Aggregation of DERs

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The Need For Better Data

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December 13, 2016

Stages of Grid Modernization

Stage	Smart Grid	DER Integration	DER Visibility	Fully Integrated Grid
Power Flow	Unidirectional	Bidirectional	Bidirectional	Multidirectional
Sensors	High	High	High	High
Behind the Meter Visibility	Limited	Low (Simulation or backcasting)	Medium	High
Behind the Meter Control	Minimal	Minimal	Low	High
PHI Progress	Integrated as Current Design	In Progress	In Progress	Future State

Current State

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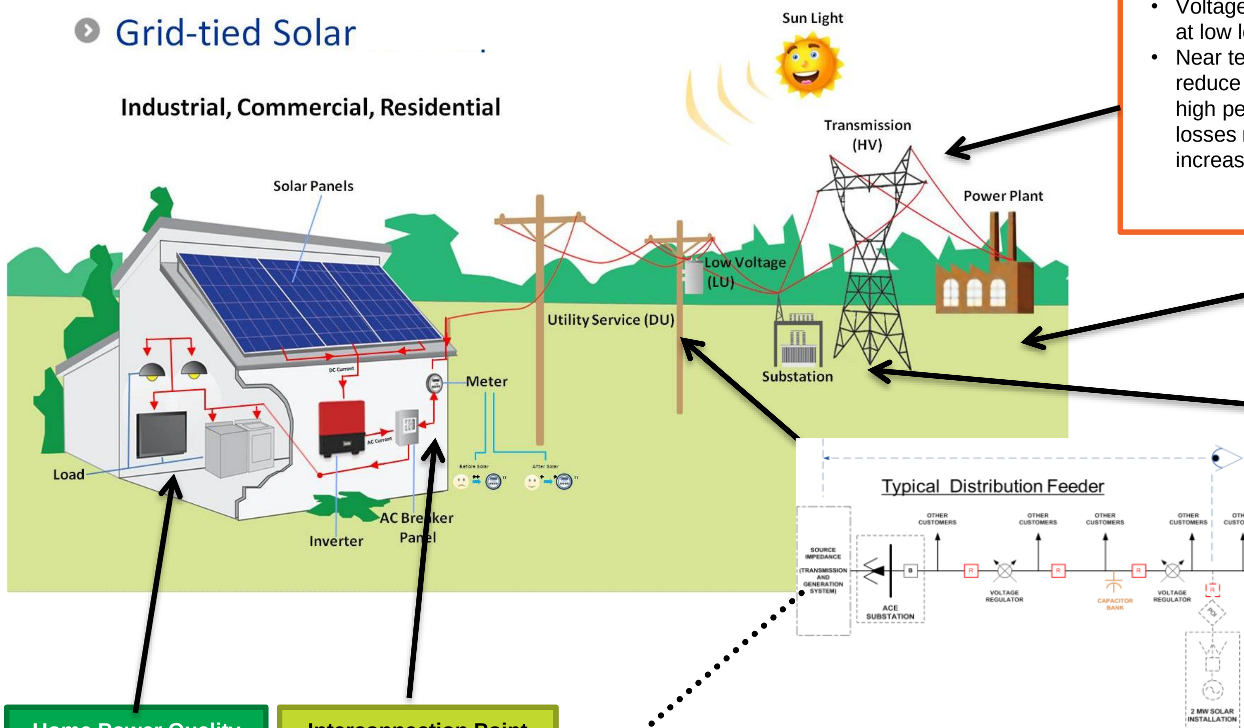
DER Affects the Entire Electric System



Transmission

- Voltage challenges at low load.
- Near term, it will reduce losses, with high penetration losses may increase

Generation

- Scheduling changes required to meet volatile load.
- May increase need for ancillary services.
- Steep ramp rate when sun goes down, impacts capacity needs

Feeder & Substation

- Increase phase unbalance for three phase circuits.
- Capacity spikes may overload equipment.

Home Power Quality

- Higher voltage caused by generation reduces efficiency of appliances and HVAC,
- Can stress appliances or motors.

Interconnection Point

- Inverters trip or cloud shear can create volatility
- Must maintain voltage within mandated bands.
- Net metering masks true load demand.

Point of Injection

- Every POI requires study to determine impacts to the system and other customers
- The customer is required to pay for the upgrades

Distribution Automation

- DER can prevent DA schemes from locating fault
- True load to be transferred not easy to calculate

Voltage

- High or low voltage can result in mis-operation, damage, or reduced equipment life – both on the grid or at premises

Safety

- Can increase fault current level
- Trip of breaker or recloser may result in inverter out of synchronization
- Reduction of protective reach

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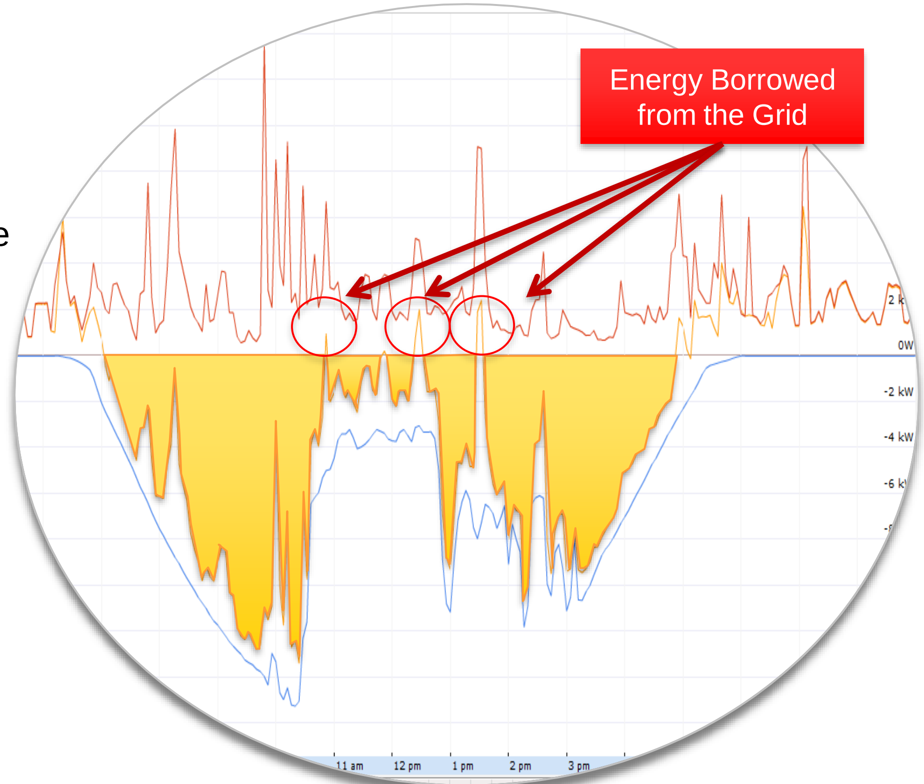
How Does DER Impact Drive the Need for Controls

Power Grid Segment	Details
Bulk Power System	Stability, Dispatch of generation, ramp rate control, Ancillary Services such as Frequency Regulation
Transmission System	Control power flow, voltages, VAR flow, state estimation and contingency mitigation, protection
Substation	Control transformer and bus loading, Voltage Regulation, mitigate reverse power flow, protection
Distribution System	Voltage regulation, Capacitor control, coordination and protection, Distribution Automation Schemes, phase balance
Premise	Load, generation and storage control, Demand response, real time pricing, avoid overload on service transformer or secondary lines, and/or elevated voltages due to export

Higher Resolution Data Shows the Value of the Grid

- 1 Second Data provides a clearer picture of the transactional nature of DG
- This is for a 19 KW residential System
- While this larger residential PV system produces more than the load much of the time when the sun is out, there are a number of times during the day: morning and evening, during cloud shear, or during high premise loading that still require power being supplied by the grid
- For average sized systems (~5KW) this situation would be higher in both frequency and magnitude



STEVE STEFFEL
Account number: [redacted]

Your electric and gas bill for the period
November 4, 2013 to December 5, 2013

Details of your Electric Charges

Residential Service – service number [redacted]
Electricity you used this period

Meter Number Energy Type	Current Reading	Previous Reading	Difference	Multiplier	Total Use
NKA076656866 Usage (kWh)	Dec 5 987635 (actual)	Nov 4 987515 (actual)	120	1	120

Your next meter reading is scheduled for January 6, 2014

Delivery Charges: These charges reflect the cost of bringing electricity to you. Current charges for 31 days, **winter rates in effect.**

Type of charge	How we calculate this charge	Amount($)
Customer Charge		10.89
Total Electric Delivery Charges		**10.89**

Supply Charges: These charges reflect the cost of producing electricity for you. You can compare this part of your bill to offers from competitive suppliers. The class average annual price to compare is 10.35 cents per kWh.

Total Electric Charges - Residential Service	10.89

Excess Generation Summary

Credit kWh Balance from Your Last Bill	-553
Adjustment to Prior Month	0
Current Month KWH	120
Total kWh Balance	-433
Credit kWh Expired on Anniversary	0
Current Net kWh Balance	-433

Electric Summary

Balance from your last bill	$563.98-
Transferred Balance	$75.57
Changes to electric balance	$75.57
Payment Nov 13	$13.18-
Total Payments	**$13.18-**
Electric Charges (Residential Service)	$10.89
New electric charges	**$10.89**
Total Credit Amount	**$490.70-**

Transferred Balance: Refers to revenue transferred to or from your account(s).

Total System Size :19KW **(Average System Size 5 KW)**

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Mitigating DER Impacts

Feeder Improvements
Base Case: circuit as-is (existing PV included)
Balanced: phase balancing performed on the base case
Capacitor Design: moves existing or places additional capacitors in order to flatten feeder voltage profile and optimize the capacitor placement
Reduced Voltage Settings: voltage regulation and LTC set-points lowered as far as possible while still maintaining acceptable customer voltages at peak load.
Dynamic Voltage Control: voltage regulation and LTC set-points are adjusted over time to be as low as possible while still maintaining acceptable customer voltages at each time point (i.e. using FSMA tool to determine optimal Vreg settings over time).
Fixed PF: power factor of randomly placed inverters are set to a fixed, absorbing power factor of 0.98. Existing PV sites are unmodified (i.e. all new PV on feeder required to operate at 0.98 absorbing).
Battery Storage: battery storage in a daily charge/discharge schedule is added to circuit in order to add effective load at peak PV production times.

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Central Controls

- Transmission and Substation have a Significant Amount of Automation
- The Distribution System will Require Significant Additions in Monitoring and Controls to Accommodate Higher Penetration of DERs. Some examples:
  - Automated Metering Infrastructure
  - Voltage Regulator and Capacitor Controls
  - Central Volt/VAR Controls
  - Telemetry to all DERs
  - Central Monitoring and Control of all DERs
  - Flexible Load Control
  - Distribution Automation
  - Central/Distributed Analysis

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Activities Underway to Help Accommodate Increased DER

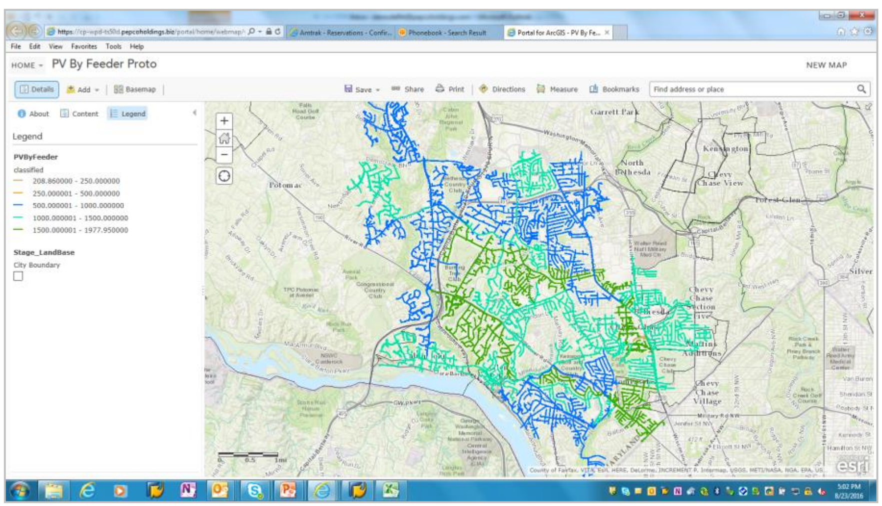
Customer Facing Improvements:

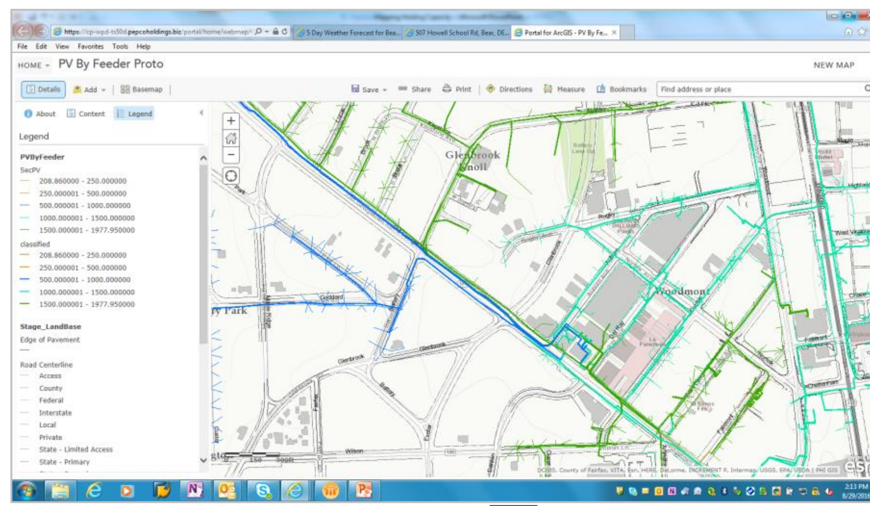
- Online application portal released March 2016, improves the accuracy and speed of processing, improves customer experience, provides real-time customer usage data over request portal for contractors
- Green Button Standard for usage data
- My Account Functionality

Modelling & Analytics: Advanced load flow being implemented, developing the capability for publishing hosting capacity to the customer level

Collaborative R & D: Inverter technology, advanced voltage regulation control, penetration studies with a variety of different partners, leveraging AMI backbone, integrating PV data into DA schemes, implementing cellular telemetry.

DER Integration into Planning: Demand Response Programs (PJM, DLC, Peak Energy Savings); Energy Efficiency Programs (Management Tools, Conservation Voltage Control, Residential Energy Efficiency, C&I Efficiency and Conservation); Distributed Generation (NEM, Non-NEM PV, Other DG)





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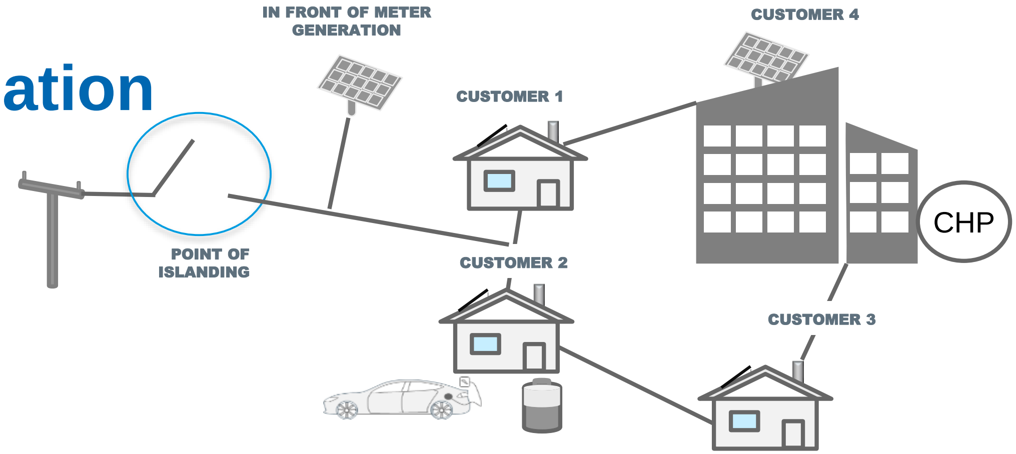
Technologies Under Evaluation



Storage

Design Considerations
- Connection Point
- Inverter Type & Functionality
- PJM Market Interaction
- Discharge rules for NEM net-exporter

Challenges
- Variable battery technical and operating characteristics
- Degradation
- Customer usage protocols

Electric Vehicles Infrastructure

Grid Investment Required for Large-Scale EV Adoption
- At-Home Charging
- Public and semi-public EV supply equipment

Utility's Role
- Maintaining Reliability
- Existing Smart Grid investments and equipment
- System knowledge and customer fairness
- Customer interface experience and education

Microgrids

Campus Microgrids
- Owned and operated by a single customer.
- Owner has complete responsibility for the operation, maintenance and performance of the system.

Public-Sited Microgrids
- Serve multiple customers.
- Owner of the generation will likely be different than the customers served by the microgrid.

MergerCommitments

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Campus Microgrid Project – Chesapeake College

- Started as a solar DER system on a high penetrations feeder
- Delmarva applied for, and received, $250K grant from MEA or installing batteries to help mitigate the effects on the Distribution System
- College is identifying critical loads to create microgrid

PV System

Size: 2.18 MW DC, 1.76 MW AC

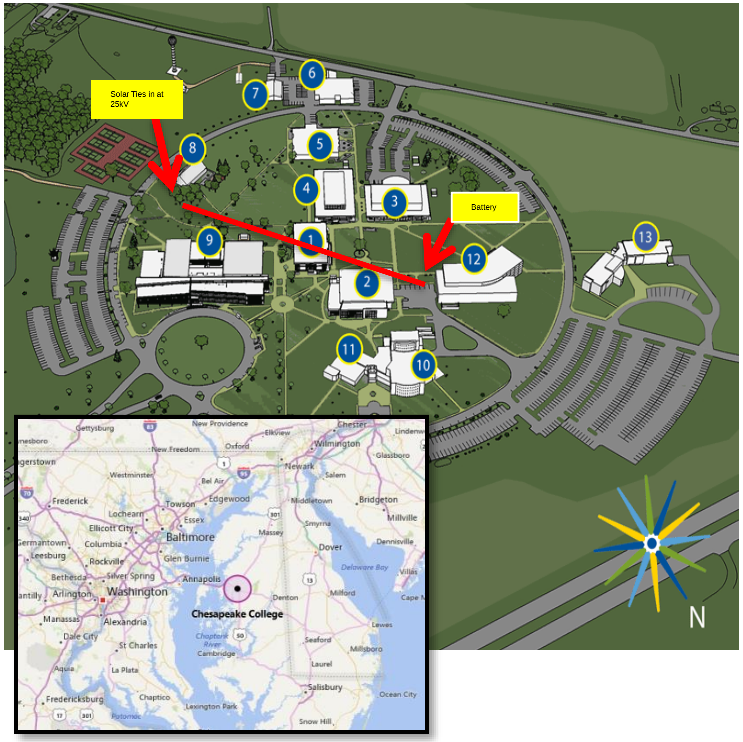
Installer/Owner: Solar City

Inverters: Solectria (with smart inverter functions)

Output from inverter will be 480V then tied to 480/25kV transformer to step up to 25kV

System is split into a 1,464 kW ground mount array and 300 kW carport with EV charging capability

In-service date: May 2016



Building Loads to Back Up:

2 – Caroline Center

12 – Learning Resource Center

The College has a 25kV system for the campus with switchgear connecting to DPL in Bldg 12

Distance from Solar Tie in at 25kV to where Battery System will be located (shown as red line) is about 2,000'

Battery System

Proposed size is 500kW, 250kWh (half hour battery)

Installer/Owner: AF Mensah

Battery and PV system will have separate inverters for independent operation

Electrical interconnection design to be proposed by AF Mensah

Next Steps

Work with Solar City, AF Mensah, and Chesapeake College to develop final design and present to appropriate stakeholders

Develop project charter and project plan

Finalize central and local control strategy after selecting Central Control vendor

Develop any needed contracts/agreements

Urban Microgrid

- Proposing a renewable and sustainable microgrid to provide reliable supply for an urban complex development:
  - 10-20% green power production from roof-top solar PV systems on buildings
  - Supplying the customers during power outages
  - Incorporating innovative technologies such as: Energy Storage, EV chargers, energy conservation schemes

Retail stores
Hotel
Residence
Parking

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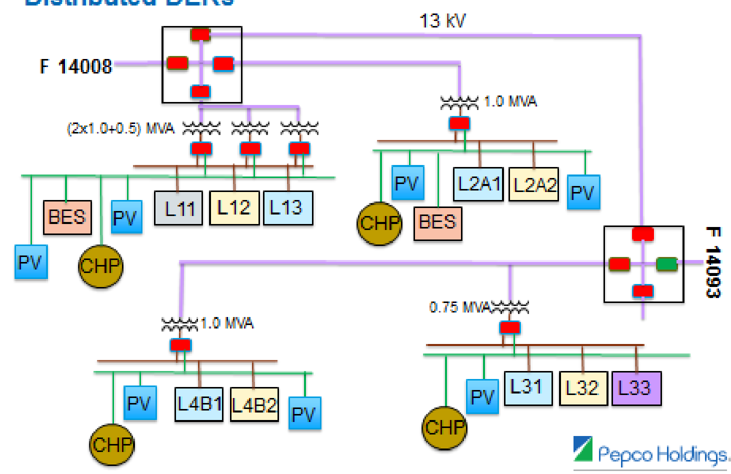
Possible Urban Microgrid Configuration

- 5MW Total Load
- Combination of generation
  - PV
  - CHP
  - Fuel Cell
  - Battery Storage
- Interconnection to OH Radial Feeders

	Power Consumption					Power Generation			
	Peak per building (MW)		Minimum per building (MW)		Annual Demand (MWh)	PV (MW)	CHP (kW)	Fuel Cell (kW)	Energy Storage
Building #	Summer	Winter	Summer	Winter					
Building1	2.112	1.307	0.989	1.056	13461.25	1.073	1000 + 600		500 kW / 2 hr
Building 2	0.430	0.252	0.243	0.165	2506.37	0.122	600		
Building 3	0.180	0.191	0.101	0.125	860.44	0.074			
Building 4	0.491	0.469	0.277	0.333	2452.26	0.142	600		
Building 5	0.038	0.024	0.022	0.022	514.24				
Building 6	0.194	0.124	0.119	0.112	1315.96				
Building 7	0.210	0.158	0.131	0.128	1468.43	0.058	800		
Building 8	0.535	0.520	0.299	0.364	2817.82	0.115			
Building 9	0.535	0.412	0.312	0.324	5139.30	0.083		400	250 kW / 2 hr

Option 1: Radial feeders, De-centralized Generation

Grid Connection: Op1 – HV connection, Radial feeders & Distributed DERs



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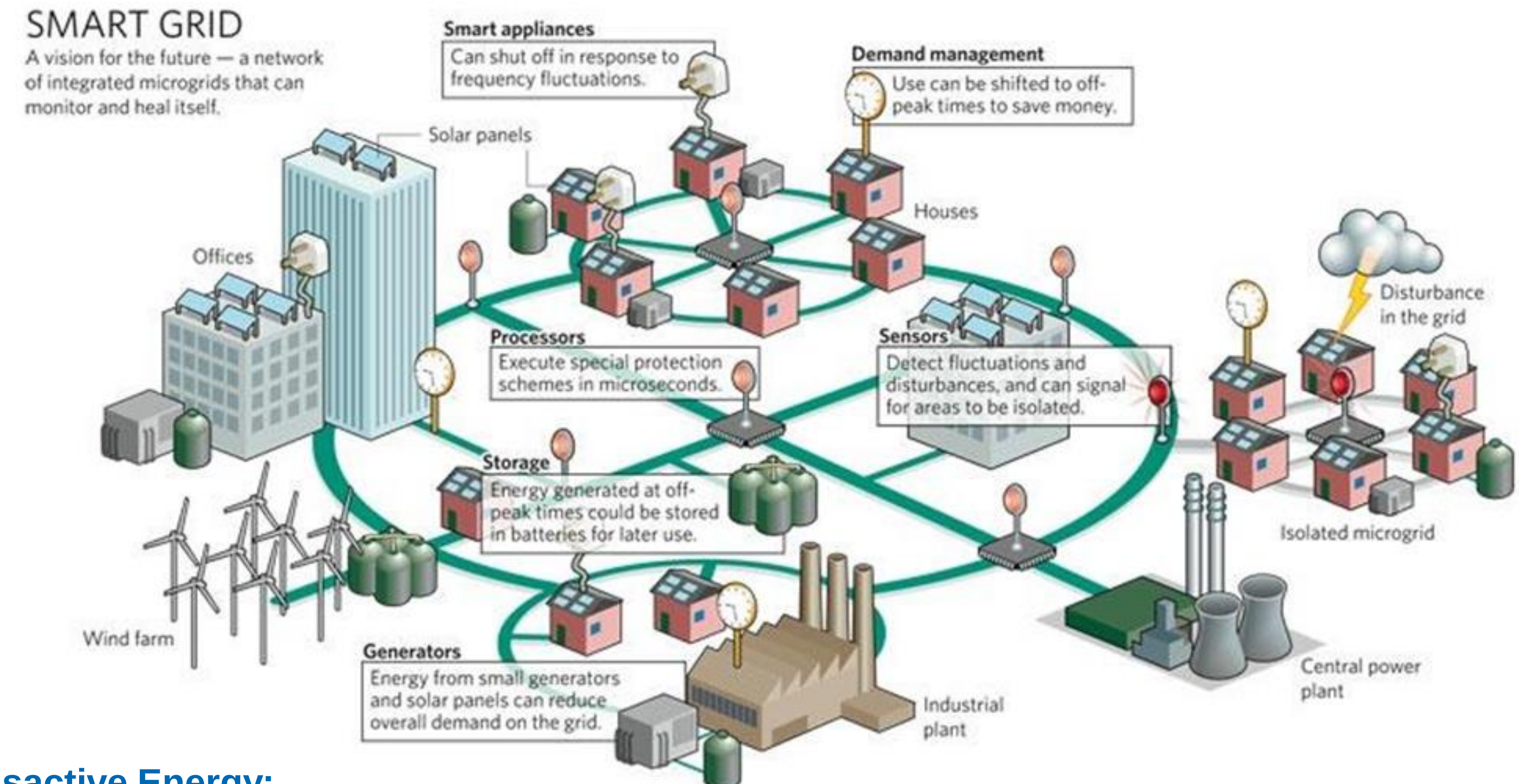
Distribution System of the Future

- With the increase of distributed and community-scale generation, energy storage, and potential new capacity loads (i.e., electric vehicle), existing distribution systems will need to change in order to manage a load that is less predicable than in the past. Distribution systems of the future will not only require internal investment in controls, but also will need to integrate with smaller networks across the larger grid and be able to monitor and dispatch small scale distributed generation.



Transactive Energy:

A system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter.

Source: Gridwise Alliance

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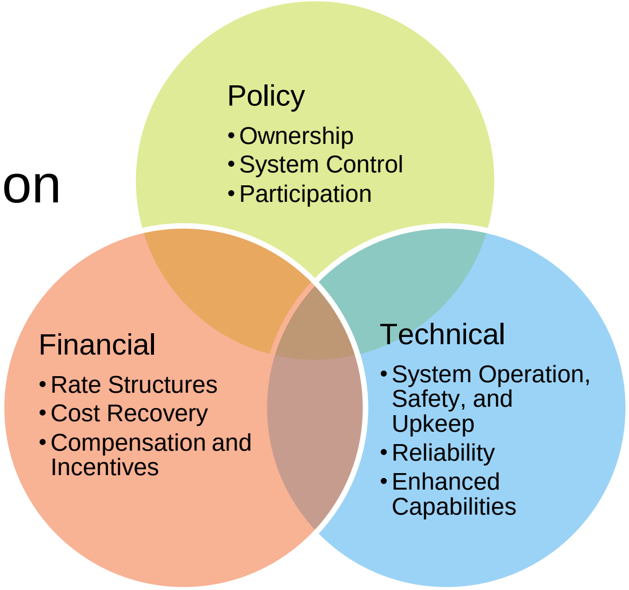
Points to Consider…



- Planning and Operating the future Distribution Grid will become more complicated
  - Higher penetrations of DER
  - Deployment of storage
  - Microgrids
  - Electric Vehicles / Vehicle to Grid
  - Advanced Demand Response
- Distribution System Operators will need to manage the Distribution System using a much higher level of visibility, control and automation
  - Control, Measure, Dispatch, Protect, Optimize
- In order to maximize the amount of DER connected to the grid, the way systems are operated and dispatched will need to be better understood

PHI is eager to support the future transactive grid with expertise, system knowledge, and technical capability.

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