FEDERAL UTILITY PARTNERSHIP WORKING GROUP SEMINAR

April 22-23, 2015
Nashville, TN

A Look at Secondary Use Energy Storage

Michael Starke, PHD
Oak Ridge National Laboratory

Hosted by:

FEMP Federal Energy Management Program

TVA

Project Overview

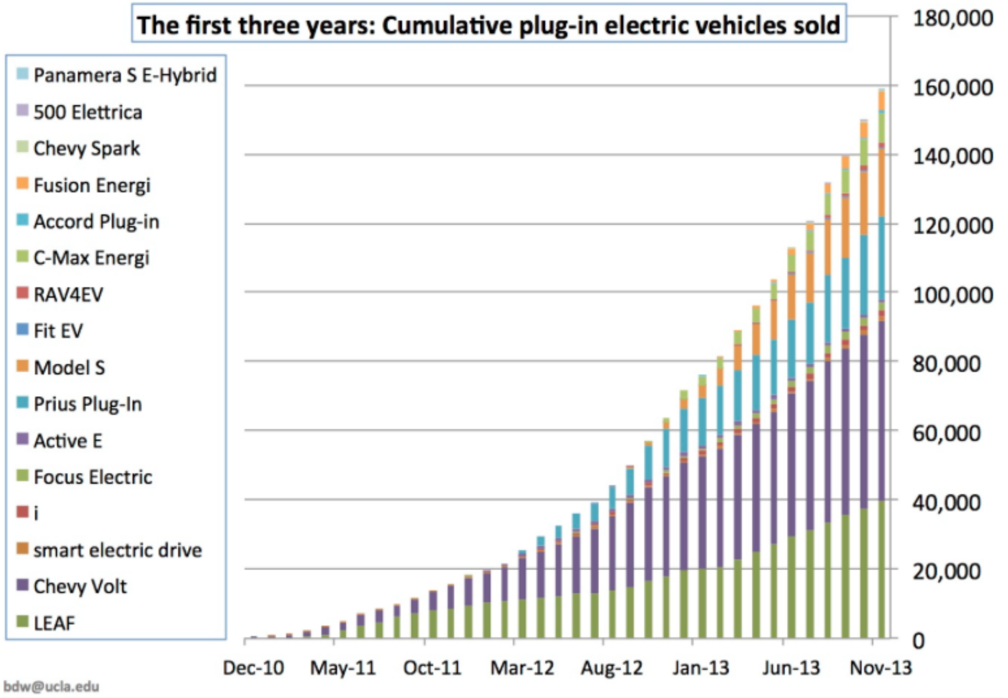
- Supporting the industry investigation into vehicle battery **secondary-use** through **testing, demonstration, and modeling.**
  - Potentially a **cost competitive** energy storage technology
  - Validate **reliability and safety** – working with industry to troubleshoot and test systems under operational conditions
  - Examining **regulatory environment** – investigating hurdles that are institutional
  - **Industry acceptance** – build confidence in this technology.

FEMP Federal Energy Management Program

TVA

Secondary Use of EV Batteries

- Potentially significant electric vehicle market.
  - Projections from different studies show significant growth.
  - March 2014, Tesla announces news on the building of a Gigafactory with projections of 500,000 vehicle production capability by 2020.
  - June 2014, Tesla is releasing all patents to encourage electric car production
- What can we do with the on-board battery technologies?



Repackage/Reuse: Could provide a low-cost grid storage solution (if design of repackaged system does not require significant modifications and added expense.)

FEMP Federal Energy Management Program TVA

Already Available in USA

- Over 150,000 plug-in electric vehicles (PEVs) currently in USA (study by UCLA Luskin Center for Innovation – December 2013)
  - ~ 55% of PEVs are PHEV and 45% are BEV
  - Near 70% of these vehicles are Nissan Leaf, Chevy Volt, or Tesla

Nissan Leaf
Nearing 40,000 Vehicles
24 kWh per pack
~960MWh

Chevy Volt
Exceeding 50,000 Vehicles
16.5 kWh per pack
~825MWh

Tesla
Nearing 20,000 Vehicles
85 kWh per pack
~1700MWh

- Leads to a an estimated 3.485GWh of existing battery storage.
- Estimates on capacity of the batteries. Detailed analysis will need to consider operational constraints, BMS level limits, and other aspects.

FEMP Federal Energy Management Program TVA

Demonstration Sites: Repurposing of Batteries

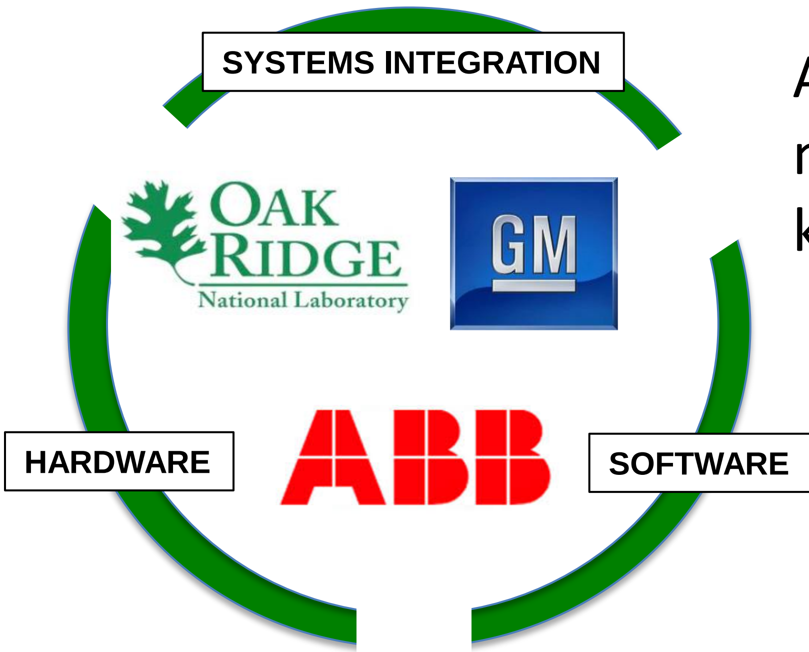
- Utilizes BMW mini-E batteries and BMS/Princeton Power Systems interface hardware
- 108 kW/180kWh with DC coupling to PV

- Utilizes General Motors Volt batteries and BMS/ABB interface hardware.
- 25kW/50kWh system connected to ORNL test-bed, PV smoothing and shifting.

FEMP
Federal Energy Management Program

TVA

Current Activities



An effective **partnership** that merges equipment, technical know-how, and infrastructure:

- Energy Storage – Used EV Batteries
- Energy Management System
- Electric Grid

ORNL is testing and demonstrating the technology as a third party.

FEMP Federal Energy Management Program

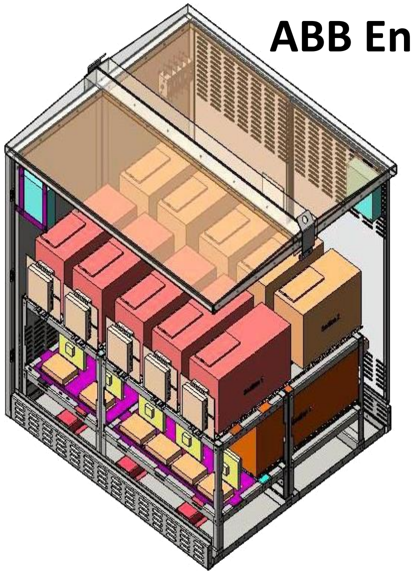
TVA

The Technology

GM Chevy Volt Battery

Re-Packaged

ABB Enclosure



Automotive Application

- Capacity for 10 Years in Automotive Application
- Power 111kW
- Liquid Cooled / Heated

Grid Application(25kW/50kWhr)

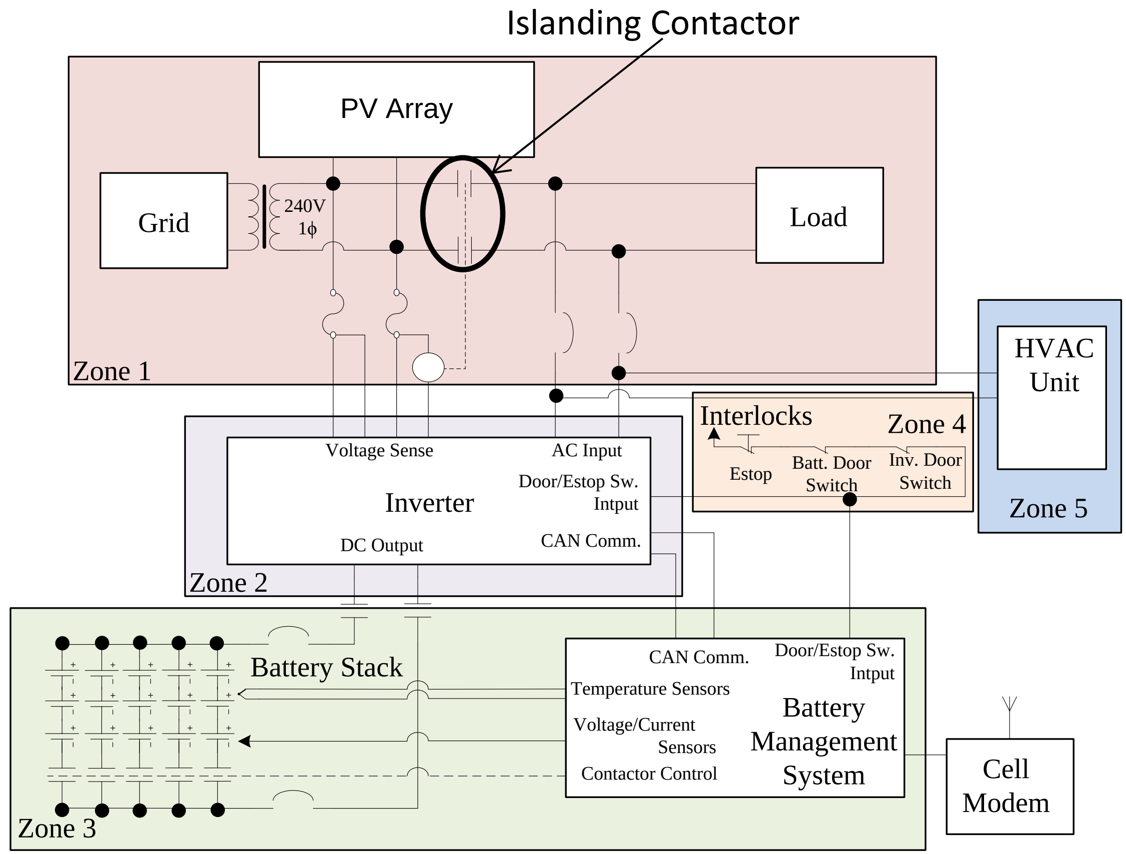
- Expected capacity for 10 Years of Operation
- 5 Volt Battery Packs
- 5 kW per Volt Battery
- Air Cooled/Heated

FEMP Federal Energy Management Program

TVA

The Working System

Zone 1: The system has a single-phase connection with the grid, PV Array, AC breakers, islanding contactor, and voltage sensing.
Zone 2: Inverter measures and senses inputs to control charging and discharging needs (4 quadrant)
Zone 3: Batteries connected on DC link and controlled by BMS. BMS uses voltage, current, and temperature information to relay control information to inverter.
Zone 4: Safety interlocks to prevent unsafe access
Zone 5: Thermal management with fans, heaters, and HVAC.



Multi-tiered layers of security are present in the system to ensure a safe operation

FEMP Federal Energy Management Program
TVA

System Benefits: CES

Local benefits:

Real and Reactive Power Support

- demonstrate that load factor and power factor can be maintained.

Service reliability

- during outage, CES unit can still supply load for a period of time.

Phase balancing

- if three units are installed (each on separate phases) additional energy can be used to balance phases.

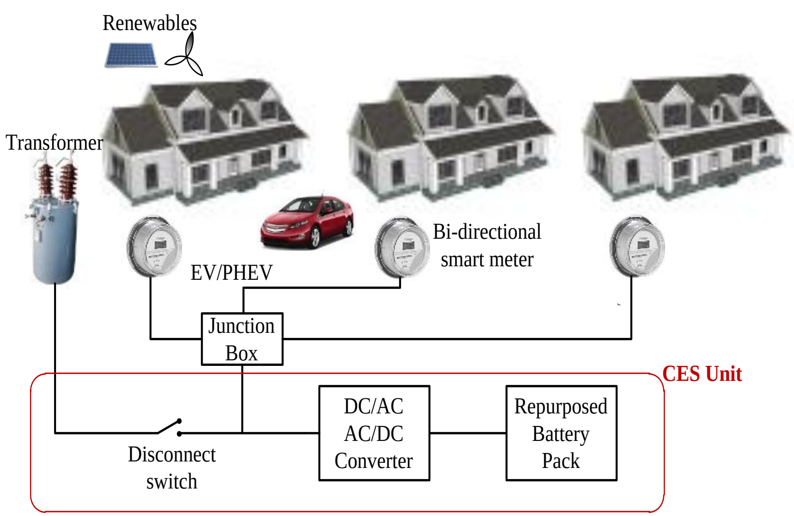
Grid benefits:

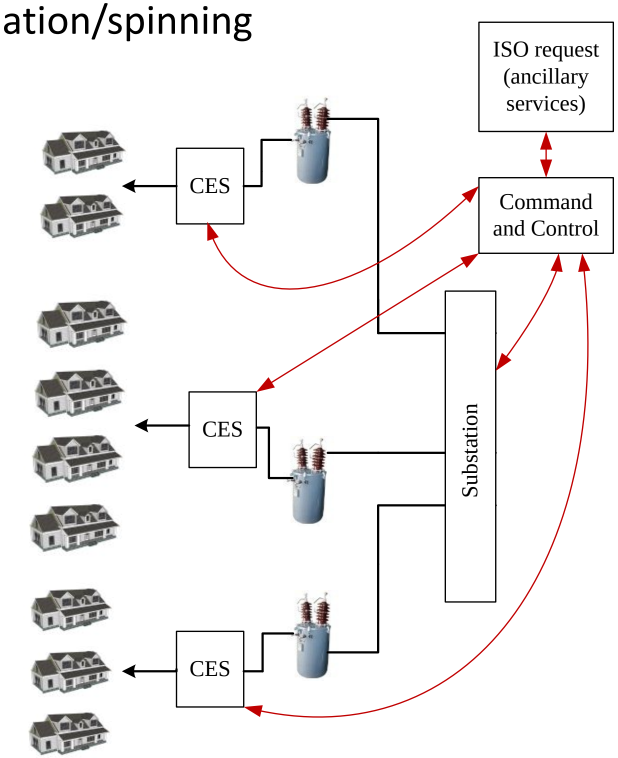
Firming and shifting Renewables and Load leveling / T&D Deferral

- battery can charge/discharge depending on control and load behavior.

Ancillary Services

- regulation/spinning





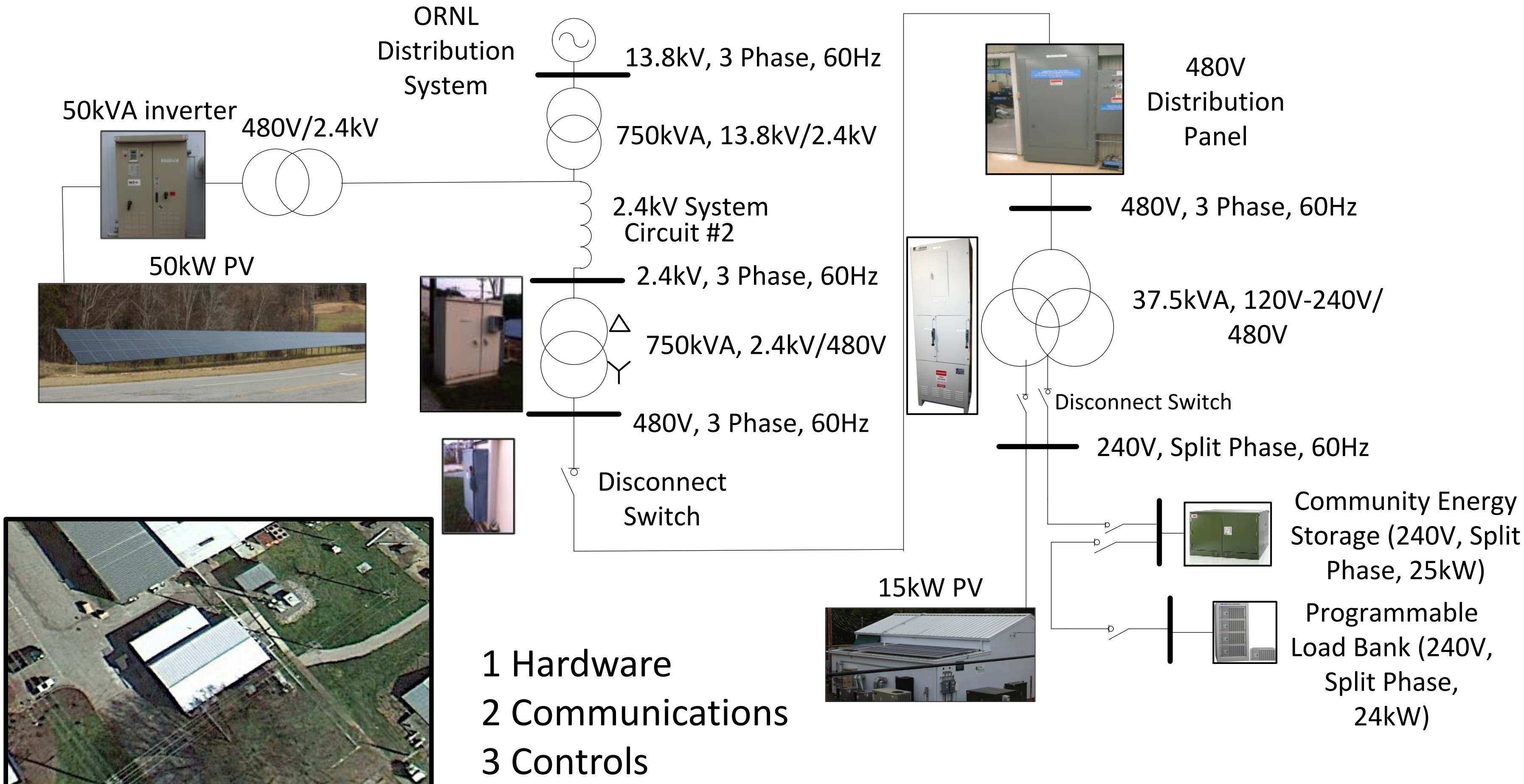
Similar benefits can be realized by distributed energy storage for commercial applications

FEMP Federal Energy Management Program

TVA

Testing Setup at ORNL

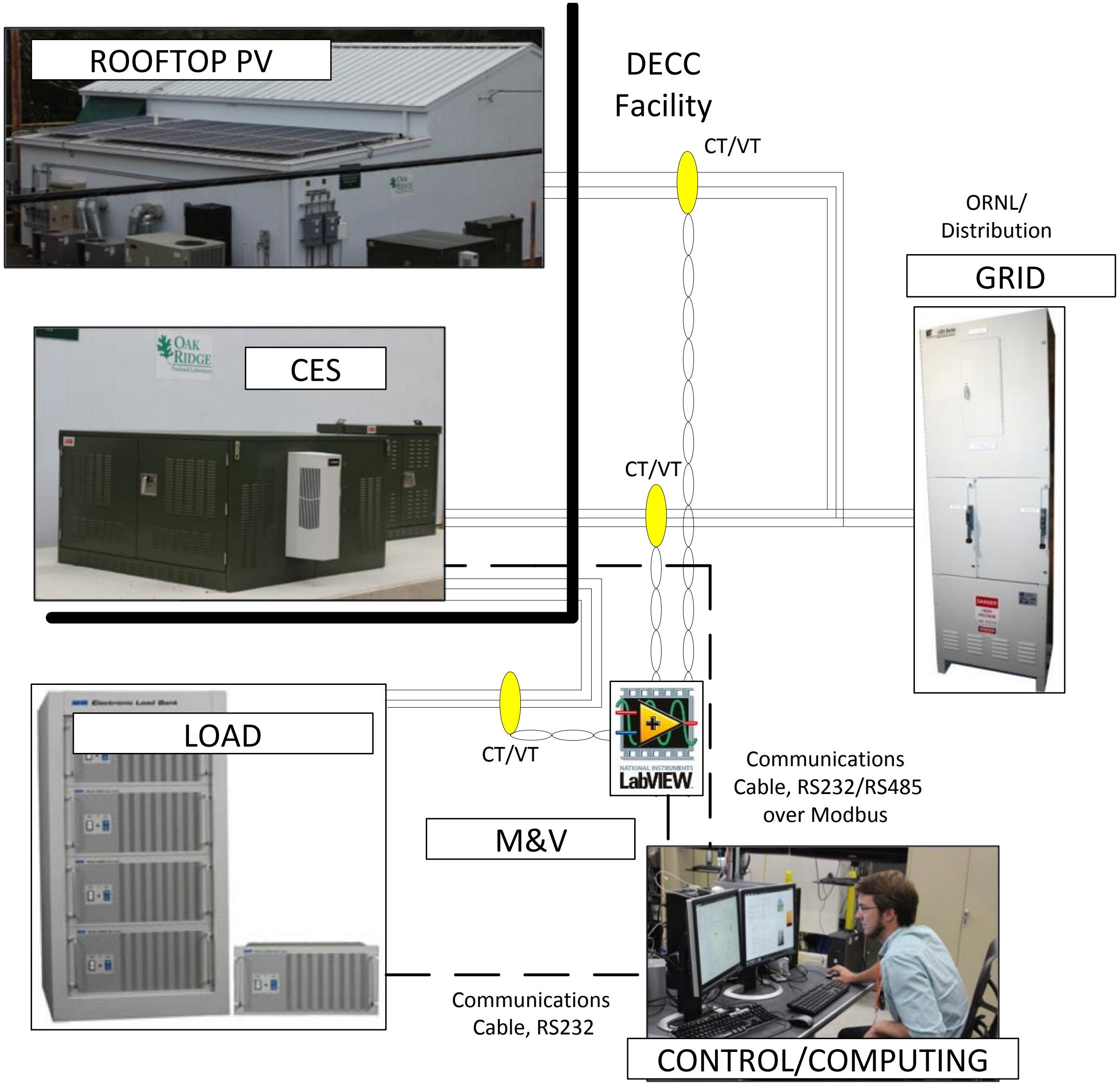
- ORNL objective for testing: Provide **real world** examination **systems integration** and **applications** with the flexibility to capture many different case scenarios.



1 Hardware
2 Communications
3 Controls

FEMP Federal Energy Management Program
TVA

Hard/Soft: Communication and Control

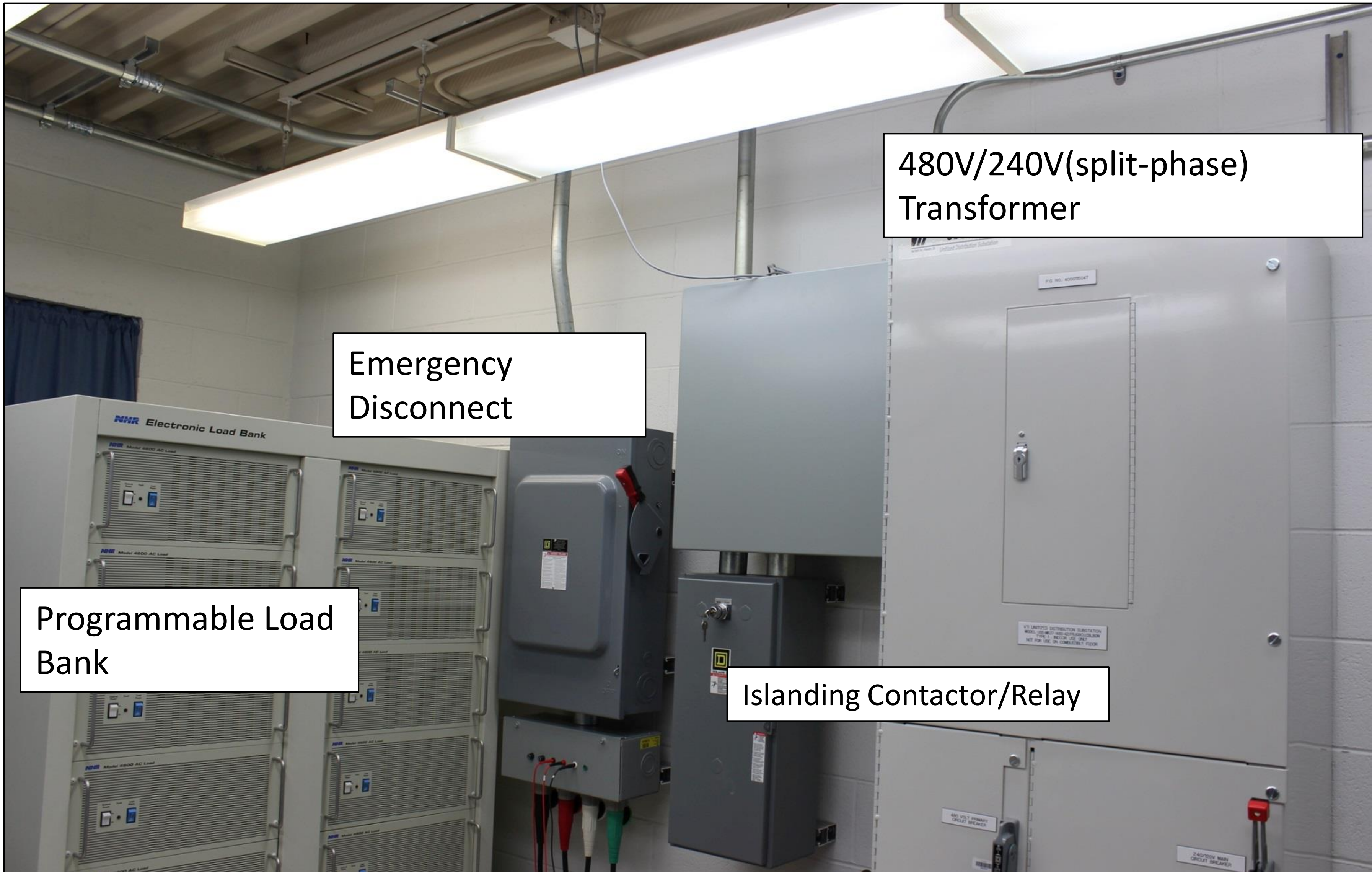


Communications and Control and Measure & Validate

- Communications and control done through Serial, Modbus over Serial, and TCP/IP
- All integrated through Matlab/Labview
- Load Bank utilized for Emulation.

FEMP Federal Energy Management Program TVA

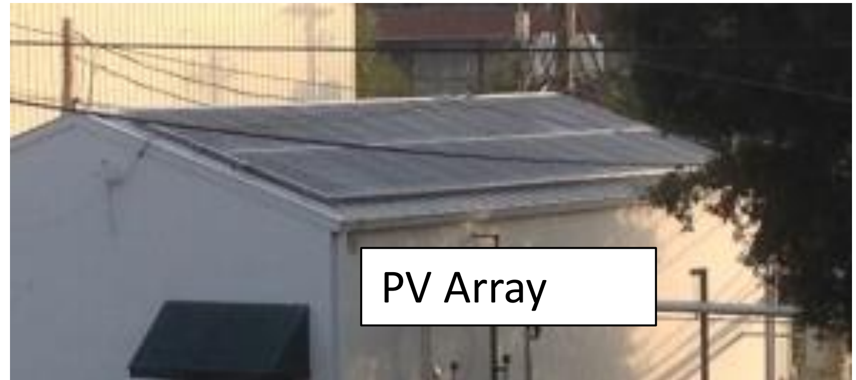
Hardware: Equipment Inside DECC



FEMP Federal Energy Management Program

TVA

Hardware: Equipment Outside DECC

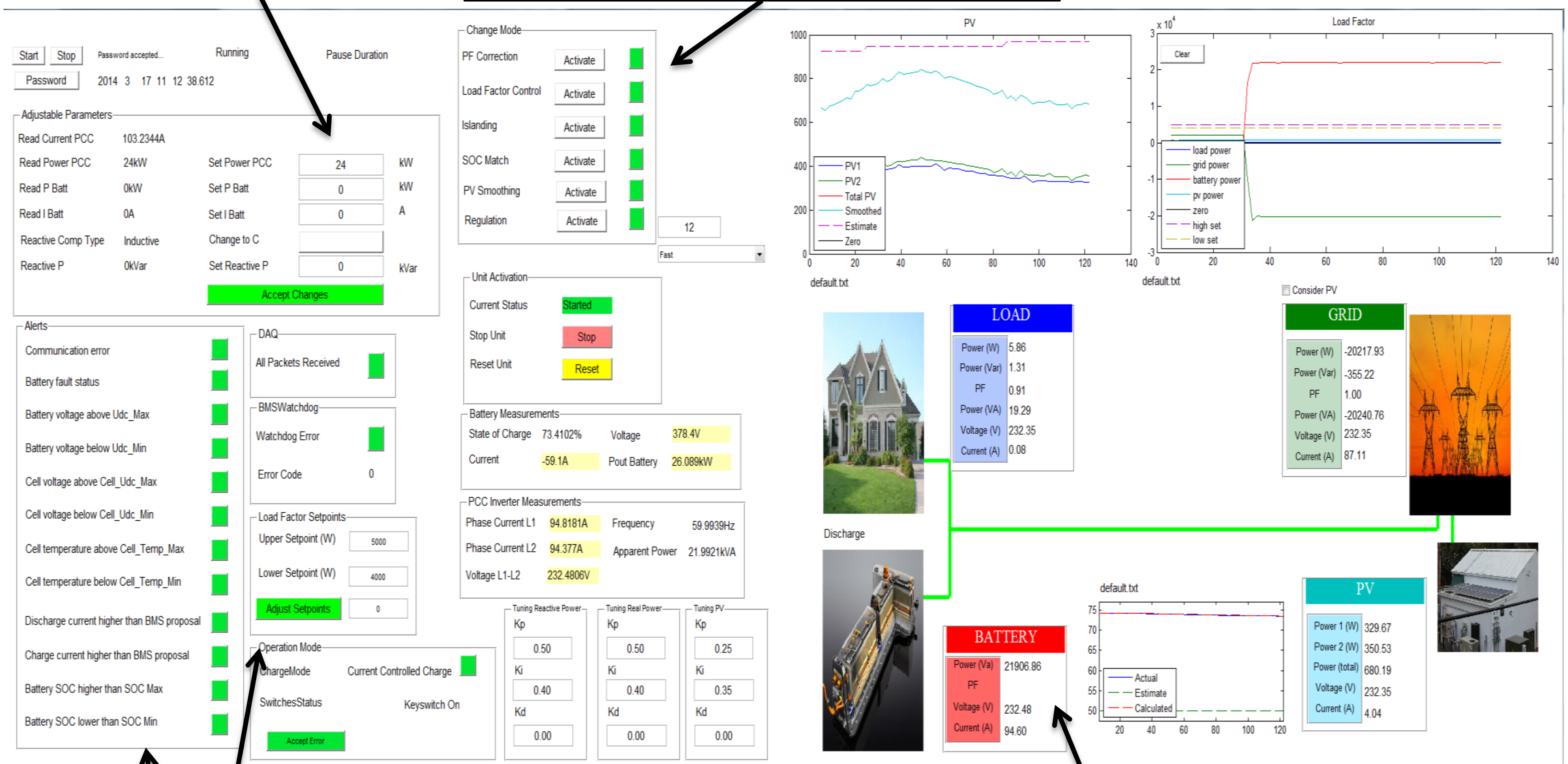


FEMP
Federal Energy Management Program
TVA

Interface

Manual Control

Set of pre-programmed controls



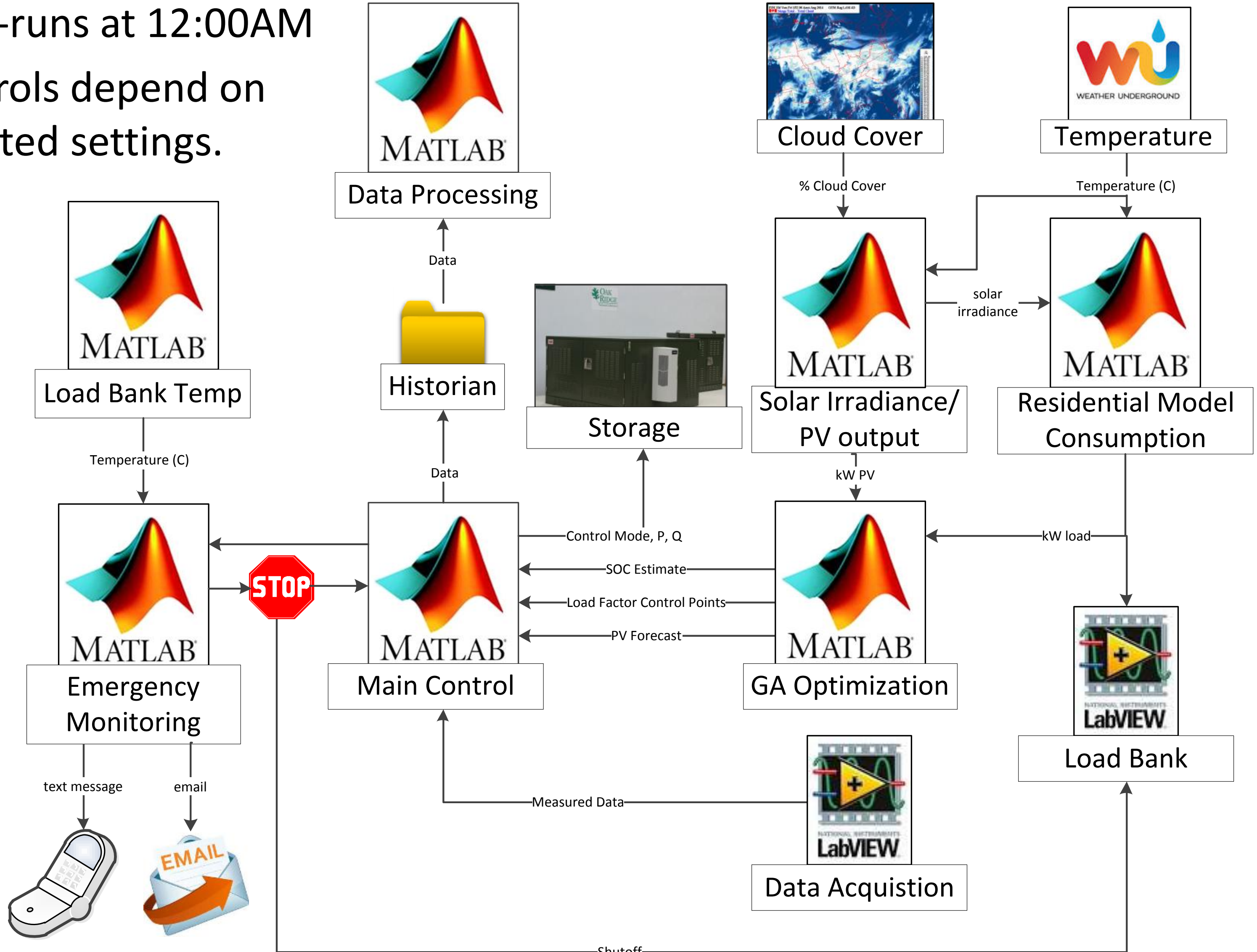
CES Alarms

State display

Federal Energy Management Program

Controls and Programs

- Auto-runs at 12:00AM
- Controls depend on selected settings.

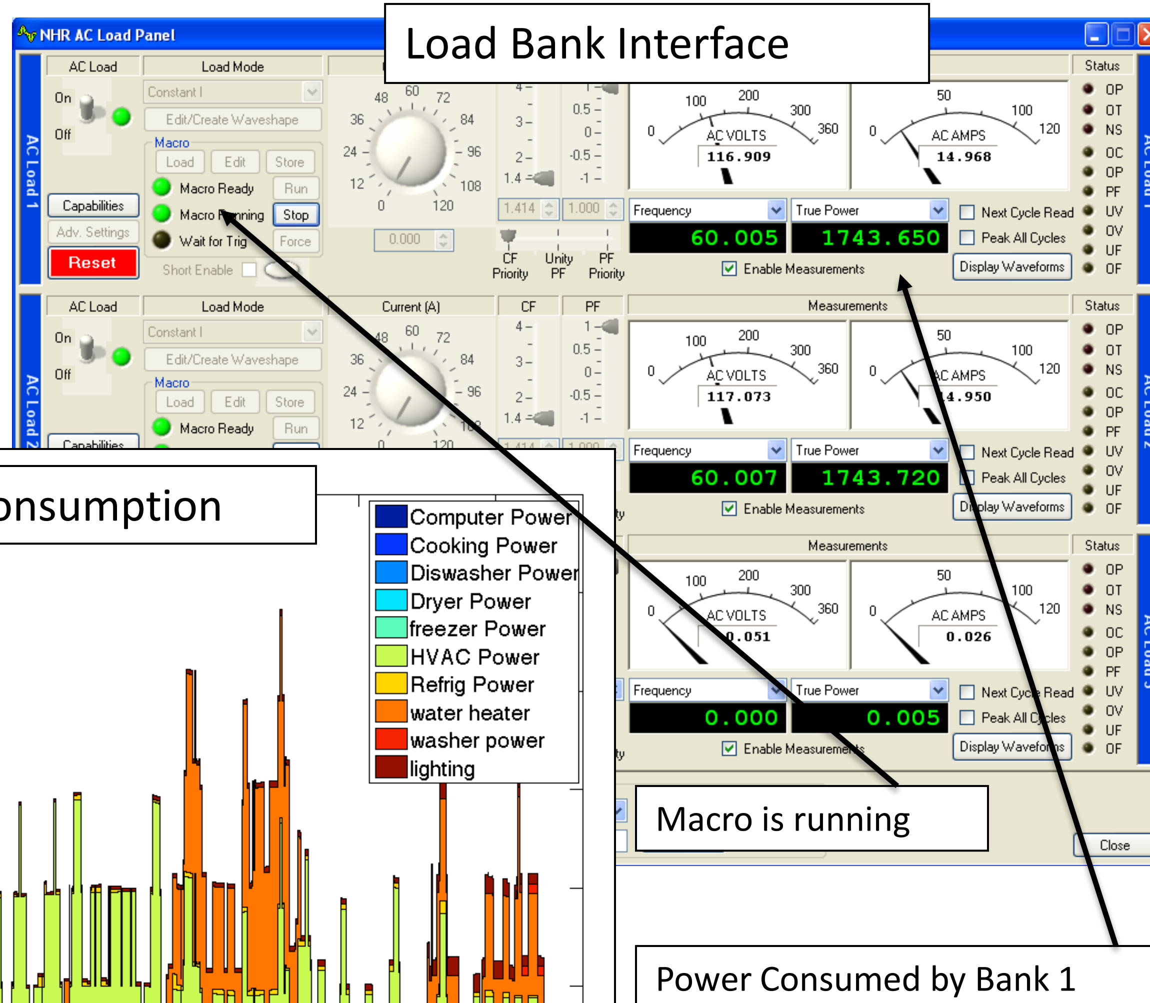


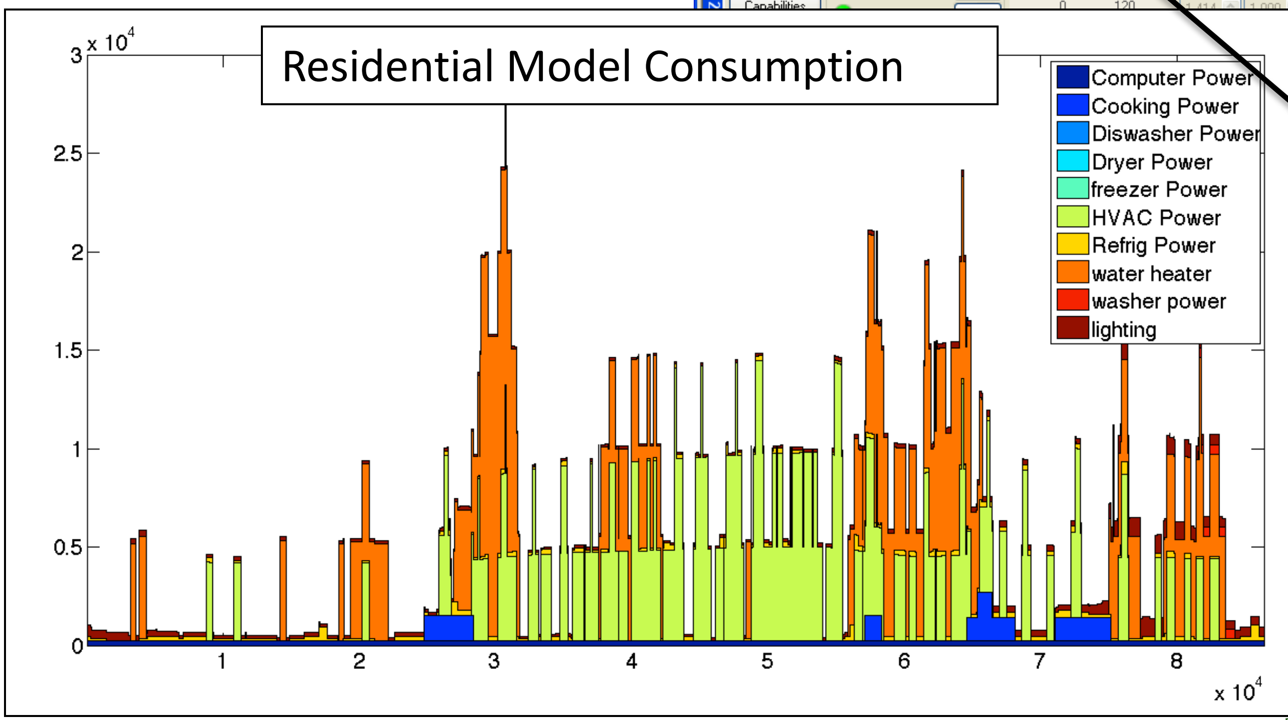
FEMP Federal Energy Management Program

TVA

Measurements and Simulation Additions

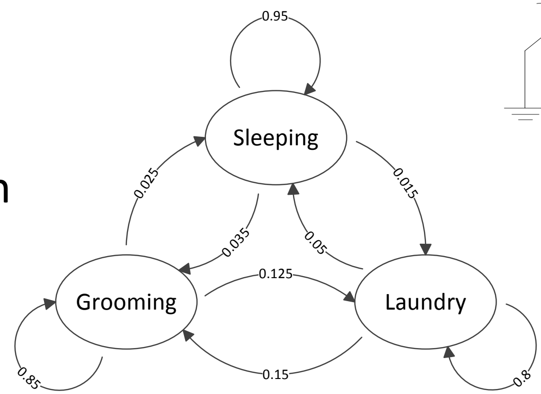
- Load Bank is controlled to follow residential load profiles through macros.
- Residential profiles are developed through modeling and historical data collection.

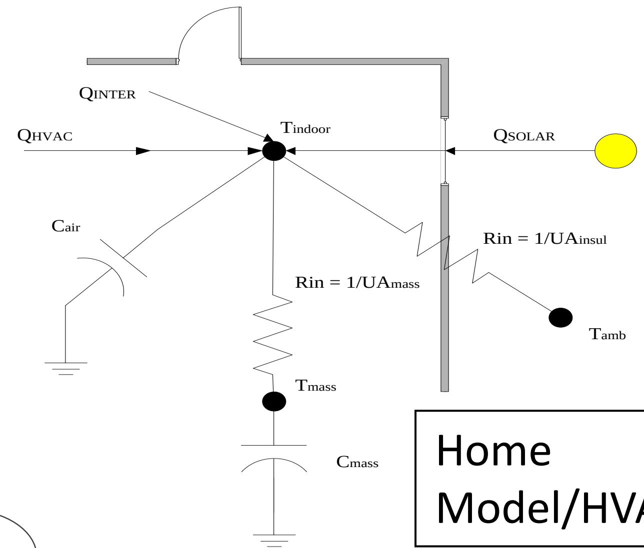




Residential Modeling

- Residential data has been sub-metered and collected for several years. Used to develop and validate load models.
- Markov Chains are used to drive residential loads such as washer/dryer/water heaters…



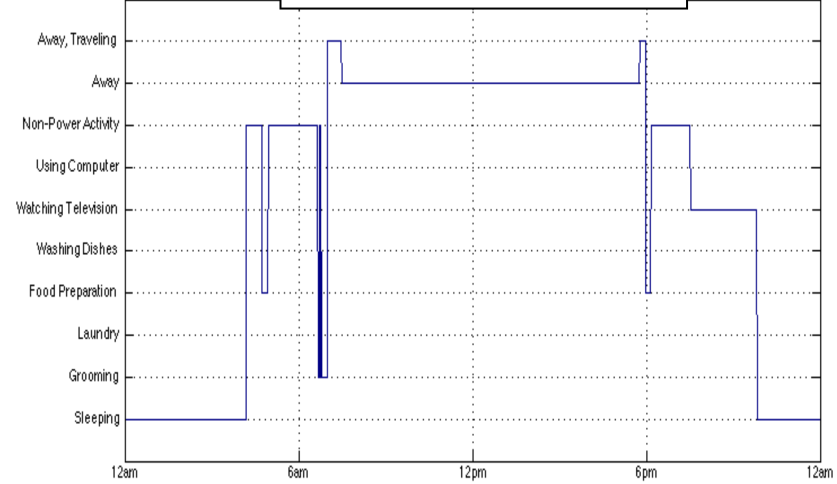


Home Model/HVAC

Markov Chains

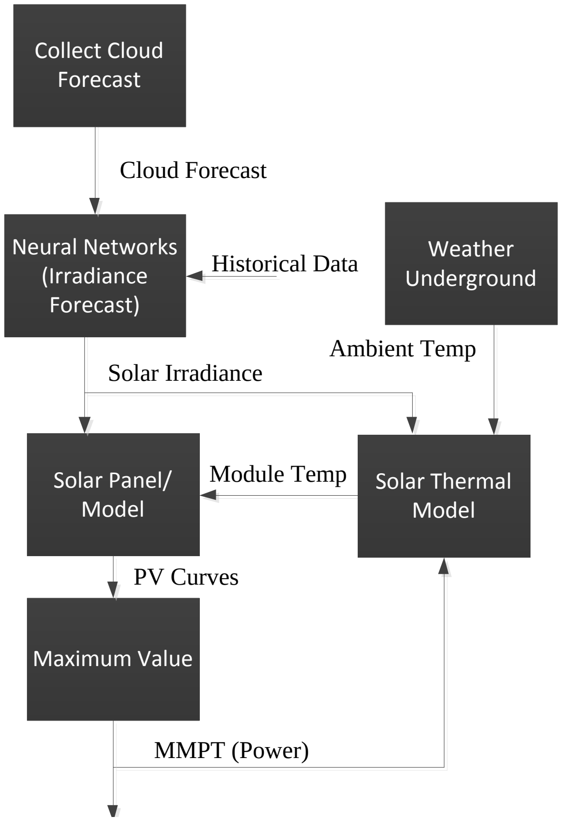
	Sleeping (7:00 pm)	Grooming (7:00 pm)	Laundry (7:00 pm)	--->	Away, Traveling (7:00 pm)
Sleeping (6:59 pm)	**99.55%**	0.08%	0.00%		0.08%
Grooming (6:59 pm)	0.26%	**96.43%**	0.05%	--->	0.64%
Laundry (6:59 pm)	0.07%	0.09%	**98.23%**		0.07%
Food Preparation (6:59 pm)	0.01%	0.03%	0.01%		0.02%
Dishwashing (6:59 pm)	0.06%	0.15%	0.10%		0.12%
Watching TV (6:59 pm)	0.05%	0.03%	0.01%	--->	0.04%
Computer Usage (6:59 pm)	0.03%	0.05%	0.03%		0.09%
Non-Power Activity (6:59 pm)	0.02%	0.08%	0.02%		0.11%
Away (6:59 pm)	0.00%	0.01%	0.00%		0.77%
Away, Traveling (6:59 pm)	0.04%	0.19%	0.04%	--->	**95.45%**

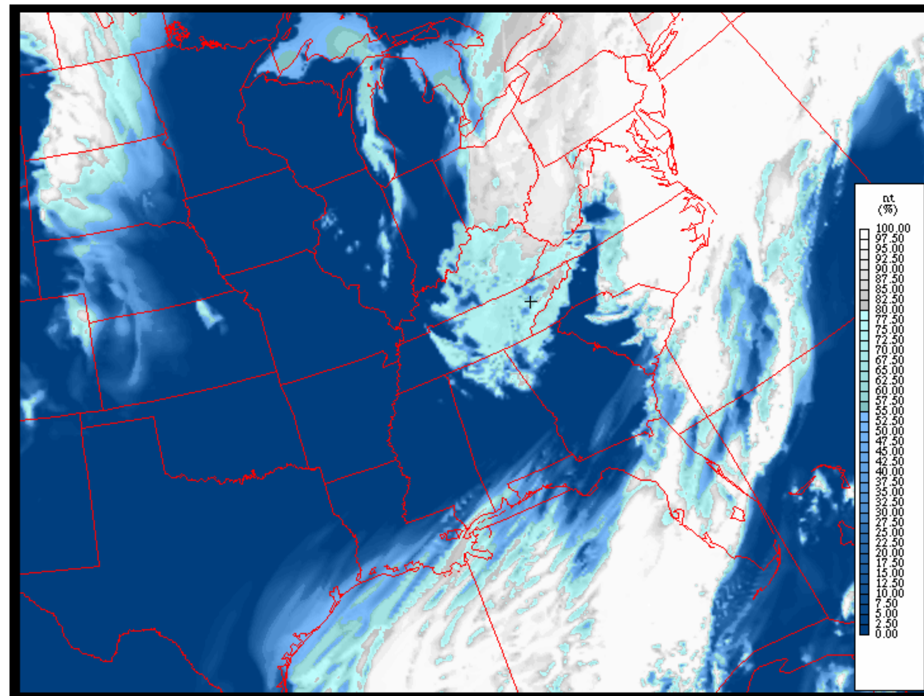
Activity Simulation

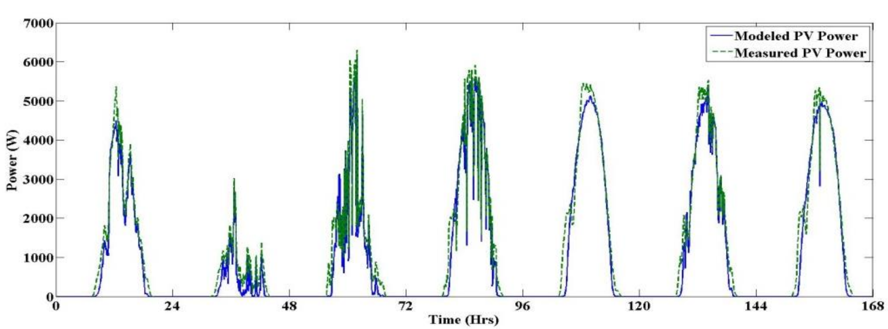


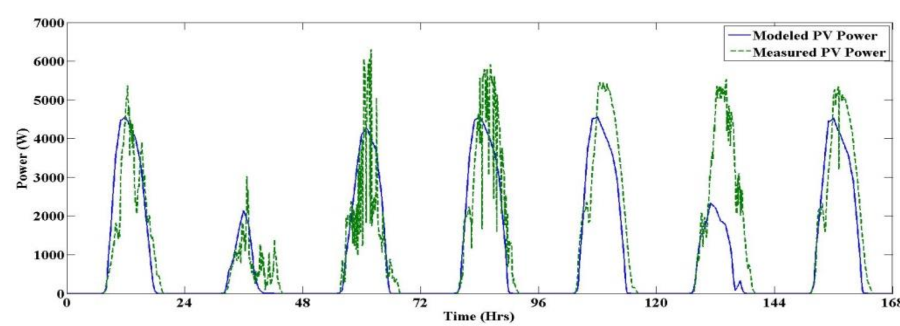
Federal Energy Management Program

PV Forecasting for Optimization







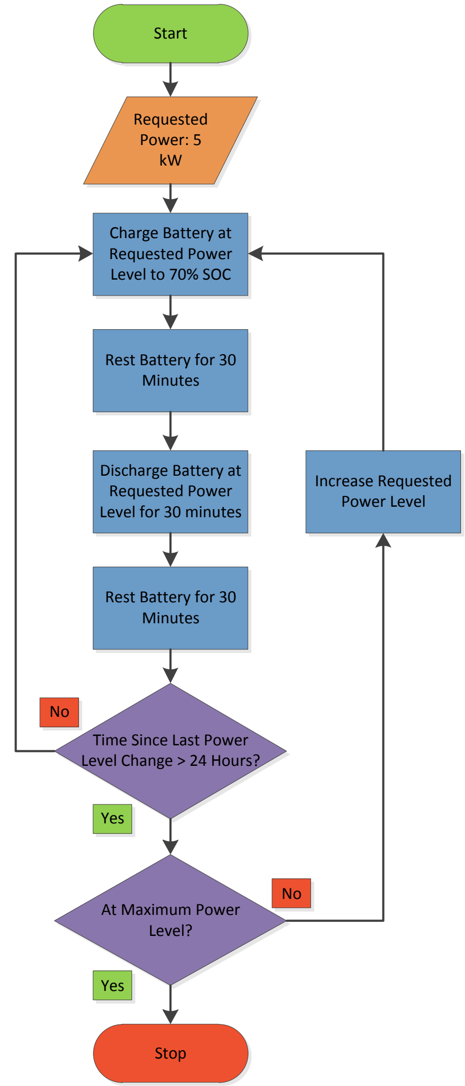


FEMP Federal Energy Management Program

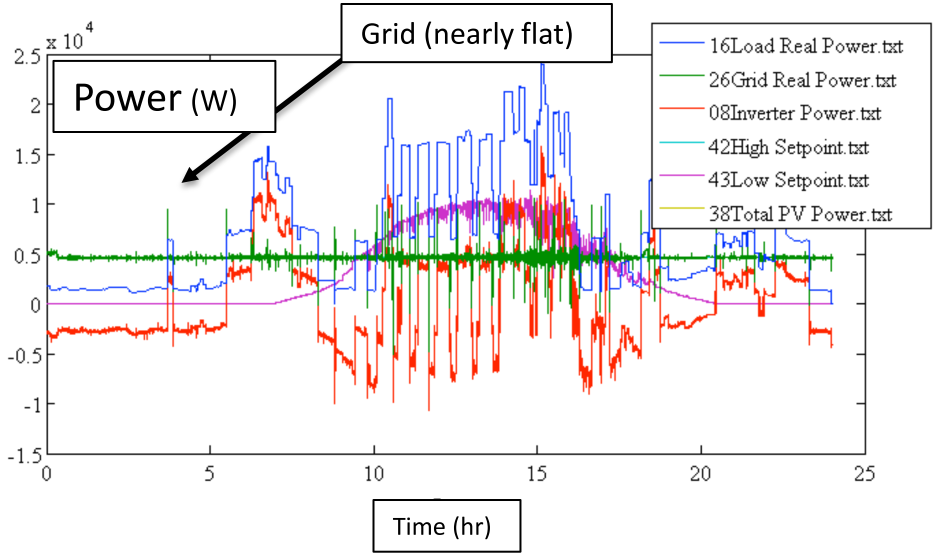
TVA

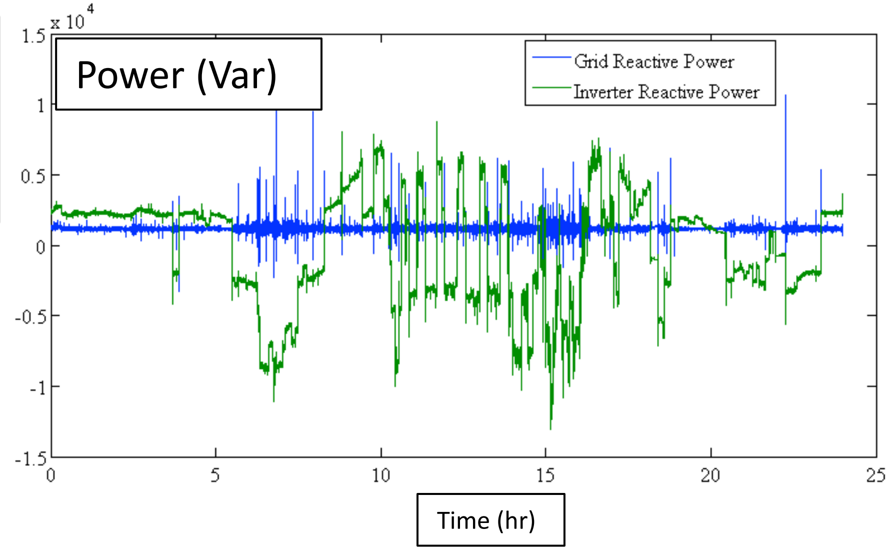
Testing Procedure (Systems Tests)

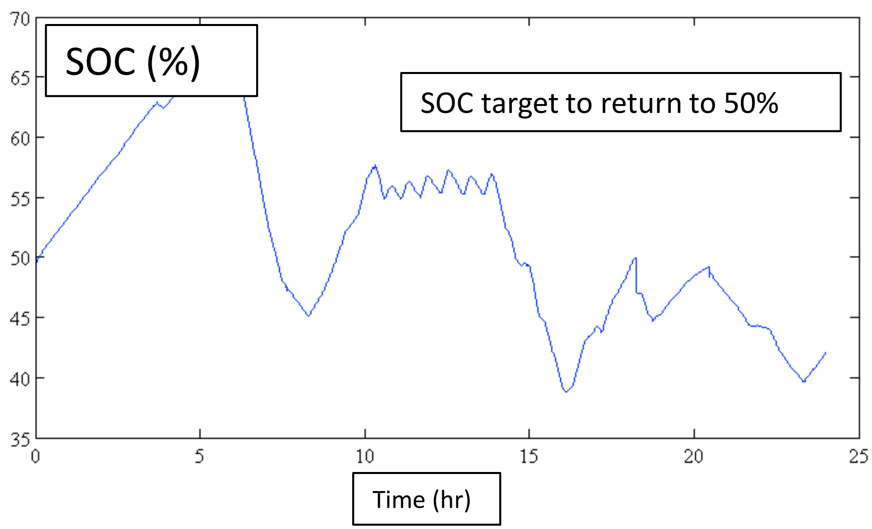
- Objectives:
  - Obtain standard metrics (round-trip efficiency/ensure within bounds of standards)
  - Demonstrate application examples
- Standard Metrics:
  - Round-trip efficiency
  - Harmonics, etc.
- Applications
  - Load factor,
  - Power factor,
  - Renewable Integration,
  - Islanding

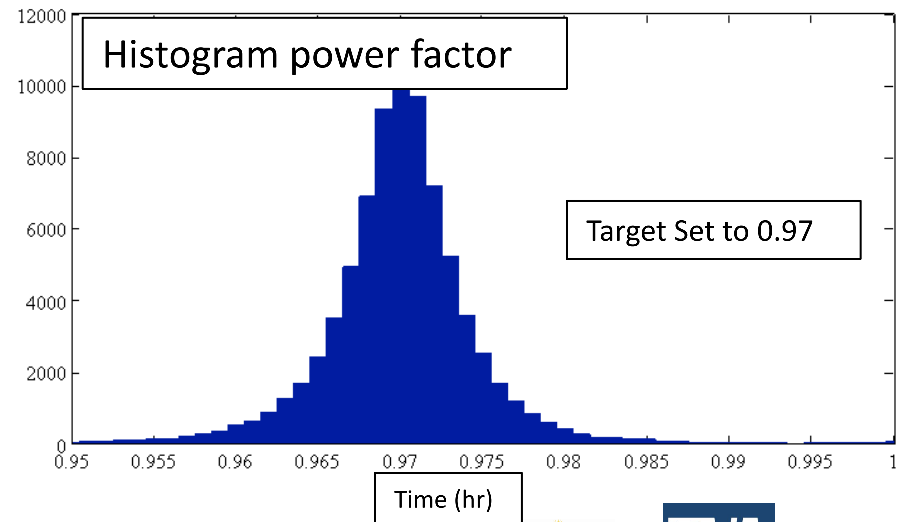


Multiple Value Streams: Stacking Benefits (Load Factor/Power Factor, Renewable Integration)





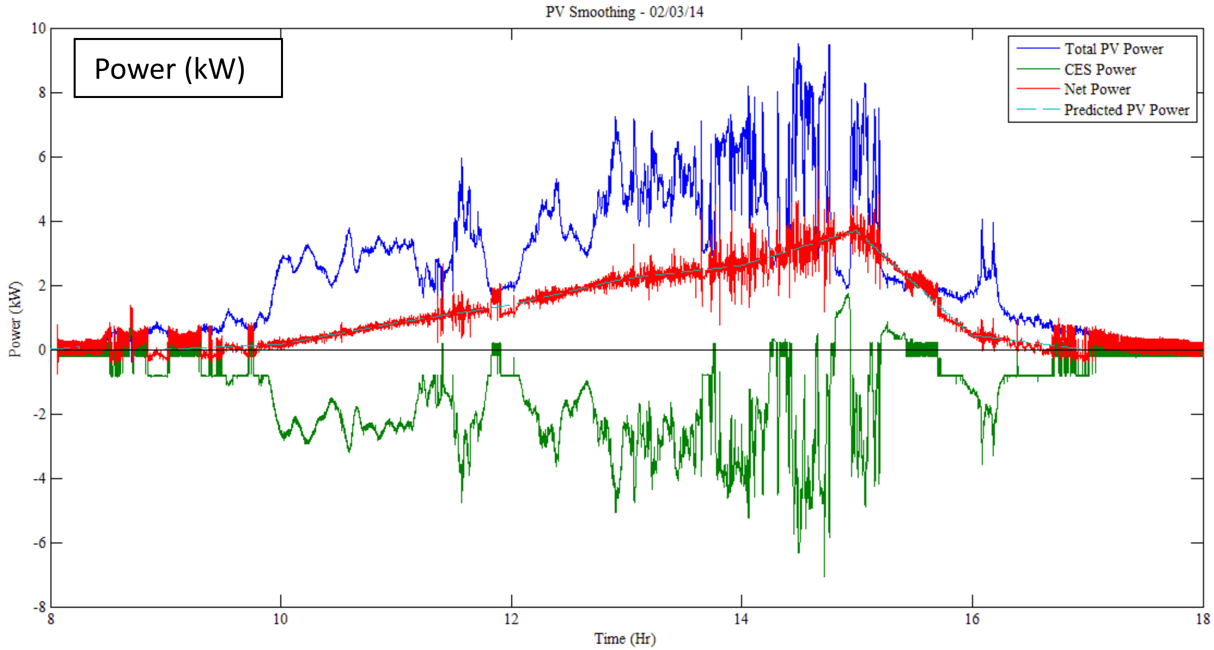


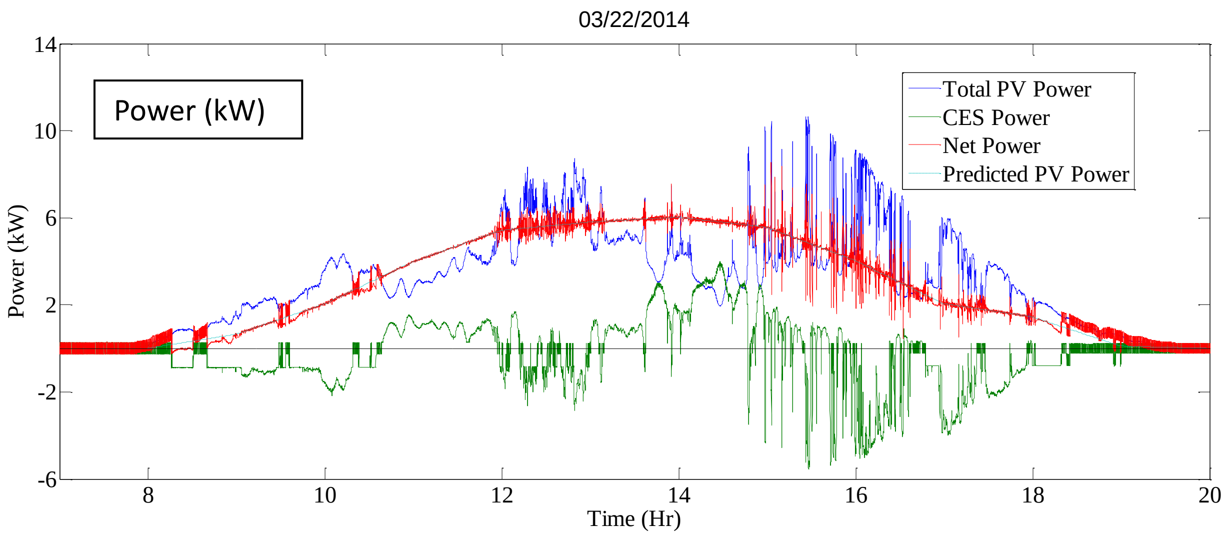


FEMP Federal Energy Management Program

TVA

TE: PV Smoothing/Capacity Firming



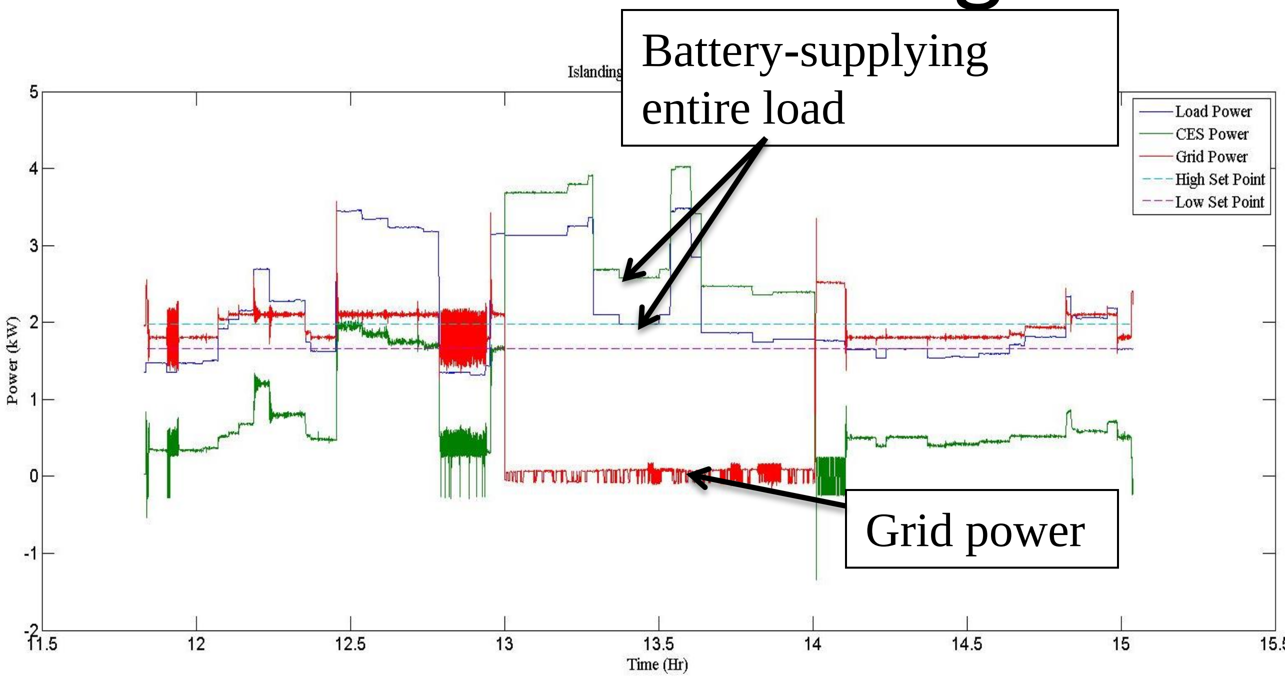


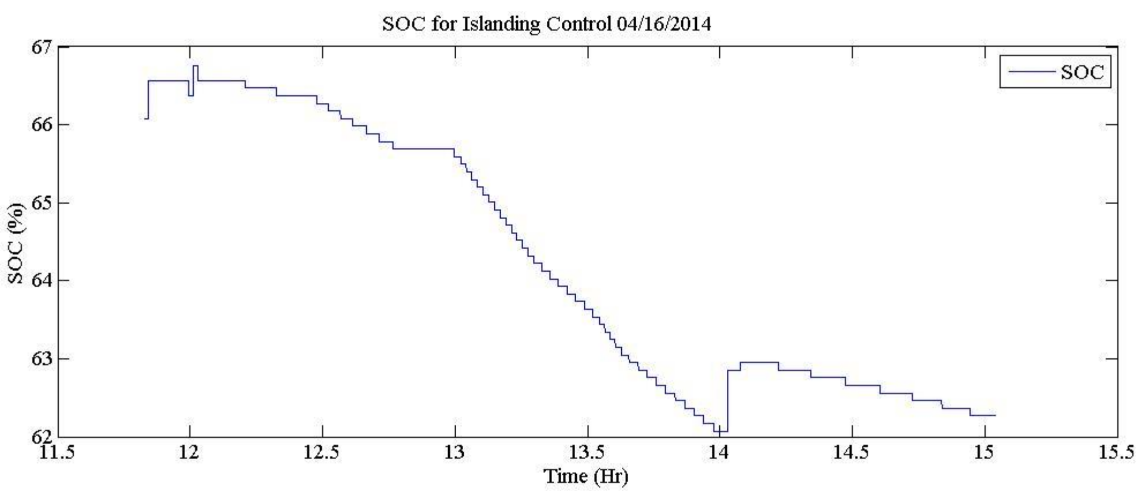
Objectives:
Integrate PV by removing oscillations and error in forecast.

Benefits:
1) Removing oscillations in PV output can impact local voltage.
2) In some cases these oscillations lead to significant tap changes in transformers. Smoothing this behavior with storage can extend transformer life.

Federal Energy Management Program

TE: Islanding Mode





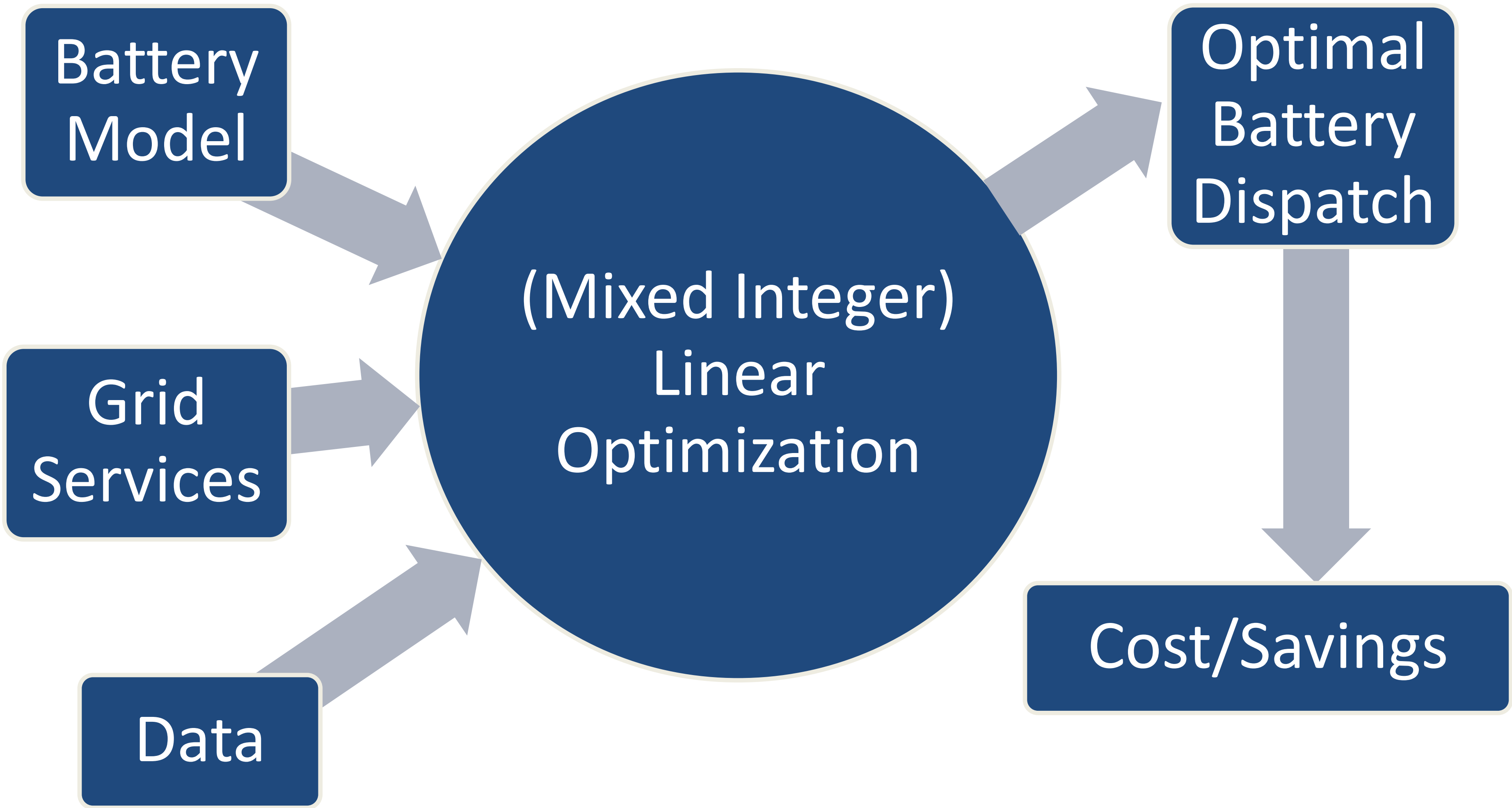
Objectives:
Utilize storage for emergency backup power

Benefits:
1) Provides power during an outage
2) Can be used to support contingency type events as well to reduce load consumption.

FEMP Federal Energy Management Program

TVA

Initial Economic Approach



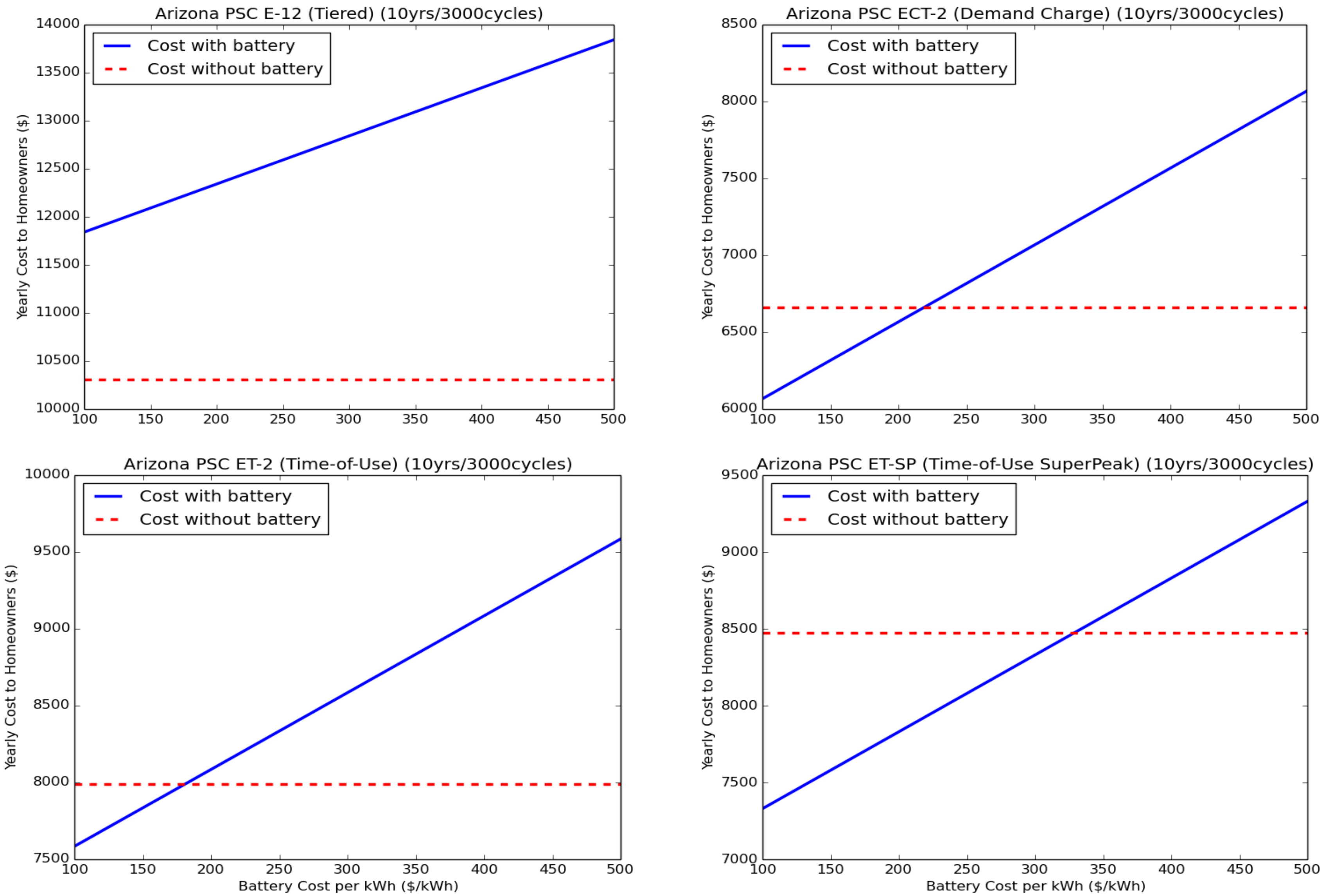
FEMP Federal Energy Management Program

TVA

Initial Economic Results

- Arizona Public Service Company residential rate structures
- Year-long simulated load for 3 homes
- Dispatch the battery to minimize the homeowners’ cost
- Utilized efficiencies of real system, 10year/3000 cycle battery

Initial Economic Results



FEMP Federal Energy Management Program

TVA

Future Tasks

- Modeling and economics assessment for DES.
- Development of refurbished secondary use ES.