DTE Energy®

# DTE Energy Implementation of Community Energy Storage System for Grid Support

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**September 23, 2015**

# Disclaimer

DOE OE supported under award DE-OE0000229

# Project Overview

- First large utility scale community energy storage (CES) project on one circuit  (1 MW of storage)
- Aggregation of CES using a Distributed Resources System Operation Center (DERMS)
- Using utility industry protocol (DNP3)
- Determining economic value of storage on a distribution circuit in MISO market
- Built and deployed secondary use EV batteries
- Integration of energy storage and PV

# Project Team and Roles
## (weekly project calls)

| Project Team Members & Roles | |
|---|---|
| **Team Member** | **Role** |
| DTE Energy | • Project lead<br>• Utility participant for CES field demo<br>• Project reporting |
| S&C; ecamion | • CES Unit suppliers<br>• Factory acceptance testing<br>• Technical Support |
| DNV·GL | • CES functional testing<br>• Economic analysis and reporting<br>• Technical Support |
| edd | • Circuit model development for baseline<br>• Reliability & economic dispatch algorithm |
| CHRYSLER | • Durability & conditioning testing of EV battery<br>• Secondary use EV battery supplier<br>• Provide baseline data for EV battery |
| NEXTENERGY | • Investigation of regulatory issues surrounding energy storage and renewable energy<br>• DOD applications |
| nationalgrid | • Utility technical advisor |

# CES System Overview

- Eighteen new units installed
  - One was installed in training yard
  - Developed engineering documents, installation and operating procedures
  - 17 on one distribution circuit
  - IEEE 1547 certification
- Two repurposed EV battery systems demonstrating secondary-use application
- 500 kW of storage co-located with 500 kW PV

| CES Parameters | Value |
|---|---|
| Power | 25 kW |
| Energy | 50 kWh |
| Voltage | 240/120V AC |
| Cells | Li-Ion |

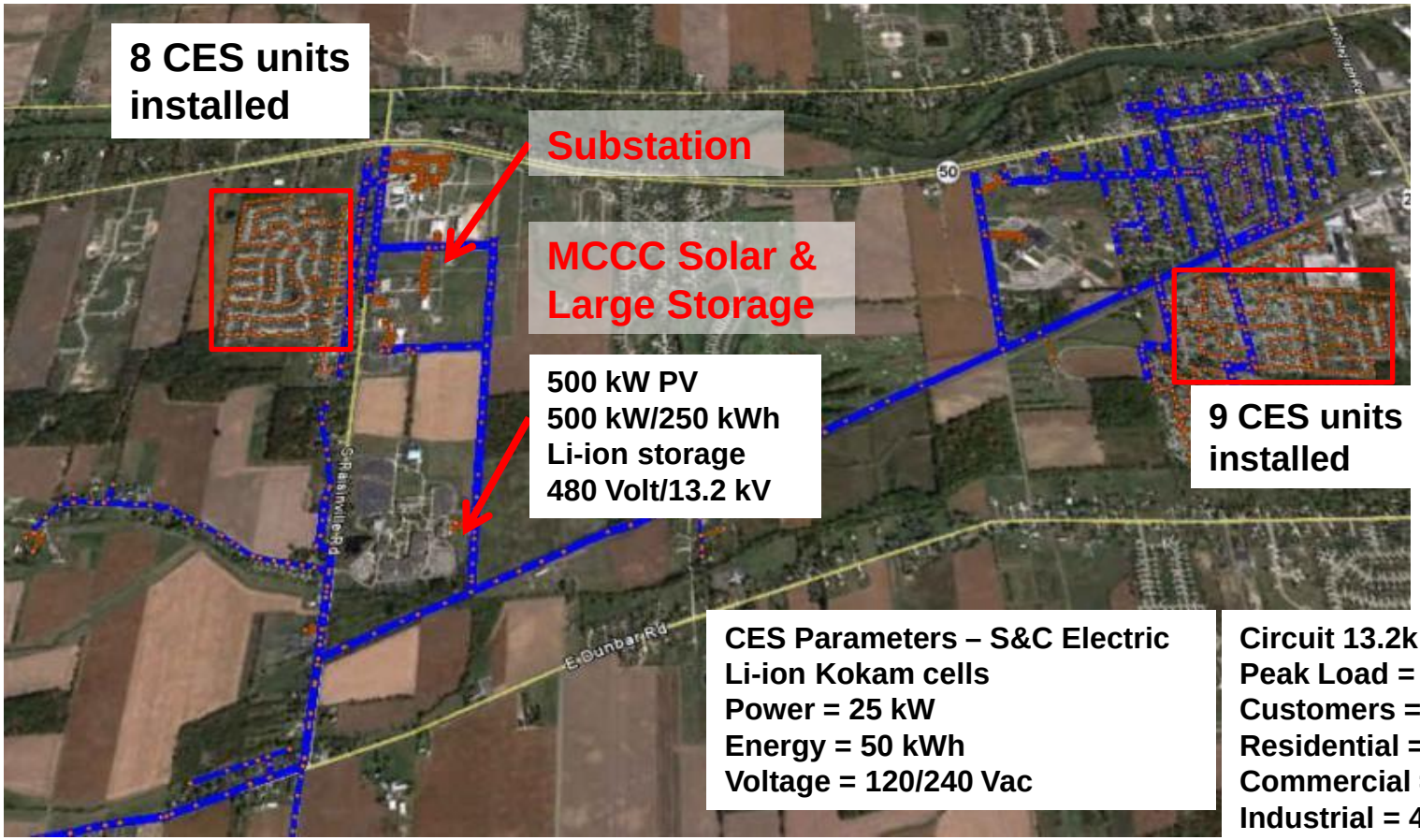
# CES Field Installation

- 18 new units installed in 2013
  - One in Training Yard
  - 17 on one circuit
- Winter reliability problems
- Desire to test as an aggregated fleet
- Uses case testing started in June 2014

# Large Storage and PV Integration

- Large storage system with PV
  - 500 kW PV
  - 500 kW Li-ion Storage-(250kWh)
- Located at MCCC
- Common 480 volt bus with 2-250 kW PV inverters
- 500 kVA Trf at 13.2 kV - Export limited

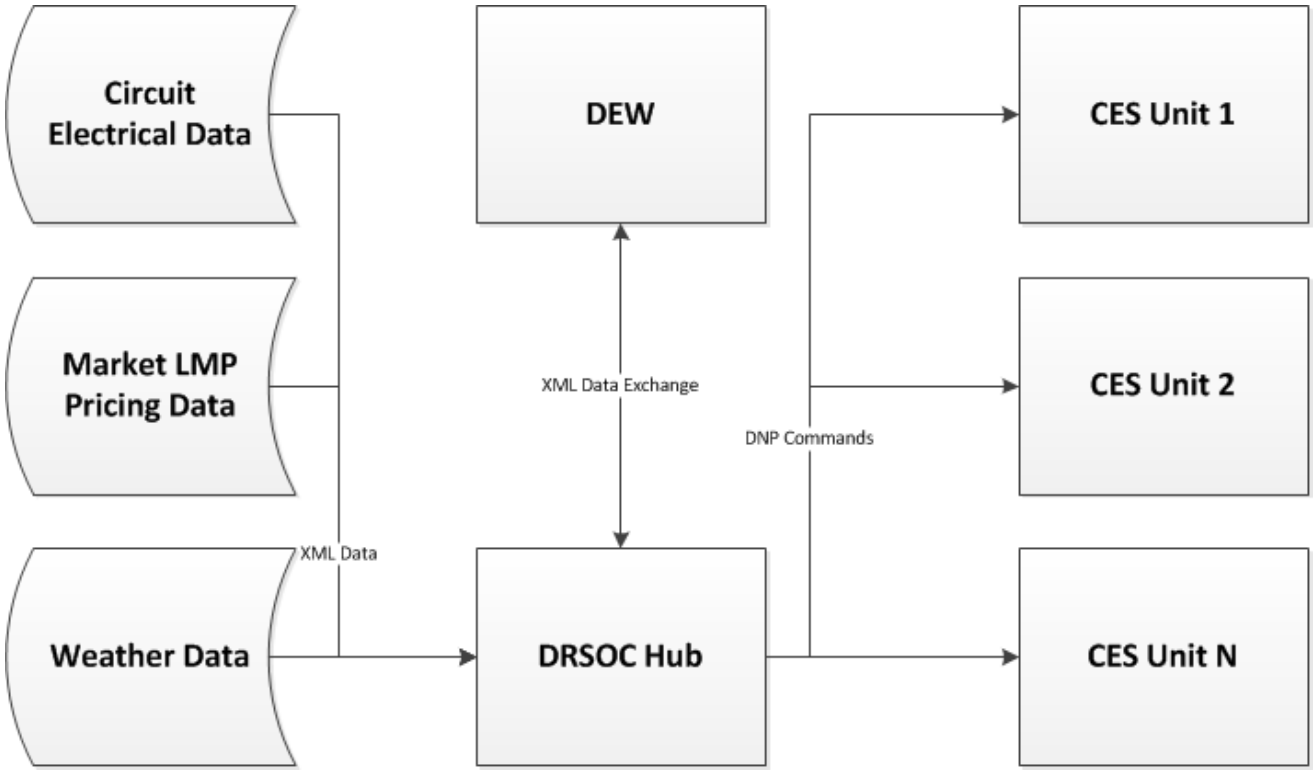

# Test Distribution Circuit




**CES Parameters – S&C Electric**
**Li-ion Kokam cells**
**Power = 25 kW**
**Energy = 50 kWh**
**Voltage = 120/240 Vac**

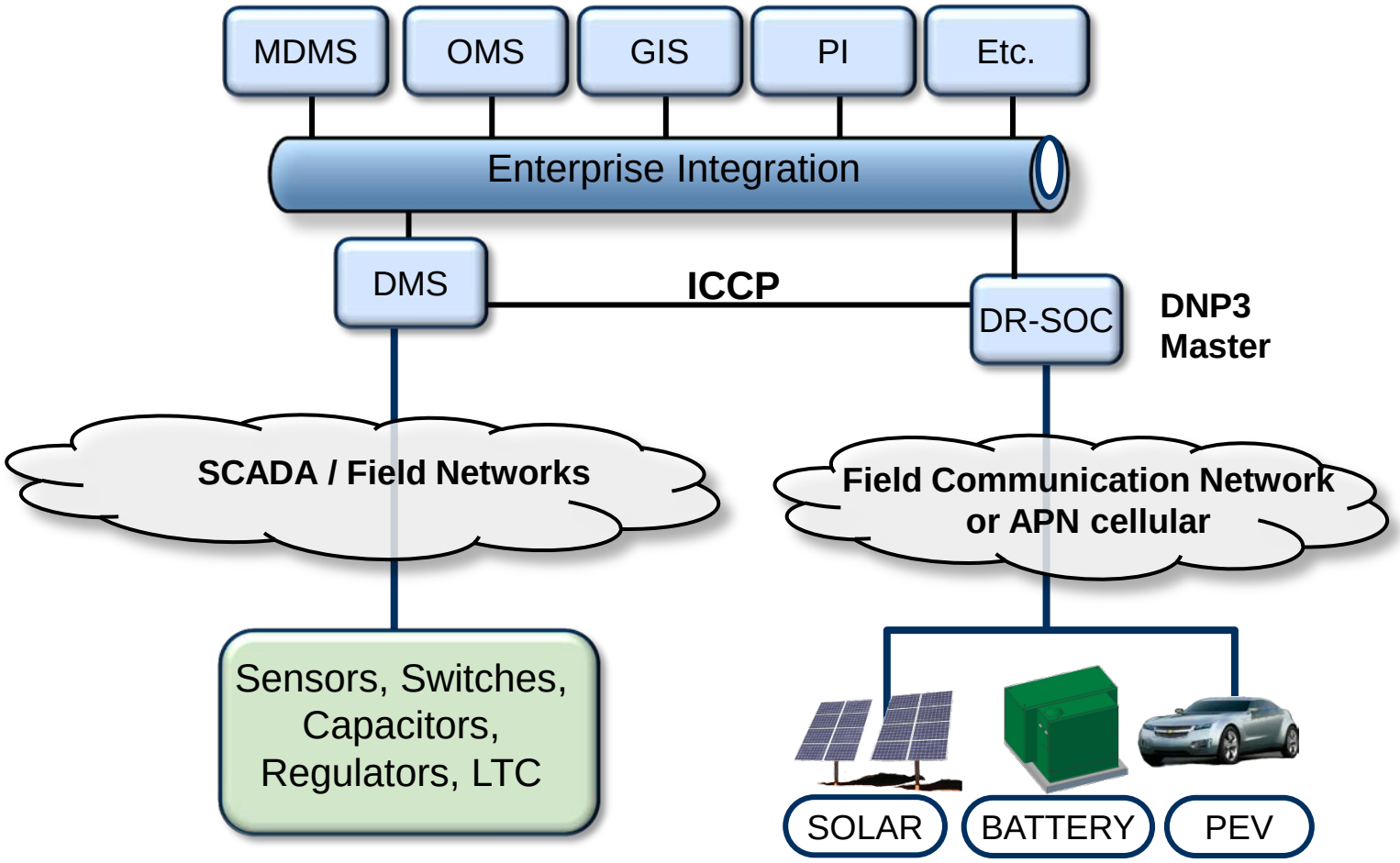
**Circuit 13.2k**
**Peak Load = 10.8MVA 2011**
**Customers = 2522**
**Residential = 2413**
**Commercial = 105**
**Industrial = 4**

# CES - Communications Architecture




**All storage systems individually addressable or in a fleet hub command mode using DNP3**

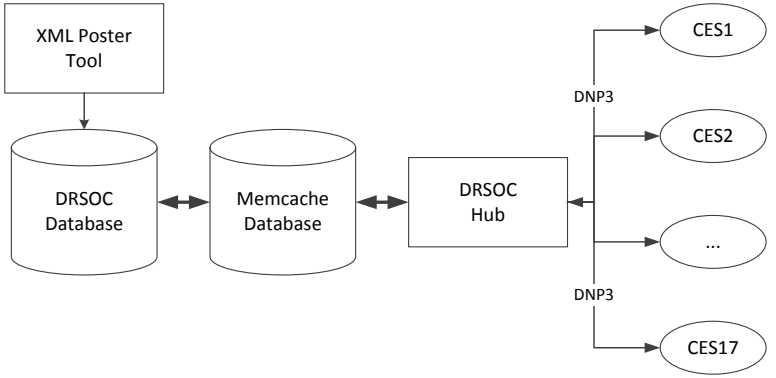
# DTE Energy DERMS

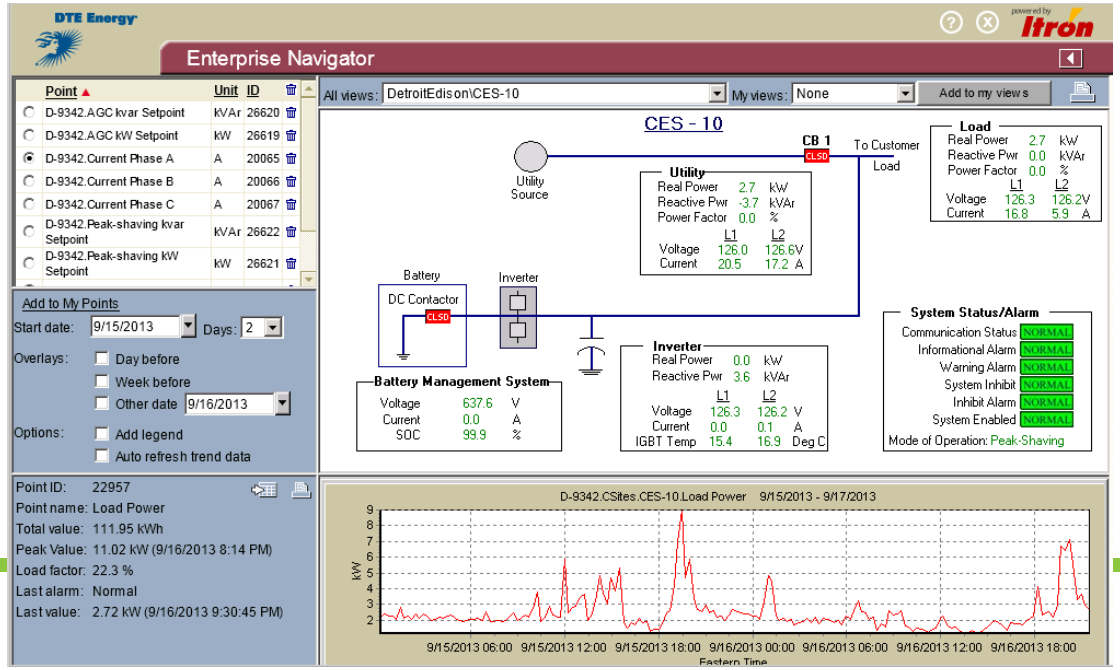


# CES Communication

## CES Site Summary

| Site | Battery SOC | Comm | PCS Power | PCS VARs | Load Power | Inhibit Alarm |
|---|---|---|---|---|---|---|
| CES-1 | 80.70 % | NORMAL | 0.00 kW | 3.46 | 0.06 kW | NORMAL |
| CES-2 | 92.80 % | NORMAL | -0.18 kW | 14.99 | 3.68 kW | NORMAL |
| CES-3 | 88.00 % | NORMAL | -0.02 kW | 15.01 | 1.94 kW | NORMAL |
| CES-4 | 96.80 % | NORMAL | 0.00 kW | 15.00 | 1.81 kW | NORMAL |
| CES-5 | 95.70 % | NORMAL | -0.29 kW | 14.99 | 1.86 kW | NORMAL |
| CES-6 | 0.00 % | NORMAL | 0.00 kW | 3.49 | 0.53 kW | ALARM |
| CES-7 | 59.40 % | NORMAL | -0.01 kW | 0.01 | -0.02 kW | ALARM |
| CES-8 | 79.50 % | NORMAL | -0.32 kW | 15.02 | 3.36 kW | NORMAL |
| CES-9 | 91.90 % | ALARM | 0.00 kW | 3.41 | 1.40 kW | ALARM |
| CES-10 | 97.90 % | NORMAL | -0.38 kW | -15.02 | 2.35 kW | NORMAL |
| CES-11 | 97.40 % | NORMAL | -0.83 kW | -14.99 | 1.15 kW | NORMAL |
| CES-12 | 96.10 % | NORMAL | -0.86 kW | -15.00 | 2.47 kW | NORMAL |
| CES-13 | 98.00 % | NORMAL | -0.68 kW | -15.02 | 2.63 kW | NORMAL |
| CES-14 | 96.10 % | NORMAL | -0.22 kW | -15.01 | 7.76 kW | NORMAL |
| CES-15 | 88.60 % | NORMAL | 0.00 kW | 3.45 | 0.89 kW | NORMAL |
| CES-16 | 0.00 % | NORMAL | 0.00 kW | 3.43 | 1.28 kW | ALARM |
| CES-17 | 97.40 % | NORMAL | -0.85 kW | -14.98 | 1.07 kW | NORMAL |




- DNP3 Master in DR-SOC
- Cell APN communication
- CES Display includes
  - Utility load and voltage
  - Customers load and voltage
  - Inverter data
  - Battery data
  - System Status and Alarms
- Graph can display any variable

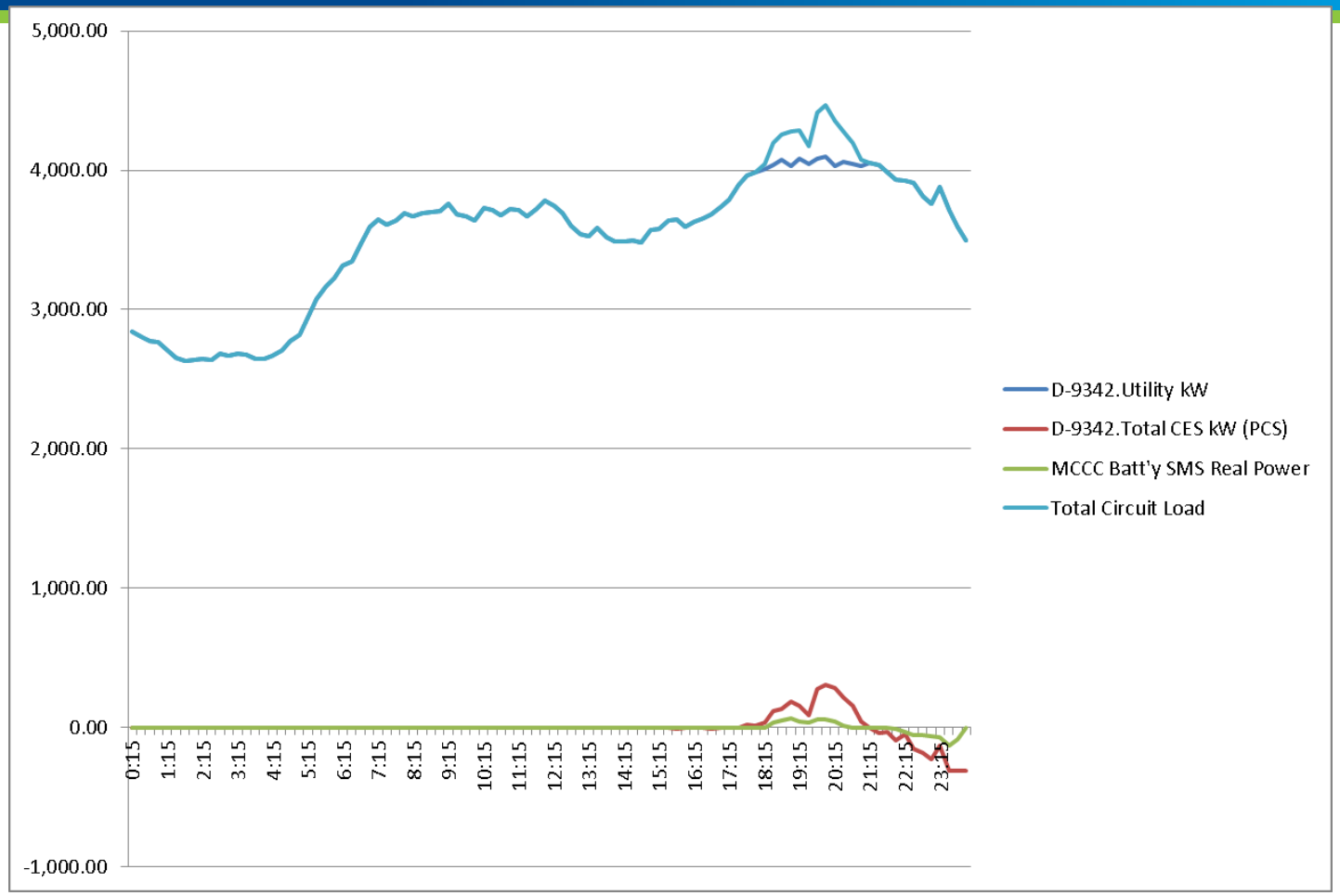
# CES Test Plan - Modes of operation document

| REQUIREMENT# | TEST PERFORMED | COMPONENT TESTED | Mode of Operation |
|---|---|---|---|
| DRSOC-CES-001 | Data usage test | Cellular communications | Stand-by / Hub Command |
| DRSOC-CES-002 | CES maintains Minimum Reserve Margin | CES controller logic | Hub Command |
| DRSOC-CES-003 | CES unit will operate safely when unit is at 100% SOC and is given a charge command. | CES controller logic | Hub Command |
| DRSOC-CES-004 | CES unit will operate safely when kW and kvar setpoints cause unit to exceed discharge kVA rating. | CES controller logic | Hub Command |
| DRSOC-CES-005 | CES unit will operate safely when kW and kvar setpoints cause unit to exceed charge kVA rating. | CES controller logic | Hub Command |
| DRSOC-CES-006 | DRSOC Hub will dispatch a reasonable set-point when algorithms command a kW set-point that exceeds unit charge rating. | DRSOC Hub | Hub Command |
| DRSOC-CES-007 | DRSOC Hub will dispatch reasonable set-point when algorithms command a kW set-point that exceeds unit discharge rating. | DRSOC Hub | Hub Command |
| DRSOC-CES-008 | DR-SOC Hub will distribute fleet kW charge or discharge across all units based on SoC of each unit. | DRSOC Hub | Hub Command |
| DRSOC-CES-009 | CES Efficiency | CES Efficiency | Hub Command |
| DRSOC-CES-010 | DR-SOC Hub will issue commands per a set schedule to produce "Renewable Energy Time Shift" | DRSOC Hub | Schedule |
| DRSOC-CES-011 | DR-SOC Hub will issue commands per a set schedule to produce "Electric Energy Time Shift" | DRSOC Hub | Schedule |
| DRSOC-CES-012 | DR-SOC Hub will send commands to CES units based on simulated AGC signal | DRSOC Hub | AGC |
| DRSOC-CES-013 | DR-SOC Hub will discharge CES fleet to maintain a maximum kW at the circuit feeder. | DRSOC Hub | Peak-Shaving |
| DRSOC-CES-014 | Charge when needed for reserve capacity | DEW Service | DEW |
| DRSOC-CES-015 | Discharge when price is high and unit is not "needed" | DEW Service | DEW |
| DRSOC-CES-016 | Do not charge when would cause overload | DEW Service | DEW |
| DRSOC-CES-017 | Do not discharge when would violate reserve capacity | DEW Service | DEW |
| DRSOC-CES-018 | Resolve transformer overload by discharging | DEW Service | DEW |
| DRSOC-CES-019 | Resolve low voltage by supplying vars | DEW Service | DEW |
| DRSOC-CES-020 | Resolve high voltage by absorbing vars | DEW Service | DEW |
| DRSOC-CES-021 | Resolve low voltage by discharging | DEW Service | DEW |
| DRSOC-CES-022 | Resolve single-phase primary overload by discharging only batteries on that phase while charging others (low price) | DEW Service | DEW |
| DRSOC-CES-023 | Currently discharging with no overload, but do not stop discharging because discharging is preventing an overload | DEW Service | DEW |
| DRSOC-CES-024 | Forecasted overload alert | DEW Service | DEW |
| DRSOC-CES-025 | Minimum profit margin test | DEW Service | DEW |

Demonstrated capabilities

- Voltage support
- VAR support
- Islanding during outages
- Frequency regulation (AGC)
- Renewable energy time shift
- Circuit peak shaving
- Discharge during high LMP price
- Circuit model commands (DEW Services)

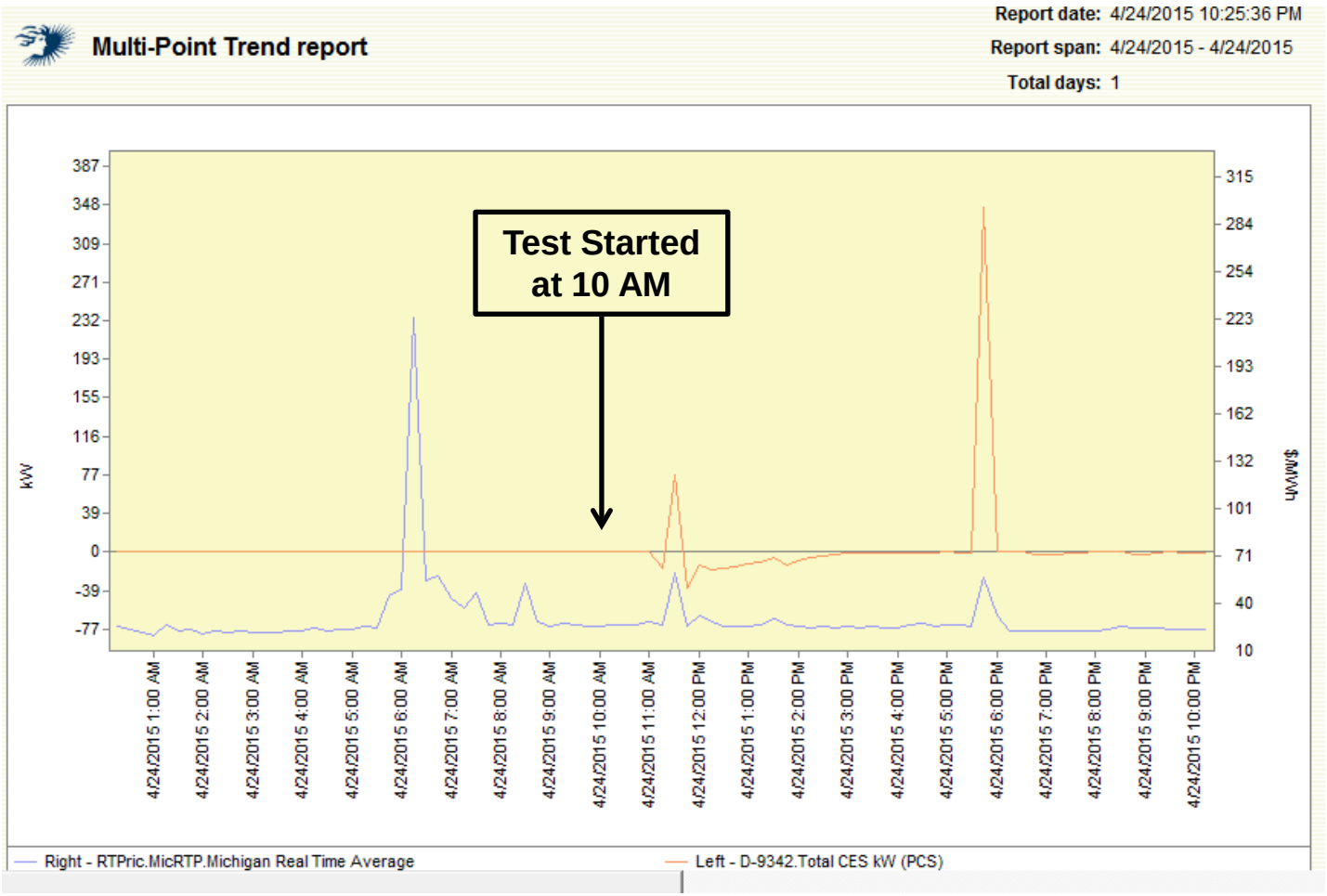
# Use case: Circuit Peak Shaving




**24 hour profile. Light blue=Total circuit load. Dark blue=Load from system. Red=CES fleet. Green=MCCC battery.**

# Use case: DEW Economics Mode

Battery Fleet kW

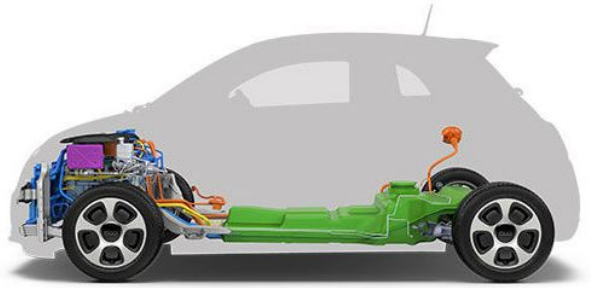


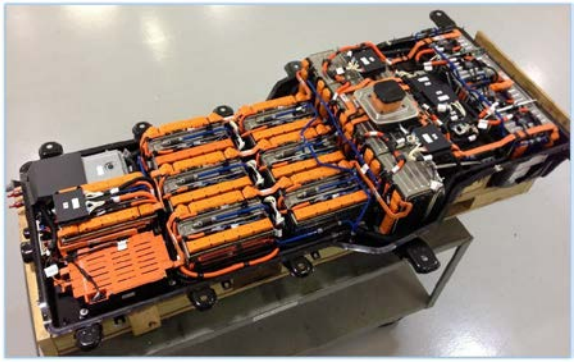

Real Time LMP $/MWh

**Orange curve battery fleet kW (left y-axis). Blue curve real time LMP $/MWh (right y-axis).**

# Repurposed EV batteries

- Six end of life automotive battery packs – Fiat 500e
- Two battery system configurations installed
  - 25 kW - 47 kWh and 94 kWh
- One CES tested at DNV GL





# Remaining work & some lessons learned

- Remaining work
  - Using EPRI Energy Storage Valuation Tool to perform sensitivity analysis
  - Initial draft report in October
  - Final report to DOE early December

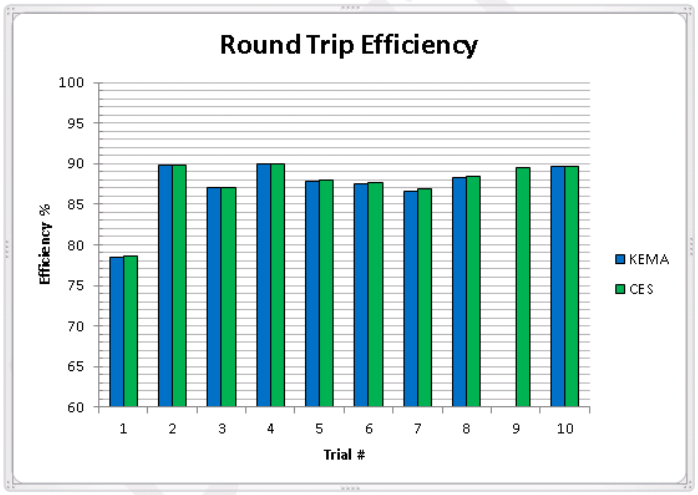
- Lesson learned
  - Change in energy storage supplier
  - Technology reliability maturity (TRL 6-7) – Automotive example
  - Reliability of hardware and software
  - Integration of communication systems
  - Physical location of CES

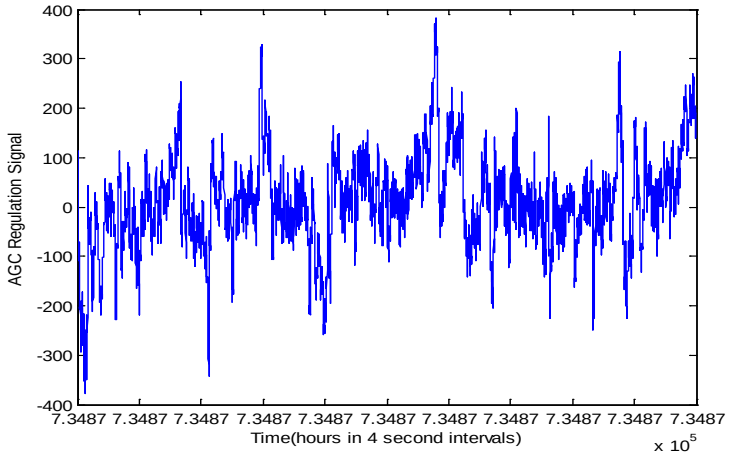
# Backup slides

# Sample test reports

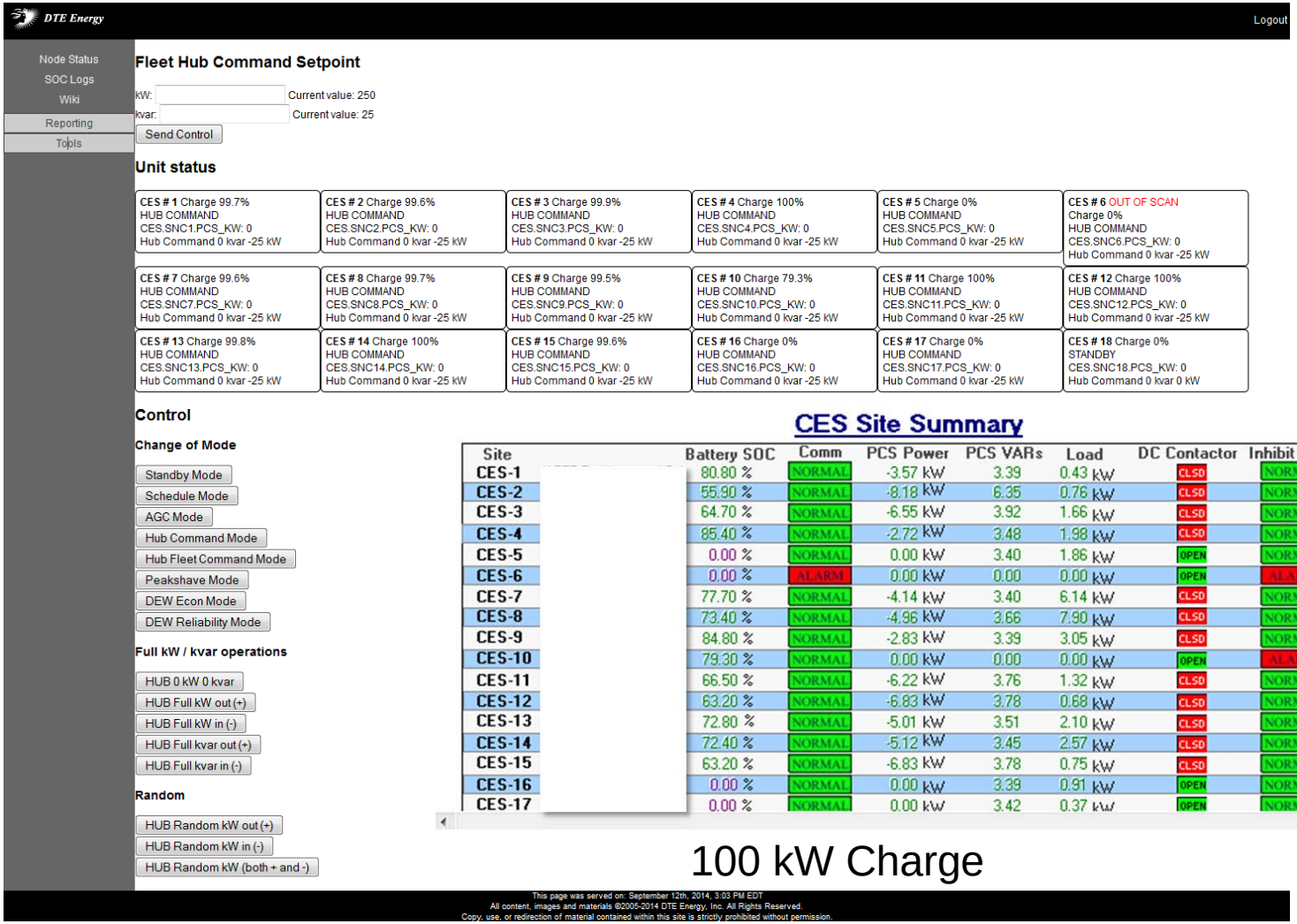
- DNV KEMA Powertest
  - Round Trip Efficiency
  - Peak Shaving profile test
  - Frequency Regulation Profile Test
  - Islanding Test
  - Harmonic Analysis
- S&C Electric commissioned IEEE 1547 certification – Passed
  - Removed conditional Relay Engineering approval
- DNV KEMA cost effectiveness reports on circuit
  - Frequency Regulation
  - Peak Shaving
- DNV GL Battery degradation testing

Table 1 AC Round Trip Efficiency



# CES Communication Hub Command




100 kW Charge

# DERMS – Distributed Energy Resource Management System

- Distributed Resources System Operation Center (DR-SOC)
- Created a DNP3 master for distributed energy storage system
- Smart inverter functionality