Field Testing Smart Inverters as Grid Assets

Panel Session

Moderated by: Fathalla Eldali (NRECA)
Distribution Optimization Engineer

TECHADVANTAGE® 2021 EXPERIENCE

NRECA America's Electric Cooperatives

Share Comments & Questions in Chat

Demonstration

Testing Smart Inverters as Grid Assets

Panelists

- John Becker
- James Moye
- JC Hernandez

With

Central Electric Power, SC

Black River Electric Cooperative, SC

Georgia Tech-NEETRAC

Smart Inverter Demonstration Objectives

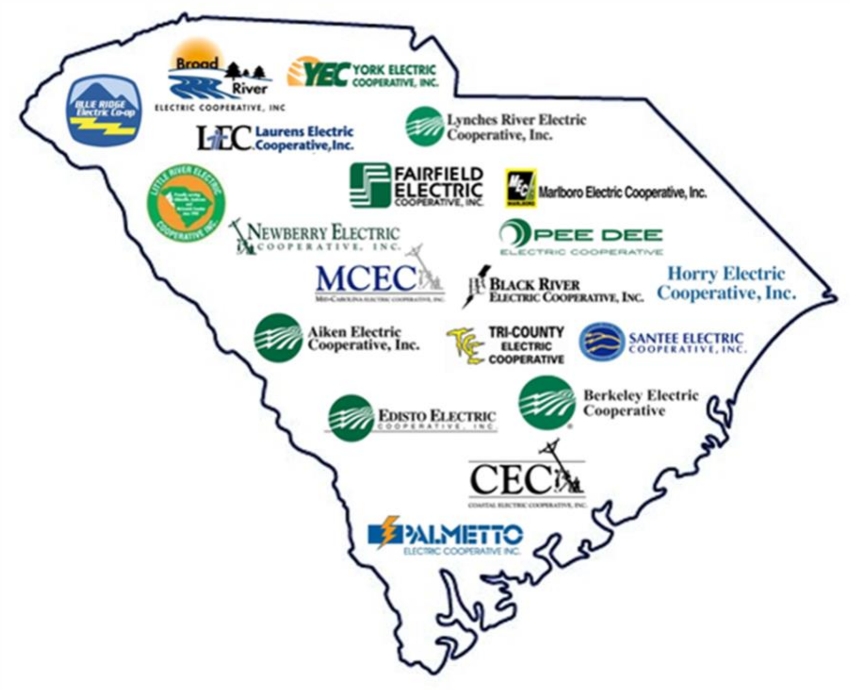
- Interconnect and test smart inverter-based DER using parameters of IEEE 1547-2018
  - Address problems
  - Find challenges and limitations
- Simulation studies to determine potential alternative settings
- Field tests and analyses on inverter performance

Scope

Perform	Conduct	Analyze
Simulation studies of alternative settings	Field tests at 2 co-ops	Analyze inverter performance

Central Electric Power Cooperative, Inc.

- 20 member cooperatives
- 800,000+ meters
- No baseload generation
- 2 long-term power purchase agreements
    - Santee Cooper & Duke Energy



Solar Capacity

- Community Solar
  - 18 member cooperatives have installed 4.2 MW to date
  - 5 MW planned for completion
  - Berkeley Electric Cooperative first integrated solar + battery system
- Residential and Commercial Solar Systems
  - 4,200+ installations
  - 3.3 MW

Solar Initiatives

- 2018 – Horry County Schools 1.2 MW
- 2019 – Announced 2 x 75 MW PPAs
- 2020 – Volvo manufacturing site 6.5 MW PPA
- 2020 – RFP for 363 MW of solar PPAs

“This will give us great long-term flexibility as well as lower pricing of renewable resources for the benefit of our member cooperatives.”

-- Robert C. Hochstetler, President & CEO of Central

Black River Electric Cooperative, Inc.

- James Moye – VP of Engineering
- Located in Sumter, SC
- Serving parts of 4 counties
  - Sumter, Clarendon, Lee and Kershaw Counties
- 35,000 meters
- Black River is one of the member co-ops with Central Electric that installed a 240 KW community solar farm
- All our energy needs are purchased through Central Electric

Solar Initiatives & Goals

- **Experience**
  - Be on the front end of knowing what to expect, how to handle and get the most from solar farms on our system
- **Partnership**
  - We were very open to partnering with NRECA and NEETRAC in utilizing our solar farm to conduct these tests

The Solar Site

- The site was commissioned 1st of 2017
  - So, we've had it now in operation for 4 years
- This site is feeder connected to our Industrial Park Substation which is 12.47 kV
- The max load on this circuit is approximately 2.7 MW
- This circuits feeds mostly commercial and some residential members
  - Serves Walmart and Lowes

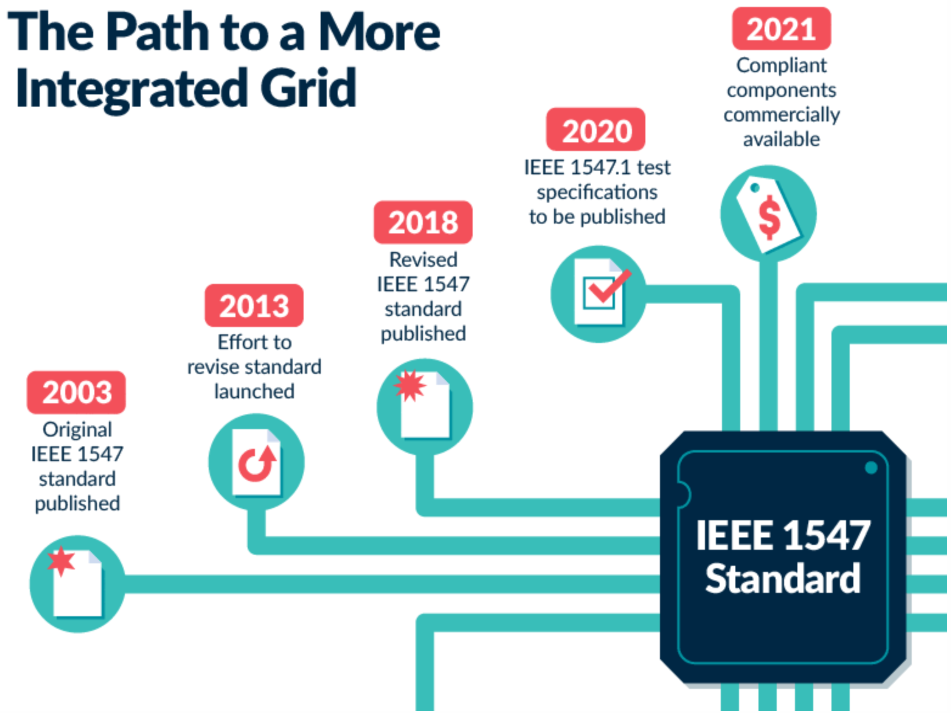
The Solar Site

- Black River owns a 4-acre open field right near the office, which was perfect for this solar project
  - We cut off 2 acres for this site, which left some room for expansion
- The distance to the substation is approximately 3500 feet
- The Solar site transformer is only 70 feet from the point of connection to the overhead circuit

Simulation Studies

Key Differences in IEEE 1547-2018

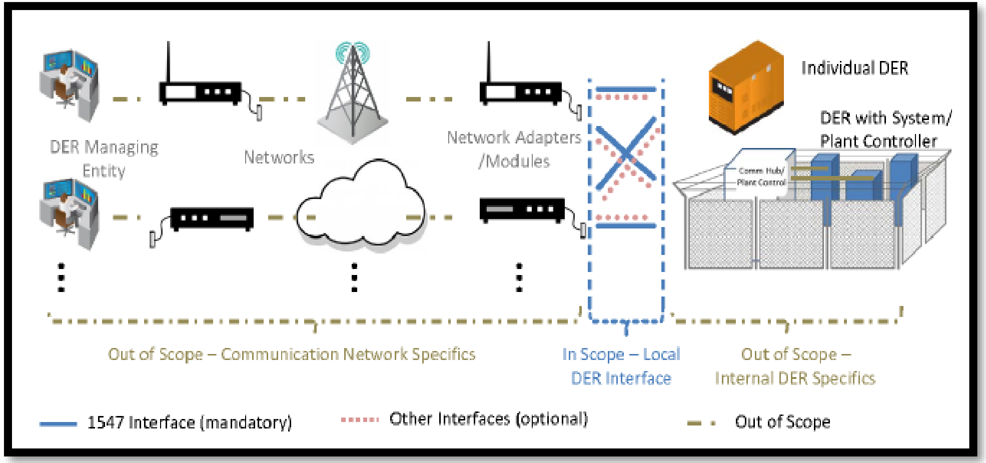
- 10 MVA Limit is removed
- Voltage Regulation via Reactive Power Control
- Interoperability Capability Required for All DER
- Clause on Intentional Islands
- Disturbance Performance
- Abnormal Operating Performance **Categories**



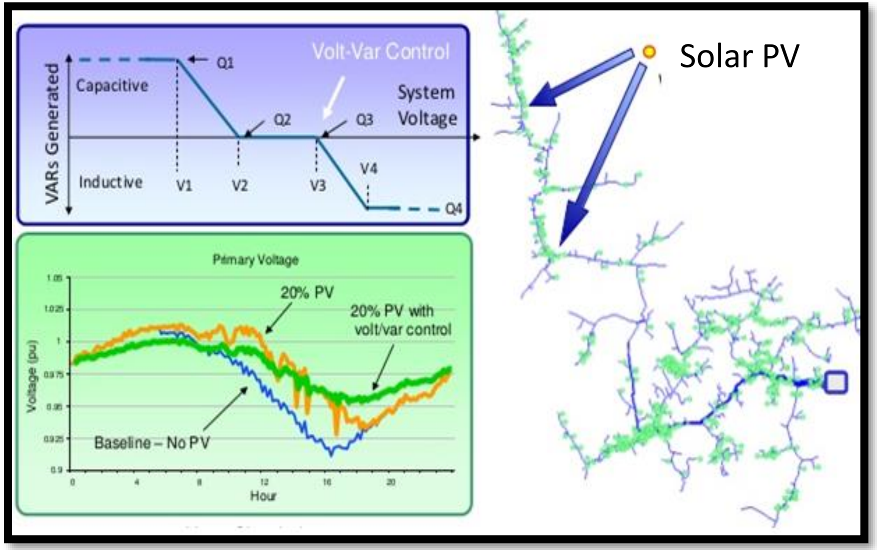
Source : A New Template for the Integrated Grid (EPRI)

Smart Inverter – Planned Tests

Test 1: Interoperability



Test 2: Voltage Regulation



Simulation Studies – Voltage Regulation

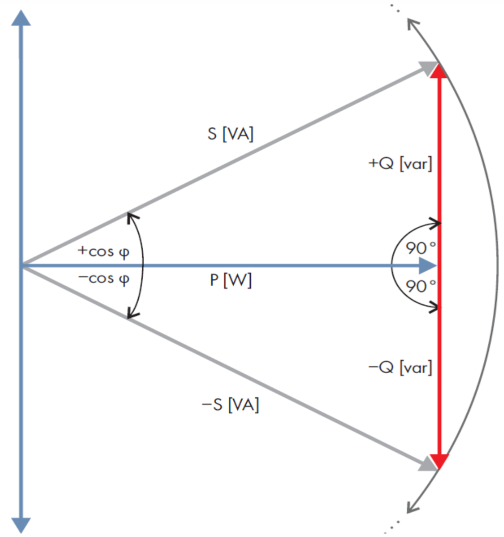
- The goal of conducting simulations to determine alternative settings
- Study the impact of changing the settings on the operations of the inverters and distribution feeder
- We use actual datasets from both sites
- We use circuit models to run dynamic simulations in **GridLAB-D**

Simulation Studies – Voltage Regulation

- **Base Case (Default Settings)**
  - Unity PF/Set and forget
  - No Voltage Regulation required (older versions IEEE 1547)
- **Case-I**
  - Fixed PF Inductive/Capacitive
- **Case-II**
  - Volt-Var Curve (with and without dead-band)
  - Considering CAT-I & CAT-II

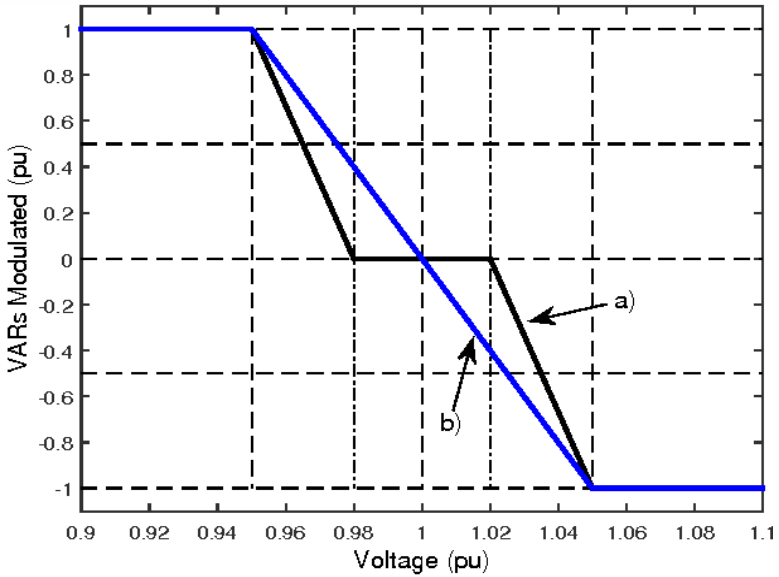
Smart Inverter Demo Project
Voltage Regulation

Case-I: Fixed PF



Considering fixed step fixed PF

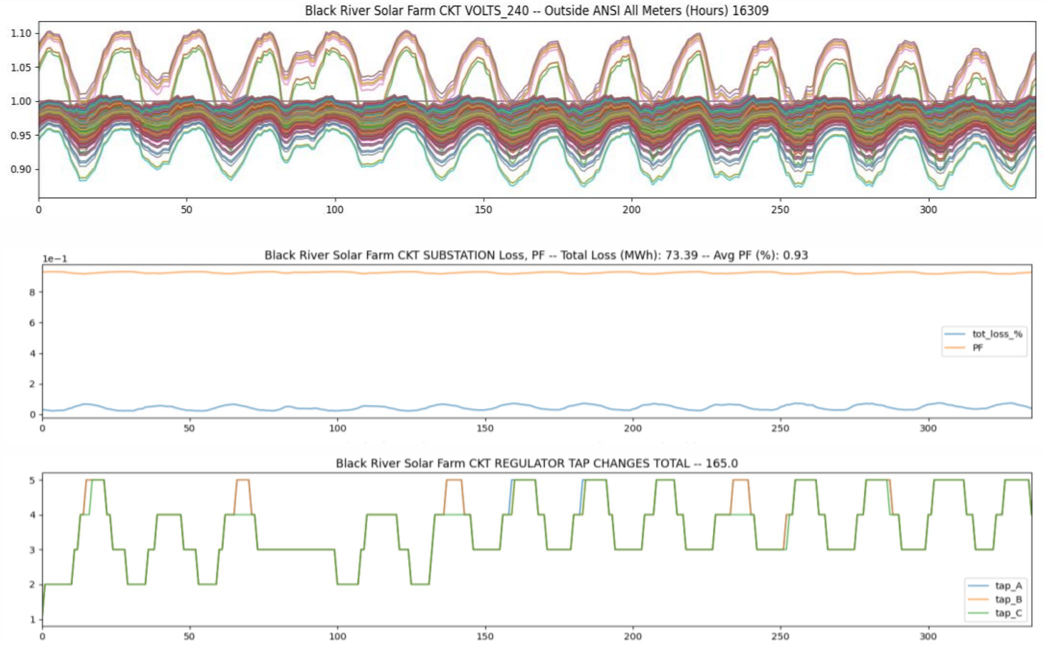
Case-II: Volt-Var Curves



Considering with and w/o dead-band curves

Smart Inverter Demo Project
Voltage Regulation

- **Simulation Studies Outputs**
  - Voltage profile along the feeder and its distance from PV system and the substation
  - Impact on losses
  - Power Factor at the substation
  - Impact on voltage regulating devices operations



Voltage Regulation- Summary of the results

- **Case-I: Fixed PF**

Output (Unit)	Unity (1)	(0.9) Ind	(0.8) Ind	(0.9) Cap	(0.8) Cap
Solar Energy (Active) (kWh)	306.8 MWh	276 MWh	245.5 MWh	276 MWh	245.4MWh
Average Sub PF	0.92	0.924	0.9327	0.917	0.917
Average line losses (%)	1.87%	1.87%	1.86%	1.87%	1.87%
No. of violations of ANSI for all meters	13273	13273	13265	13276	13277
No. of violations of ANSI for surrounding sub/solar meters	20	17	15	19	20
Regulator changes	1170	1170	1162	1188	1204

Voltage Regulation- Summary of the results

- **Case-II: Volt-Var Curve**

WDB: with dead-band
NDW: No dead-band

Output (Unit)	Unity (1)	CAT-I NDB	CAT-II NDB	CAT-I WDB	CAT-II WDB
Solar Energy (Active) (kWh)	306.8 MWh	306.6 MWh	306.4 MWh	305.88 MWh	305.7 MWh
Average Sub PF	0.92	0.926	0.925	0.923	0.923
Average line losses (%)	1.87%	1.87%	1.87%	1.87%	1.87%
No. of violations of ANSI for all meters	13273	13270	13271	13273	13271
No. of violations of ANSI for surrounding sub/solar meters	20	10	13	20	16
Regulator changes	1170	1136	1146	1170	1156

Discussion of the Simulation Results

- Not a significant impact of the setting changes on the outputs
  - Stiff distribution system that is very well regulated
  - PV system is not big enough to make a significant impact in the voltage of the system
  - Solar Farm location near the substation
  - Simulations limitation (low resolution data)
- But, what if :
  - PV system is bigger
  - Weaker distribution system (higher source impedance)

Field Testing Initial Results

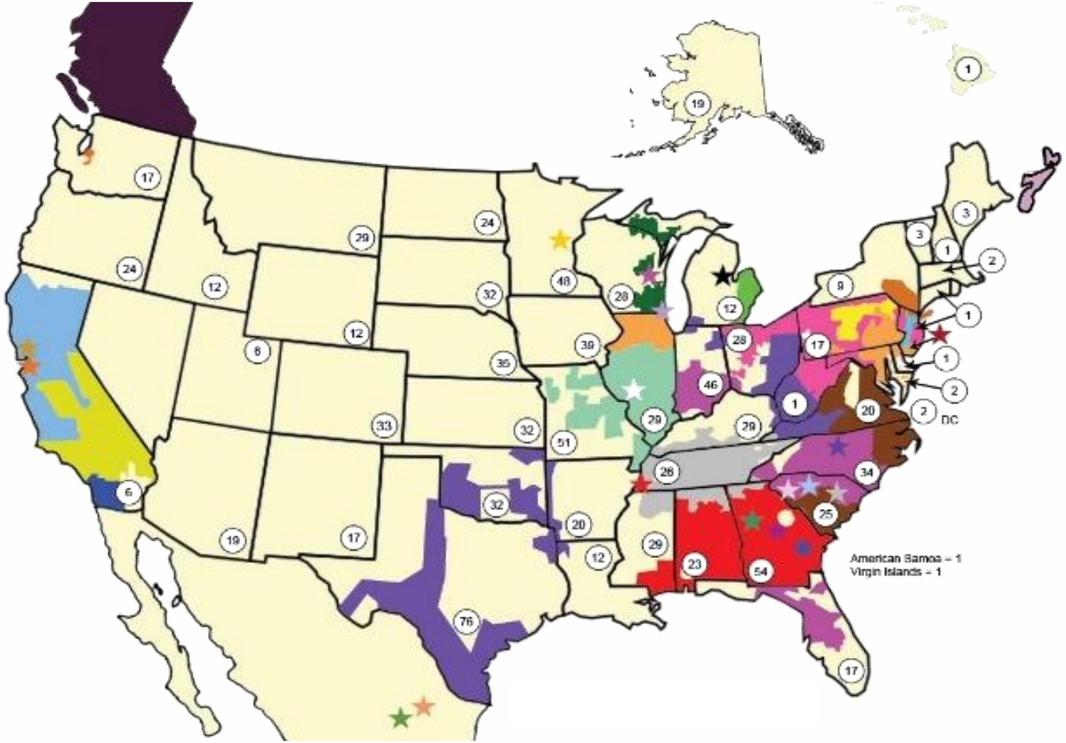
About NEETRAC

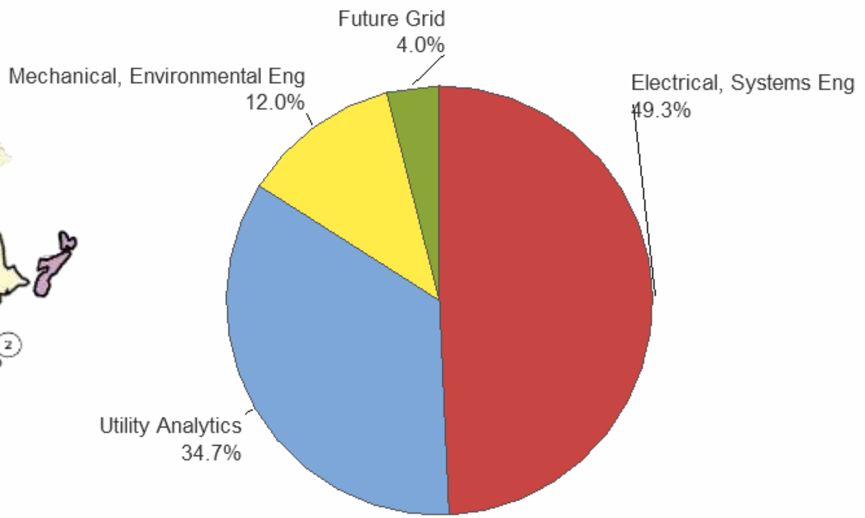
- *National*
- *Electric*
- *Energy*
- *Testing*
- *Research*
- *Application*
- *Center*

In Electrical & Computer Engineering at Georgia Tech

<ins>Scope</ins>: *Electric Energy Delivery*
<ins>Approach</ins>: *Self-supporting Membership Consortium*
<ins>Expertise</ins>: *Asset Management, Condition Evaluation, Diagnostics, High & Medium voltage, Utility Analytics*

NEETRAC & NRECA





NRECA America's Electric Cooperatives

831 Co-op's

88 million US Electric Customers
> 60% of US Customer Base

EIA 2017

Approach

- Locate potential sites – NRECA members
- Discuss project details and assess feasibility with local utility and related parties
- Obtained and digest site technical information
- NRECA conducts simulations
- Develop test program - specific conditions for each case
- Conduct field test program
- Analyze data
- Report on findings

Identified PV-Sites

Black River - Sumter, SC – 240 kW

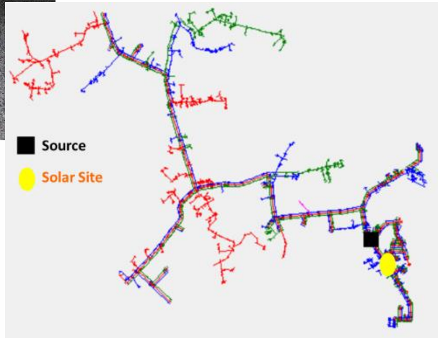
White River - Meeker, CO – 4 MW

Central Black River PV Station

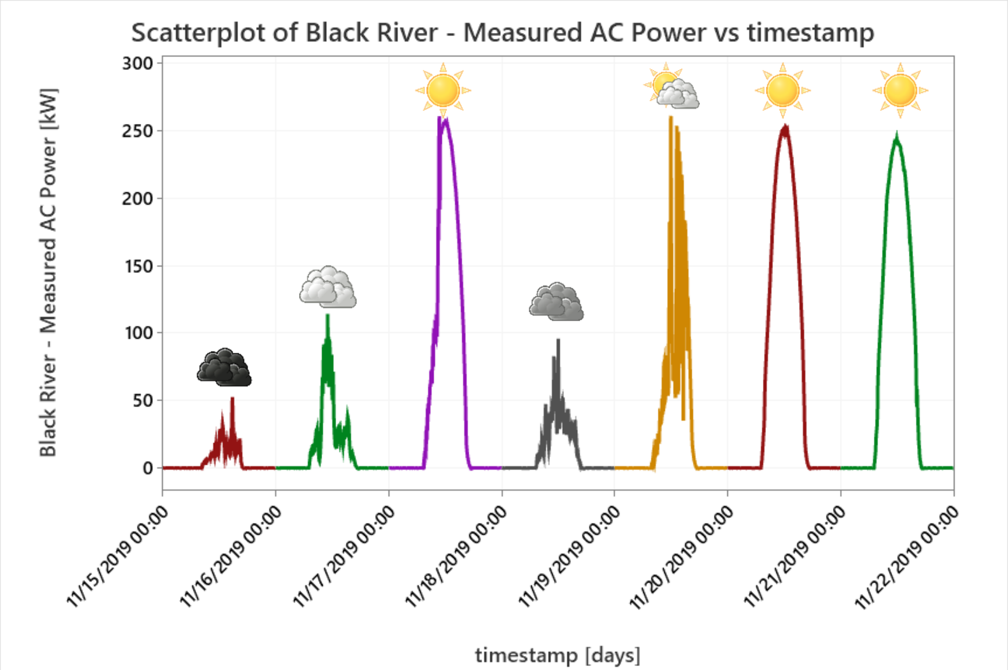
Community Solar Site Size: 240 kW AC / 338 kW DC
Location: Sumter, SC
Inverters: (4) 60 kW

Locally Controlled



PV- Station Production for 2019

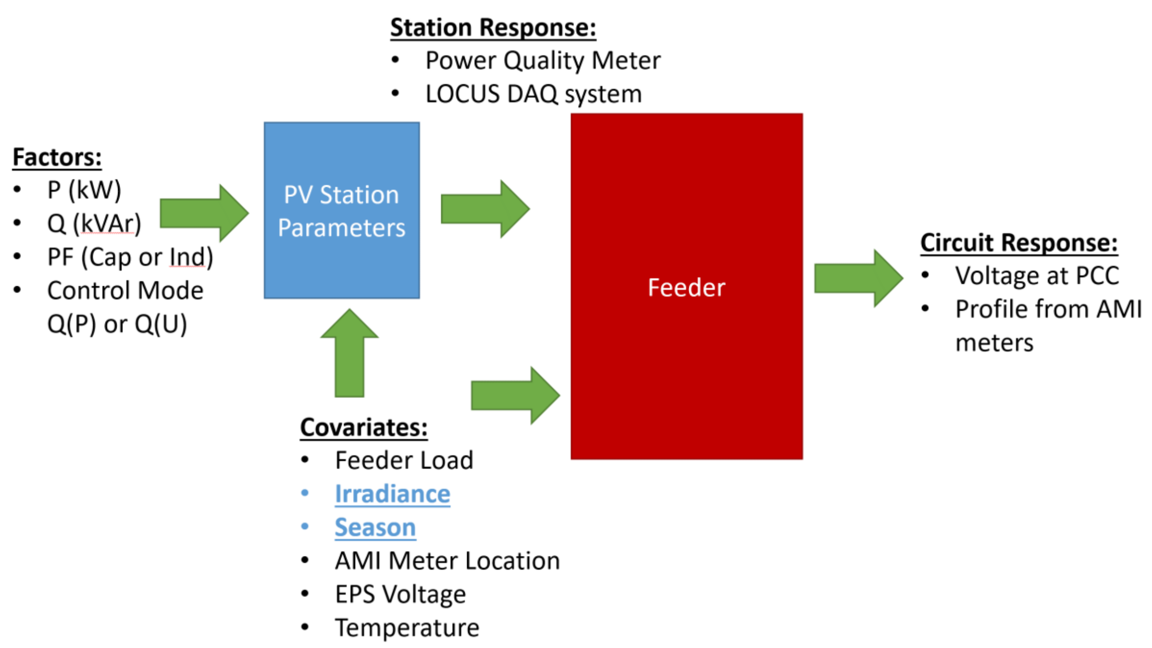


- Production for a week in Nov. 2019
- Same dates for planned field test in 2020
- Need to consider the <u>random</u> nature of variables – station & others
- Solid test program
- Design of Experiments (DoE)
- Relevant data

Design of Experiment (DoE)

- Applied statistics - plan, conduct, analyze, and interpret controlled tests
- Evaluate variables that influence a parameter or group of parameters
- Be bold - explore the full variable range when possible
- Variables are classified as follows:
  - **Factors:** Variables that can be controlled, i.e. inverter settings
  - **Covariates:** Variables that cannot be controlled but known to have an effect on the responses
  - **Responses:** Measurable outputs that are directly related to the issues under analysis

DoE and Test Program



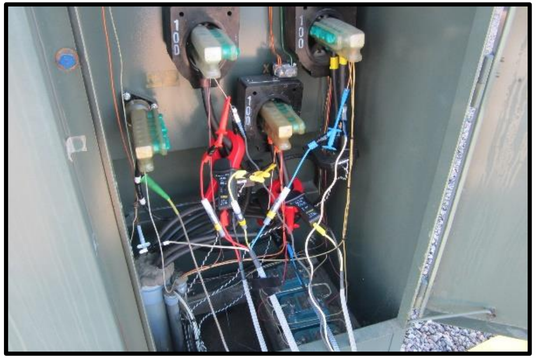
- Full factorial design with two factors and three levels each
- The factors take on all possible combinations of their levels
- A series of replicate and repeat measurements are needed for the experiment design to be robust
- Factor combinations are set and tested in random order in three sets per day

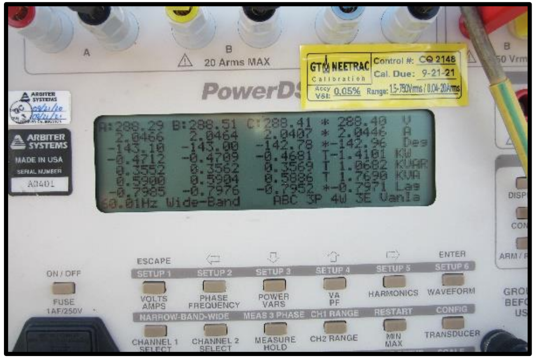
Test Program

Factors	No. Levels	Covariates	Responses
Output Active Power (P)	3 (33-67-100%)	• Load • Irradiance • AMI Meter's location • EPS Voltage • Temperature	Station Response: • Active Power • Reactive Power Circuit Response: • Voltage at PCC • Voltage Profile from AMI meters
Output Reactive Power (PF)	3 (-0.8 cap, 1, 0.8 ind)		

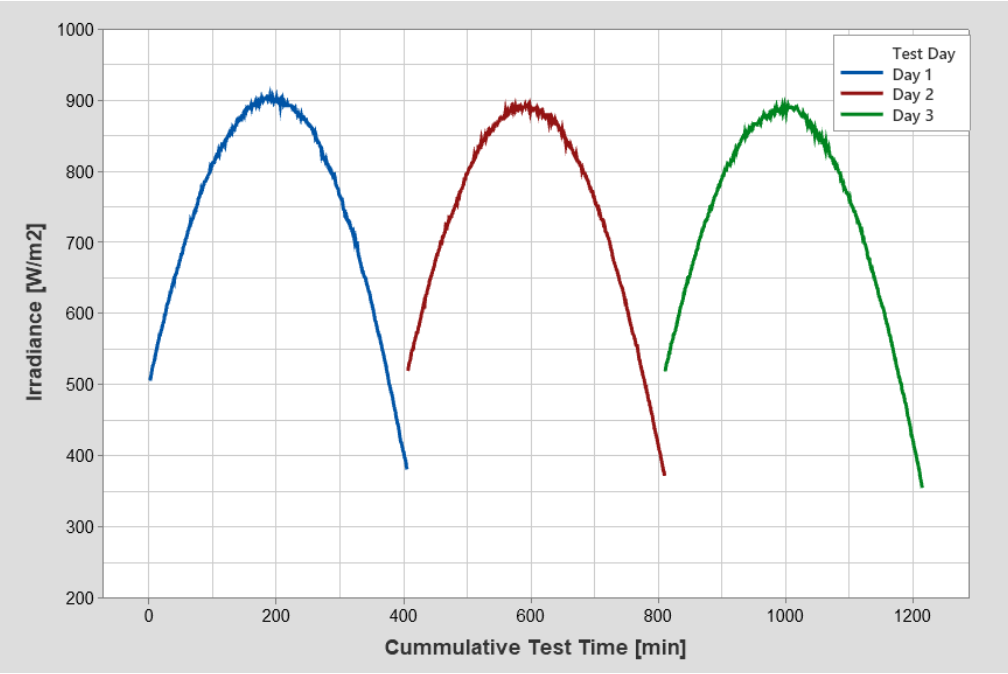
Repeats: 3 – Parameter changes every 15 min in 6.75 hour period
Replicates: 3 days of testing

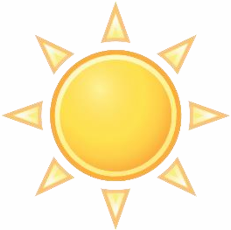
Field Test



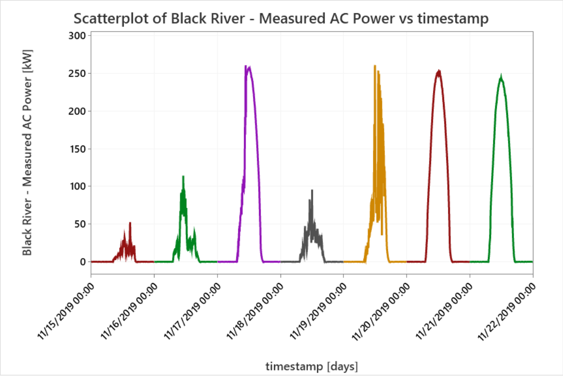

20 Arms MAX
NEETRAC
Control #: CQ 2148
Cal. Due: 9-21-21
ARBITER SYSTEMS
MADE IN USA
ESCAPE
SETUP 1
SETUP 2
SETUP 3
SETUP 4
SETUP 5
SETUP 6
ENTER
ON / OFF
VOLTS AMPS
PHASE FREQUENCY
POWER VARS
VA PF
HARMONICS
WAVEFORM
NARROW-BAND-WIDE
MEAS 3 PHASE
CH1 RANGE
RESTART
CONFIG
CHANNEL 1 SELECT
CHANNEL 2 SELECT
MEASURE HOLD
CH2 RANGE
MIN MAX
TRANSDUCER
FUSE 1AF/250V

Prelim Results – Irradiance



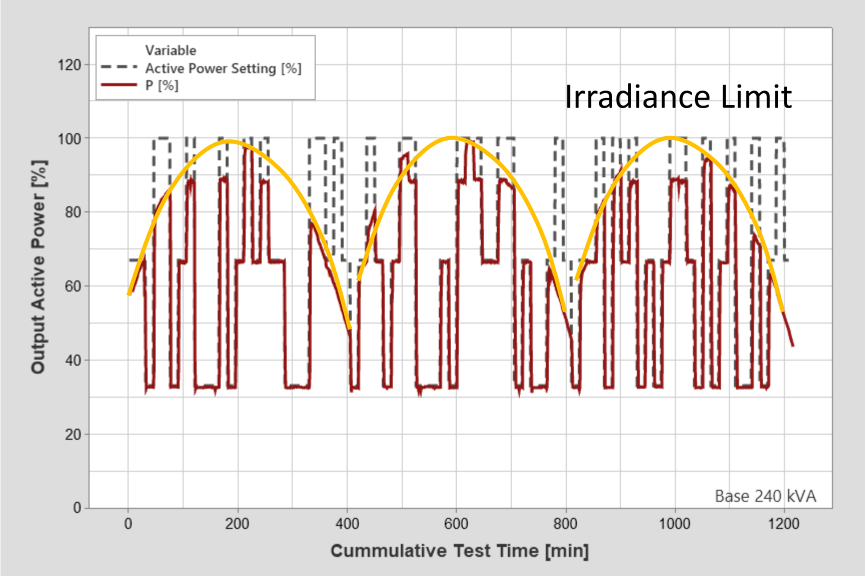


Three sunny almost identical days!

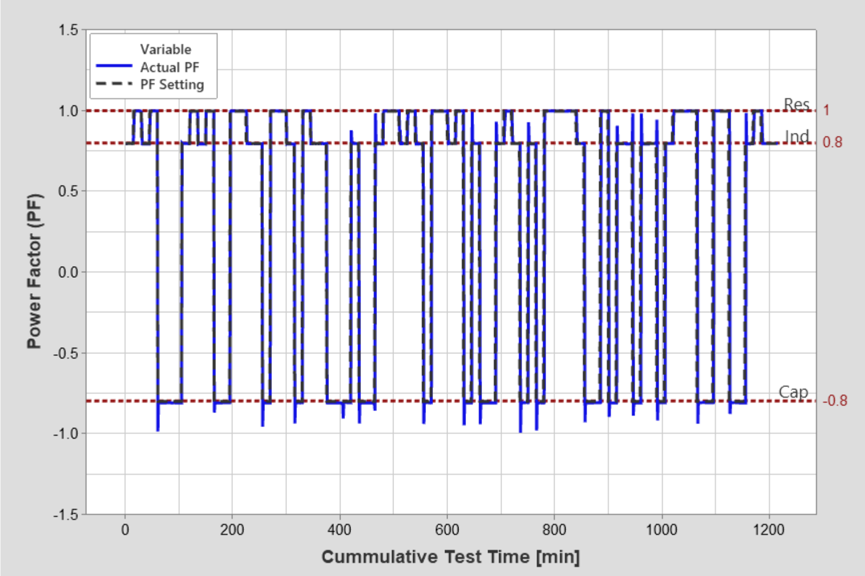


Prelim Results – Active Power & PF

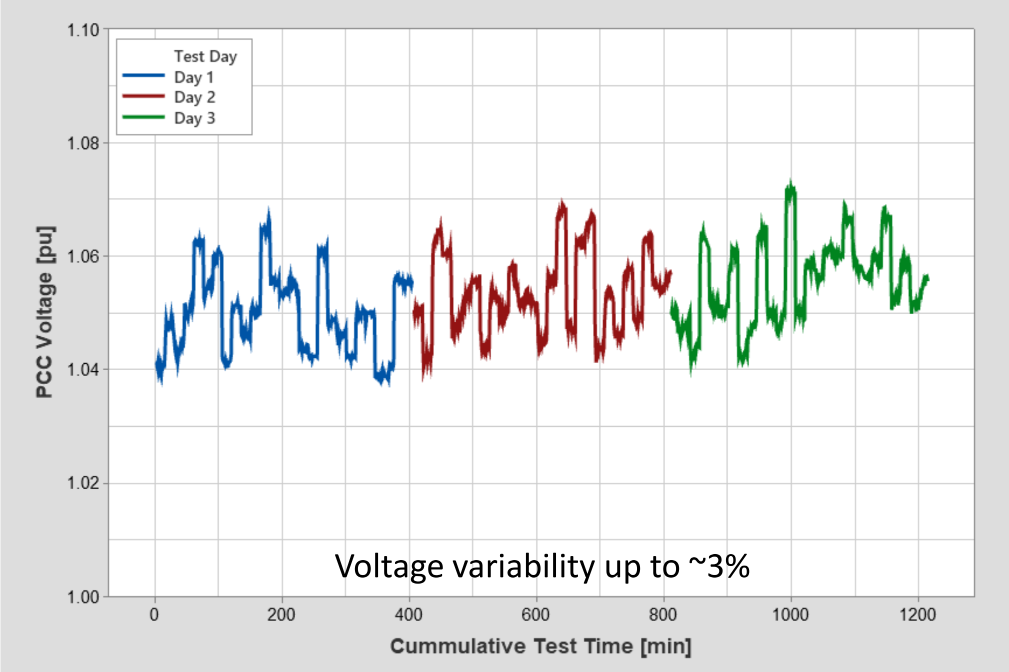
Active Power



Power Factor - PF



Prelim Results – PCC Voltage



Point of Common Coupling (PCC)

Main Takeaways

- Planning intensive – several iterations required
- Focus on safety – (PES) personnel – equipment – system
- Experience is imperative
- Need for understanding/modelling coupled with firm analytics and test deployment in the field
- Robust test program - random nature of variables
- Supported by theoretical and experimental work
- Novel method to assess dynamic voltage support

Summary and Acknowledgements

- Helping NRECA's members to use smart inverters to provide grid services such voltage regulations
- Helping NRECA's members understand the implications of the issues and standards related to DER interconnection
- Acknowledgements
  - Joshua Perkel, & Nigel Hampton — NEETRAC
  - Robert Harris, David Pinney, &Venkat Banunarayanan — NRECA
  - Scott Hammond — Central Electric Coop
  - Matthew Compton — Black River Electric Coop

Thank You!

Questions?

John Becker
Member Services Analyst
Central Electric Power, SC
JBecker@CEPCI.ORG

JC Hernandez
Research Engineer
Georgia Tech-NEETRAC
jh480@gatech.edu

James Moye
VP of Engineering
Black River Electric Cooperative, SC
james.moye@blackriver.coop

Fathalla Eldali
Distribution Optimization Engineer
Business and Technology Strategies, NRECA
Fathalla.Eldali@nreca.coop