FLORIDA SOLAR ENERGY CENTER™

Creating Energy Independence

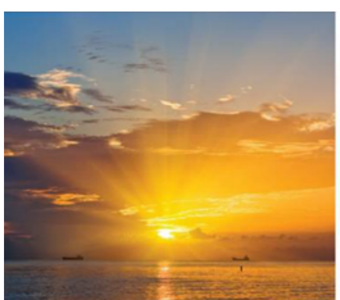
Energy Systems Integration Division

(New)

Issa Batarseh

Outline

- My Background
- Research Areas
- ESI Programs
- Future Direction




EDUCATIONAL BACKGROUND

- **BS, MS, Ph.D. Electrical Engineering, *University of Illinois, Chicago, June 1990.***
  - ***Research in Power Electronics***
- **Post-Doc at University of Illinois, 1990-1991.**
- **At UCF since 1991.**

Florida Power Electronics Center (FPEC) Team Members

Ph.D: Students:

- Seyed Milad Tayebi
- Mahmood Ali Alharbi
- Xi Chen
- Gustavo Gamboa

M.S Students:

- Anirudh Ashok Pise
- Siddhesh Shinde

Undergraduate Students:

- Luis Hurtado
- Daniel Betancourt
- Houman Pousti

Associated Researchers:

- Mr. Charlie Jourdan, Associate Researcher
- Dr. Khalid Rustom, ACT
- Dr. Haibing Hu, Visiting Scholar, China
- Dr. John Elmes, APECOR
- Dr. Nasser Kutkut, Associate Researcher

UCF's Administrative Experience

- Director, ESI Division at FSEC, Starting October 2016.
- Director, of the Florida Power Electronics Center in the School of EECS (http://fpec.ucf.edu). 1997-Present.
- Director, School of Electrical Engineering and Computer Science since 2003-2010.
- President of the Electrical and Computer Engineering Department Heads Association (ECEDHA) since 2007.
- Associate Dean for Graduate Studies,1998-2003.
- Assistant Chair of ECE from 1997-1998.
- Assistant, Associate and Full Professor, EECS, August 1991 –Present.

Accomplishments in the Power Electronics Center:

- **Major research area is in smart solar energy conversion systems by utilizing power electronics.**
- **Funded Research Projects totaling $12 Million.**
- **U.S. Issued Patents : 28**
- **Refereed Journal/conference publications: : 300**
- **Co-Founded two start-ups: ApECOR and Petra Systems**
- **M.S. Theses Supervised: 43**
- **Ph.D. Dissertation Supervised: 34**
- **Honor Undergraduate Theses Completed: 15**
- **Published Book And Book Chapters: 5**

Research Focus Areas

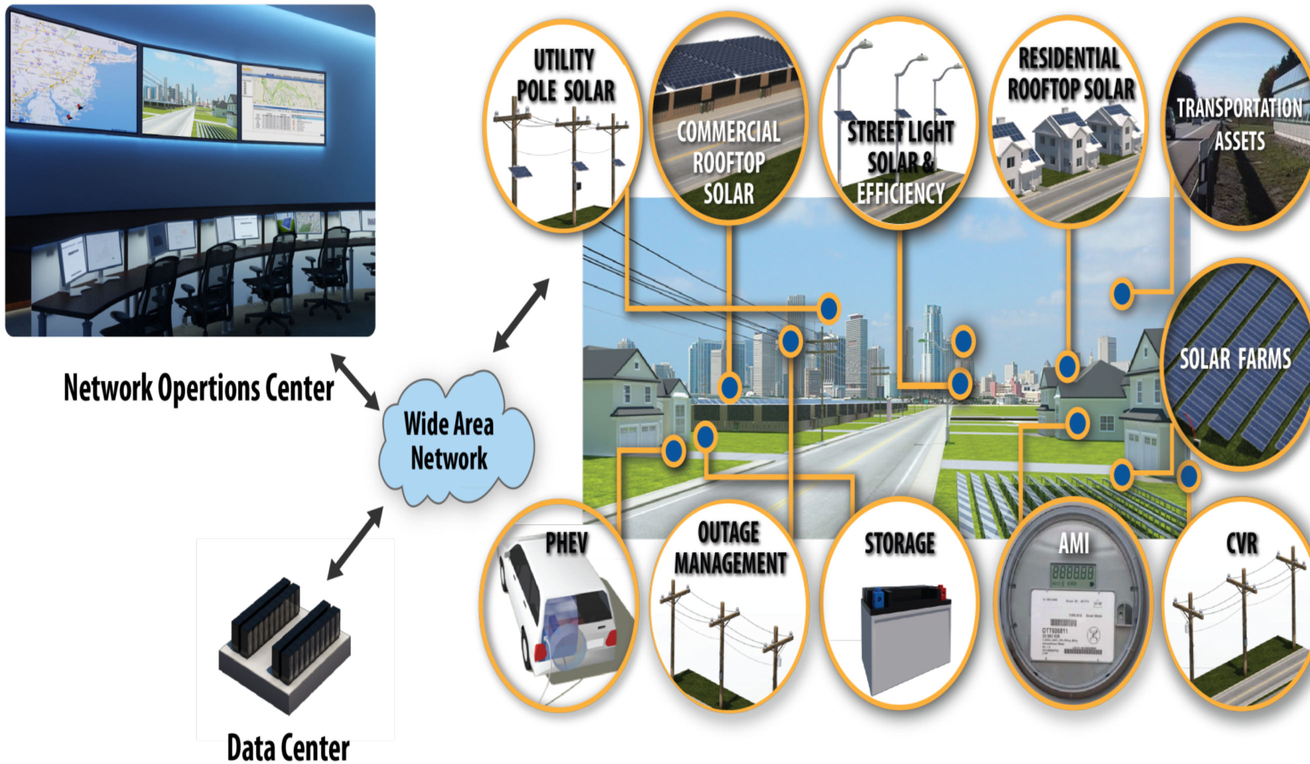
PV System Architecture with Storage to Enable Highly Integrated Ecosystem

- Control, Devices and Topology
- Integrated Smart Inverters
- Frequency Regulation (AC Battery)
- Firmed PV
- EV Charging Systems

Building a Powerful Ecosystem

Command and control of Urban and Remote Smart Communities from a centralized location

- ✓ Street light controls
- ✓ Surveillance
- ✓ Digital signage
- ✓ E-parking meters & ticketing
- ✓ EV charging
- ✓ Intelligent Transportation Systems (ITS)
- ✓ Integration:
  - Water & gas meters
  - Demand side management

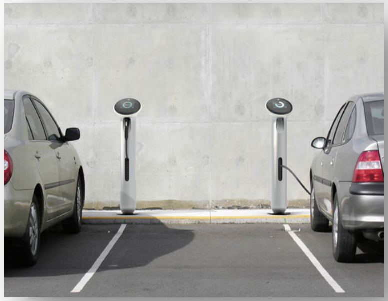


Ubiquitous renewable energy and smart grid technology coupled with autonomous and centralized command and control

Smart Distributed Solar

Solar is most effective as distributed:

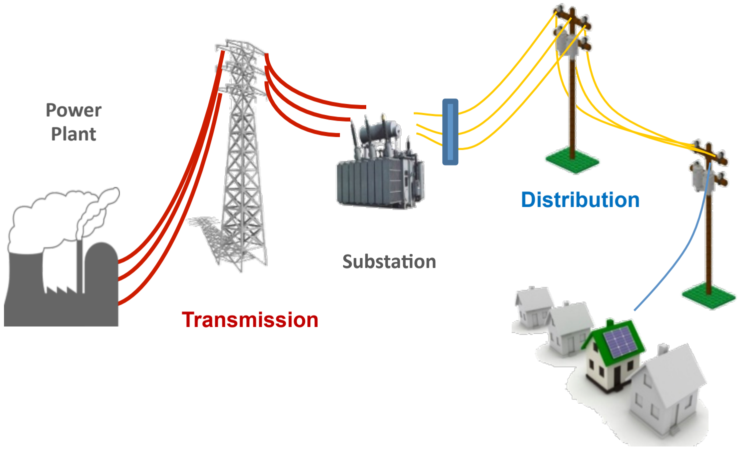
- Highest value when deployed at point of use → Responds to load variation more effectively
- Relieves T&D capacity → Delays T&D upgrades
- Avoids T&D losses
- Utilizes existing assets: rooftops. Carports, streetlights, utility poles
- Distributed solar can be deployed fairly rapidly
- Avoids infrastructure investments for large centralized solar farms



Grid Evolution

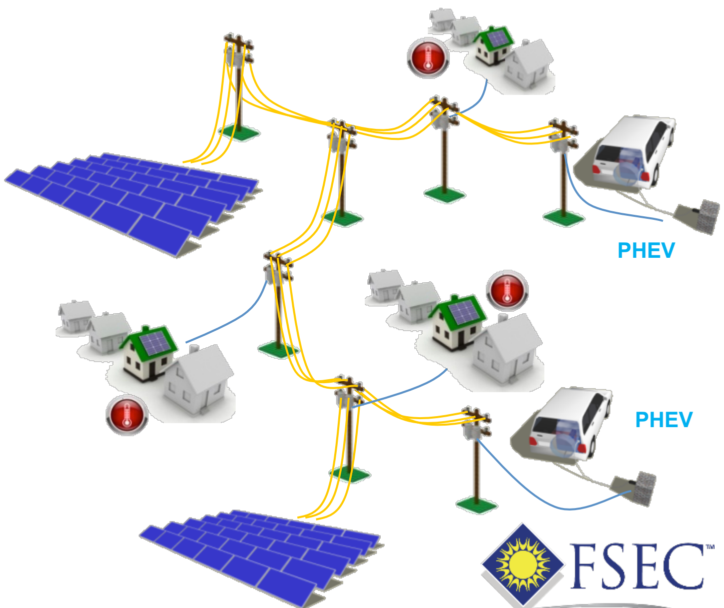
Today's Grid

- Large power plants
- Top-down power flow model
- Synchronous-machine dominated



Future Grid

- Small distributed generation
- Modular micro-grid architecture
- Inverter-dominated



FSEC

Courtesy of Gluon.Power

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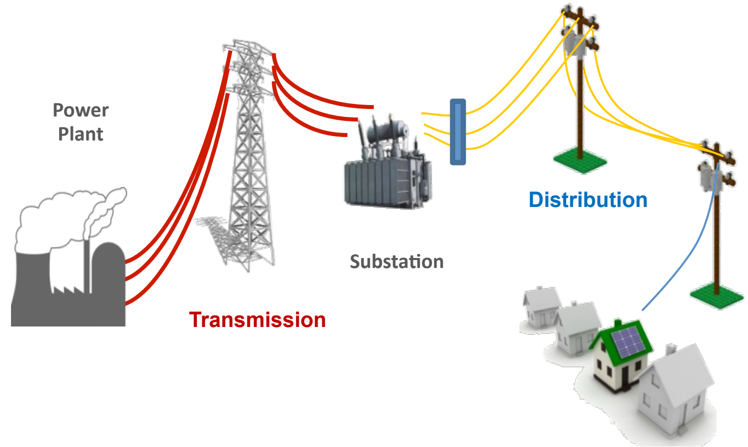

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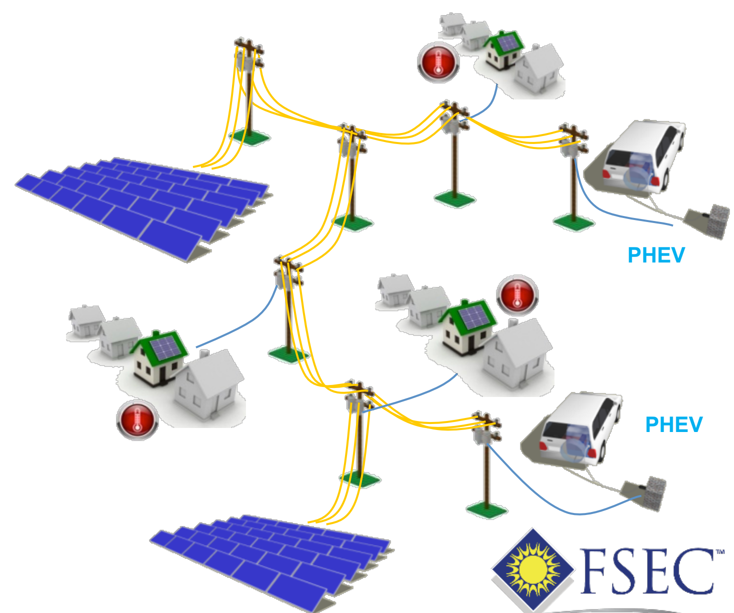
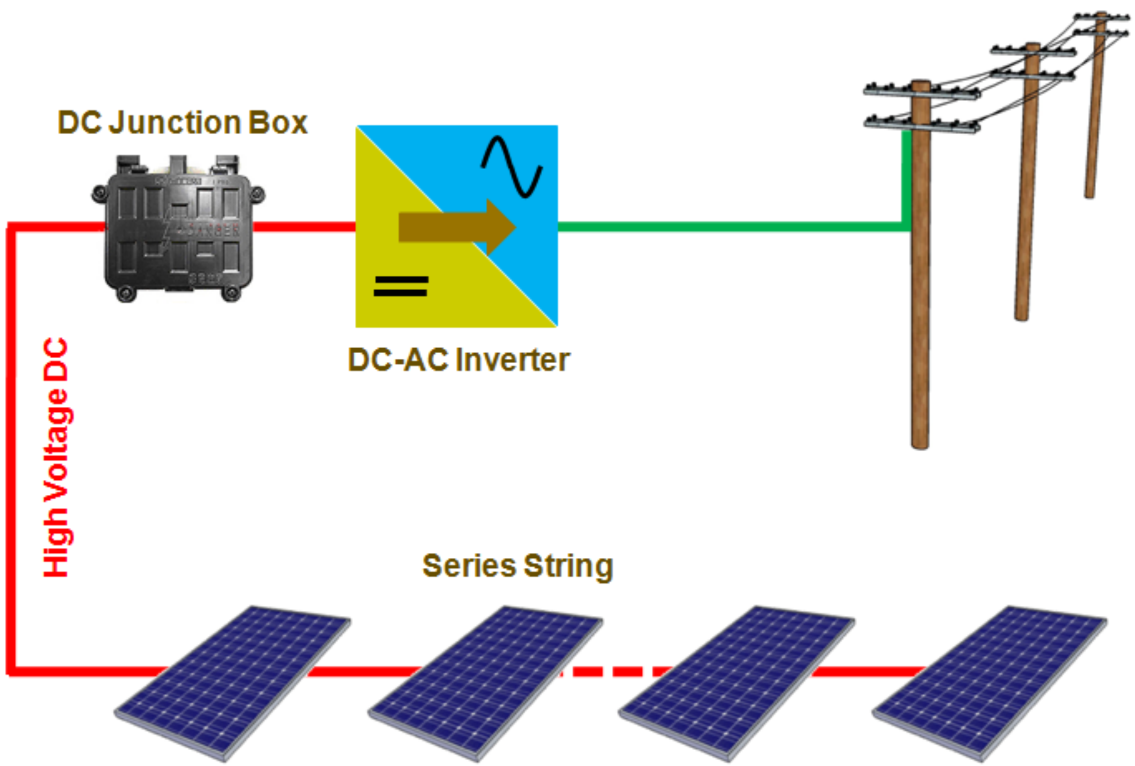


Opportunity for innovation

PV System Architectures

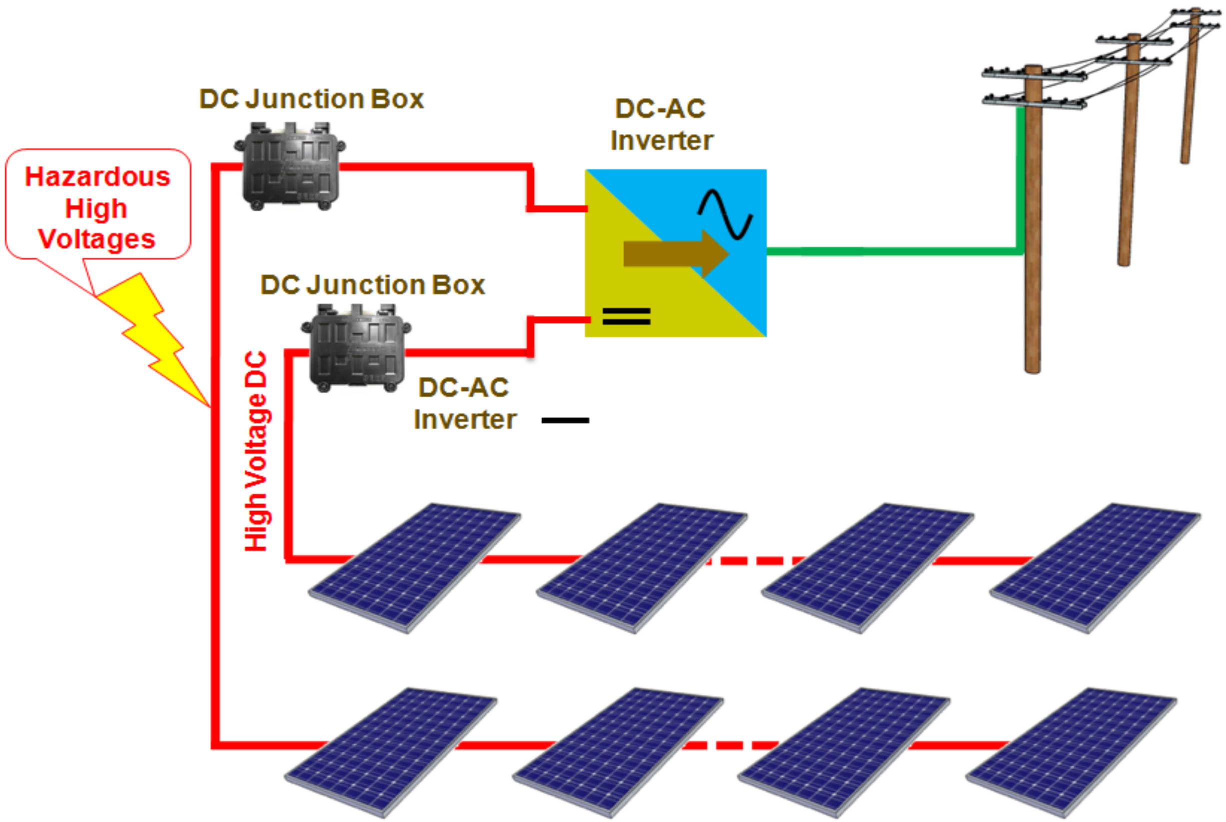
- The inverter technology drives the PV power system architecture
- Presently, the market is dominated by:
  - Centralized PV System
  - String inverter PV systems
  - Multi-string inverter systems
- New PV system architectures can greatly impact overall PV system costs
  - Micro inverters: Single panel inverters
  - AC PV modules (*Plug'N'Gen*)

PV System Architectures



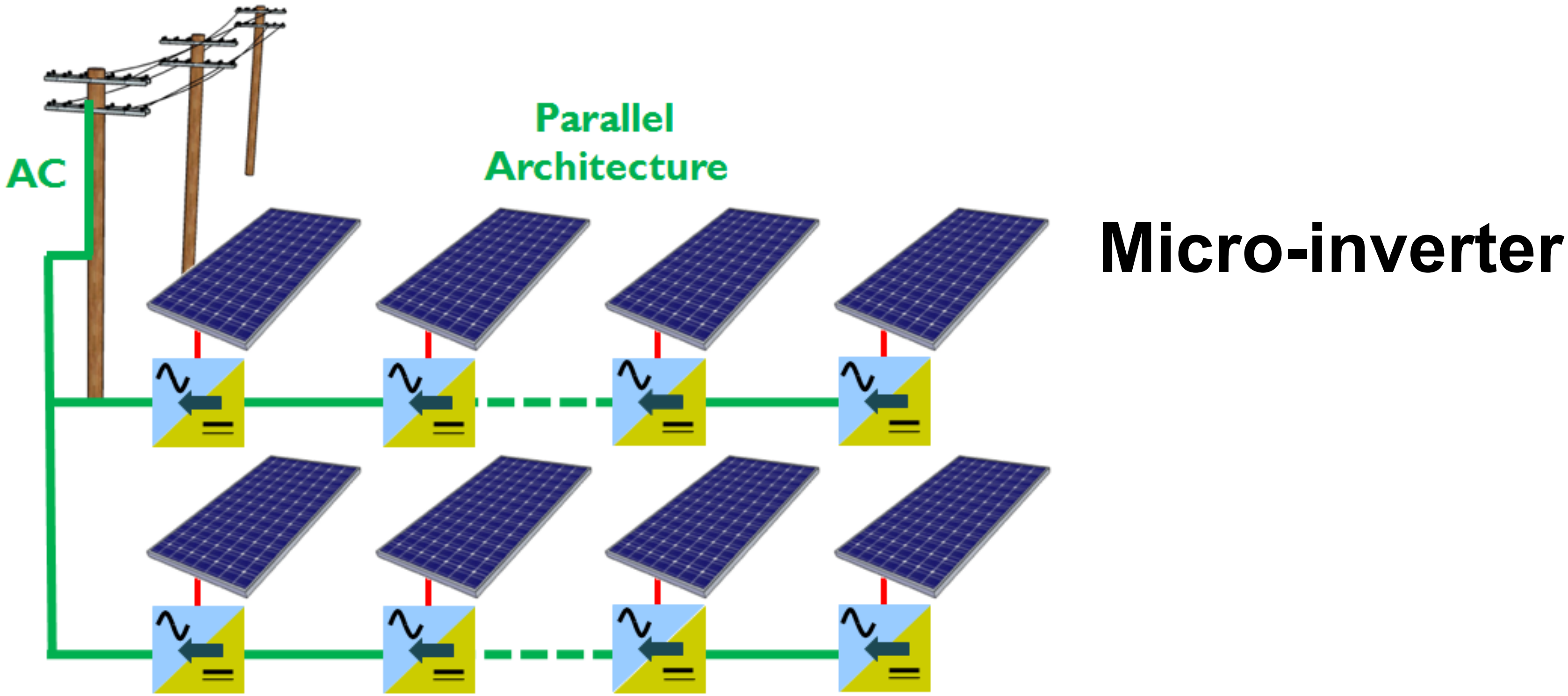
String inverter

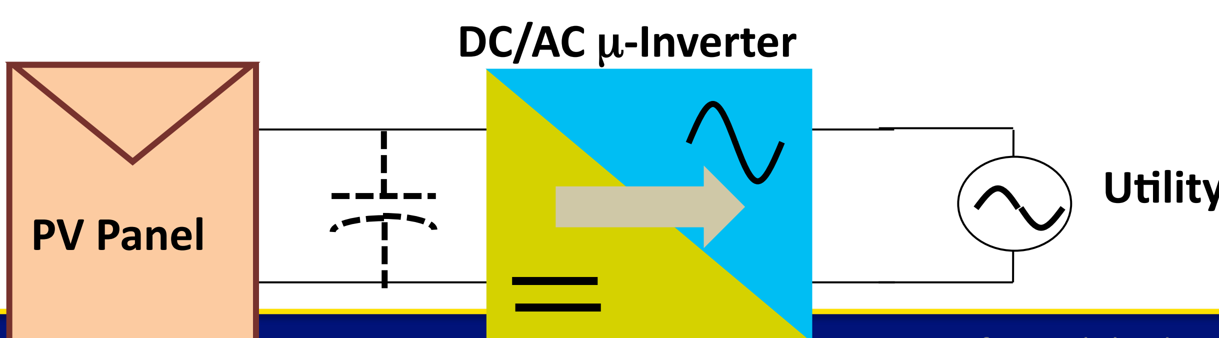
PV System Architectures



Multi-string inverter

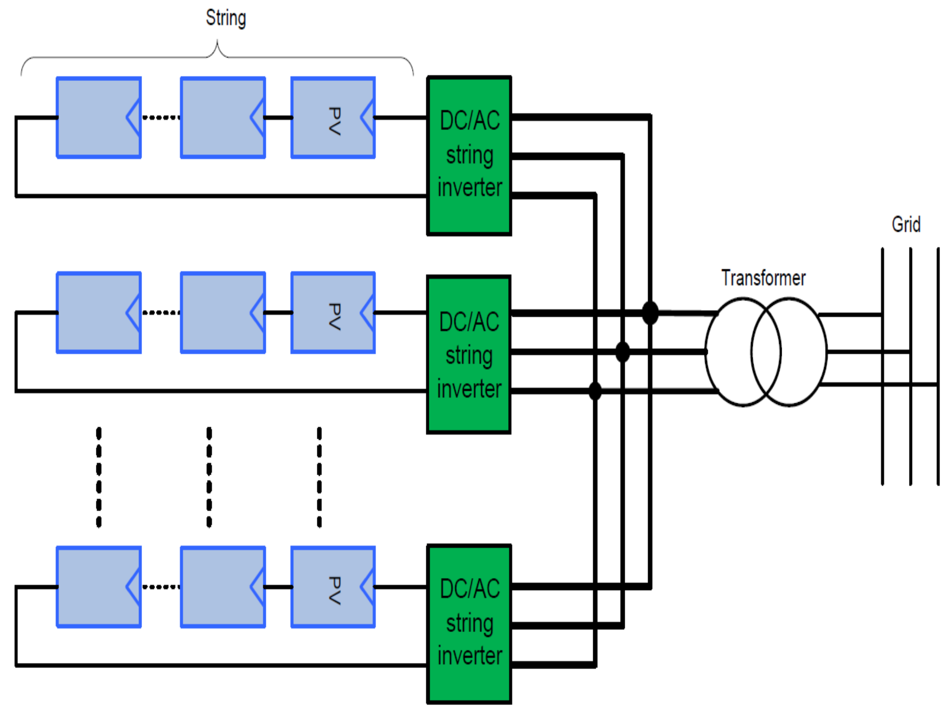
PV System Architectures





String inverter system architecture

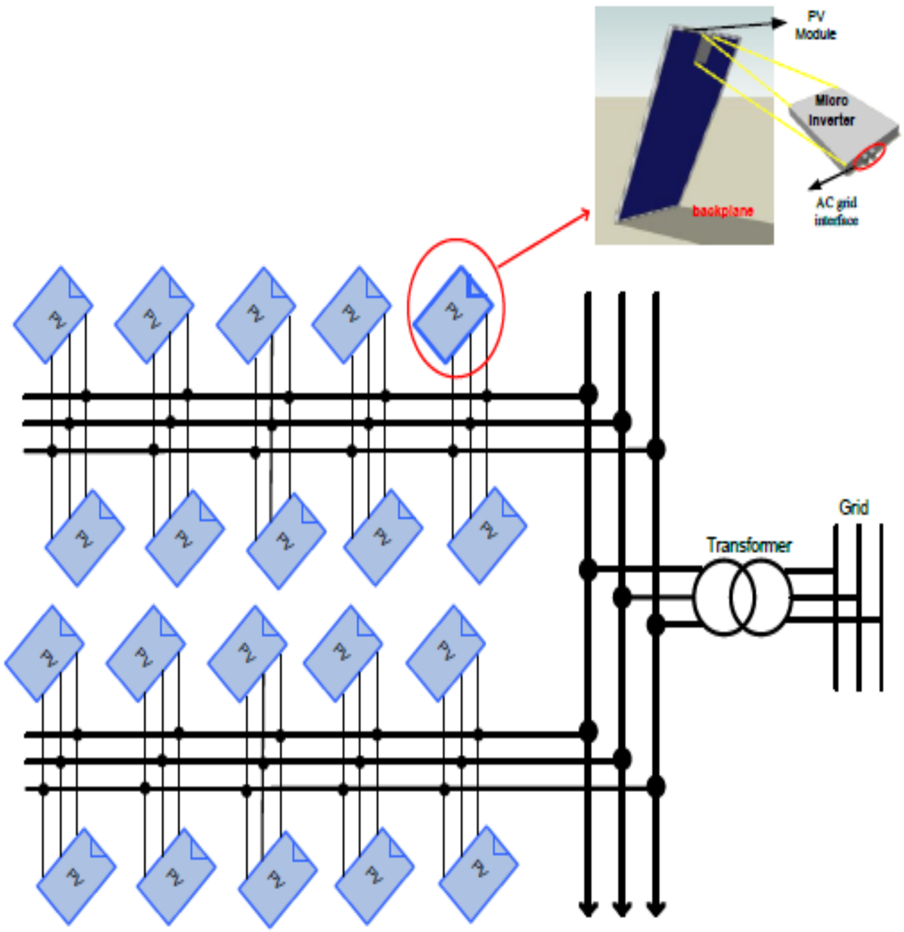
- Each PV module may not operate at its **maximum power point** which results in less energy harvested
- Additional losses are introduced by string diodes and junction box
- **Single point of failure**: and mismatch of each string or PV panel affects the PV array efficiency.
- **Hazardous:** High-voltage strings → Arcing potential



- **Complex system design:** String sizing; module matching: direction, shading, ageing
- **Costly Installation:** Special installation codes and procedures; certified installers
DC disconnects and wiring conduit

Micro inverter system architecture

- Each micro-inverter operates independently regardless of the other micro-inverters' failure
- Maximum Power Point Tracking (MPPT) for individual panels
- Ease of installation through flexible and modular solar farm architecture
- Preventing mismatch losses due to parallel connection of PV modules
- Lower DC distribution losses and lower installation costs
- Higher reliability



Flexibility in Installation Types

Carport Parking Shades

Solar Trees

Street Light Poles

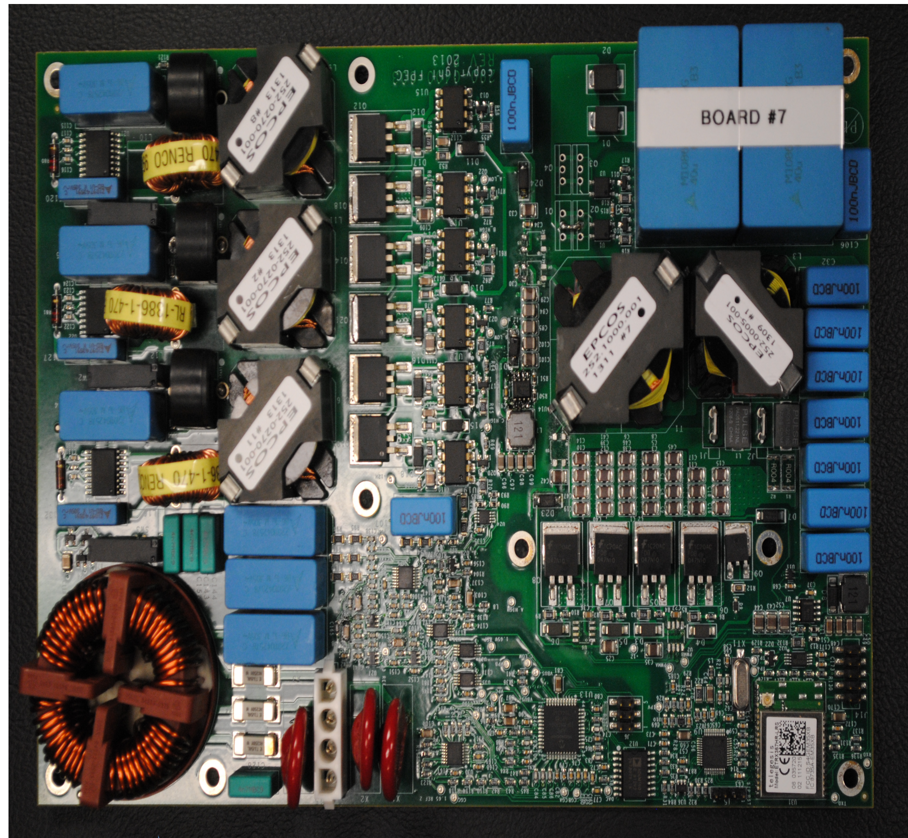
Roof Top

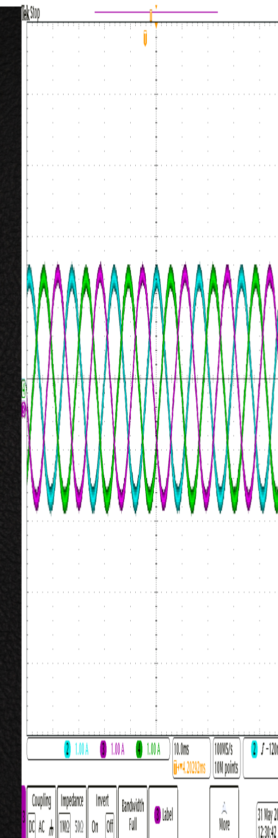
Ground Mount

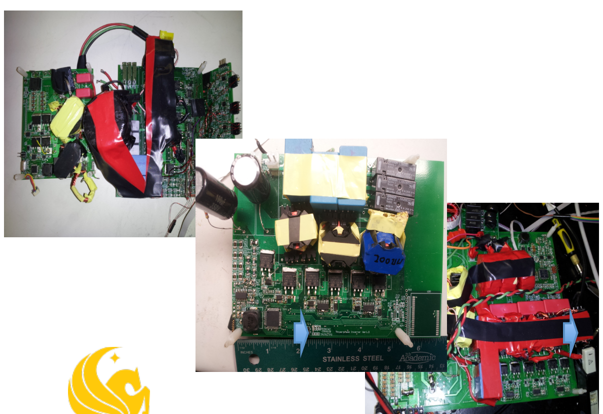
Three-phase Micro-inverter

Overview:

- 400W Nominal Output Power
- 50 VDC Nominal Input Voltage
- 208 VAC Three-phase Output Voltage
- 60Hz Output Frequency
- Two Stage Topology







Efficiency Curve:

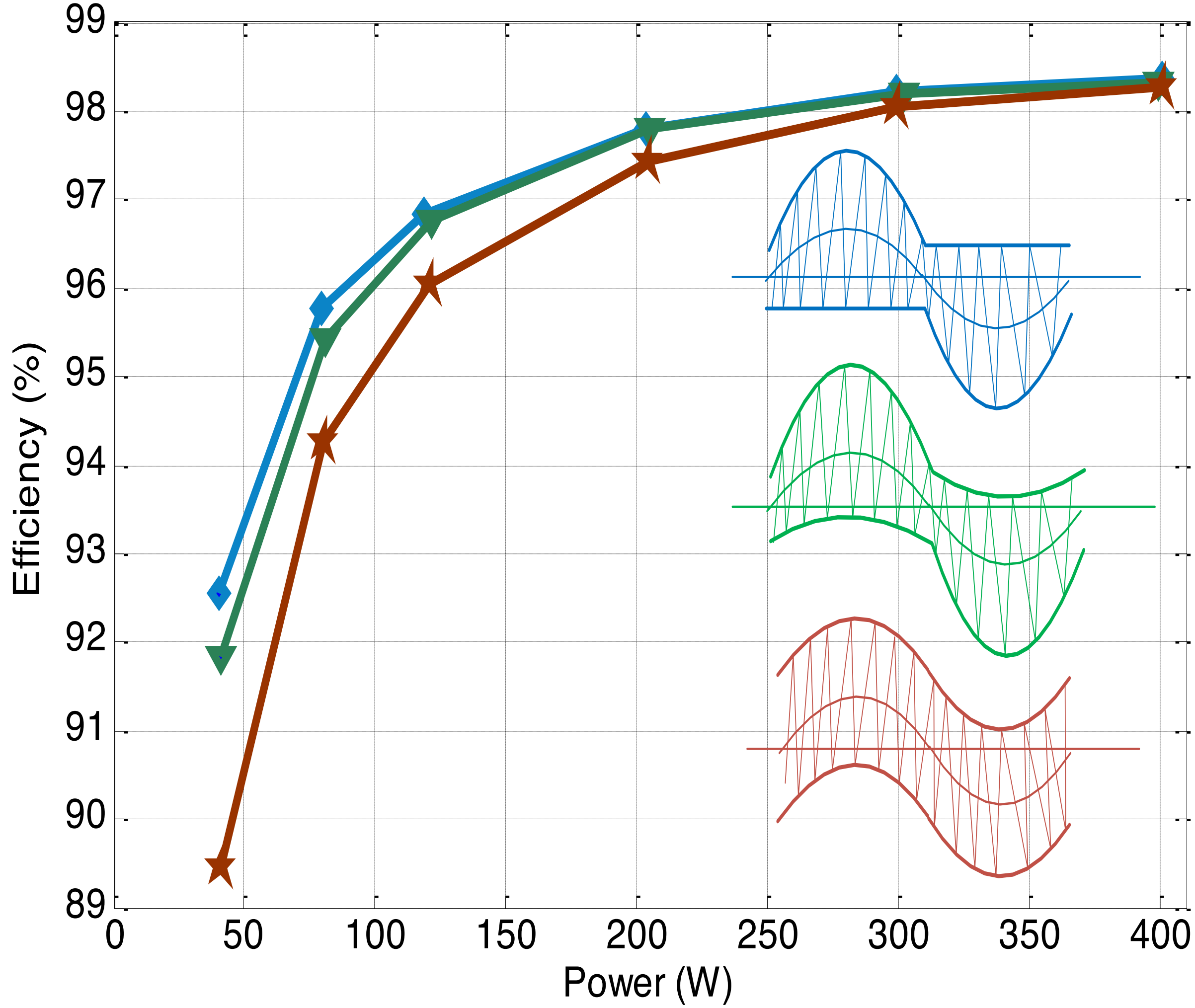
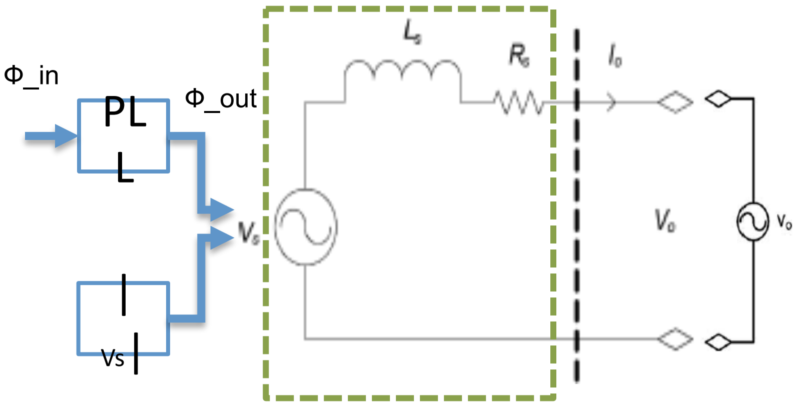


Figure. Converter Efficiency versus Output Power (Experimental Measurement)

Generator Emulation Inverters



Virtual impedance and EMF

S-domain equation for i_o

$$i_o = i_L = \frac{1}{L}\int (|V_s| - V_o - V_{Rs}) * dt$$

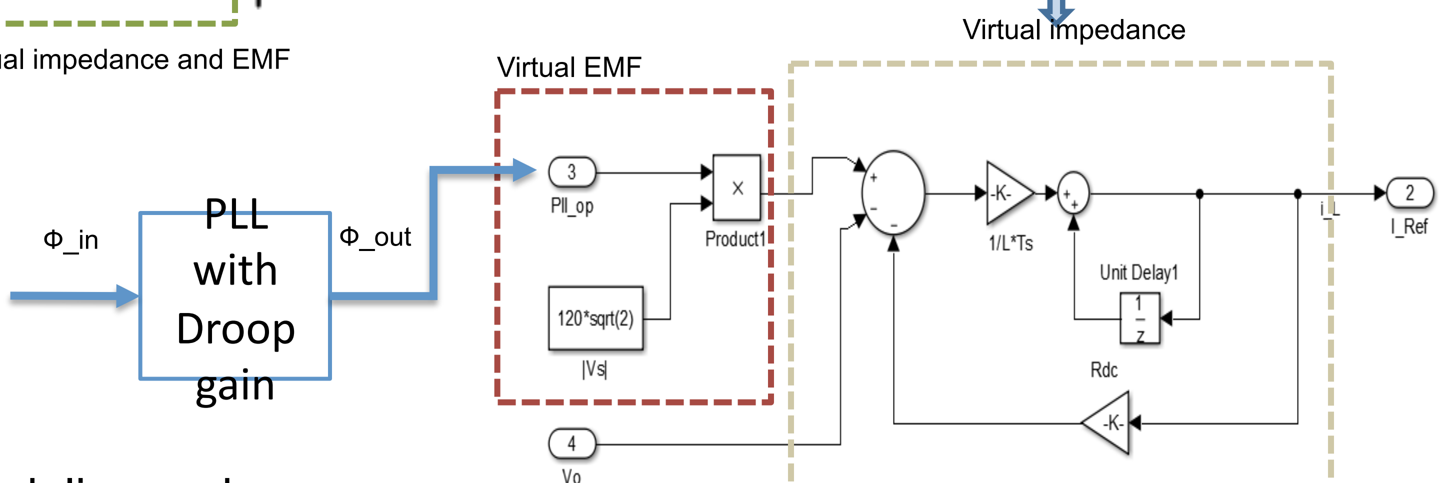
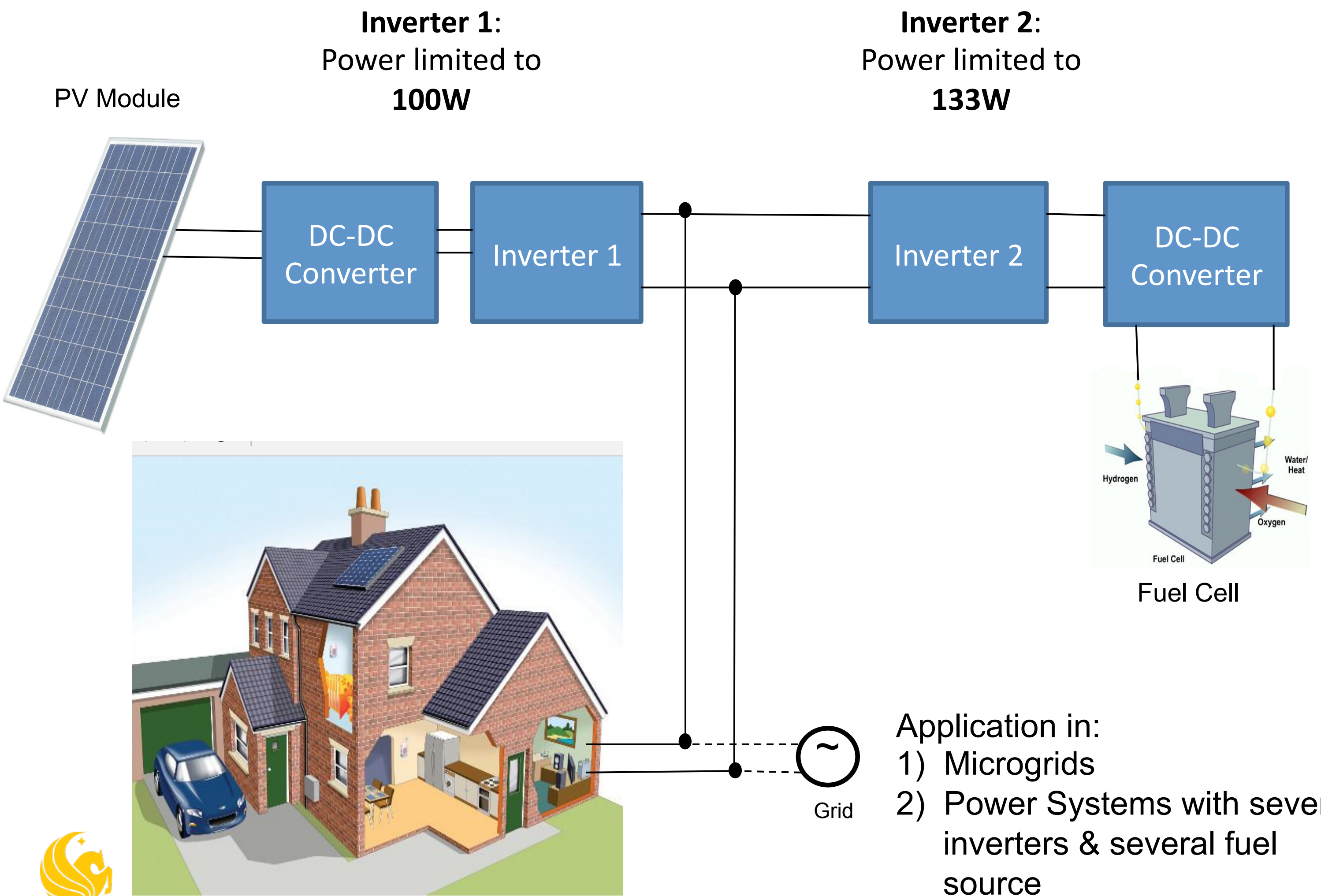


Fig. GEC modeling and implementation

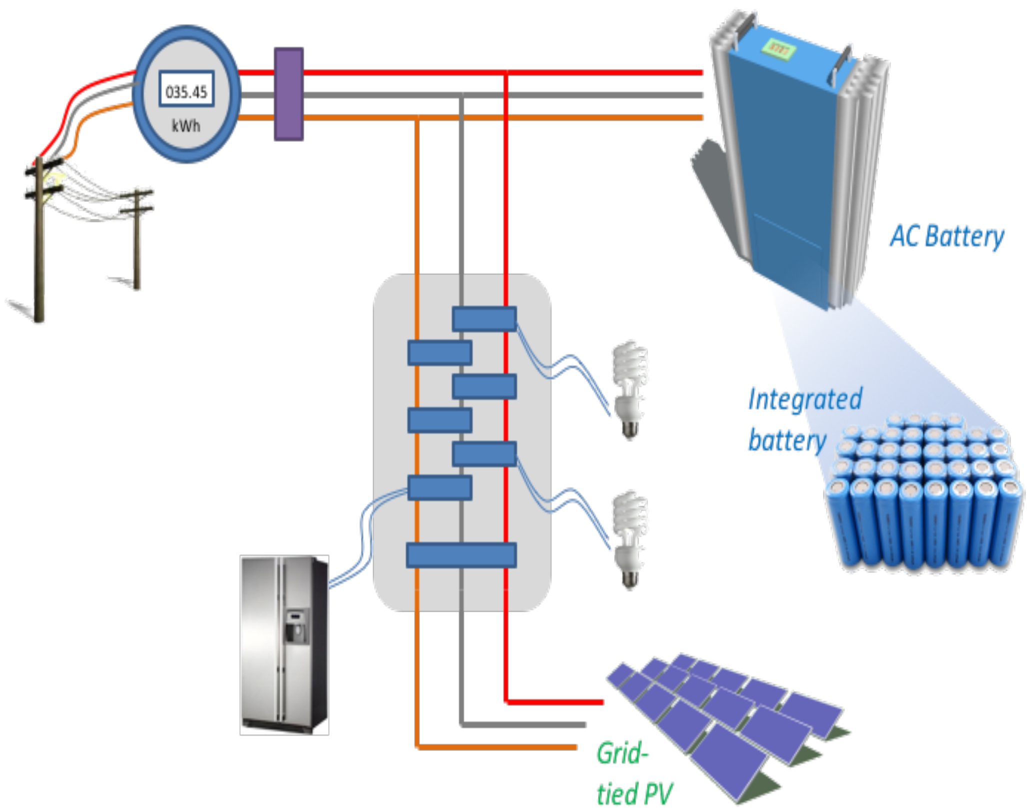
KEY POINT: GEC block gives access to control Active power based on Phase angle.

Power sharing between Parallel Inverters



Application in:
1) Microgrids
2) Power Systems with several inverters & several fuel source

The AC Battery



AC Battery for Residential Microgrid

Distributed AC Battery Micro-grid Systems

- ✓ 2kW/2kWh AC battery storage system, 98.5% efficiency
- ✓ Designed to emulate a synchronous machine
- ✓ Applications:
- ✓ Grid-tied residential microgrids
- ✓ Off-grid systems
- ✓ PV-firming
- ✓ Commercial energy storage systems
- ✓ AC Battery Innovative Control Techniques

New Solar – Storage + PV

Solar industry began with storage in the 1970's.

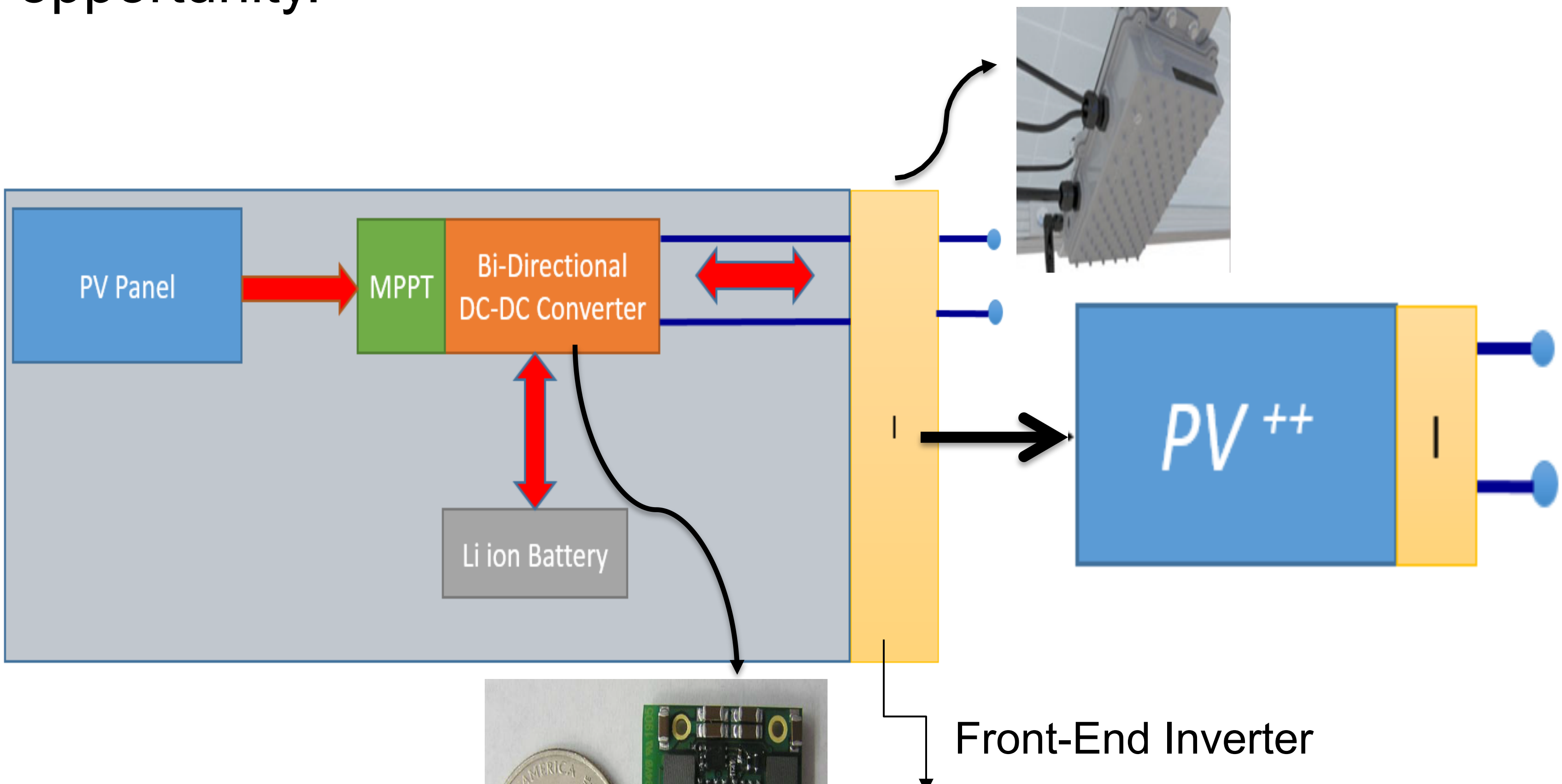
As batteries get cheaper, solar penetration reaches high enough levels to worry utilities, with incentives to reward storage in place, renewed interest in PV and storage is back.

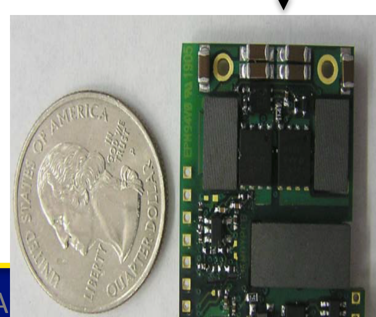
New disruptive Hybrid Technology:

Integrated PV and storage → Firmed PV (FPV)

It will solve the solar intermittence challenge.

Interest in Storage Technology pioneers in Silicon Valley and savvy industry veterans who see it as the next big business opportunity.





Energy Systems Integration Division

Vision

Help FSEC become a leader in the state and the nation in advanced integrated power electronics-enabled energy solutions in terms of research, development and commercialization. And continue to build expertise and capabilities in energy systems integration, implementations, power electronics, devices, utility system modeling and systems.

Current Programs in ESI

1) Regional Test Center

2) Electric Vehicle Transportation Center (EVTC)

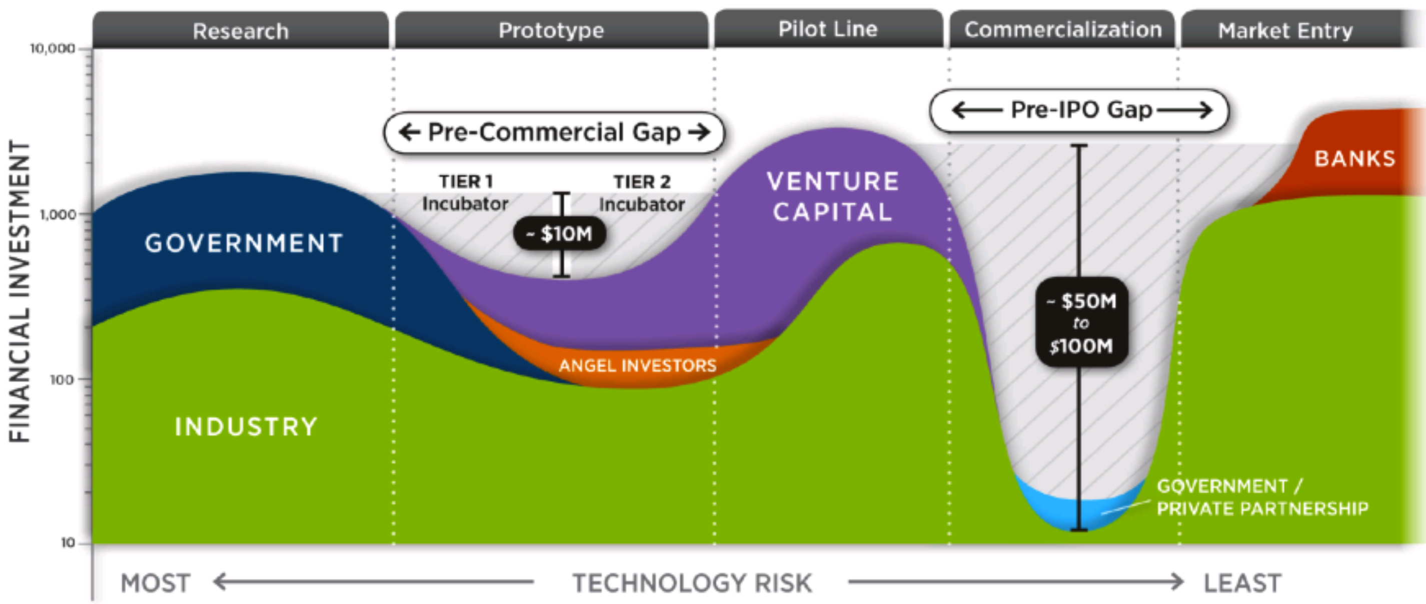
3) Florida Solar System Certification

4) Serving as General Technical Assistance

Regional Test Centers

Differentiating PV Quality

- Developed to support the DoE *SunShot* Initiative
- Helping accelerate technological evolution
- Increasing PV deployment



1. Albuquerque, NM	hot, dry climate	Sandia National Laboratories
2. Denver, CO	steppe climate	National Renewable Energy Laboratory
3. Cocoa, FL	hot, humid climate	UCF's Florida Solar Energy Center
4. Williston, VT	cold, humid climate	IBM
5. Las Vegas, NV	hot, dry climate	Univ. of Nevada–Las Vegas

Electric Vehicle Transportation Center

- EVTC is a U.S. DoT funded center focused on transforming the transportation system to accommodate the influx of plug-in electric vehicles (PEV) and their power demands.

- Help prepare transportation planners with the ability to accommodate the influx of EVs, while enhancing in the grid modernization efforts.

- Consists of a consortium of transportation and energy experts:
  - FSEC/UCF,
  - University of Hawaii
  - Tuskegee University in Alabama

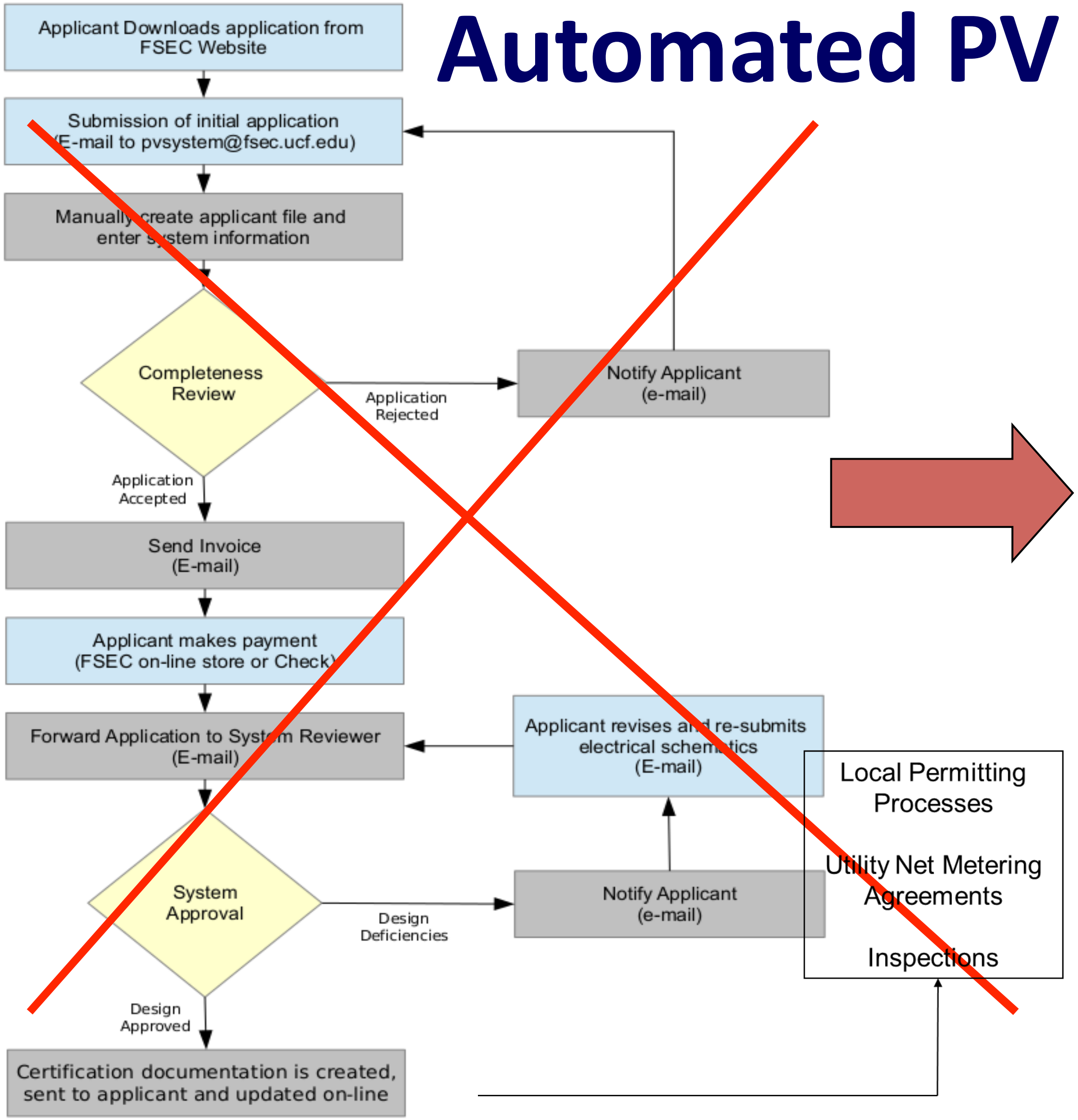
- The EVTC will leverage the resources of its partner universities to conduct the needed R&D and to inspire, train, and support the future scientists, engineers, and technicians expectations

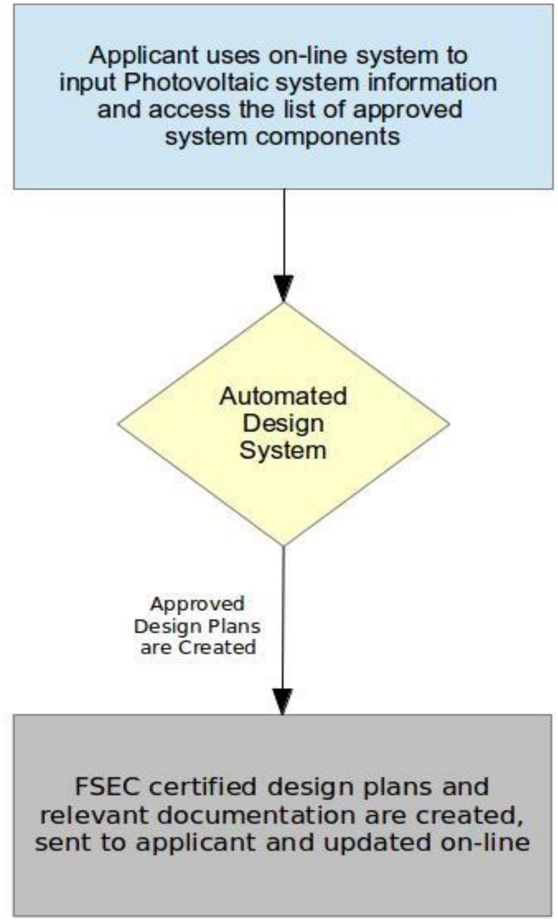
Go SOLAR / FSEC
PV System Certification Process

- Purpose
  - Verify use of UL listed components
  - Ensure code compliant electrical design for PV systems
  - Verify performance expectations




Go SOLAR Florida
Automated PV Design Tool





GO SOLAR | FLORIDA

EIS's Expanded Focus

- ✓Strengthen and expand joint collaboration between FSEC and units across UCF campus in R&D and education efforts in new areas such as grid modernization, and energy storage.
- ✓Help build and coordinate faculty-students teams to work on senior design projects, competitions and campus-wide energy awareness activities.
- ✓Expand the engagement and participation of industry partners interested in product and service that focus on the system level integration development efforts.
- ✓Actively organize joint multidisciplinary energy teams in collaboration with industry to pursue large federal projects…i.e. NSF's ERC in Storage.
- ✓Help aggressive implementation of **UCF's Sustainability Initiatives Climate Action Plan** that calls for of 15% renewable resource energy contribution by 2020.
- ✓Work closely with the new the *Resilient, Intelligent and Sustainable Energy Systems* (RISES) cluster faculty members, and help create new joint clusters between FSEC and CECS.

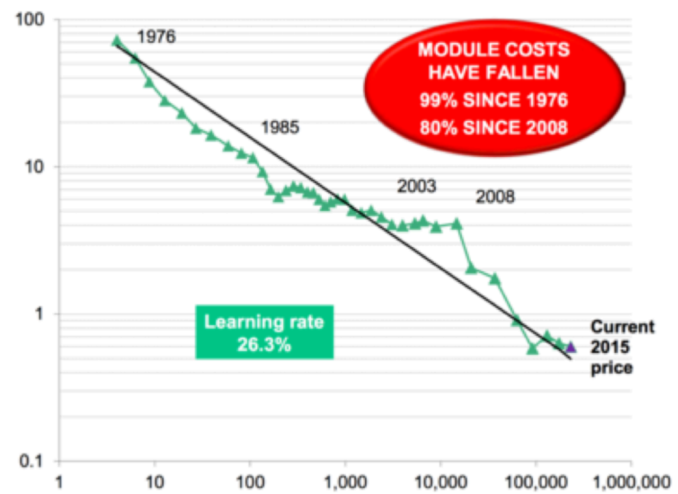
National Science Foundation
Engineering Research Center (ERC)
Integrated Smart Building Energy Storage (IS-BEST)

ERC Director: Dr. James Fenton, FSEC

Vision: To be the de facto epicenter for the RD&D and integration of next-generation **smart energy storage**, solar energy production, electric vehicles and advanced high frequency power-electronics systems, all integrated into the built environment for increased energy efficiency and grid resiliency.

Main Thrust Areas:

Thrust 1: Building Energy Demand
Thrust 2: Energy Storage
Thrust 3: Solar Energy Production.
Thrust 4: Vehicle-to-X
Thrust 5: Smart Power Electronics and Communication



FSEC

National Science Foundation
Engineering Research Center (ERC)
Integrated Smart Building Energy Storage (IS-BEST)

Lead Institution: University of Central Florida

8 Participating Universities:

- Case Western Reserve University
- Georgia Tech University
- New Mexico State University
- Texas A&M University.
- University of Hawaii
- Illinois Institute of Technology
- University of Southern California
- Washington University/St. Louis

Participating National Laboratories:
National Renewable Energy Laboratory (NREL)
Argonne National Laboratory (ANL)
(other: LANL, ANL, INL, LBNL, SNL)

Community Partner: City of Orlando

Several Industrial and Utility Partners:.

Industrial Community Collaborative Partnerships

PV, EVs, Energy Efficient Buildings, Load Management, Batteries, Alternative Fuels, Hydrogen, Fuel Cells, Smart Grid Electronics, V2X, Training & Education

Thank You

Creating and Capturing value through Technological Innovation in Energy