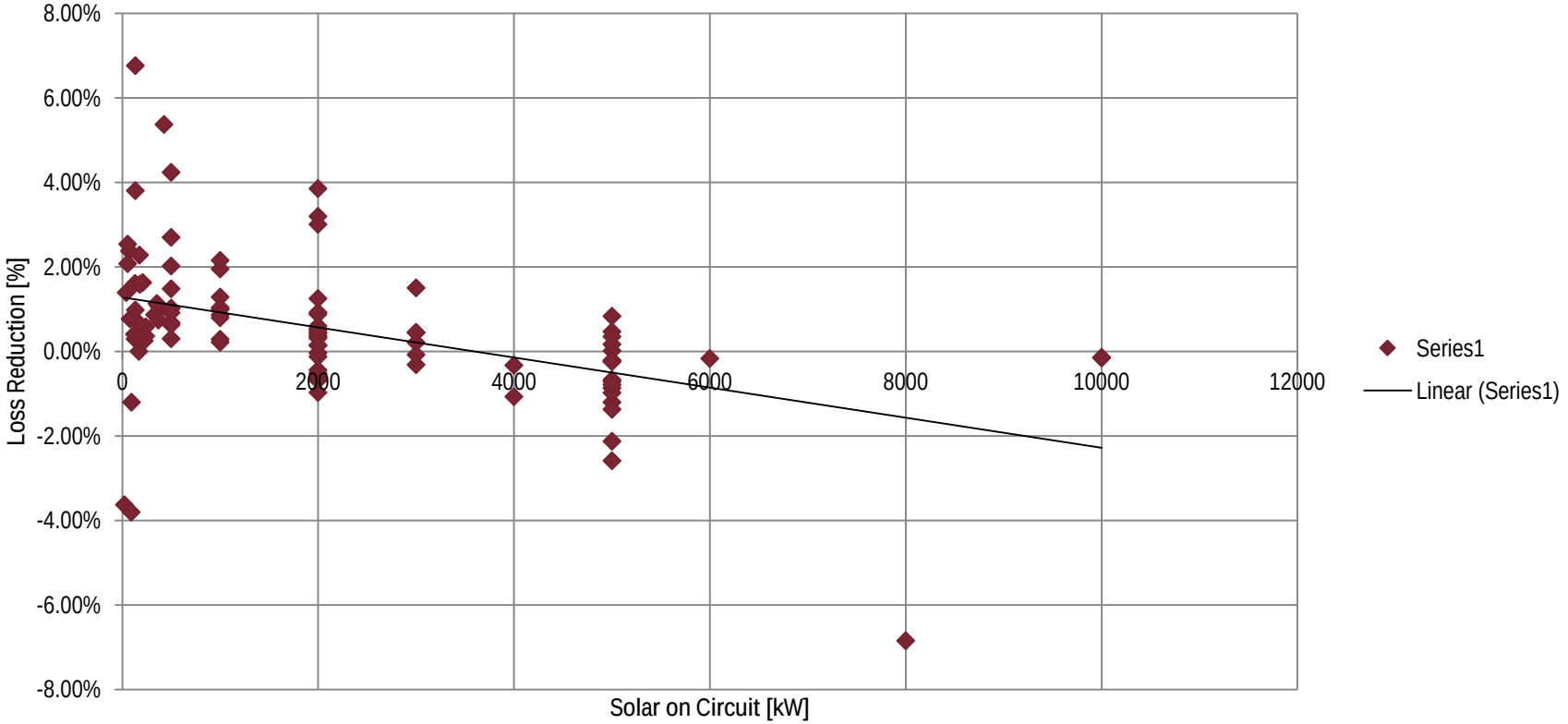


Zoomed in to a 2 hour window.
Due to solar variability, the circuit's power flow can change directions from 4 MW towards load to 3 MW reverse towards the system in just 5 minutes.

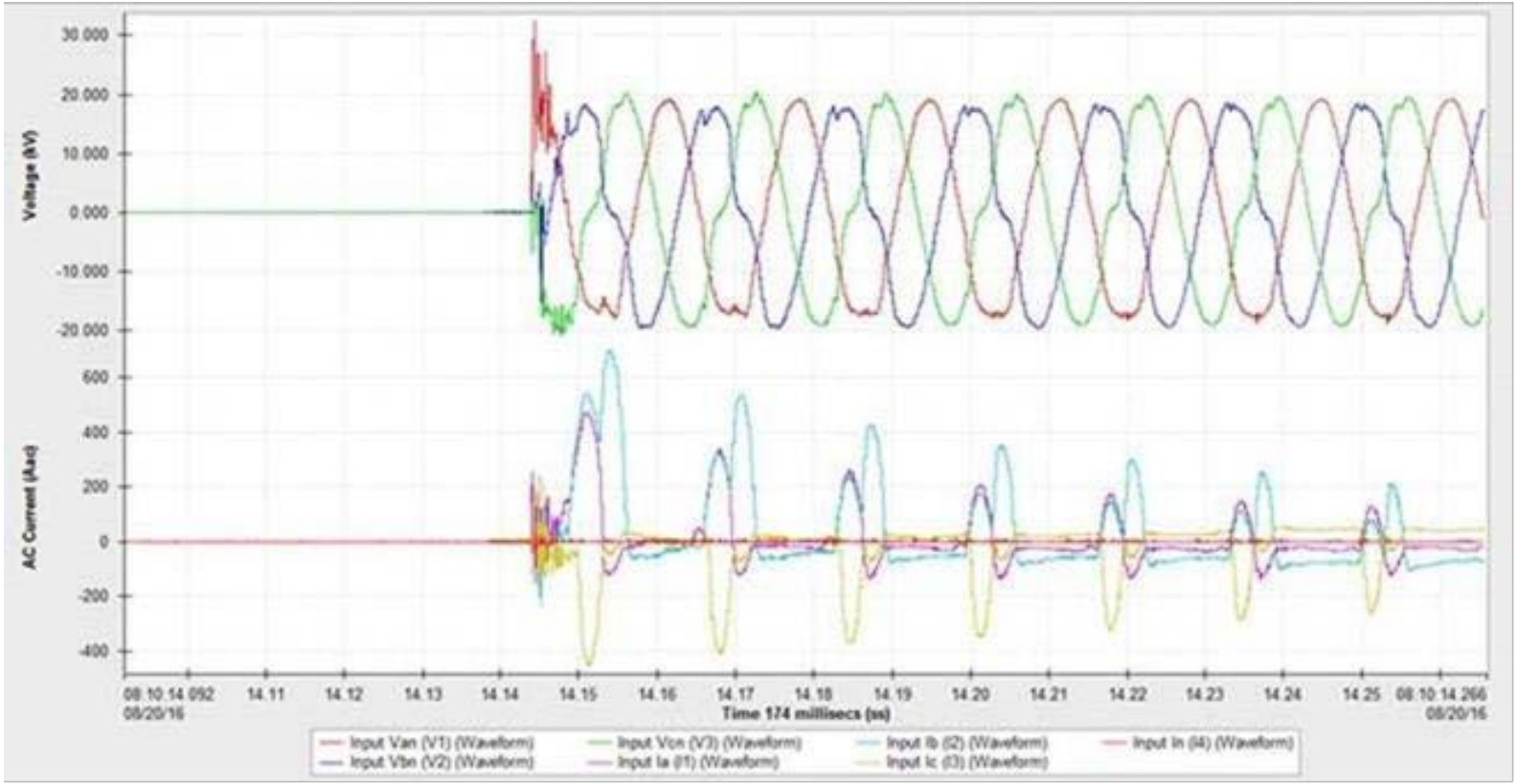
Impact of PV on Feeder Losses



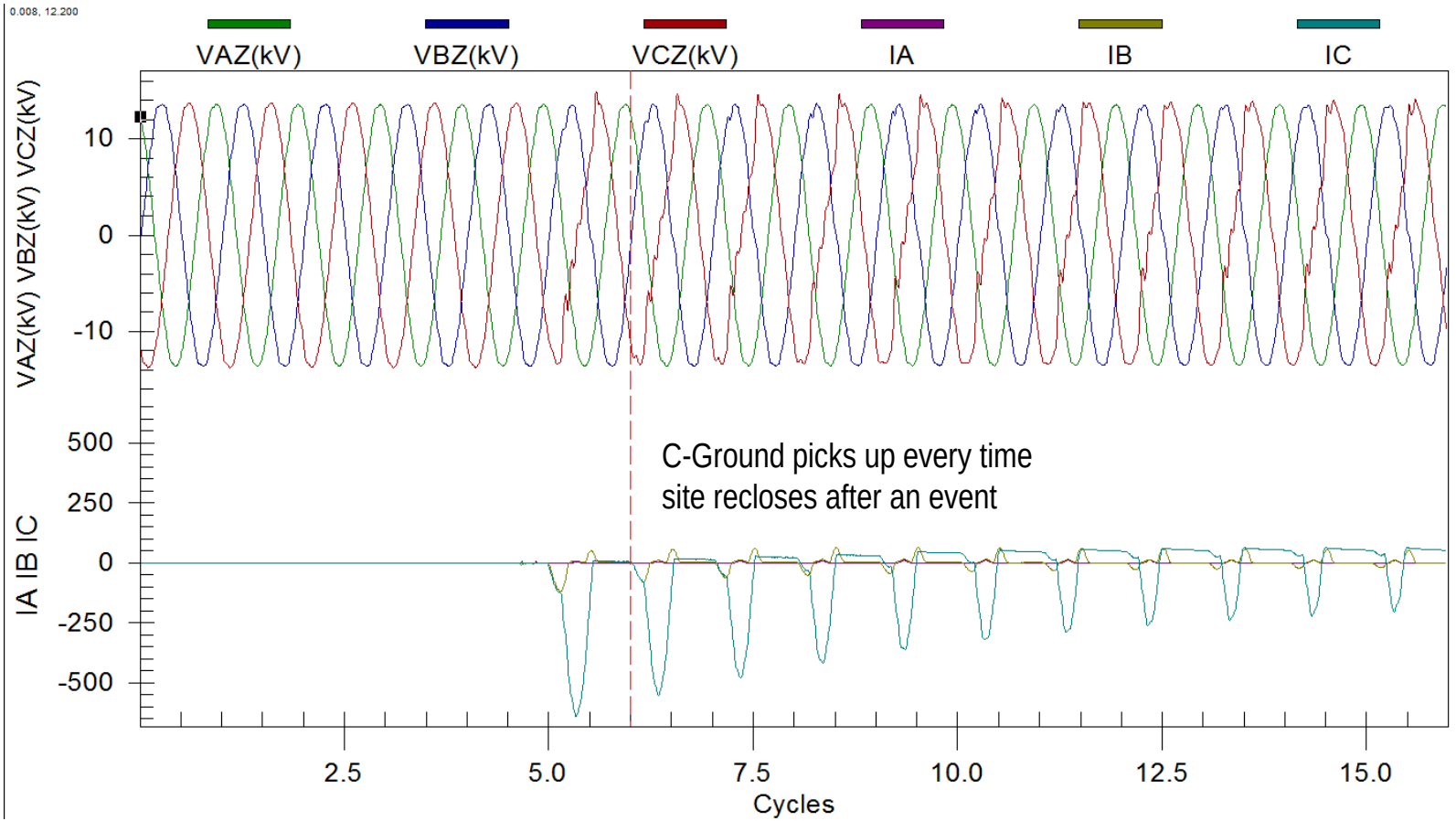
DER Concerns during Operations

- As more of these sites come online, the utility concerns are evolving.
- Inrush
  - Voltage sags and Harmonics reducing PQ for customer's
  - The size of transformers located at PV sites relative to the circuit size
- Voltage Control
  - Unity power factor at most Distribution-connected sites
  - Some sites temporarily move off of their power factor
- Equipment Failures
  - Some sites tripping due to poorly designed medium voltage systems

What is Typical Inrush for a PV Site?
Example 1

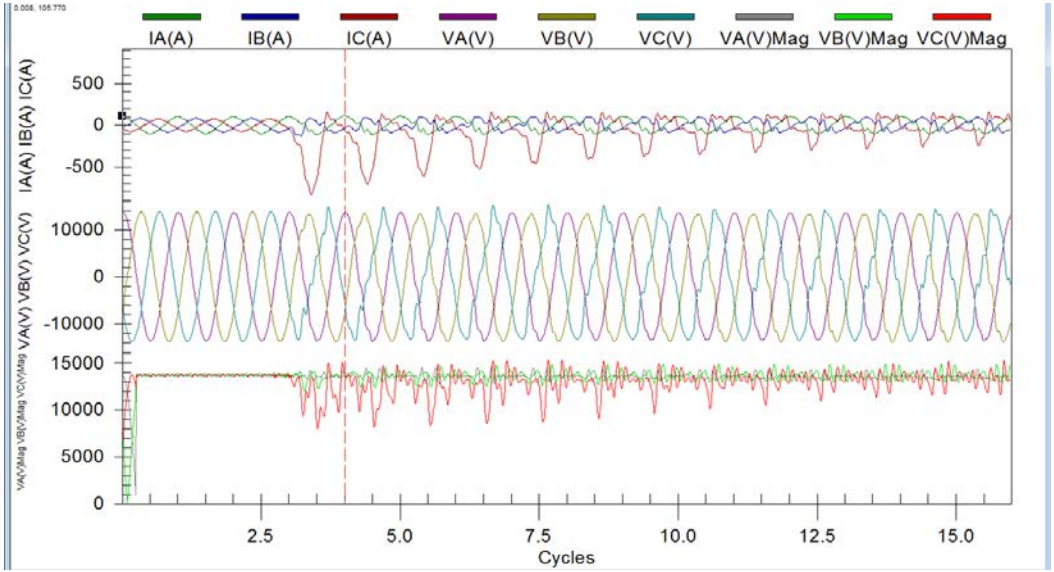


What is Typical Inrush for a PV Site?
Example 2

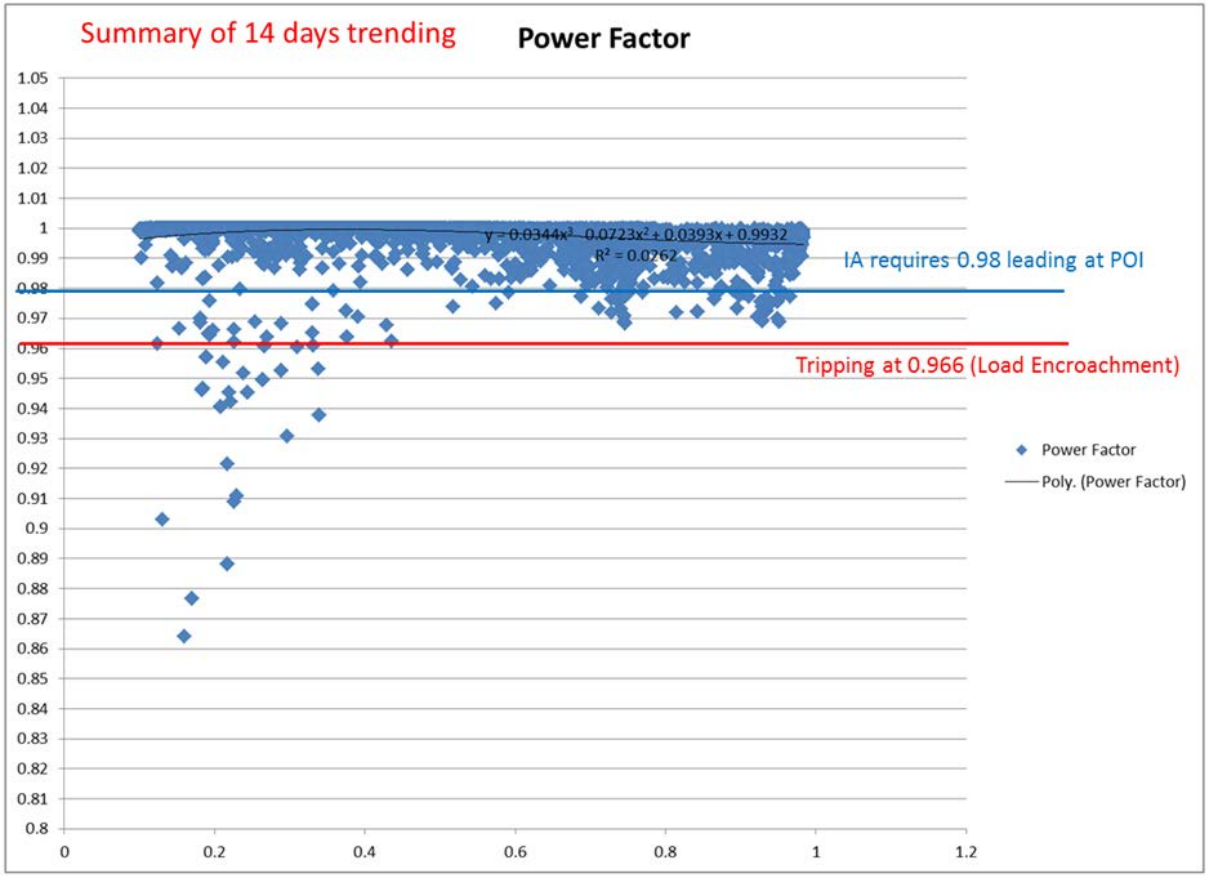


Why be Concerned about Inrush?

- The large size of the PV sites relative to the distribution loads and impedances allow them to move the voltage around on the entire feeder or even substation.
- Started investigating due to industrial customer complaints and/or motor tripping.
- The example below shows the currents and voltages measured at the feeder breaker for inrush on the previous slide. The magnitude, duration and number of voltage sags need monitoring.



What is Acceptable Power Factor Stability?



Addressing Distribution Operational Concerns

- Duke is spending more time investigating, recording and working to resolve concerns.
- Inrush
  - Research into what is normal and why
  - Tracking events for customer impacts
  - Sharing anomalies with developers to look for solutions
- Voltage Control
  - Meeting with developers and manufacturers to explain the issue
  - Testing inverter control changes
  - Evaluating appropriate recloser controller settings
- Equipment Failures
  - Sharing Duke's distribution standards with developers
  - Developing a commissioning inspection process for new sites
  - Requiring medium voltage inspections for existing sites, as needed