Inverter/Storage functions to Support Renewable Integration

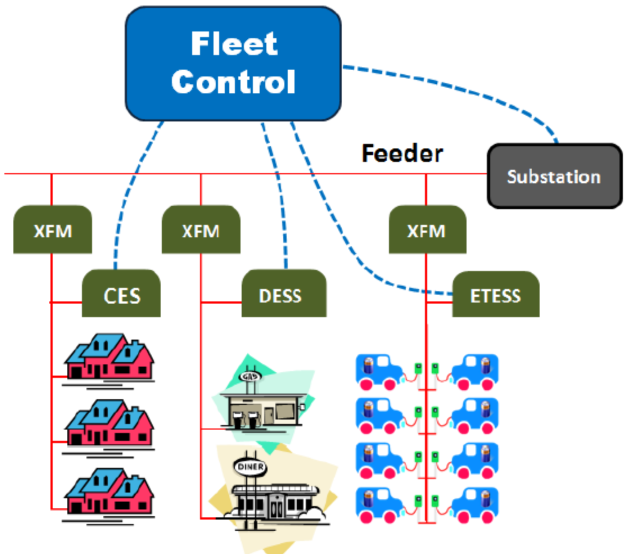
NIST Workshop on Power Conditioning System Architectures for Plugin-Vehicle Fleets as Grid Storage

Session 2.3: How might a PEV Fleet aid in integration of distributed variable renewable generators?

Glenn Skutt

PEV Integration with Storage

ETESS is a Smart Grid Asset



Voltage	Phases	Power	Energy
240VAC	1ϕ	75kW	225kWh
240VAC	3ϕ	150kW	450kWh

ETESS is a Distributed Energy Storage System – an upsized Community Energy Storage unit.

ETESS units can be controlled individually and as a fleet to support the needs of the grid for peak load management, voltage (VAR) support, and frequency regulation.

ETESS can also autonomously and intelligently control and optimize the PEV loads to manage the aggregate site demand.

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One vision: Distributed energy storage units controlled as a part of PEV fleet management

Requires storage system inverter control and integration with PEV activities

http://www.neny.org/download.cfm/McGlynn.pdf?AssetID=1492

PEV Rapid Charge Stations

And then there is *ETESS-DC*

AEYCH

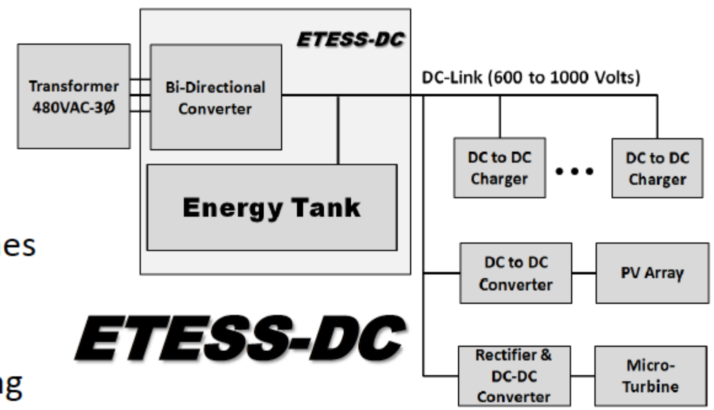
For your consideration …

When EVs come with "500 mile" batteries
Use 60% of capacity to go 300 miles (75 kWh)
And refuel in 18 minutes at 250 kW

First there are no EVs at the station;
Then there are 12 EVs surging **3,000 kW**
And then there are none again

AKER WADE

- Vehicles draw power as needed
- Energy Tank primarily a dynamic buffer
- Energy Tank can also do energy arbitrage
- High Voltage DC-Link – "Stationary HEV"
- DC-Link integrates PV, Wind, Micro-turbines
- Not a Utility Asset – Behind the Meter
- Can be an IPP for ISO/RTO (Aggregated)
- Site Demand Management & Peak Clipping



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Integration of stationary storage with the intermittent load of rapid charging PEVs.

Stationary storage managed for PEV charging AND for grid integration

http://www.neny.org/download.cfm/McGlynn.pdf?AssetID=1492

Inverter Control/Communications Development Efforts

- Standards Development:

EPRI: "PV & Storage Inverter Interactions using IEC 61850 Object Models and Capabilities"

NIST Priority Action Plan 7: "Electric Storage Interconnection Guidelines"

IEC 61850-4-720 and others

IEEE 1547.8: Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies For Expanded Use of IEEE Standard 1547

- Various Demonstration Programs

Standards: Communications Functions

- The DER/ES control standardization efforts share some basic functions
- Use Case driven design
- Example: (from NIST PAP07 Use Case Document)

BROADCAST/MULTICAST REQUEST FUNCTIONS

4.1 Energy Use Cases

4.1.1 Use Case: Electric Vehicle Load Management
4.1.2 Use Case: PEV Participates in Utility Events

4.2 Utility Distribution Modeling and Analysis of ES-DER

4.2.1 Use Case: Distributed Energy Resource (DER) Management
4.2.2 Use Case: Management of DER Systems
4.2.3 Use Case: Secondary DA Functions – Automated Distribution Systems with Significant DER
4.2.4 Use Case: Short-Term DER Generation and Storage Impact Studies
4.2.5 Use Case: Optimal Placements of Switches, Capacitors, Regulators, and DER

4.3 Ancillary Services Functions

4.3.1 Use Case: Volt/Var Optimization: Energy Conservation Mode
4.3.2 Use Case: Emergency Override: Maximum Var Support Mode
4.3.3 Use Case: Static Var Mode
4.3.4 VAR Mode PV4: Passive Mode

NIST Smart Grid PAP07

- Examples of direct commands to an ES-DER system include:
  - Connect/disconnect from grid
  - Charge to % of capacity at specified ramp rate or for specified length of time
  - Discharge to % of capacity at specified ramp rate or for specified length of time
  - Pricing signal to provide information to an autonomous ES-DER system on which to make charging/discharging decisions.

Example: EPRI Inverter Volt-VAR Control for Energy Conservation Mode

- One example of a function being defined for Inverter functionality in a DER/ES environment
- Normal Energy Conservation Mode –utility's calculation of the most efficient and reliable VAR levels for PV inverters at specific distribution points of common coupling (PCC). Can also help compensate for local low voltage due to PEV kW loads on the circuit.
- Uses an array voltage levels and their corresponding VAR levels.
- Voltage levels range between V1 and V2 in increasing voltage values.
- Values between setpoints are interpolated to create at a piecewise linear volt/var function.
- The corresponding VAR levels define the percent of Qmax (ranging between -100% and +100%) being requested for the voltage level.

Volt/Var Function (cont.)

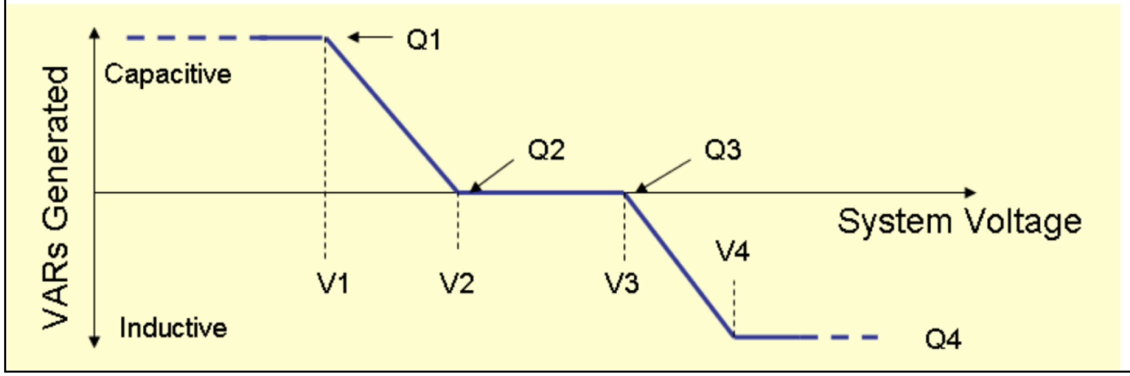
- An example of volt/var settings for this mode.
- VAR value between V_{min} and V1 is assumed the same as for V1 (Q_{max} in this example).
- Same is true for the VAR value between V4 and V_{max} ($-Q_{max}$ in this example).

Mode PV1 – Normal Energy Conservation Mode

Example Settings

Voltage Array		VAR Array (%)	
V1	115	Q1	100
V2	118	Q2	0
V3	122	Q3	0
V4	126	Q4	-100

VAR Ramp Rate Limit – fastest allowed change in VAR output in response to either power or voltage changes	50 [%/second]
Randomization Interval – time window over which mode or setting changes are to be made effective	60 seconds



Example: Request Real Power (Charge or Discharge Storage)

The utility/ESP or the Customer EMS takes the following actions:

1. (Optional) Request status of PV/Storage system: Request a pre-defined set of the status information, including the status values, the quality flag, and the timestamp of the status (see Function PC6 for details of status points).
2. Issue command to request real power (charge/discharge) setpoint for the storage system:
    a. Command **to adjust the real power charge/discharge setpoint for the storage system**
    b. Requested **ramp time for the PV/storage system** to move from the current setpoint to the new setpoint (optional – if not included, then use previously established default ramp rate)
    c. Time window within which to randomly execute the command. If the time window is zero, the command will be executed immediately, (optional – if not included, then default time window for this function will be used)
    d. Timeout period, after which the PV/Storage system will revert to its default status (optional – if not included, then default timeout period for this function will be used)
    e. Storage charge from grid setting (yes/no)
3. Receive response to the command:
    a. Successful (plus actual real power setpoint)
    b. Rejected (plus reason)

General List of Inverter/Storage Functions for PEV/DER Integration

Top Level Functions:

- Scheduled charge/discharge and advanced scheduling
- Volt VAR Control
- Watt/Frequency control
- Energy Arbitrage
- Renewables integration
- Harmonic Cancellation
- Voltage Sag Ride-Through

Implementation level:

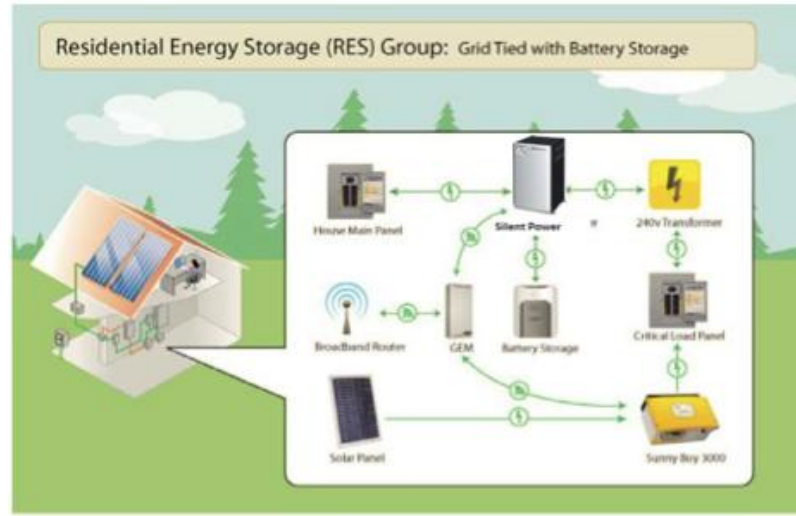
- Sense Voltage and Frequency
- Sense time rate of change of voltage and frequency
- Determine actual +/- real/reactive power output
- Determine maximum available +/- real/reactive power available
- Change to any given combination of available +/- real/reactive power
- Report nameplate information
- Report current state of V, f, P, Q, P/Q available

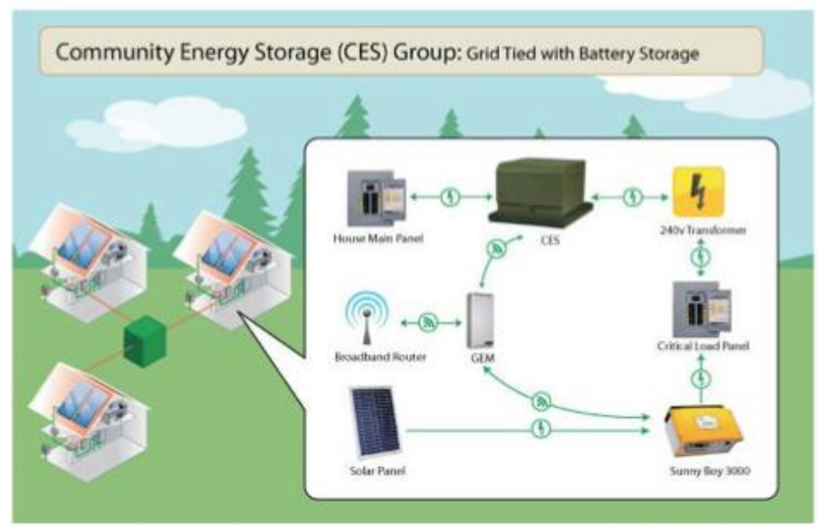
High level functions of converters or systems that control converters :

- Implement P/f schedule, i.e. P(f)
- Implement Q/V schedule i.e. Q(V)
- Implement +/- P activity as function of price information
- Provide maximum available +/- P/Q on demand subject to limits (available P/Q, V/f limits, machine limits)

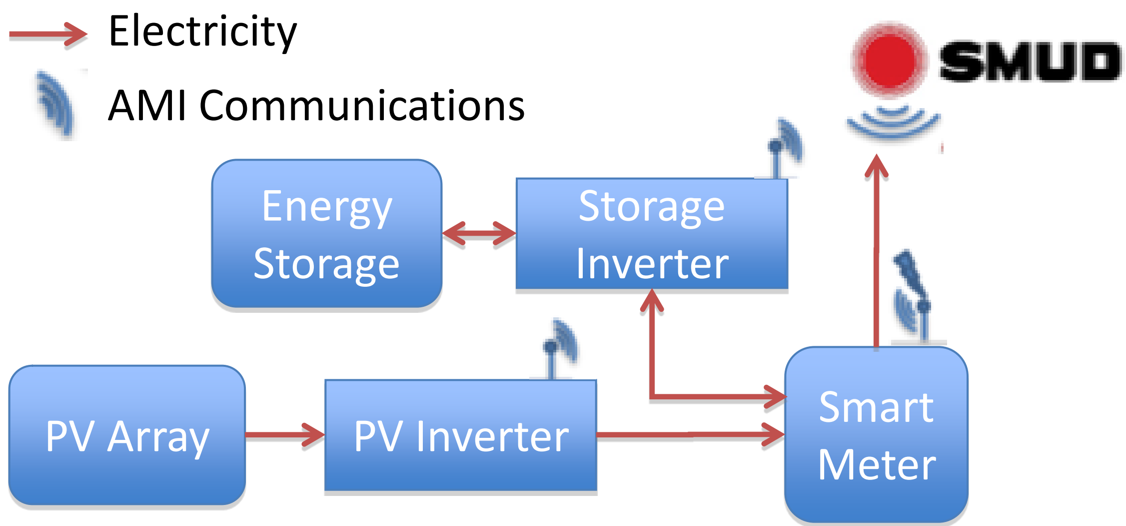
Demonstration Example: Sacramento High Penetration Solar Demonstration Project

- Control group of 25 homes with PV
  - RES Group – 15 units
    - UL listed units
    - 10kWpeak/8.8 kWh Li-ion batteries
  - CES Group – 3 units
    - Connected to secondary of 50 kVA pad mounted transformers serving 9-12 homes
    - 30 kW/30 kWh Li-ion batteries
- Utility/Customer portals monitor PV, storage, customer load
- Sending price signals to affect changes in customer usage
- Quantifying costs and benefits of this storage deployment to gain insights to broader application for SMUD





SMUD Demo Inverter Functionality



- Inverter Communications
  - Demonstrate Inverter Monitoring via AMI communication from smart meter to inverter
  - Demonstrate receiving data, querying for faults, sending control signals
  - Utilized as actively controlled contributors versus passive devices on the grid
- Functions include
  - firming of PV output through active regulation of energy storage inverter to compensate for fluctuations in PV output
  - scheduled charge and recharge for load shifting

Summary

- Plenty of opportunity for inverters to interact with PEV and other DER deployments
- Emerging standards for inverter control
- Inverters are generally underutilized relative to the functionality they can provide
- Combination of storage with PEV charging will be important for high PEV use levels