New Mexico
Research Spotlight Forum

10.17.2019 Grid Resiliency

Grid Resiliency Research Programs at NMSU

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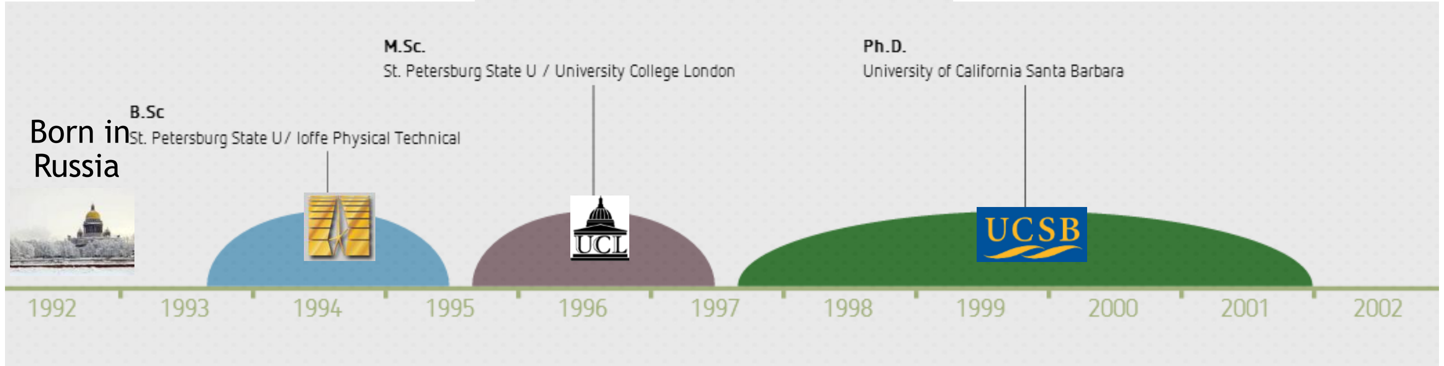
Sandia National Laboratories | Georgia Institute of Technology | ILLINOIS | PURDUE UNIVERSITY | THE UNIVERSITY OF TEXAS AT AUSTIN | THE UNIVERSITY OF NEW MEXICO | NM STATE UNIVERSITY | NEW MEXICO TECH SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

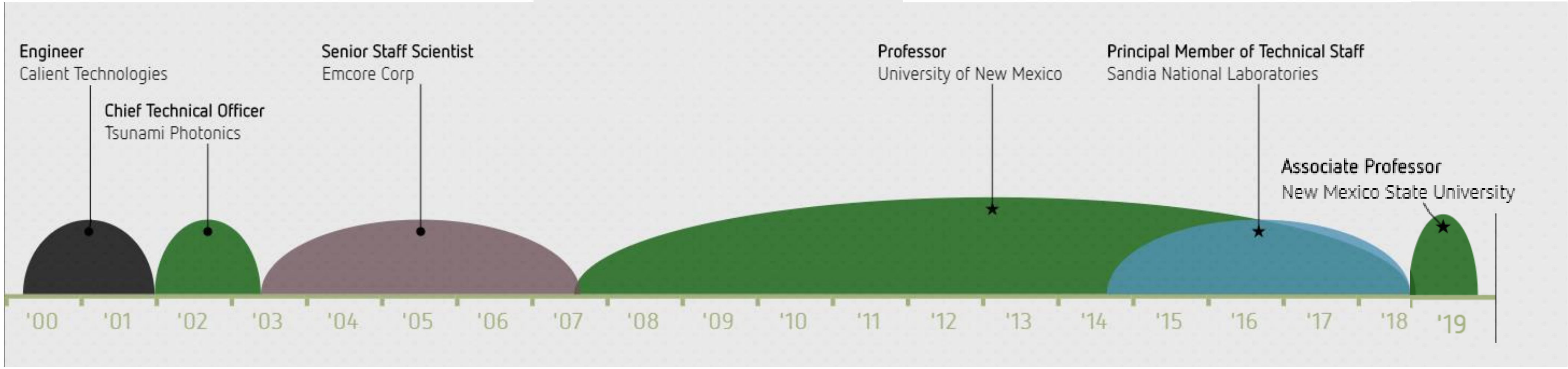
SAND2019-13650 PE

Brief Bio:

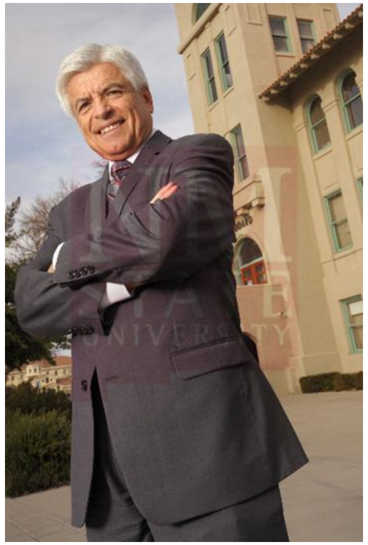
EDUCATION



EXPERIENCE



A work of many :


Chancellor Dan Arvizu


Prof. Satish Ranade

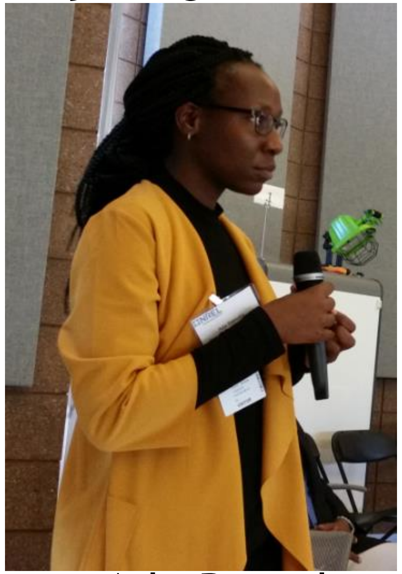

Dr. Nataraj Pragallapati


Dr. Sijo Augustine


Dean Phillip DeLeon


Dean Enrico Pontelli


Prof. Olga Lavrova

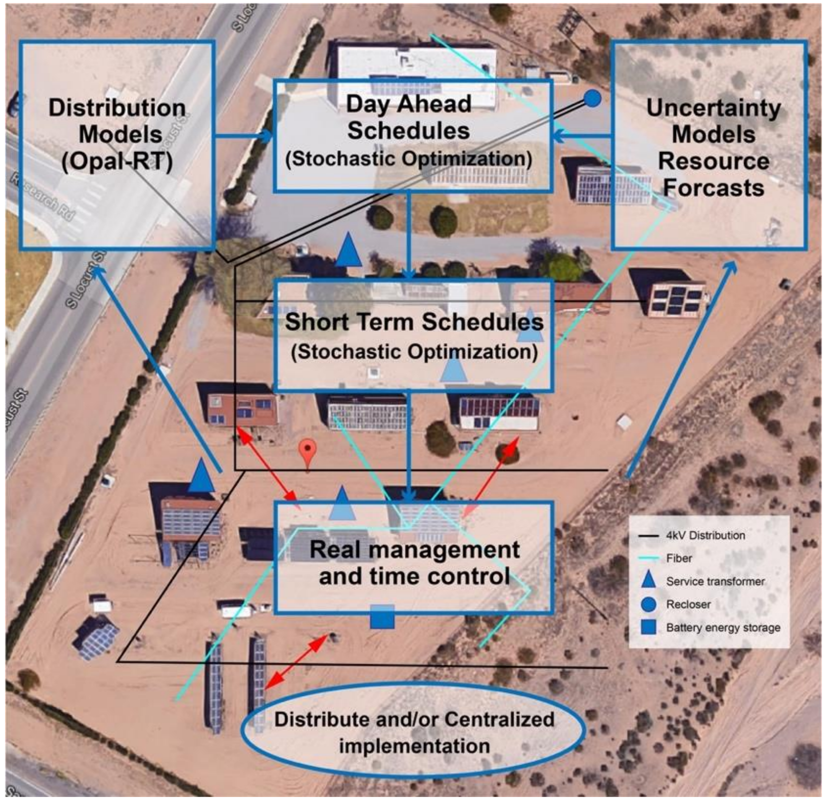

Ada Ramoko

And many more !

SouthWest Technology Development Institute - SWTDI

- Original 1978 DOE PV Program
  - Residential PV Demo
  - 4 kV distribution network
  - PV and Storage
  - Can be islanded
  - ‘Real’ Tested for future distribution

- Potential Infrastructure Additions
  - Water Desalination Hub
  - XFC EV charging
  - DC microgrid
  - cyber-security work



What is energy system resilience ?

National Academies of Sciences, Engineering, and Medicine's "Enhancing the Resilience of the Nation's Electricity System" (July 2017) "Resilience is not just about lessening the likelihood that that these outages will occur. It is also about limiting the scope and impact of outages when they do occur, restoring power rapidly afterwards, and learning from these experiences to better deal with the events in the future."

PJM's "Evolving Resource Mix and System Reliability" (March 2017) "Resilience, in the context of the bulk electric system, relates to preparing for, operating through and recovering from a high-impact, low-frequency event. Resilience is remaining reliable even during these events."

President Barack Obama's Presidential Policy Directive-Critical Infrastructure Security and Resilience (February 2013) "The term 'resilience' means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."

Electric Power Research Institute's "Electric Power System Resiliency: Challenges and Opportunities" (February 2016) "In the context of the power system, resiliency includes the ability to harden the system against—and quickly recover from—high-impact, low-frequency events."

(GAO) The nation's electricity grid is essential to modern life. We expect the grid to be resilient—to adapt to changing conditions, withstand disruptive events, and recover rapidly.

In a 2015 paper focused on developing a framework for resilience metrics, the Sandia National Laboratory recommended that metrics use a 'risk based approach.' This implies 1) resilience should be defined with respect to a specific threat (e.g. resilient to hurricanes); 2) resilience metrics should be focused on the consequences of a system failure rather than the system failure itself; and 3) resilience should be defined with respect to a specific system. Sandia created a seven-step Resilience Analysis Process to help utilities think through the creation of risk-based metrics.

Or is it Agility that we seek ??

"...a stable trajectory of healthy functioning after a highly adverse event...,"

"...the capacity of a dynamic system to adapt successfully..."

The Presidential directive defines resilience as "...the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions..."

Resiliency seems to be closely connected to notions such as robustness, redundancy, resourcefulness, and rapidity

Agility – how do we make distribution Agile??

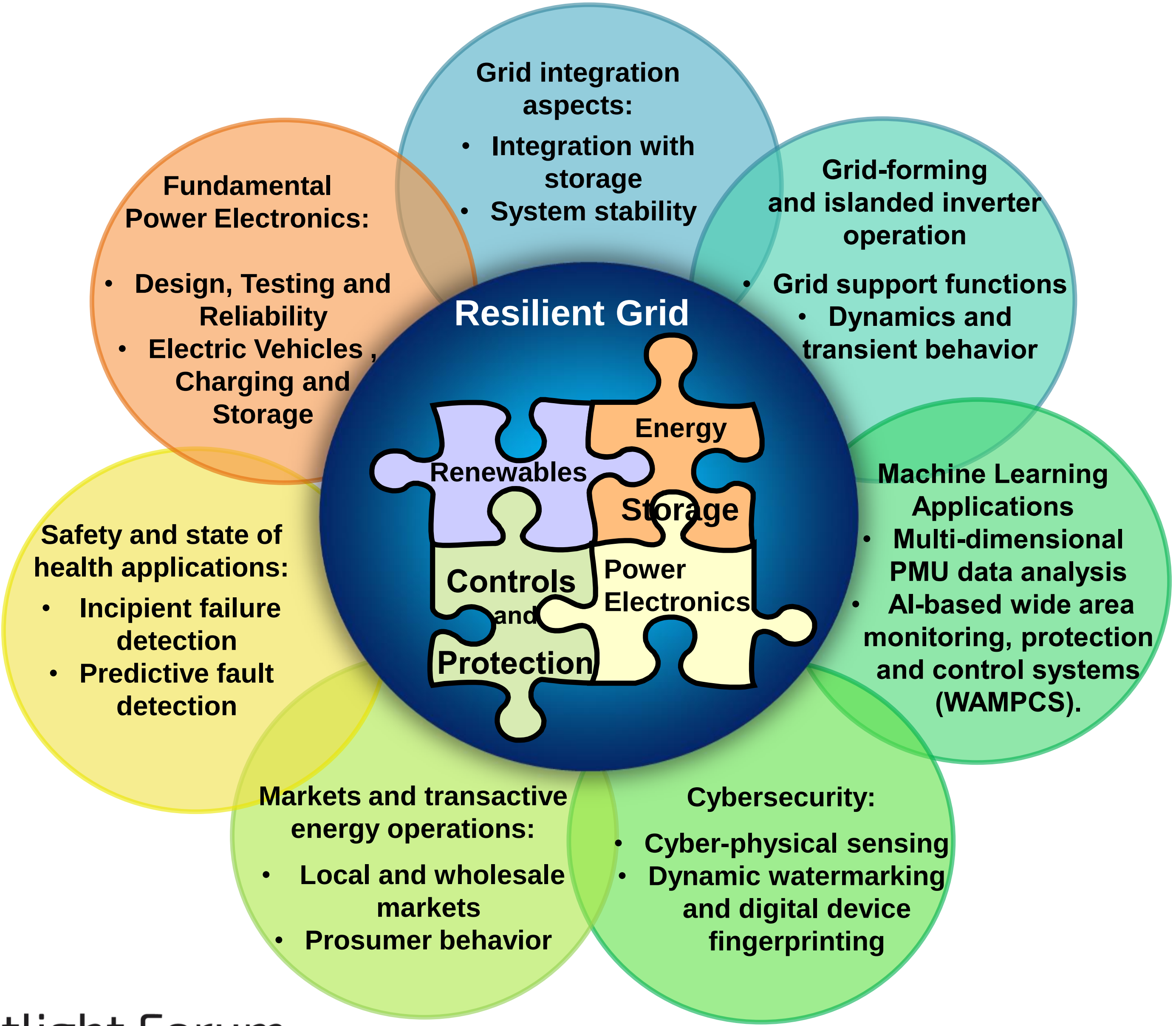
How to design distribution systems so we can maximize energy from resource(s) to critical demand(s) under treat scenarios / vectors?

- Pervasive use of Power Electronics allows distribution to adapt

- Scheduling and Control that responds to natural threats as they emerge

Machine Learning + Mining to detect threats we cannot anticipate

Current work in Grid Resiliency at NMSU



Funding Portfolio

- NM EPSCOR SMART Research Center – NSF
- CREST i-Credits Smartgrid center – NSF
- DOE GMLC Radiance
- DOE GMLC Secured
- DOE ESS Advance batteries/BMS
- Other DOE / GMLC upcoming

Highlighted Project: NM EPSCoR

Sustainable, Modular, Adaptive, Resilient, Transactive

Objective:Our goal is to create a comprehensive framework for distribution feeders to evolve into managed microgrids. We address key questions such as:

1) What generation and storage resources should be deployed, and where should they be sited, based on local generation and demand patterns?

2) How should distribution topology and sectionalizing be organized to enable reconfiguration and resilience?

3) How to develop local energy markets?, i.e. how can transmission and distribution system operators source grid flexibility services directly from end users, including residential customers?

4) What tariff designs could be used to engage and benefit participants (both producers and consumers) ?

5) How to ensure traditional reliability, resiliency and quality of service of the electric grid given new grid services model ?

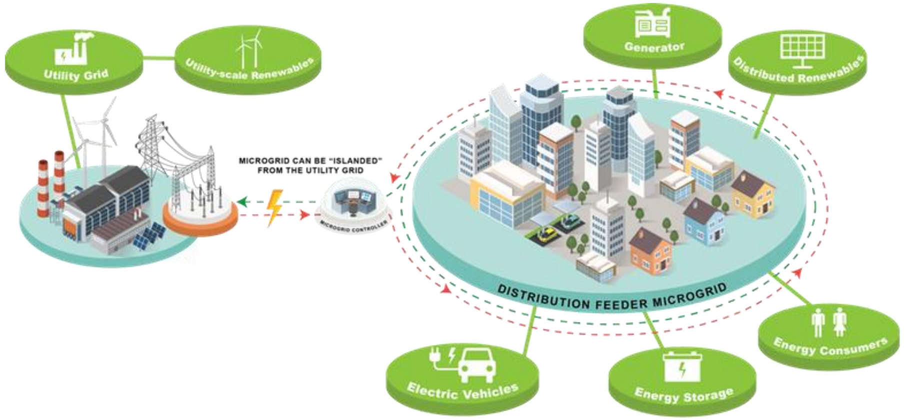
6) What services are considered critical, and how can these services be guaranteed?

7) How do we develop adequate protection schemes for the new grid with high renewables penetration?

8) What are the additional sensing needs for the new SMART grids and what new types of sensors are needed ?

9) How can we source Restoration and Black start services from distribution feeders?

The Distribution Feeder Microgrid (DFM) is a SMART evolution of conventional feeder design



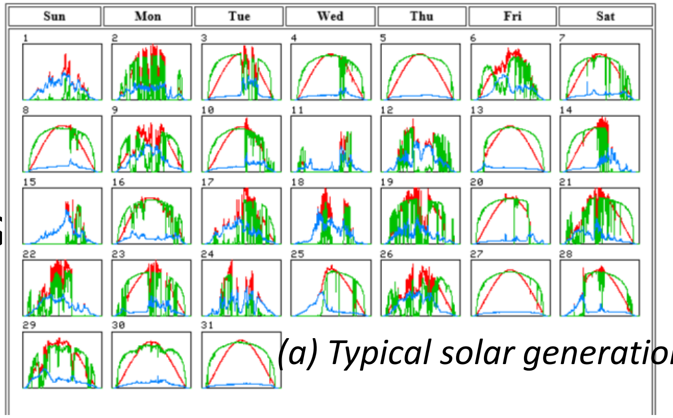
Secure
Modular
Adaptive
Resilient
Transactive

New Mexico EPSCoR SMART Grid Center:

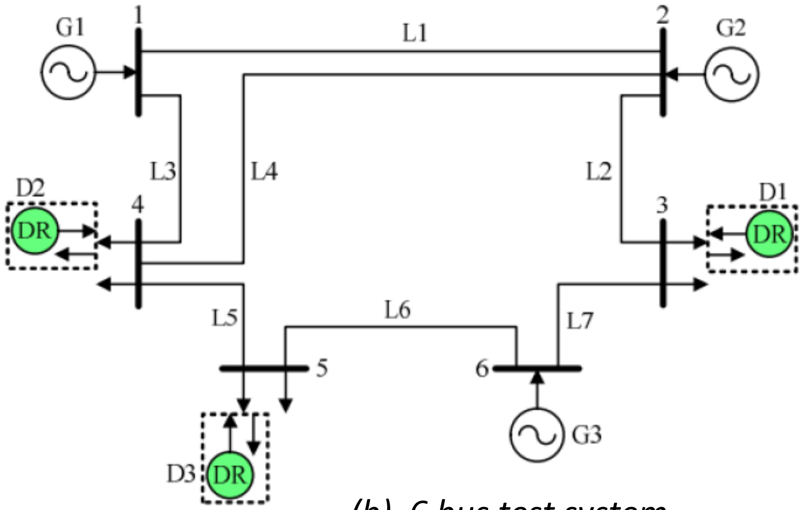
Sustainable, Modular, Adaptive, Resilient, Transactive

- Decentralized Robust Optimization for Transactive Scheduling of Distributed Resources
- Implemented using only low-power Raspberry PI processors/bus
  - Jose Tabarez Ph.D. Dissertation, graduated April 2019
  - Currently with LANL

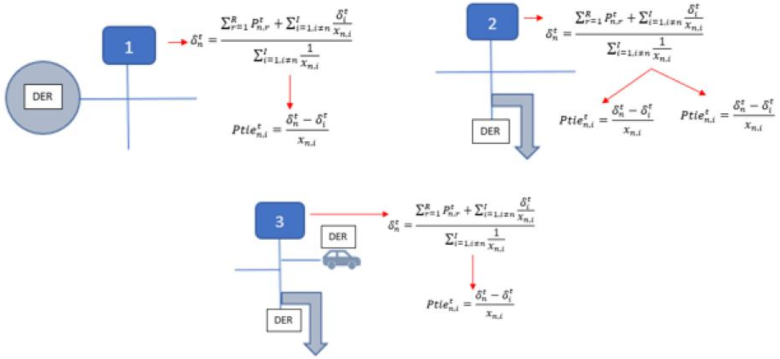
Given uncertain distributed solar resource (a) and demand, distributed agents in a six bus system (b) develop day-ahead robust resource schedules (c) via neighbor-neighbor communication (d).



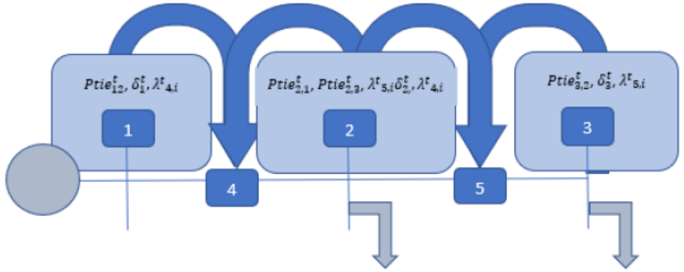
(a) Typical solar generation profiles



(b) 6 bus test system



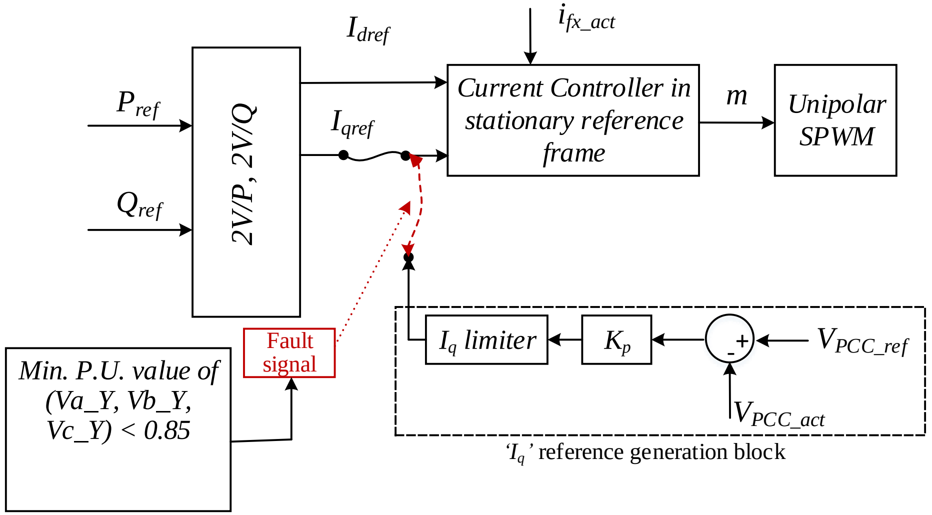
(c) Day-ahead robust scheduling optimization

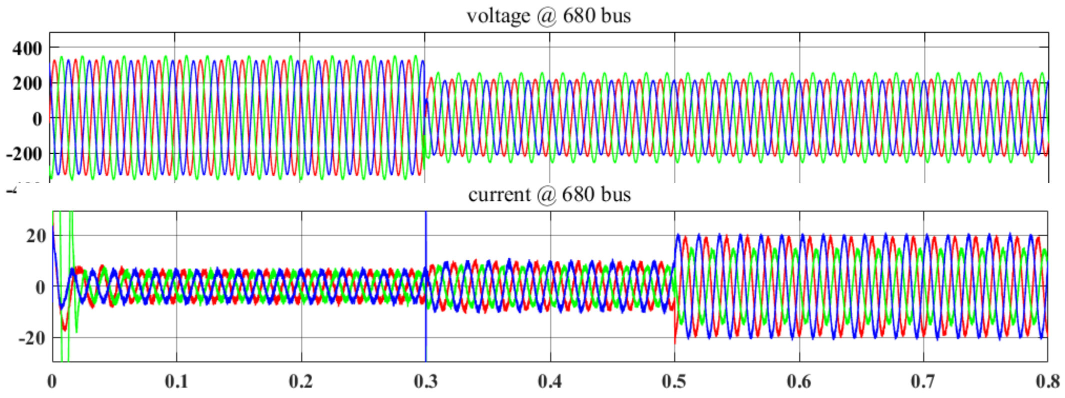


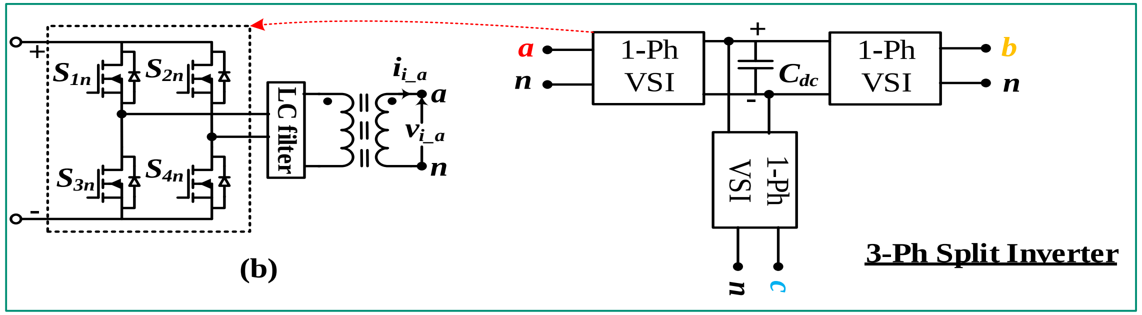
(d) Bus agents transmitting data to Branch Agents

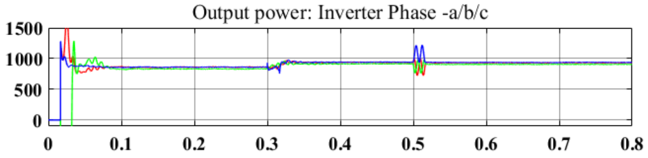
Highlighted Project:
Protection Schemes for unbalanced renewable energy-based low voltage distribution systems

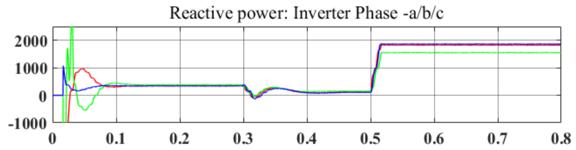
- **Motivation:** More and more inverters are capable of unbalanced operation. As penetration of renewables-based generation is increasing, greater accuracy of understanding of unbalanced operation is needed. Further, better models for islanded operation for HIL modeling are needed.
- **Objective(s):** Investigate Resilience, Protection and Reliability of distribution systems using Inverters capable of grid-forming and unbalanced operation; Develop a Simulink model for a battery fed inverter (3-phase split inverter); Demonstrate Grid Following and Grid Forming Inverter operation in an unbalanced feeder ;   Demonstrate the islanding sequence.







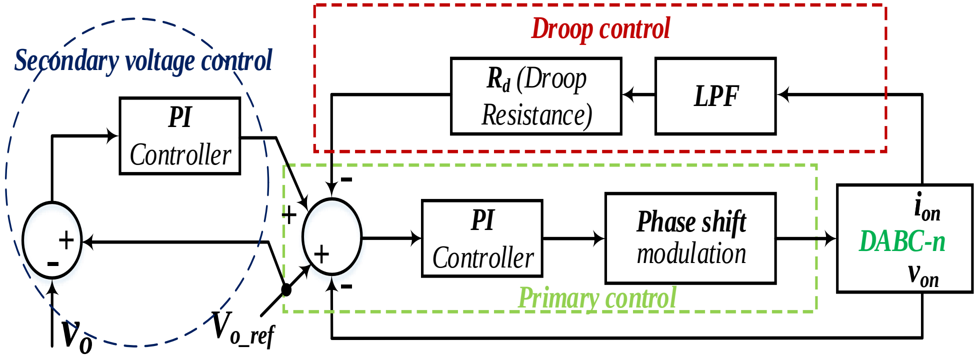




Highlighted Project:

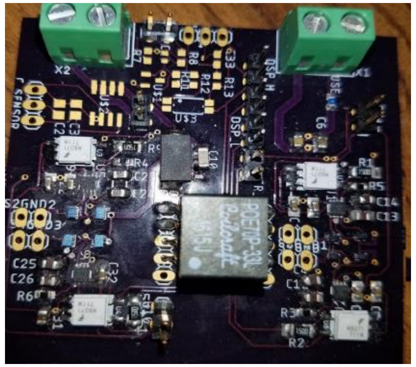
Distributed Power Processing Structure for a Cell Level BESS and Integrated Solar PV and Battery

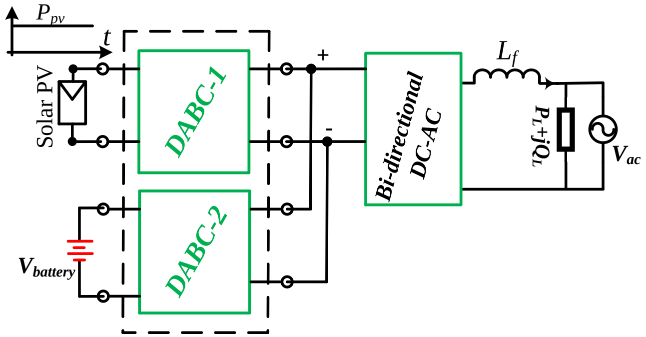
- **Motivation:** Ubiquitous and pervasive power electronics deployment in distribution systems requires deeper granularity of state observation and asset health monitoring.
- **Objective(s):** Design and development of Distributed Power Conversion circuits based Battery Energy Storage System (DPCC-BESS) for the stationary grid-tied applications;
- Demonstrate DAB in small as close to the size of battery cell. (2.2’’x2.1’’);
- Demonstrate High-frequency Solid State Transformer design and Bi-directional power control of DAB at cell level.
- Optimized Power processing of battery at the cell level; Overall system efficiency improvement and improved safety and reliability through battery level analytics

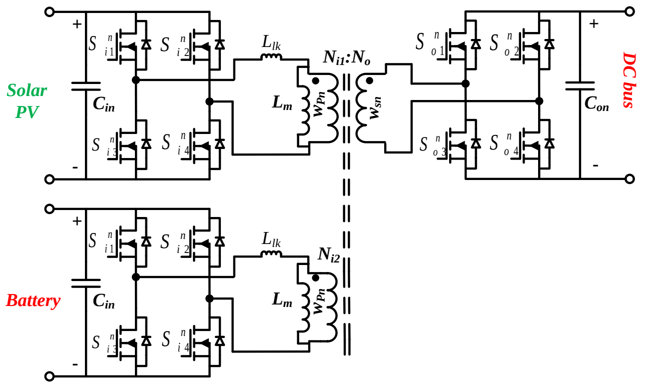


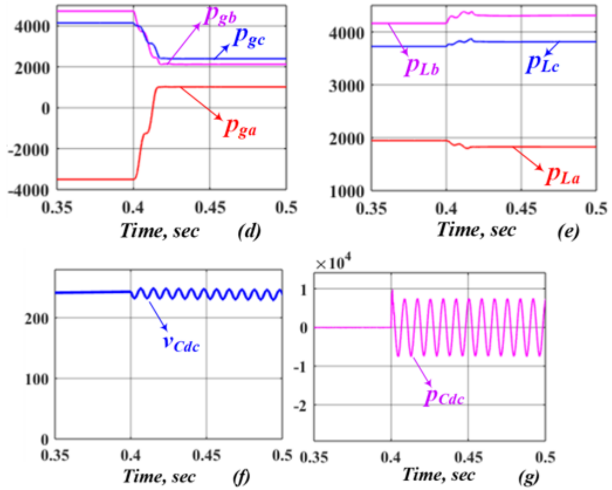
Three Stage control scheme for the DABC-n.

DAB based Micro-Inverter for the Integrated Solar PV & Battery device









Highlighted Project:

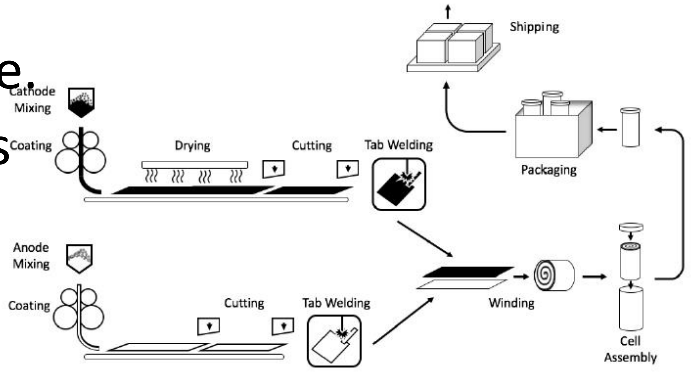
Integrated Redox (Zn-MnO_2) batteries with solar PV modules and microinverters

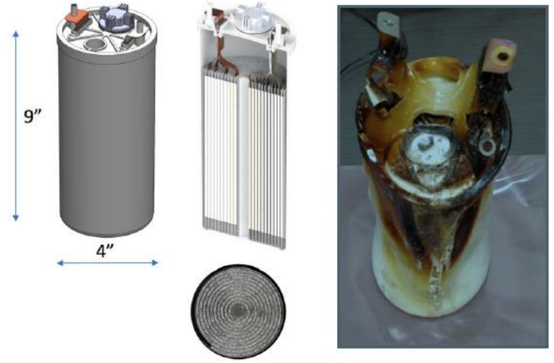
- **Motivation:** Objective(s) : Increase grid resiliency by holistically combining distributed energy generation with storage.
- **Objective(s):** Integrate Zn-MnO_2 batteries by Urban Electric Power (UEP) with solar panels and microinverters;

  Design and demonstrate miniature bi -directional DC/DC converter to manage power flow between PV and storage

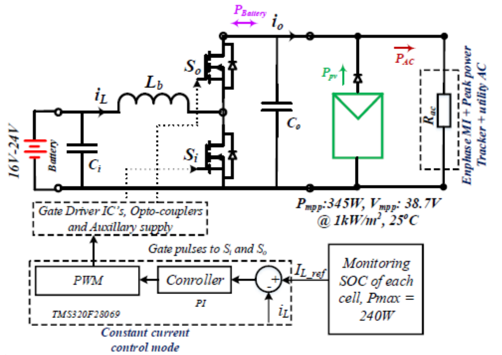
  Demonstrate integration with PV panel and microinverter

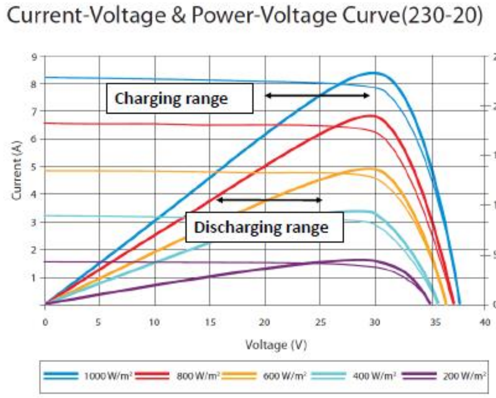
Safe, Low-cost, wide window of power charging conditions, safe to operate up to 60°C





1973 UL certified





This work is supported by the Department of Energy, Energy Storage Program, Dr. Imre Guyk.

Highlighted Project: NSF i-CREDITS Security @Edge: Edge Computing: Potential, Security and Privacy

Jay Misra

Trojan AI: Adversarial sample crafting to selectively alter outcomes of machine learning models. e. g, mis-classification of critical events by minimal perturbation of data from input sensors.

Our preliminary work crafts coordinated adversaries which minimally alter the measurements sensed by a small set of selective PMUs to fool the AI-based wide area monitoring, protection and control systems (WAMPCS).

We also focus on the defense mechanisms that could potentially minimize adversary crafting. Extend to data driven microgrid management / control, and smart meter data analytics.

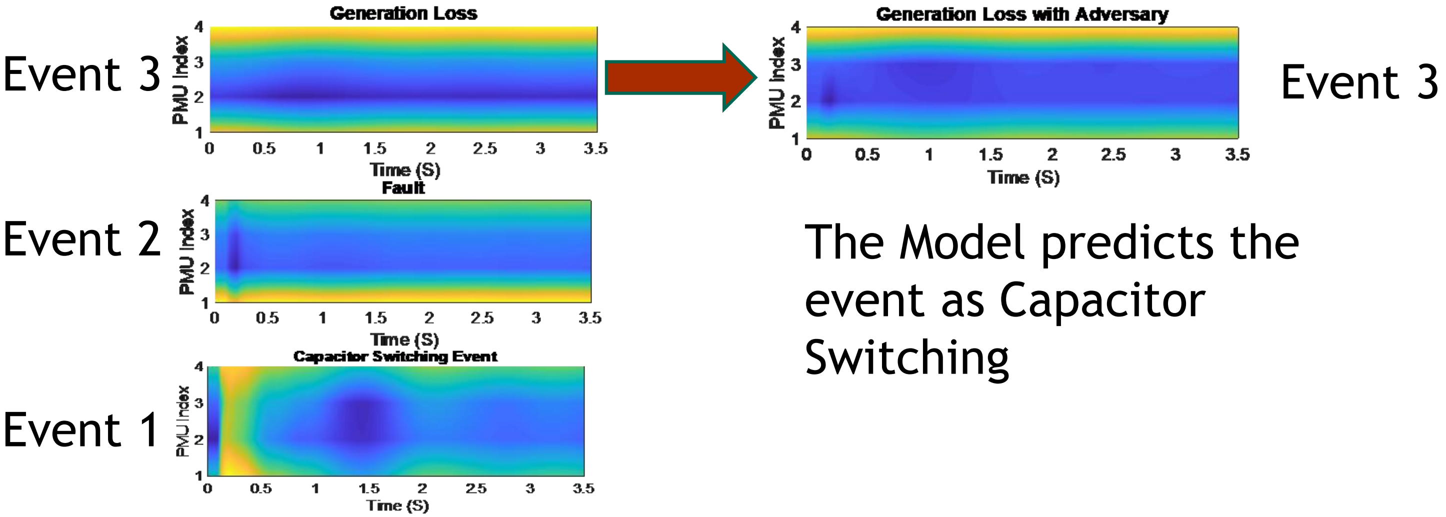
Multi-dimensional PMU data

↓

Trained Machine Learning Model (CNN)

↓

Disturbance Classification



The Model predicts the event as Capacitor Switching

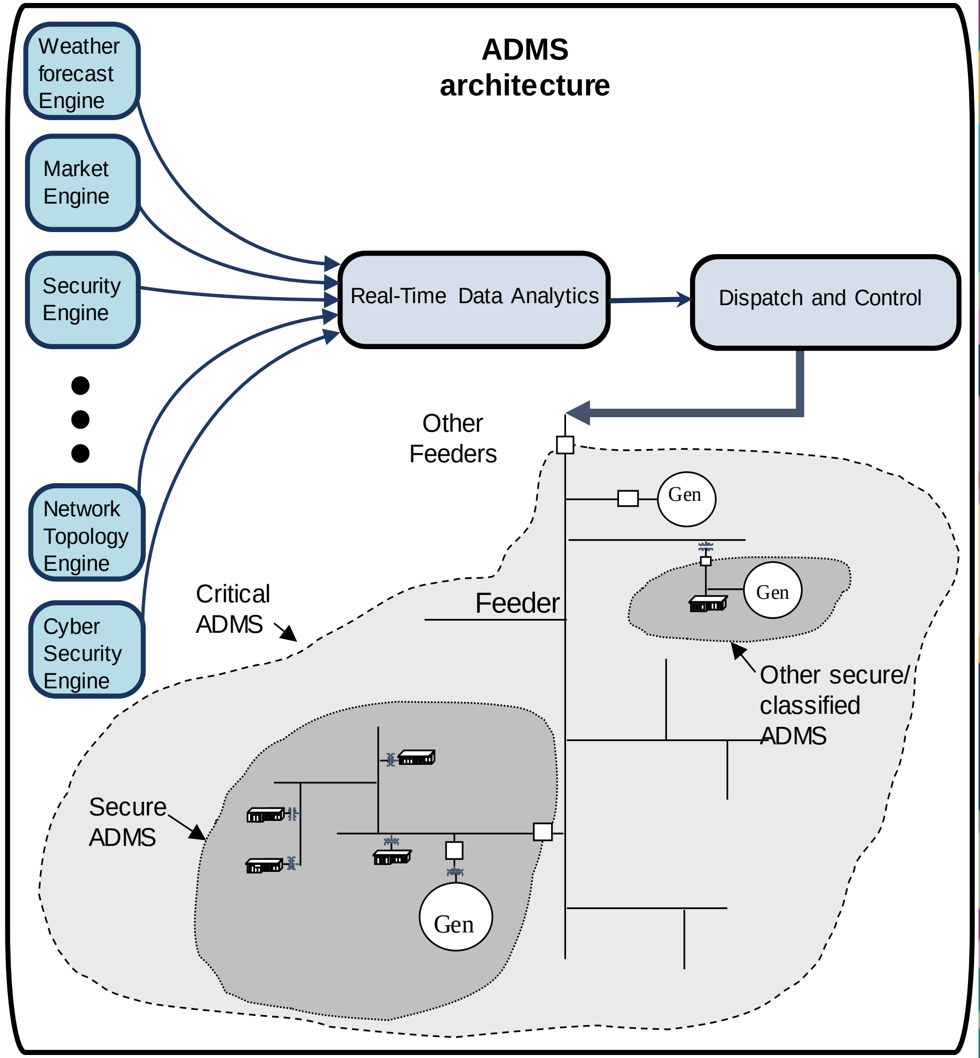
Collaboration Opportunity:

ARMS: Adaptive Resource Management System

- **Objective(s):** Create an industry standard experimental platform to manage diverse energy ecosystems within distribution system. Platform will be used for researchers to demonstrate analytics, forecasting, optimization, grid support, and resilience solutions.

- Coordinated Portfolio Operation of all energy resources, processing and utilization will minimize cost, provide grid support and improve customer and grid resilience

- Involve leading software developer (Oracle) to deliver software which can be readily implemented by utilities operations centers.



Over-arching research areas for collaboration opportunities:

- Generation
  - (including power electronics, Grid Forming Inverters, PV, Bi-facial PV, BIPV)
- Power System stability
  - (including systems of networked microgrids)
- North American Resilience Modeling
- Electric Vehicles and Drives
  - (including High Power Charging)
- Physical Security and Cybersecurity
- Advanced Sensors
- Energy Storage
- Sustainability
- Adversarial machine learning and impact on critical infrastructure
- Quantum-safe computing and security

Devices and Integrated Systems

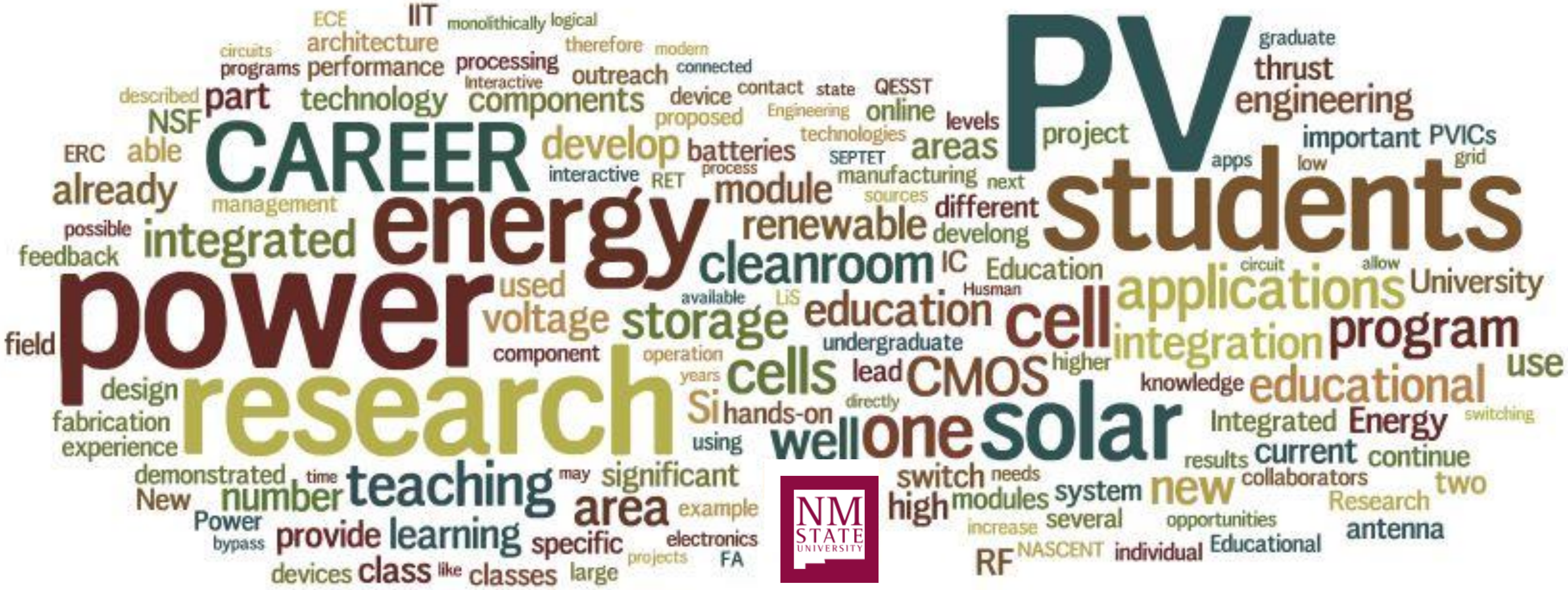
Sensing and Measurement

System Operations and Control

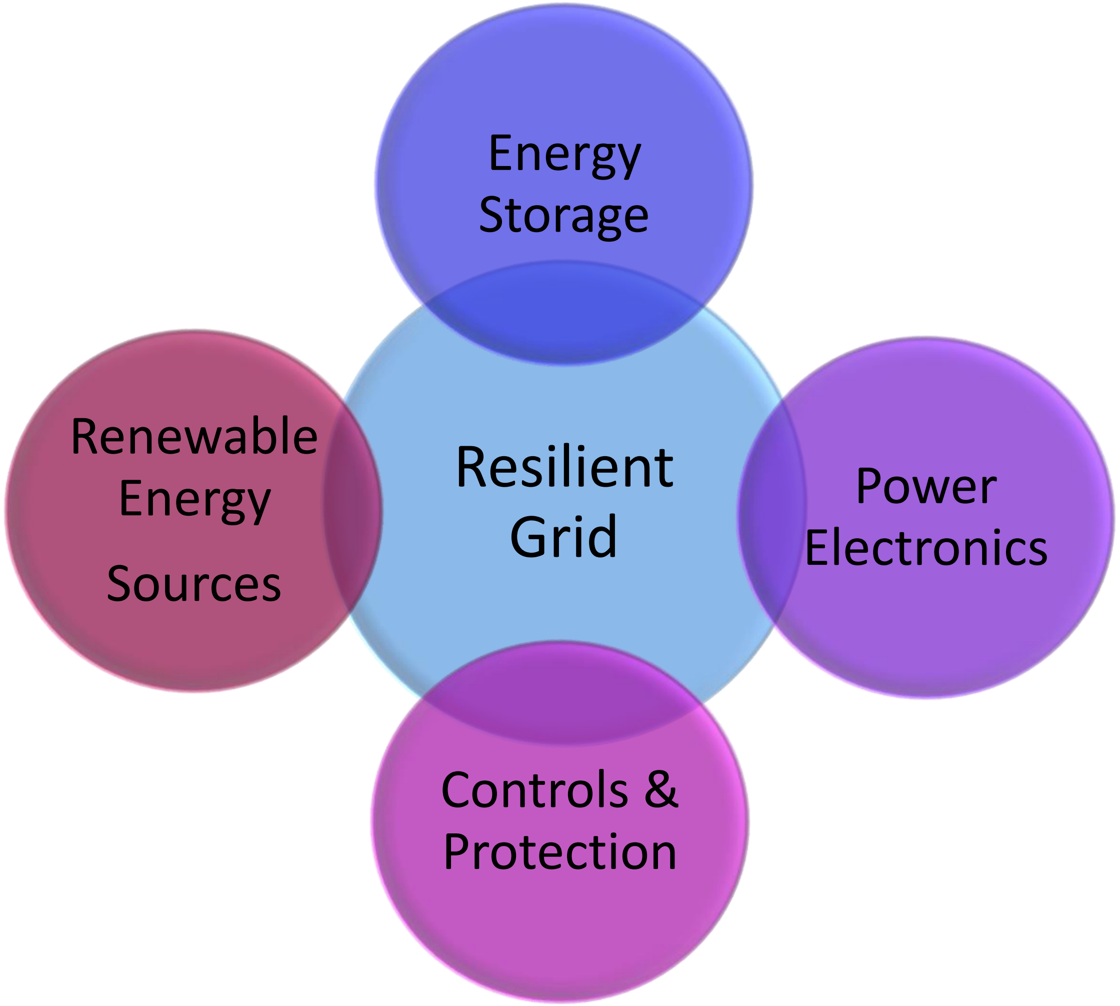
Design and Planning Tools

Security and Resilience

Thank you for your attention



Summary



Synergistic Expertise at NMSU

Machine Learning
Hardware-based security
Networks/Communications
Signals and Processing

Strong collaboration with CS

Cybersecurity degree
Smartgrid minor
iCredits and SMART centers
Data Science
AI/Planning/Optimization
Knowledge Programming