Japan – United States Island Smart Grid Demonstration Project

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February 17, 2011
Kawasaki, Japan

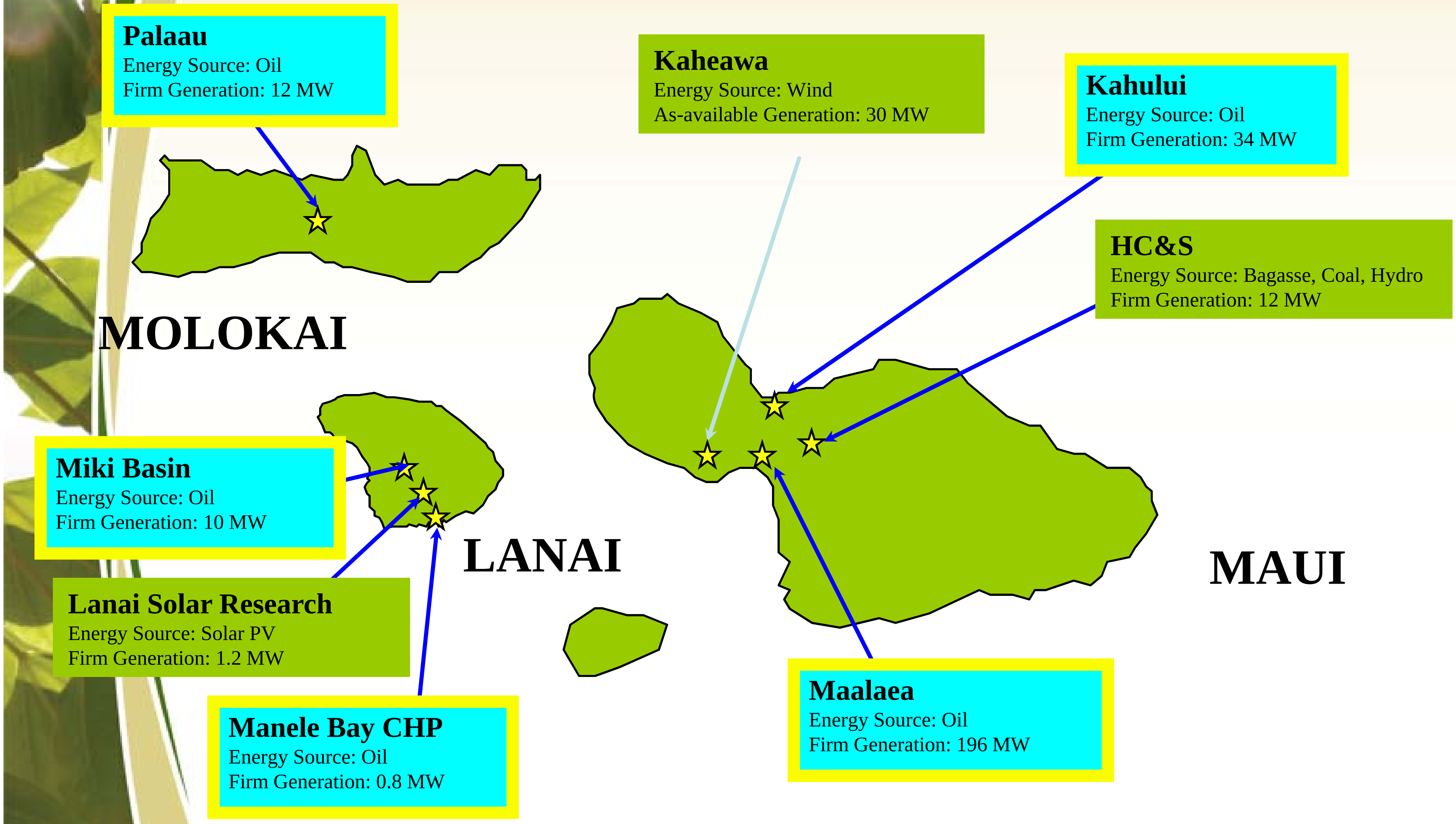
Hawaiian Electric Company Overview

- Hawaiian Electric Company (HECO)
  - Maui Electric Company (MECO)
  - Hawaii Electric Light Company (HELCO)
- Locally owned and operated
- Vertically Integrated Regulated Investor Owned Utility
- 400,000 customers (Oahu, Maui County, Hawaii)
- Each Island system is an independent autonomous grid

Maui

- 63,000 Customers
- 190 MW Peak - 90 MW Minimum Load
- 242 MW Firm Generation
- EMS/AGC controlled
- 12 MW biomass
- 30 MW wind farm
- 21 MW wind PPA just approved by PUC
- 21 MW additional wind proposed
- 2 MW wave generation in development
- Several 2 MW PV proposals have been submitted
- High growth rate in distributed PV

Maui, Molokai and Lanai Electricity Generation



Palaau
Energy Source: Oil
Firm Generation: 12 MW

Kaheawa
Energy Source: Wind
As-available Generation: 30 MW

Kahului
Energy Source: Oil
Firm Generation: 34 MW

HC&S
Energy Source: Bagasse, Coal, Hydro
Firm Generation: 12 MW

Miki Basin
Energy Source: Oil
Firm Generation: 10 MW

Lanai Solar Research
Energy Source: Solar PV
Firm Generation: 1.2 MW

Manele Bay CHP
Energy Source: Oil
Firm Generation: 0.8 MW

Maalaea
Energy Source: Oil
Firm Generation: 196 MW

Issues Facing Hawaii Grids

- Balancing and Frequency regulation
- Ride-Through
- Anti-Islanding
- Reserve Requirements
- Excess Energy

Hawaiian Islands
PV Penetration Overview

	HELCO	MECO			HECO
	Big Island	Maui	Molokai	Lanai	Oahu
Installed/Pre-Approved PV (kW)	9,070	6,320	472	1,223	19,600
2009 Peak Load (MW)	173	200	5.9	4.7	1200
Island PV Penetration (%)	5.2%	3.2%	7.9%	26%	1.6%

Japan – United States
Island Smart Grid Demonstration Project

- Objectives
  - Build the capability to integrate more renewable energy while managing costs
  - Leverage external resources to test new smart grid technologies and concepts in Hawaii
  - Enhance grid operability and reliability
  - Ensure cyber security

Project Thesis

Our challenge

- Rapid growth in distributed PV and potential rapid growth of EV with limited knowledge of the most effective means to manage the impacts and enable increased levels each

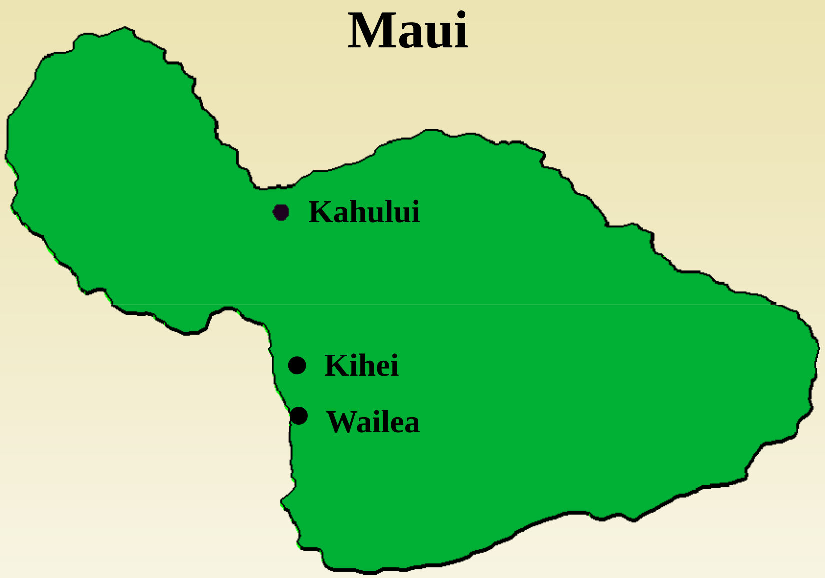
Thesis

- Distributed PV and EV can be most effectively managed with “smarts” first embedded closest to the resource, then at the distribution feeder and substation level, yielding reduced impacts and aggregated information managed at the utility operations control center

Issues to Address

- Power output variability
  - System frequency impact
  - Distribution feeder voltage
- Over-voltage under high PV output / low load conditions
  - Power quality / PV trip events
- Over/under-voltage and frequency ride-through
  - Grid integrity
- Anti-islanding
  - Safety and protection of customer equipment
- EV charge management
  - Use as a resource to manage local and system variability
  - Manage Charging to manage circuit and transformer overloads
- Localized Feeder monitoring and control
  - Enhance operator visibility
  - Minimize operator intervention
- Customer engagement, acceptance and feedback

Project Location



Japan – U.S. SG Project will manage the 5 circuits @ Kihei Sub

2 circuits will be used to implement µDMS control systems at the transformer level

Kihei Substation ≈ 9,300 homes / 25 MW

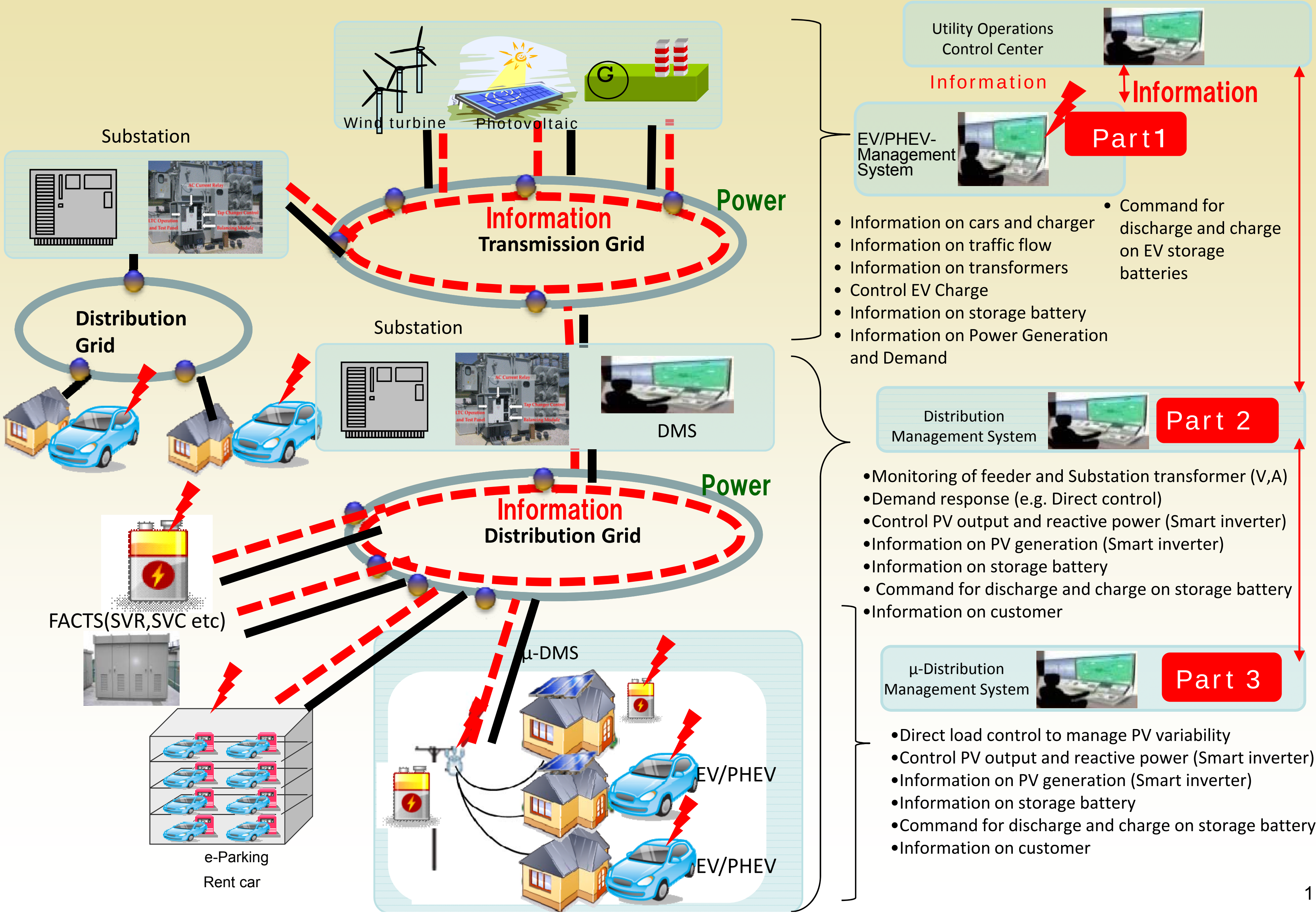
Ranging from 1,500 to 6,800 homes per circuit

RDSI Project will use 2 circuits @ Wailea Sub. - circuits 1517 and 1518

Ckt 1517: 500+ homes

Other circuit with resorts and commercial

Project Architecture



- Information on cars and charger
- Information on traffic flow
- Information on transformers
- Control EV Charge
- Information on storage battery
- Information on Power Generation and Demand

- Command for discharge and charge on EV storage batteries

- Monitoring of feeder and Substation transformer (V,A)
- Demand response (e.g. Direct control)
- Control PV output and reactive power (Smart inverter)
- Information on PV generation (Smart inverter)
- Information on storage battery
- Command for discharge and charge on storage battery
- Information on customer

- Direct load control to manage PV variability
- Control PV output and reactive power (Smart inverter)
- Information on PV generation (Smart inverter)
- Information on storage battery
- Command for discharge and charge on storage battery
- Information on customer

Part 1

EV/PHEV Management System

- One (1) EV Management System to manage system power balance and estimate transformer EV usage
  - Power balancing through:
    - Automatic frequency control
    - Manual control from Utility Operations Center
  - Control Battery Energy Storage (500 KW to 1,000 KW) used to simulate Electric Vehicles

Part 2

Distribution Management System

- Remotely monitor and control the five (5) Kihei Substation Distribution Circuits through terminal devices
- Control power variability and circuit voltages on two Kihei Substation Circuits.
- Communicate with at least two (2) µ-Distribution Management systems (µDMS) on the two Kihei Substation circuits. Incorporate µDMS information into DMS control scheme
- Mitigate voltage and variability issues not mitigated by µDMS.
- Provide Demand-Response functions incorporated with µDMS and/or other devices. The details shall be proposed by the contractor
- Control Smart Inverters (5 to 10) and Community Battery Energy Storage Systems (500 KW to 1,000 KW)
- Communicate with terminal devices to perform “SCADA” (Supervisory Control And Data Acquisition) function.

Part 3

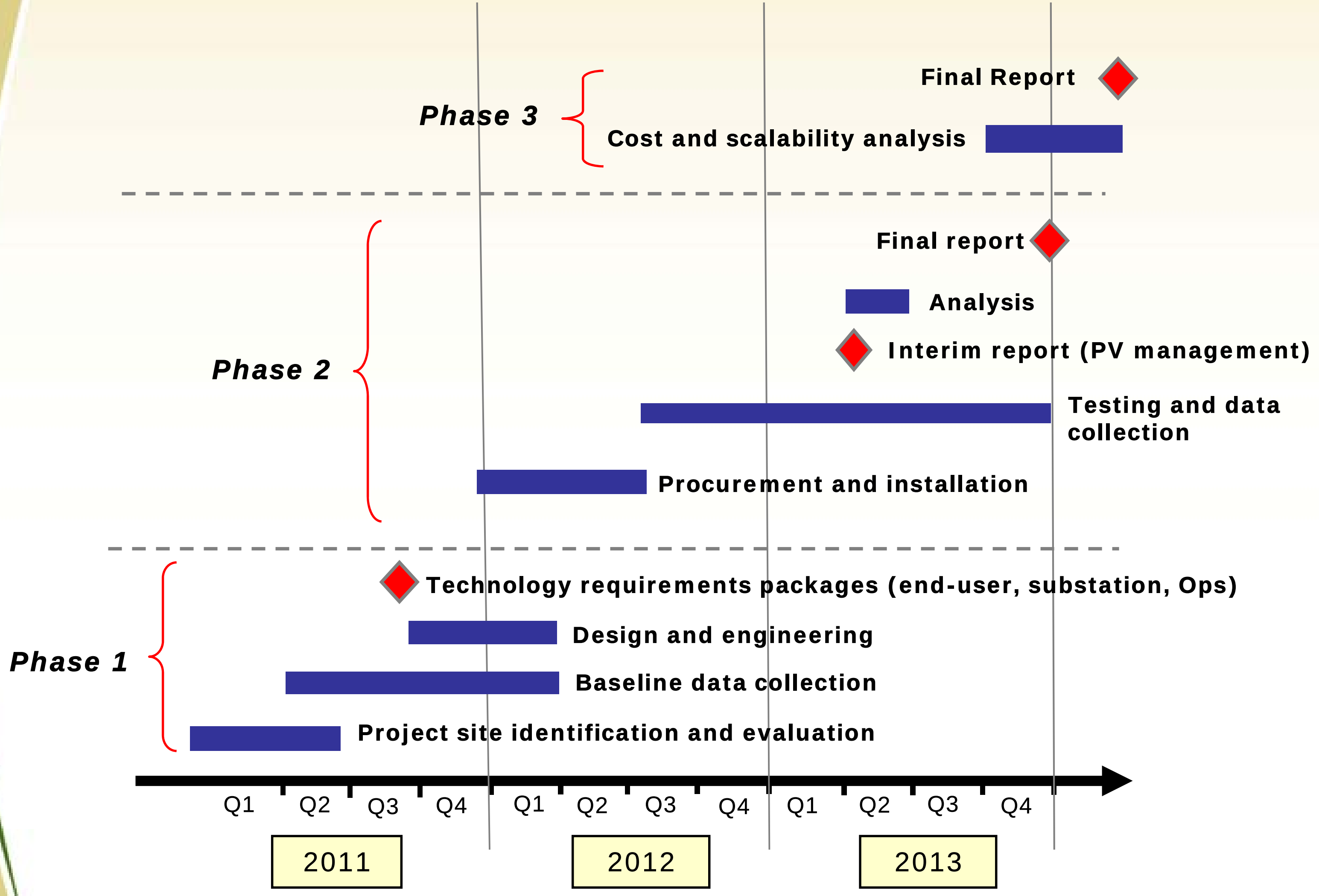
µ-Distribution Management System

- At least two (2) µDMS installed on Kihei substation circuits to monitor and control the power variability by managing PV, EV, and other distribution resources connected to a pole top transformer.
- One (1) µDMS installed on a Wailea circuit to perform the same functions and communicate with a GE DMS
- Eliminate overload and overvoltage at distribution transformer and customer services.
- Monitor and control PV, smart inverters, HEMS (if applicable), PCS/Battery and EV, which connect to a lower voltage side of a transformer
- Perform Demand-Response function including demand control function communicating with DMS.

Project Process

- Model existing circuits, PV, and load resources
- Add Smart Inverters and EV Systems to model and identify issues to be addressed and propose systems and equipment to be installed
- Install equipment and control systems to prove concepts and gather information and validate model information

Project Milestones and Schedule



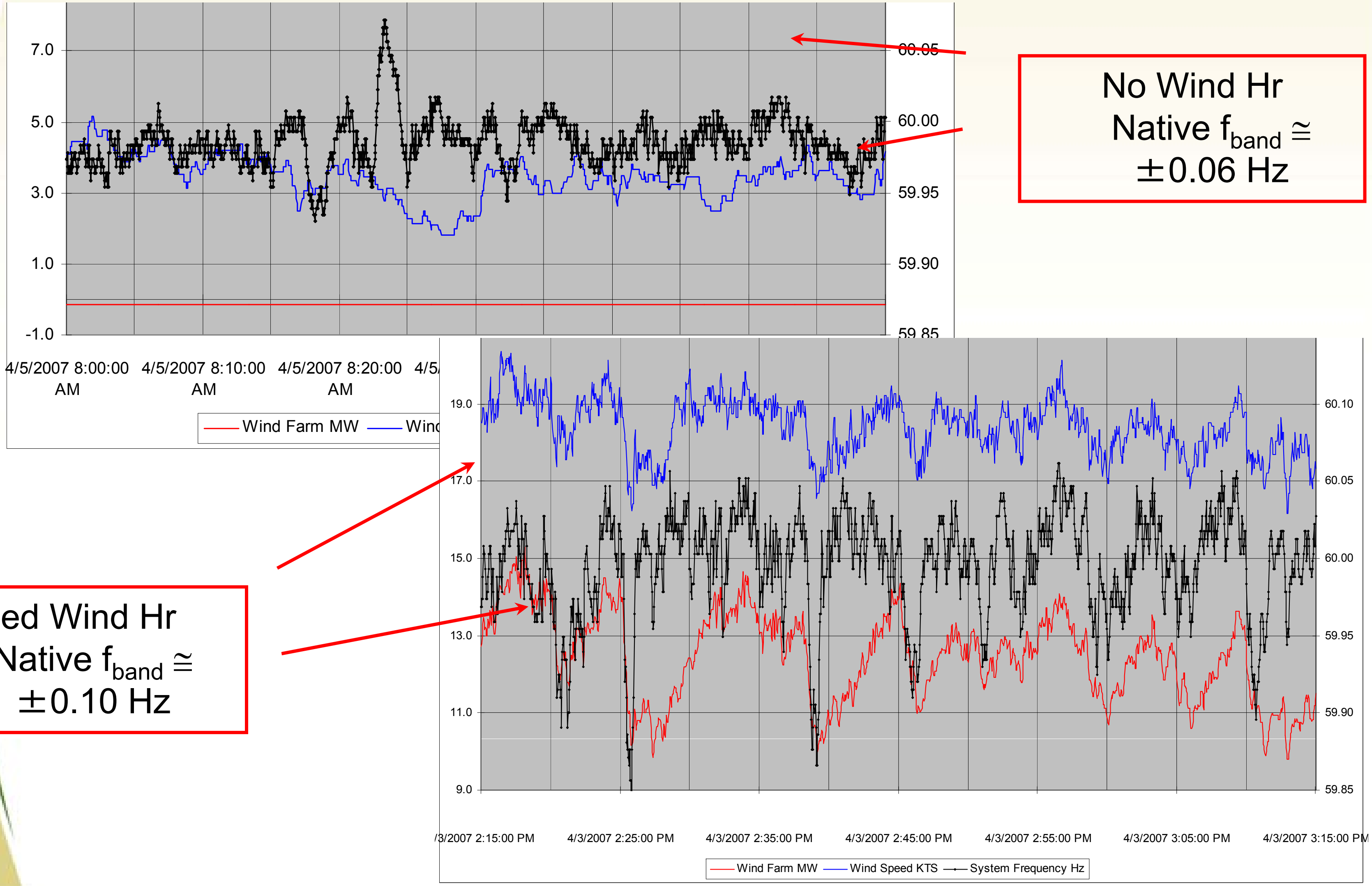
Thank You

Back-up Slides

Issues Facing Hawaii Grids

- Balancing and Frequency regulation
  - Variable generation increases AGC control actions
  - High variability can cause AGC to over correct
  - High variability can cause the system to be off normal frequency more often.
  - Larger reserves can help with this, but at a cost
  - http://www.nerc.com/docs/oc/rs/NERC_Balancing_and_Frequency_Control_Part_1_9Nov2009_(Revision2).pdf
  - *“Frequency can therefore be thought of as the pulse of the grid and a fundamental indicator of the health of the power system”.*

Second-to-second variability

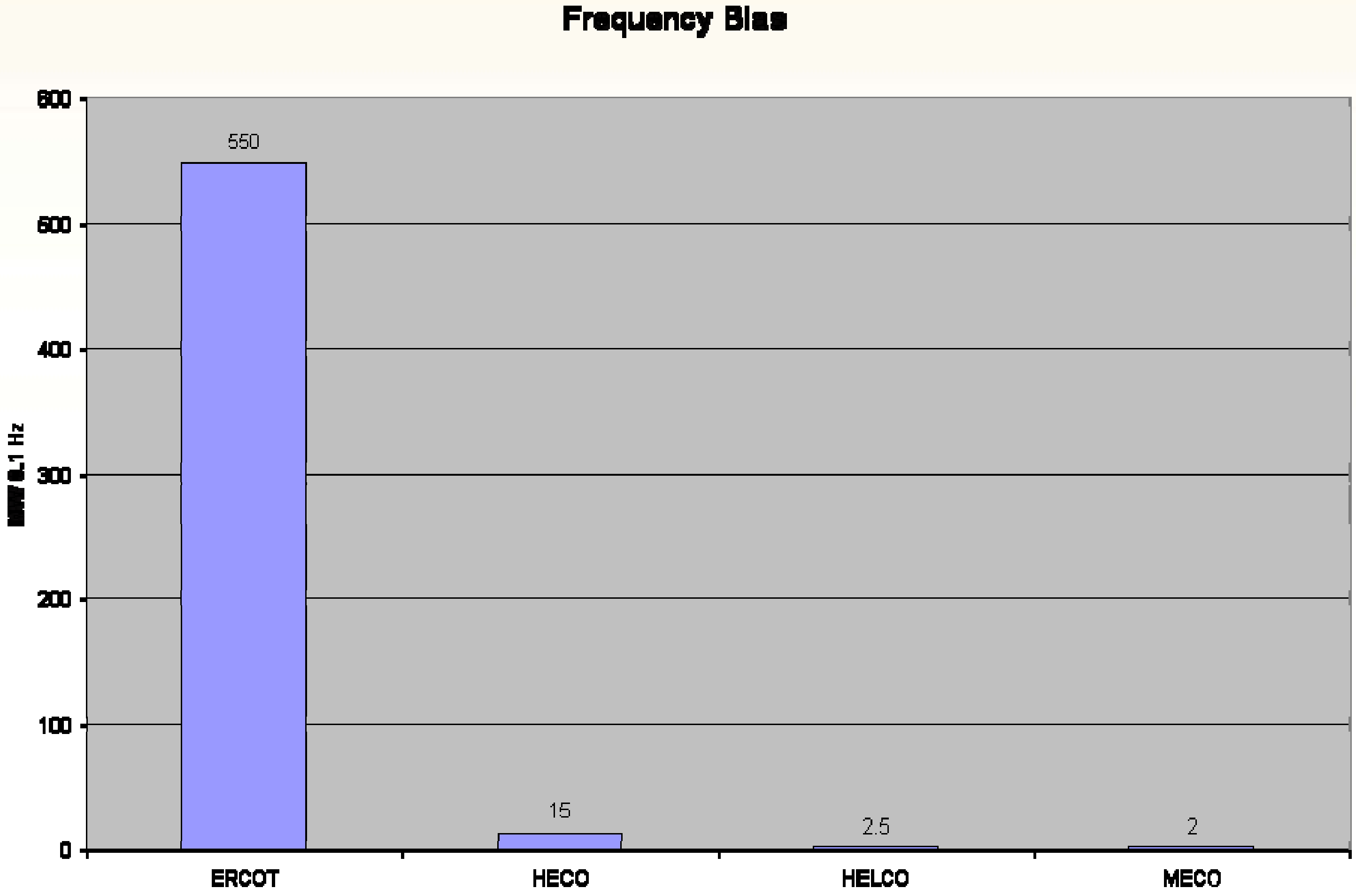


No Wind Hr
Native f_{band} ≅
±0.06 Hz

Med Wind Hr
Native f_{band} ≅
±0.10 Hz

Issues Facing Hawaii Grids

- Balancing and Frequency regulation



Issues Facing Hawaii Grids

- Balancing and Frequency regulation
  - Utilities are working with their units to improve stability and responsiveness
  - BESS systems being deployed to manage ramp rates and frequency
  - AGC systems being tuned for greater variability and automatic curtailment in response to system events.

Issues Facing Hawaii Grids

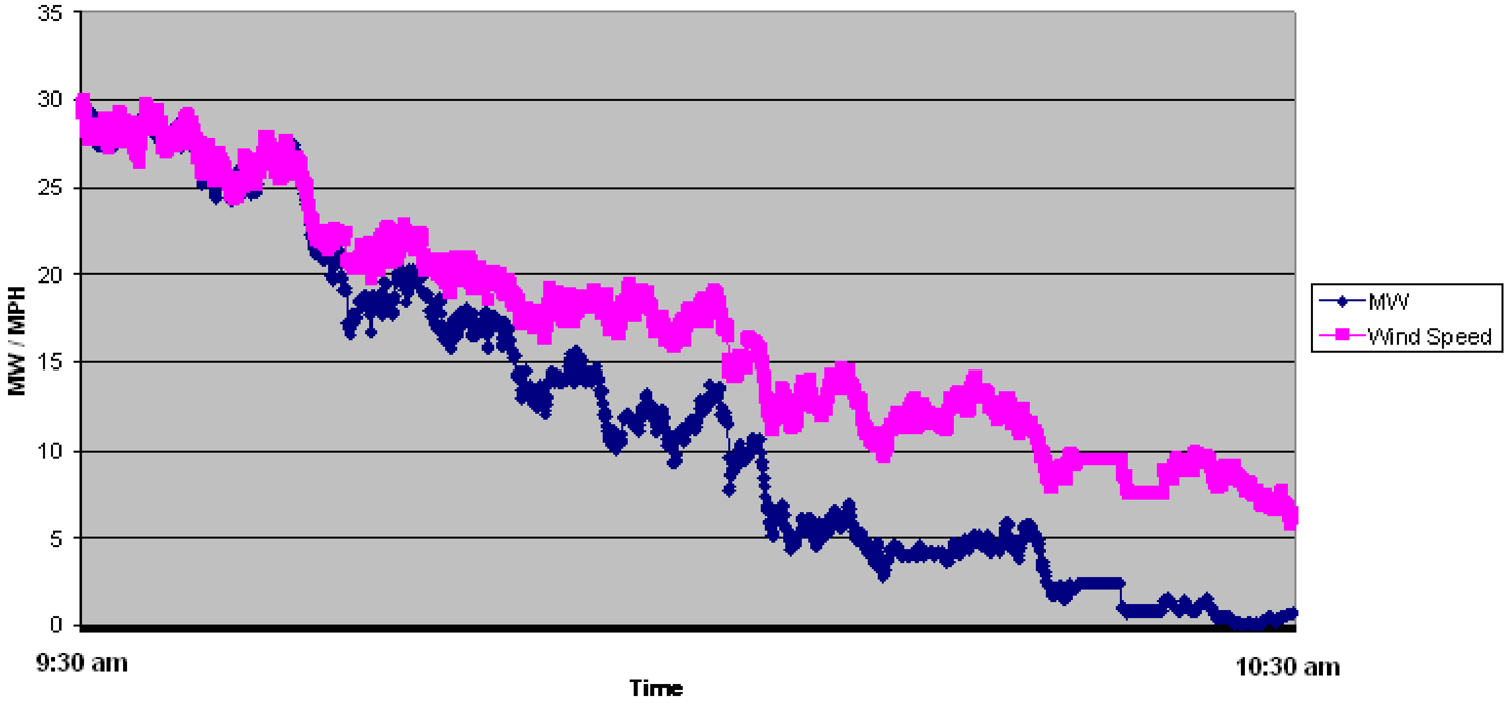
- Ride-Through
  - A single wind plant is a large percentage of the on-island generation
  - Transmission faults have a local and grid wide impact
  - Faults on distribution have an impact on transmission grid.
  - Smaller grids can see frequencies down to 59 Hz and below
  - Large penetration of IEEE 1547 inverters
  - Conflicting requirements; anti-Islanding vs. staying connected for grid support

Issues Facing Hawaii Grids

- Ride-Through
  - Transfer Trip Schemes being deployed for larger projects to allow for wider ride-through requirements
  - Wider ride-through ranges being implemented for small PV systems

Issues Facing Hawaii Grids

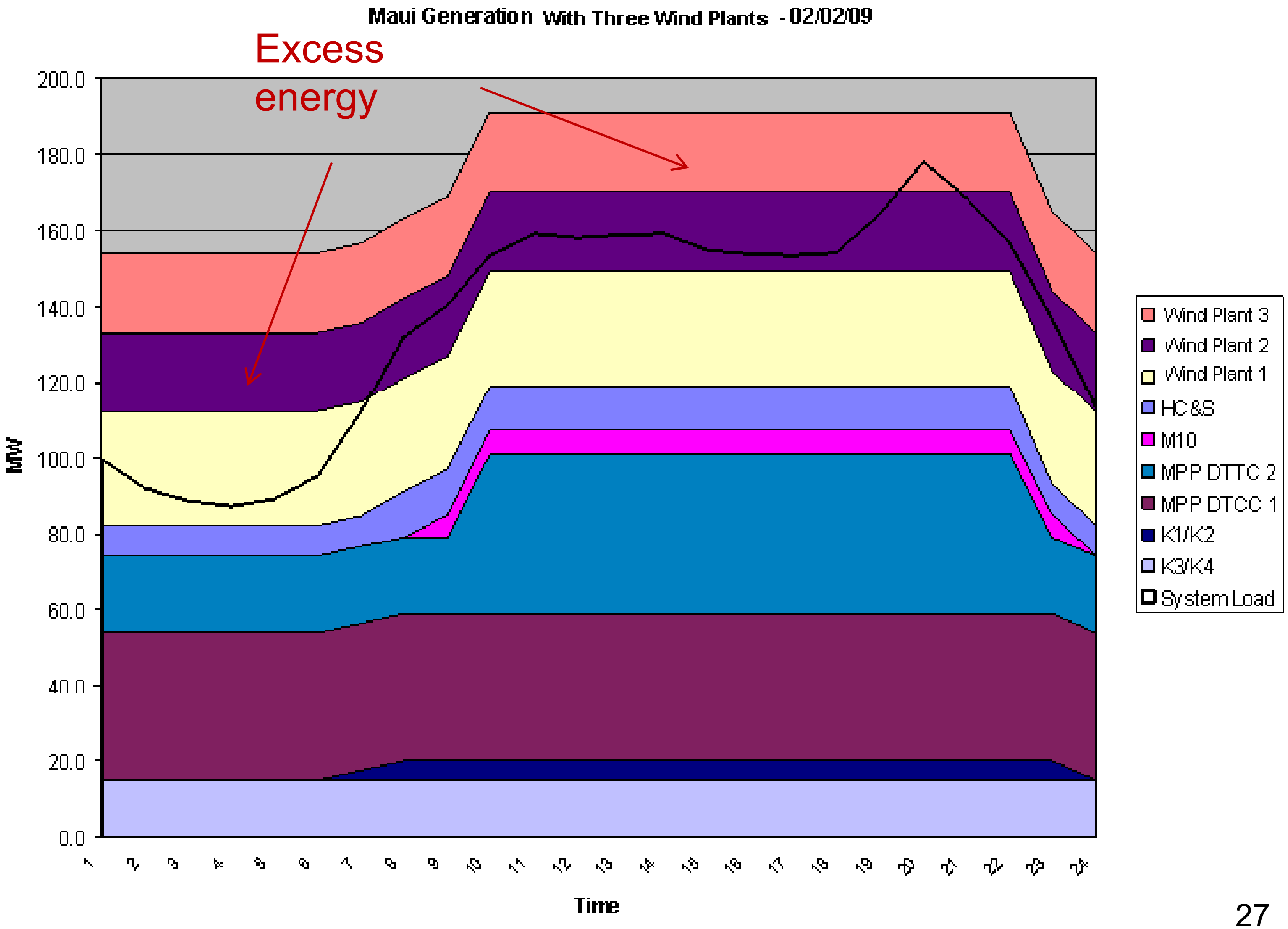
- Reserve Requirements
  - Upward Reserve
    - 6 MW or 50% of wind output up to 30 MW
    - Above 30 MW, 1 MW for each 1 MW of wind output up to 50 MW
  - Down Reserve
    - 6 to 8 MW (nominal)



Issues Facing Hawaii Grids

- Reserve Requirements
  - Quick start units are counted in reserve requirements
  - Reserve Requirements capped based on expected wind power diversity
  - BESS systems used as reserve to bridge to larger slow starting units

Issues Facing Hawaii Grids



Excess energy

Source: MECO, Feb 2009, Unit Dispatch with wind plants at full potential output

Issues Facing Hawaii Grids

- Excess Energy
  - Investigating lower turndown of units
  - BESS use for down reserve
  - Automatic curtailment following loss of load events
  - EV’s and Time Of Use rates are on the horizon

Issue – PV Output Variability

- Smart Grid Applications
  - In-premise, embedded intelligence and control
    - Smart inverters to control up-ramp rate
    - Direct control of customer loads to balance down-ramp, including demonstration of smart appliances, thermal energy storage, and EV control if available
  - Distribution transformer cluster control
    - Direct control of the cluster loads to balance down-ramp of the aggregated cluster variability, including demonstration of smart appliances, thermal energy storage, and EV control if available
  - Substation/feeder control
    - Evaluate community energy storage systems (electrical and/or thermal)

Issue - Feeder over-voltage under high PV output/low load scenarios

- Smart Grid Applications:
  - Substation embedded intelligence and control interface using the following inputs and control points
    - Voltage monitoring (e.g. smart meters)
    - PV MW/MVar management control
    - Substation LTC transformer control
    - Switched capacitor control
    - Community energy storage systems (electrical and/or thermal) control
    - Flexible AC Transmission Systems if needed

Issue - Voltage and Frequency Ride-through Capability

- Smart Grid Applications:
  - Grid Friendly inverters
    - Provide grid support during system transients
  - Data/event capture

Issue: *Anti-islanding for breaker and fused laterals*

- Smart Grid Applications:
  - Smart inverter interaction (Compatible schemes)
  - Direct Transfer Trip capabilities
  - Data/event capture

Issue – EV Charge Management

- Smart Grid Applications:
  - In-premise, embedded intelligence and control
    - HEMS (if applicable) coordination of PV resource with EV charging with other loads such as dryers, water heaters, air-conditioning units, etc.
  - Distribution transformer cluster control
    - Direct control of the cluster EV and other loads to balance down-ramp of the aggregated cluster variability
    - Manage Charging to avoid transformer Overloads
  - Substation/feeder control
    - Aggregate EV information and manage circuit overloads

Issue - Feeder monitoring, operator visibility and response

- Smart Grid Applications:
  - Monitor and aggregate distributed PV output on a feeder
  - Power output control via an Ops Center-substation-distributed PV interface
  - Distributed sensors, including use of AMI and other wireless communications (e.g. voltage alarm, “last gasp”)
  - Control room operator visualization tools

Issue - *Customer engagement, acceptance and feedback*

- Acceptance of Smart Grid Applications:
  - Smart appliances
  - Direct (on/off) control of select loads
  - EV charging control
  - Conduct Customer behavior and acceptance evaluation

Communications Infrastructure / Cyber-Security

The Secure Smart Grid communications network should:

- Be scalable and flexible
- Eliminate the need for “one-off” communications backhaul and security for each Smart Grid application
- Use a logical network architecture based on standard protocols (Such as IP/MPLS):
  - Security functions should be separated from the underlying physical media and allow the secure use of 3rd party leased communication
  - The network should be segmented between applications and security domains in the field
  - High priority control signals should take precedence over other less time critical data

Substation Information

- Kihei (Substation 35)
  - Circuit 1253: Load - 1,558 KW; Customers – 670;
    PV - 145 KW (11 Systems)
  - Circuit 1515: Load – 4,500 KW; Customers – 1,800;
    PV – 125 KW (29 Systems)
  - Circuit 1254: Load – 5,898 KW; Customers – 1,720;
    PV – 176 KW (27 Systems)
  - Circuit 1473: Load – 6,800 KW; Customers – 2,289:
    PV – 99 KW (30 Systems)
  - Circuit 1384: Load – 6,842 KW; Customers – 2,883;
    PV – 79 KW (3 systems, 209 KW Potential)

Substation Information

- Wailea (Substation 25) – RDSI Project
  - Circuit 1517: Load – 3,000 KW; Customers – 500;
    PV - 136 KW (34 Systems)
  - Circuit 1518: Load – 2,800 KW; Customers – 560;
    PV – 196 KW (10 Systems)
  - Other 5 Circuits not included in RDSI Project Scope

Equipment Requirements

One (1) EV Control Center (Island Wide Control)

- Charging reduction for system (automatic frequency control and emergency event manual control) and local distribution issues
- Includes EV communication system to communicate with EV manufacturer charge management systems and EV charging station control systems

One (1) DMS (Kihei Substation)

- Communicate with µDMS
- Address system issues not mitigated by the µDMS
- Circuit variability control
- Circuit voltage control (load tap changer, substation capacitor, line capacitor, etc.)
- Outage restoration (optional)
- Direct Load control via µDMS

Equipment Requirements

Three (3) µDMS (Distribution transformer level)

- EV charger control
- PV variability control via direct load control and EV control
- Voltage control
- Interface with GE DMS (Wailea project)
- Communication performance requirements to home and to DMS

Five (5) to Ten (10) Smart Inverters

- Voltage control
- Ramp rate control
- Curtailment control
- Anti-Islanding
- Ride-through (voltage and frequency)
- Communication of PV output to DMS (to disaggregate PV and Load data)

Equipment Requirements

500 KW to 1,000 KW of Community BESS Systems

- Voltage regulation
- Variability Mgmt
- Power Quality Conditioner
- Load shifting to offset PV ramp down and capture wind power and minimum load

500 KW to 1,000 KW EV-BESS

- Simulate EV charging (potential for tracking conventional car to estimate charging levels)

FACTS Devices

- Flexible AC Transmission System devices as needed to control voltage issues not managed by smart PV inverters and other installed equipment

Equipment Requirements

Communication and Cyber Security

- Propose Communication method (WiMAX, AMI Mesh, Celular, Internet, etc.) for communication systems between:
  - DMS and µDMS
  - µDMS and homes
- Propose Cyber Security assurance method (data / physical)