University of Pittsburgh

The University of Pittsburgh Involvement with the GTC Focusing on System Modeling & Simulation

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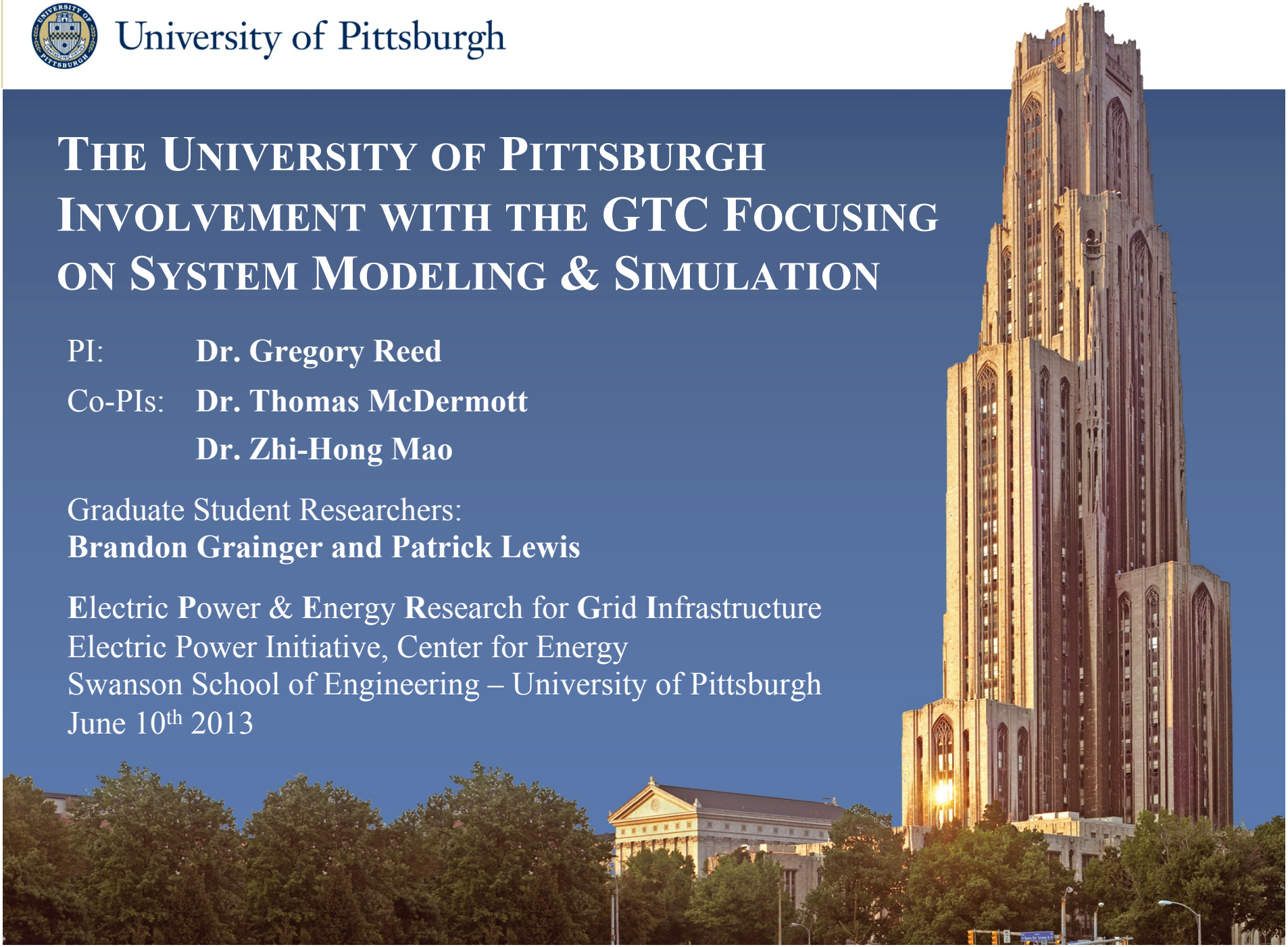
Electric **P**ower & **E**nergy **R**esearch for **G**rid **I**nfrastructure
Electric Power Initiative, Center for Energy
Swanson School of Engineering – University of Pittsburgh

June 10th 2013



OBJECTIVES OF BREAKOUT SESSION

- Define future research agenda based on assessment of current work on the next generation power converter.
- Identify possible government and industry partners to provide advice and direction, and sponsor research.
- Ensure alignment of future research plans with government and industry needs.

General Questions to Answer

Define research needs (What are the research needs?)

- Is the current research addressing high-priority government and industry needs?
- What are the future research needs for advanced power electronics in a modern grid including applications served by power electronics?
- Where are the opportunities for improvement of power electronics?
- In general, what are the future research needs for grid modernization that could best be addressed by an academic collaborative group?

Opportunities (Who are participants in the research, i.e., sponsors, advisors, researchers?)

- Identify likely sponsors, advisors, and other collaborators to guide and support future research. Identify both key organizations and people.
- Identify potential roles for key organizations and people.
- Where are the opportunities to test, demonstrate and validate the applications of power converters and other advanced technologies in meeting the needs of the modern grid?
- Identify opportunities to leverage ongoing work within the government and public and private sectors.

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Overview of Pitt Research for Fiscal Year

IEEE Standard 1547 Research

Inverter Testing Strategies & Simulation

Laboratory Equipment

Breakout Session Discussion

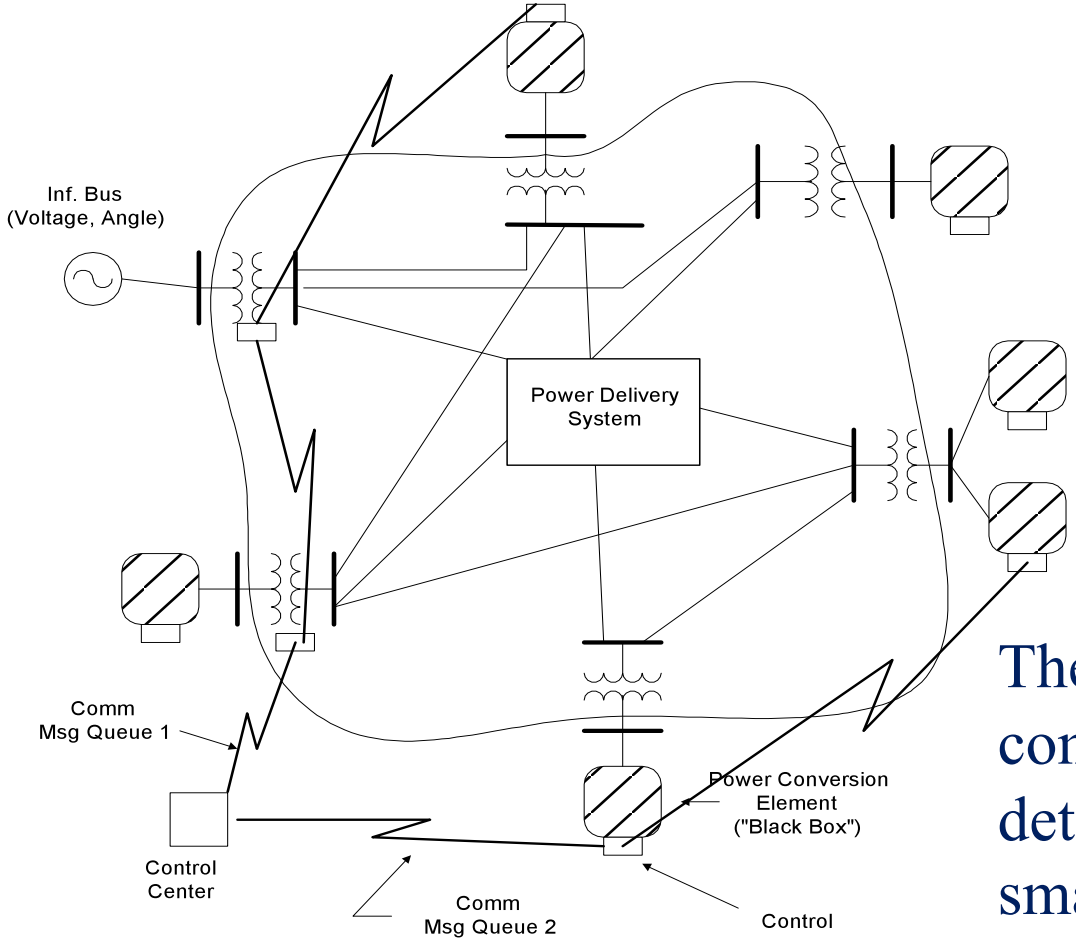
IEEE Standard 1547 Research

- Description of IEEE 1547
  - *IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems*
  - Scope: This standard establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS).
  - Purpose: This document provides a uniform standard for interconnection of distributed resources with electric power systems It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.
  - **Anti-islanding: Requires that upon detection of an electrical islanding condition, all distributed resources are disconnected from the electric power grid within 2 seconds.**

IEEE Standard 1547 Research

- Shortcomings of IEEE 1547
  - Detection of an island becomes less reliable as the total capacity of distributed generation (DG) increases relative to the load.
  - Electric utilities are using accepted and understood methods to analyze DG interconnections, but these do not cover situations with large amounts of inverter-based DG connected to feeders.

IEEE STANDARD 1547 RESEARCH

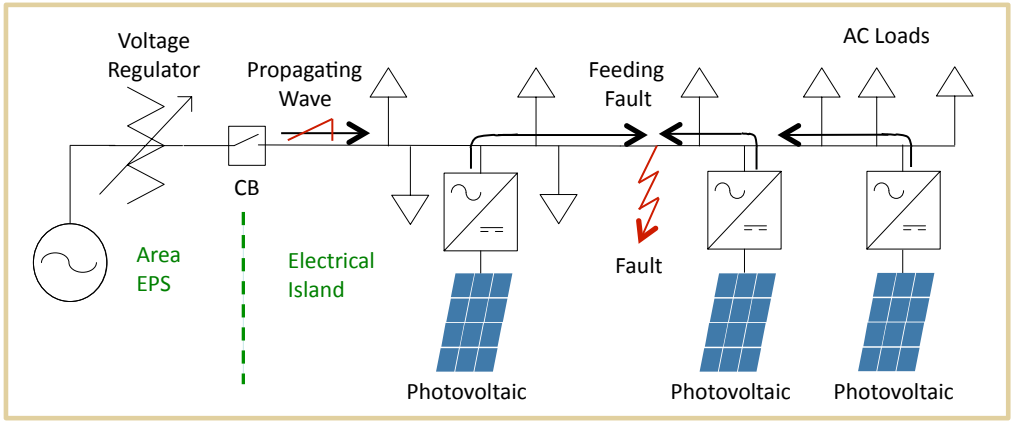


The power system and the communication system both determine performance of the smart grid.

Source: McDermott, Dugan, King and McGranaghan, "Modeling Distribution Automation Schemes with a Control Systems Overlay", IEEE PES General Meeting, Calgary, AB, July 2009

IEEE Standard 1547 Research

- Shortcomings of IEEE 1547 Continued
  - With the large amounts of inverter-based DG interconnections, damaging transient overvoltages can occur within a 2 second interval.



  - Testing inverters one at a time (UL standard 1741-2005)
    - National labs declare that further evaluation should be done to develop standard procedures for the condition of multiple inverters of different sizes and types connected to the same electrical island.

SHORTFALLS OF IEEE 1547 BENEFIT THE GTC PROGRAM (RESEARCH SPEAKING!)

- Value for the GTC
  - Creating a potential hub for standard testing and certification.
    - Developing "in-house" inverter testing capability that will be helpful in developing and testing new power electronic systems before deployment in the Navy Yard.
  - Eventually this task has the potential of being incorporated into standard revisions creating stronger GTC recognition at IEEE level
  - Synergy with Objectives of Virginia Tech's research for the fiscal year.

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OVERVIEW OF PITT RESEARCH FOR FISCAL YEAR

IEEE STANDARD 1547 RESEARCH

INVERTER TESTING STRATEGIES & SIMULATION

LABORATORY EQUIPMENT

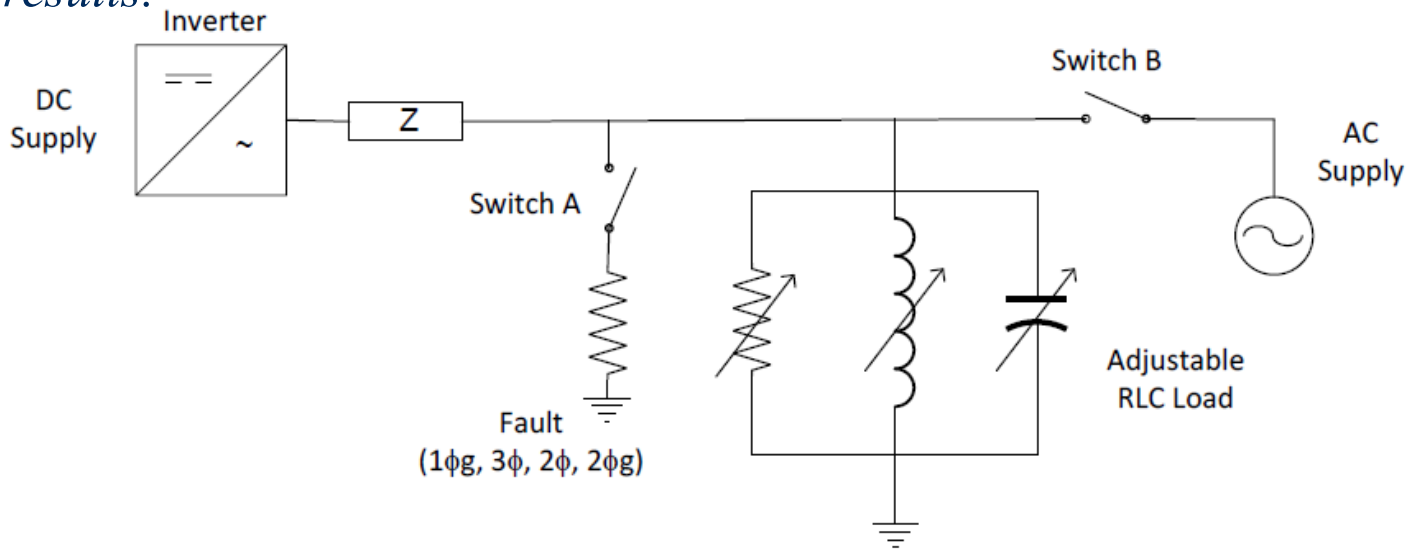
BREAKOUT SESSION DISCUSSION

INVERTER TESTING STRATEGIES & SIMULATION

- Fronius IG Plus 10.0-1
  - Output: 10 kW single phase
  - Recommended PV-power: 8.5-11.5 kW
  - MPPT-voltage range: 230-500 V
  - Max input voltage range: 600 V
  - Nominal AC output voltage: 208/240/277V
  - Total harmonic distortion: < 3%
  - Islanding protection: Internal, in accordance with UL 1741-2005, IEEE 1547-2003 and NEC

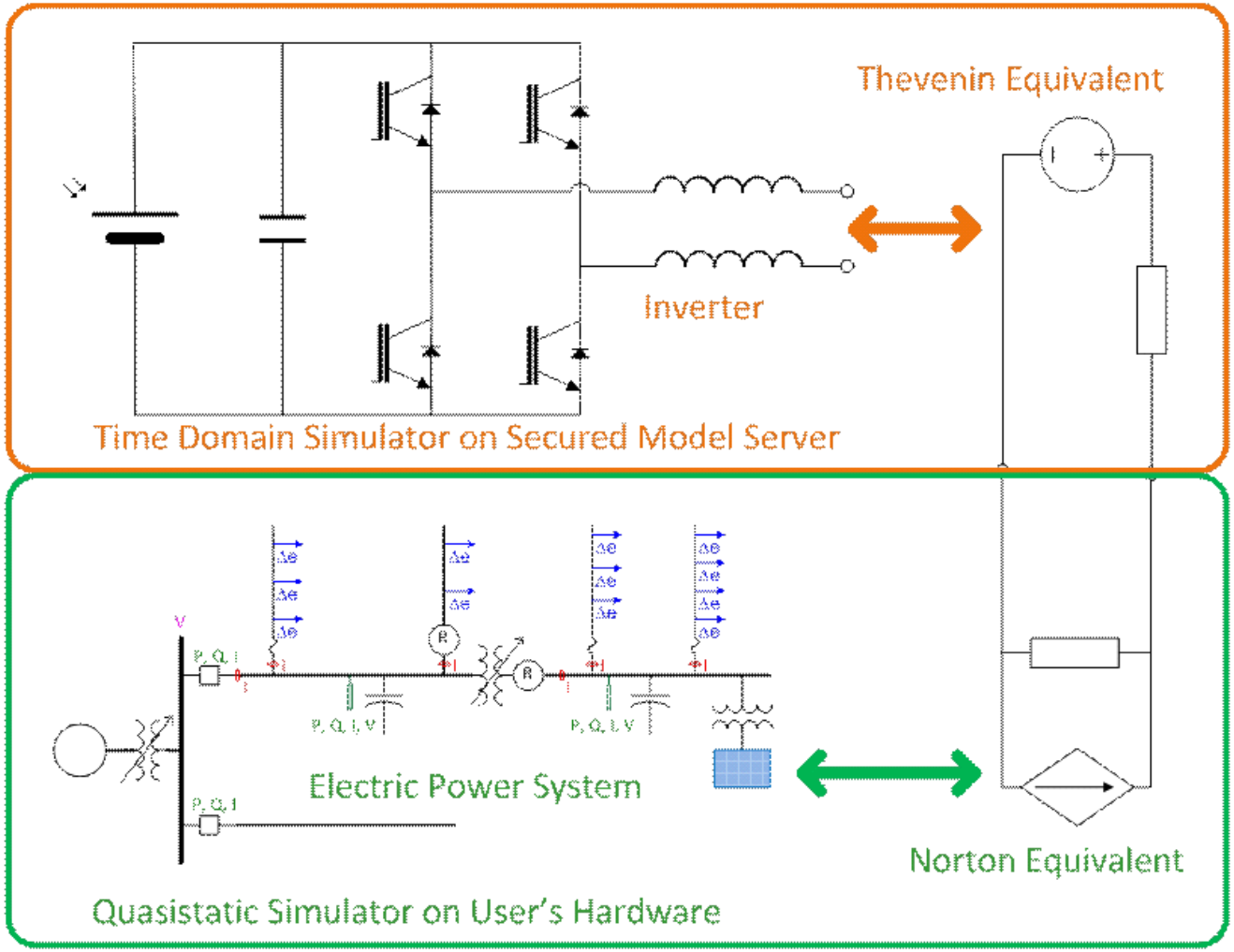
INVERTER TESTING STRATEGIES & SIMULATION

- Modeling and Testing
  - Perform open-circuit and short-circuit tests on inverters and verify the model performance against the experimental transient voltages and currents. *This may require collaboration with the inverter vendor to improve the existing model so that it adequately reproduces the test results.*



Configuration for Inverter Short-Circuit Tests (Switch A open-close, Switch B close-open) and Open-Circuit Tests (Switch B close-open, Switch A stays open)

INVERTER TESTING STRATEGIES & SIMULATION



A co-simulation architecture lets the utility engineer use detailed, proprietary vendor models in studies.

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Overview of Pitt Research for Fiscal Year

IEEE Standard 1547 Research

Inverter Testing Strategies & Simulation

Laboratory Equipment

Breakout Session Discussion

Laboratory Equipment

- Comparing and Selecting Lab Equipment
  - Fluke 434 or 435 Series II Energy Analyzer
  - Dranetz PowerXplorer PX5 Power Quality Analyzer
    - Determining which will fit our needs, as well as the needs of the Electric Power Systems Lab

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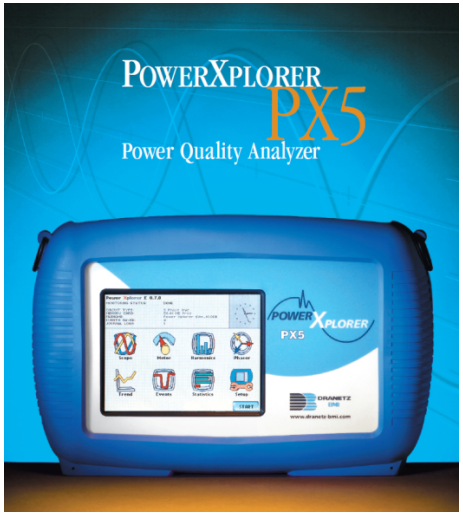

Laboratory Equipment

- Fluke 435 Series II Power Quality and Energy Analyzer
  - Applications
    - PowerWave data capture
    - Power inverter efficiency
    - Energy monetization
    - Energy assessment
    - Frontline troubleshooting
    - Predictive maintenance
    - Long-term analysis
    - Load studies

- Dranetz PowerXplorer PX5 Power Quality Analyzer
  - Applications
    - Fast transient capture
    - Power quality surveys and diagnostics
    - Capacitor switching events
    - Load distortion and imbalance
    - Flicker
    - Compliance Monitoring
    - Harmonics

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OPEN FLOOR DISCUSSION ON SYSTEM MODELING & SIMULATION

IEEE 1547

MICROGRIDS

TESTING & CERTIFICATION

DC SYSTEMS

POWER ELECTRONIC SYSTEMS ADOPTION & DESIGN

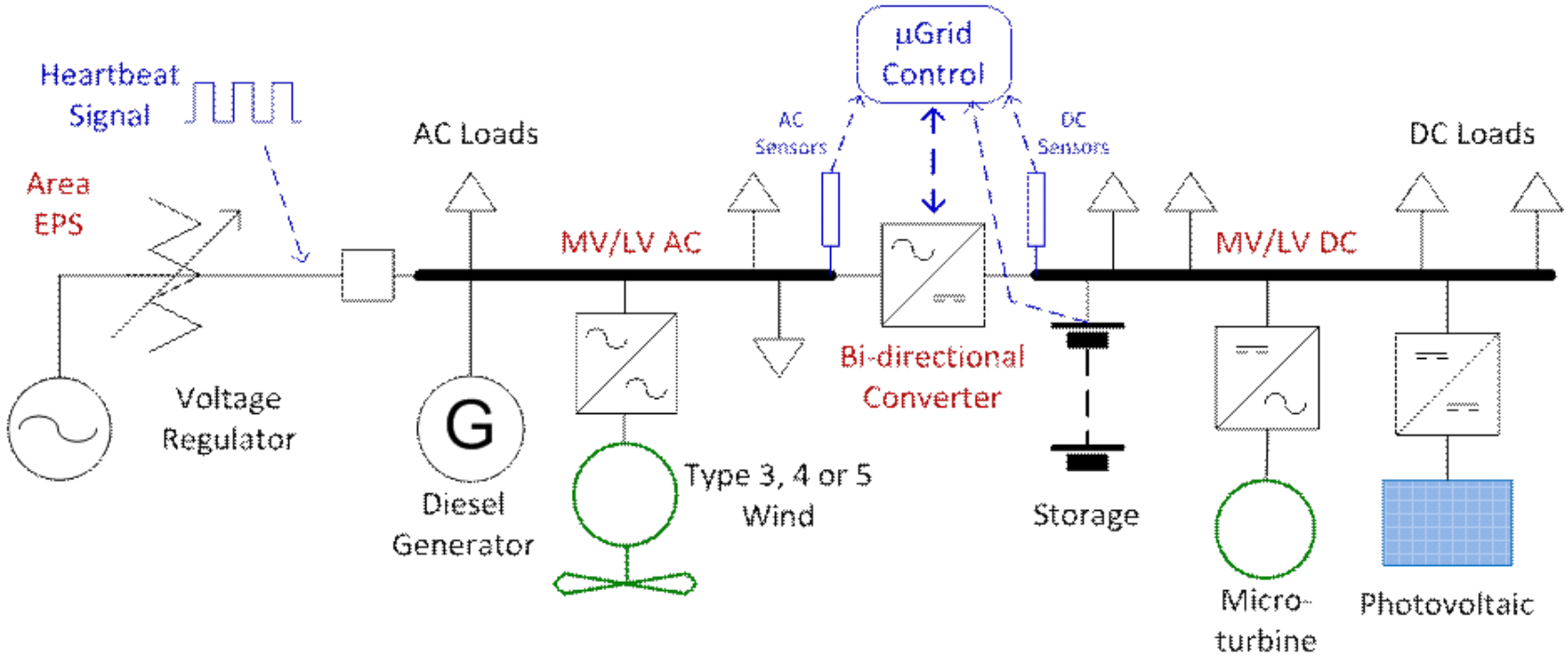
POWER ELECTRONIC PROTECTION

Discussion Questions For GTC Refinement: IEEE 1547

- After seeing the direction Pitt is taking with regards to IEEE 1547, what are the current hurdles the manufacturers are facing to meet government mandates for renewable integration?
- Comments/Headlines:
  - It is important to leverage industry software packages throughout the research process. There needs to be better communication between academia and industry (i.e. ANSYS). The capabilities are not known by students and the needs are not known by industry
  - MATLAB is used in a limited way in industry. Industry is moving to more efficient scripts like Python, C or C++. MATLAB is good for research, but within engineering consulting it is not as beneficial. There is a disconnect between industry/academic research and consulting environments.
  - There is a need to address both smaller and more significant renewable penetration on the grid. There is a need for utilization of renewable generation in a microgrid perspective. The presented perspective and approach presented by the GTC is appropriate (Seimens).
  - There are a diversity of perspectives on standard development. There are two themes that represent the modeling and analytics: diversity and uncertainty. Examples: regulatory/ institutional, technology and resource (GTT).
  - There is a need for uniformity within the standards across the board (long-term). There is a need for models to address differing standards (short-term).
  - There is a desire from industry to be involved in the development of the standards throughout the entire process in contrast to involvement simply at the end of the process.

Discussion Questions For GTC Refinement: Microgrids

A hybrid AC/DC microgrid facilitates energy surety, renewable integration, and storage.



Discussion Questions For GTC Refinement: Microgrids

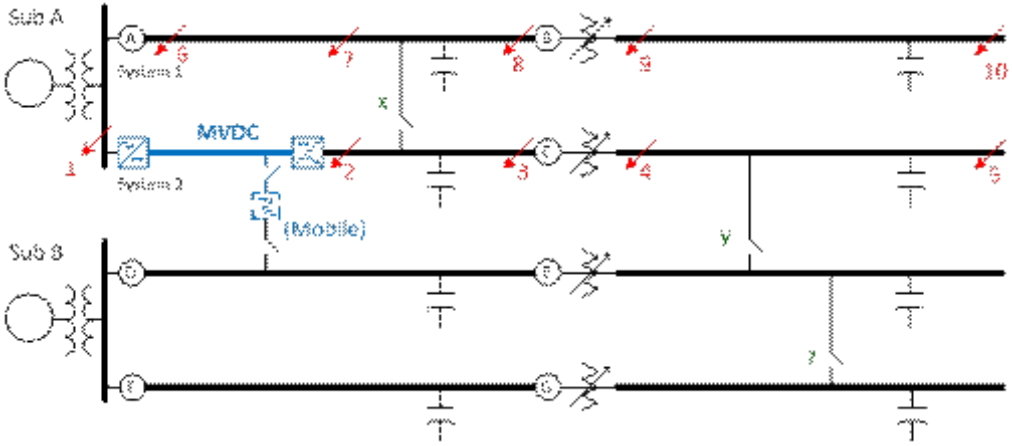
- Microgrids should be able to operate both in grid-connected and islanded modes and involves a bypass switch for connecting the microgrid to the main grid. IEEE 1547.4 discusses the design, operation, and integration of renewables in an islanded state. Are microgrids of particular interest to industry or is it felt as an academic exploration?
- Comments/Headlines:
  - Why microgrids? Military perspective: high reliability, functioning in isolation (expensive)
  - A DC emphasis within microgrids will benefit the integration of renewables
  - Microgrids are beneficial in serving critical loads during stressful situations
  - Approach system modeling from a perspective of criticality and security
    - Microgrids could be crucial in supplying stability, criticality and security
  - Cost effective evaluations of microgrids is a critical challenge
  - Level of voltage at which we interface microgrids to the grid: A distribution-level makes sense, but there are also transmission-level applications that should be considered
  - What is the impact of disconnecting a microgrid from the grid
  - Geographic location of microgrids should be considered
  - Need to identify appropriate tools to model and simulate microgrids
  - The modeling challenge is multi-layered. There is no one tool that meets all needs within modeling. Force-fitting is occurring within industry
  - There should be a module of modeling that is capable of interfacing various elements (energy storage, renewable energy supply and demand…etc.)
  - Modeling and designing the converter as a two-way interface between the grid and microgrids will be key

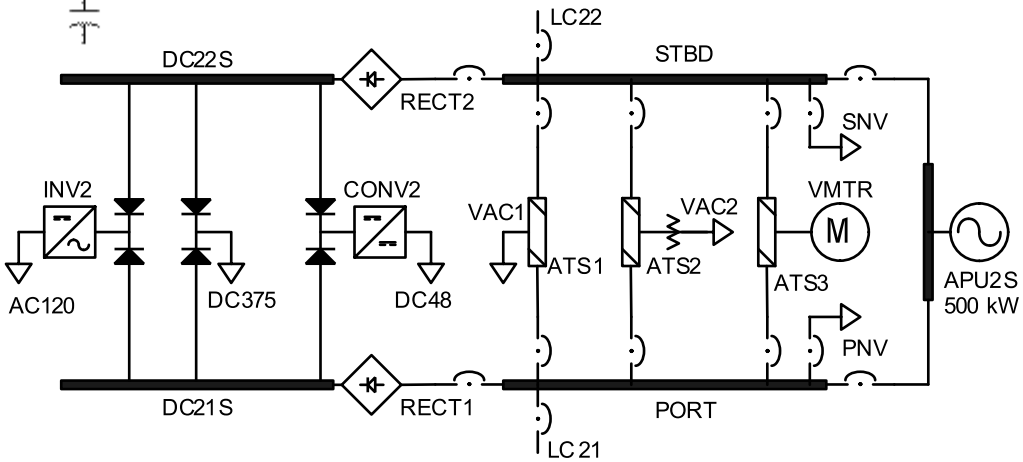
Discussion Questions For GTC Refinement: Testing & Certification

- The University of Pittsburgh is developing in-house testing capability that will be helpful towards developing and testing new power electronic systems. With intentions of fostering industry relations, these developments have the potential of creating a hub for standards testing of equipment. Is there interest in such relationships between academia and industry, i.e., do you see value in providing testing capability through the university environment?
- Comments/Headlines:
  - Recommended Purpose: Testing and certification of products and system suites
  - Business perspective of testing: client pays for testing
  - Niche Ideas:
    - Technology incubation – commercialization of developing products
    - Support for small businesses in the energy market
    - Dedicate RTDS towards testing within U.S.
    - Standard development within the lab
    - Exposure of high voltage capability to students
    - Having hardware immediately adjacent to simulation

Discussion Questions For GTC Refinement: DC Systems

There is an un-met need for efficient modeling and simulation of hybrid AC/DC power systems.





Discussion Questions For GTC Refinement: DC Systems

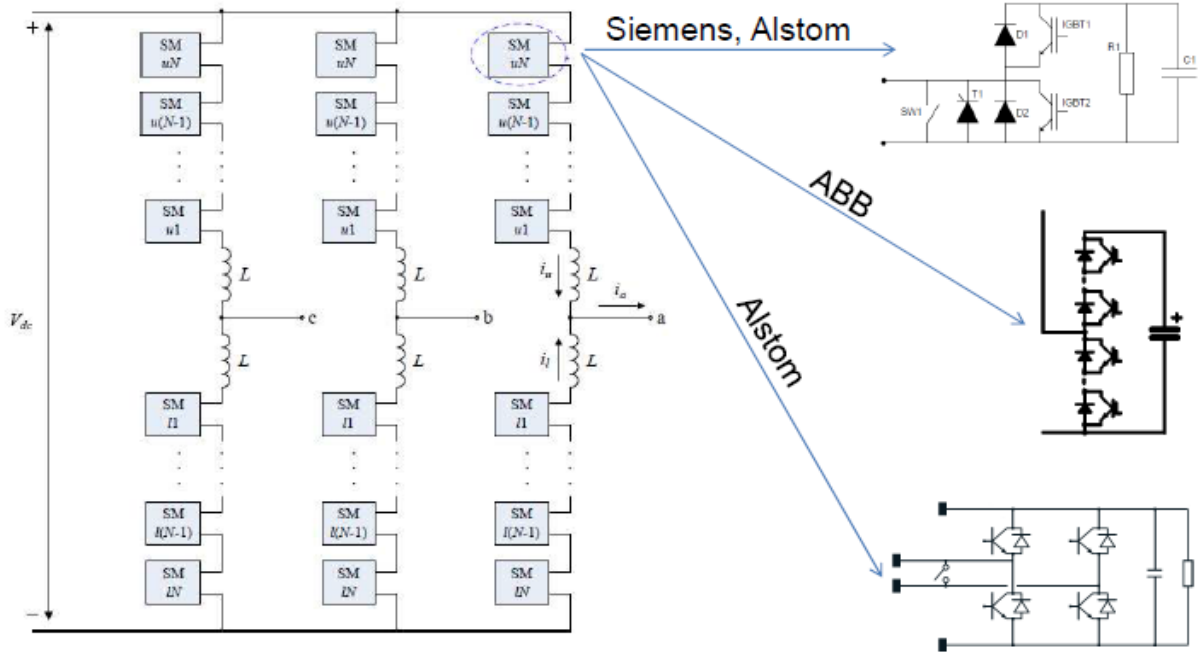
- Very few academic institutions are exploring DC system based research. For the industry representatives in attendance, is anyone seriously exploring the use of DC infrastructure and its potential applications?
- Comments/Headlines:
  - Modeling needs to be done to determine the advantages and disadvantages of increasing DC infrastructure
  - Look into the simulation package Digsilent for the benefit of combined AC and DC modeling capabilities
  - We are definitely seeing increasing DC infrastructure on the datacenter and campus (building) level. Yes, we are looking more and more into DC infrastructure (Siemens)

Discussion Questions For GTC Refinement: DC Systems

- Very few academic institutions are exploring DC system based research. For the industry representatives in attendance, is anyone seriously exploring the use of DC infrastructure and its potential applications?
- Is there industry interest in the development of DC technologies? If so, how will the industry deal with DC voltage transformation?
- Comments/Headlines:
  - High voltage transformation is more of a future consideration
    - Need to see what future DC networks will look like
  - Building level DC voltage transformation: power electronics applications
  - Consideration: converting existing AC infrastructure into DC systems of the future
    - Economics play heavily into whether industry will take part in developing these DC technologies

Discussion Questions For GTC Refinement: Power Electronics System Adoption & Design

- Many multilevel topologies have been proposed since the 1980s with only a few being adopted by industry. A promising topology is the modular multi-level converter (MMC), today!
  - Who, within the audience, is considering modifications to their power electronic systems?
  - Besides economics, what factors are highly considered in the adoption of new technology?



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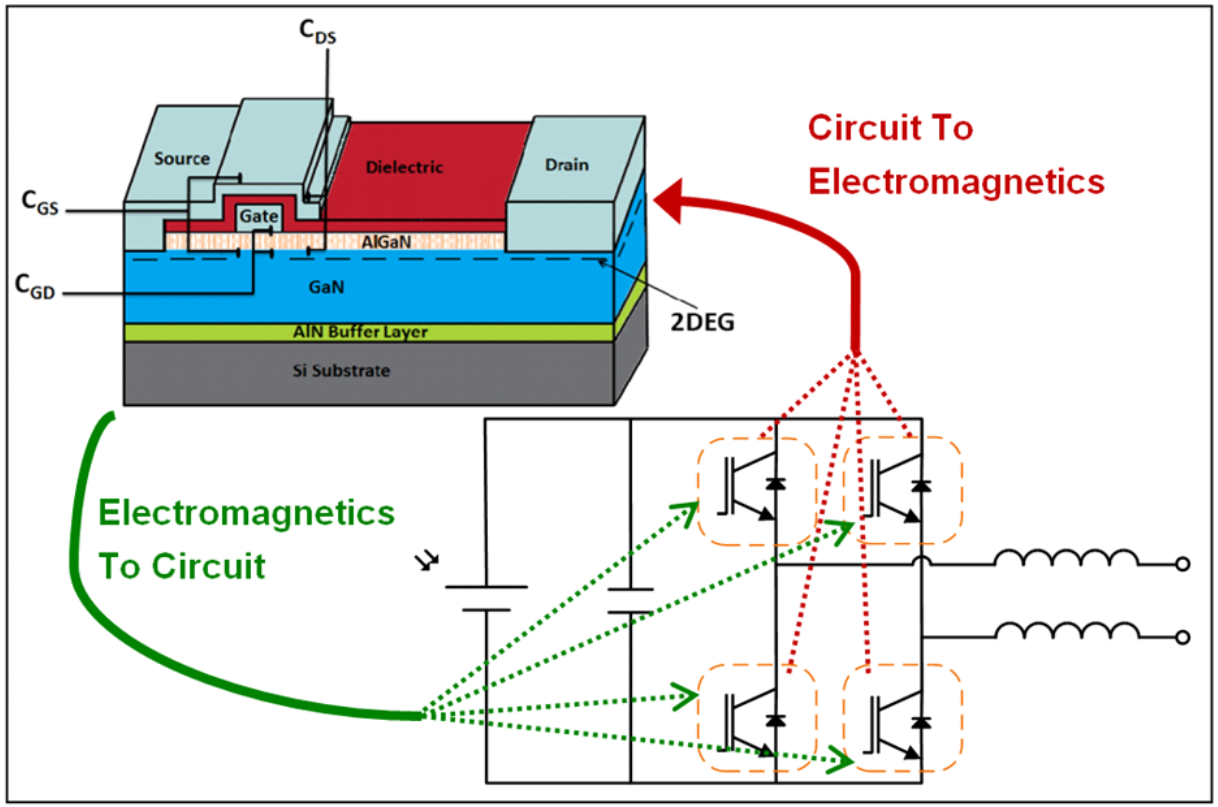
- Comments/Headlines:
  - SVC design has not changed in 20 years
  - Economics play heavily into what the technologies of the future will be
  - Future considerations: radio frequency issues being incorporated into modeling
  - Modeling is multi-faceted – there are many challenges in the details
    - Averaging is beneficial even though pieces would be missing (i.e. RF)

Discussion Questions For GTC Refinement: Power Electronics System Adoption & Design



Coupled circuit, electromagnetic and thermal simulation to predict wide band-gap device reliability

Discussion Questions For GTC Refinement: Power Electronics System Adoption & Design

- Multiphysics Simulation Comments/Headlines:
  - Important Considerations:
    - Predicting yield and reliability
    - Circuit protection design
    - Monitoring and failure prediction

Discussion Questions For GTC Refinement: Closing Comments

- Comments/Headlines:
- Critical Question: How long will the transition take to get to a DC infrastructure?
- We need to begin to look at modeling the devices, plugging devices into converters, and then seeing the impacts on the system (power flow).