NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Distribution Level Metering and Visualization Applications

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Data Collection Network Objectives

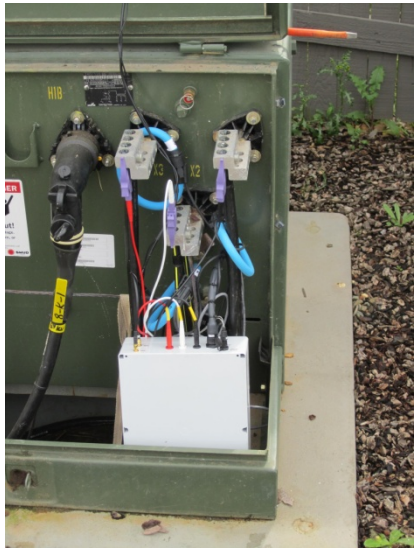
- In order to support research projects related to the integration of distributed generation NREL has developed a solution for high-speed, real-time, measurement of electrical quantities a low voltage points in a distribution system
- Remote measurement devices stream data back to a set of central data collection servers, in a network architecture similar to those used for PMUs
- The servers collect and store this data which is then made available for end users through a set of query tools and visualization applications
- Most off-the-shelf products did not meet all the requirements for data rates, compact size, all weather capability, and real-time data transmission

Distribution Monitoring Units

- Based in National Instruments sbRIO hardware and C-series modules
- GPS equipped for timestamping and Phasor calculations
- Developed specifically for metering at low voltage points on the distribution level
- Each Unit measures voltage and current phasors, RMS values, real, reactive and apparent power, power factor and temperature (external and internal)
- Output data rate configurable from 1 Hz up to 60 Hz
- Designed for metering at points up to 300 Vrms, higher voltage levels can be achieved with PTs or divider circuits
- Uses clip on voltage probes and Rogowski coils
- 9” x 11” x 3.5”

Distribution Monitoring Units

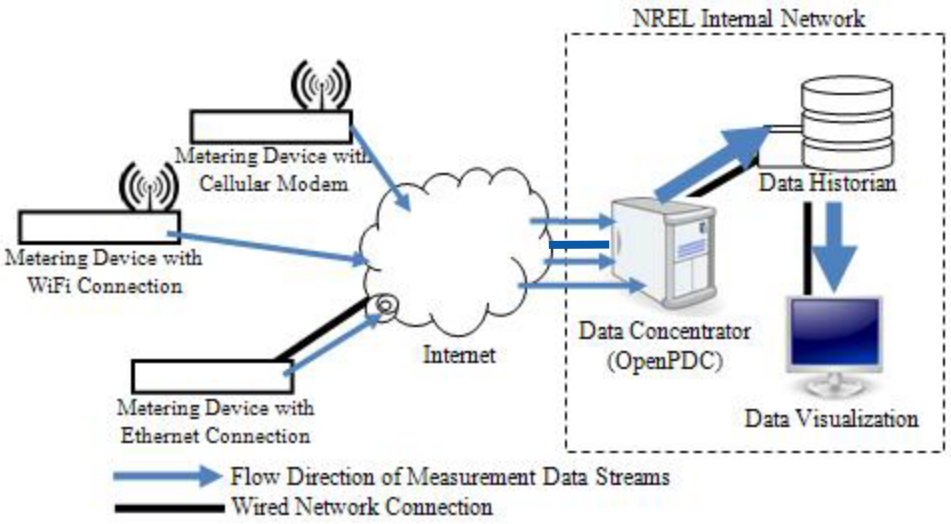
- High temperature and weather rated for outdoor installations
- Data transmitted in real-time through a Ethernet, WiFi or Cellular internet connection
- 120/240 Split-Phase and 277 Y models have been developed
- Twelve units have been fielded into SMUD's Anatolia Circuit
- Five units have been installed on the Kihei Circuit on Maui



Meter installation on a Pad Mount Residential Transformer in Sacramento

Data Collection Network

- DMU measurements are immediately sent out through the onboard cellular modem, ethernet or Wi-Fi connection using the PMU communication protocol specified by the IEEE C37.118 Standard
- The data streams pass through the internet, arriving at the Data Concentrator housed at NREL
- The Data Concentrator time-aligns these streams and condenses them into one data set containing all of the measurement data
- The concentrator data stream is sent to the Historian for archival, then onto the Data Visualization applications and any other end users requiring live data feeds.
- The Data Concentrator is capable of receiving data from any internet connected device that can transmit using the C37.118 protocol, which includes almost all off the shelf PMUs and Phasor Data Concentrators
- The OpenPDC software package (*http://openpdc.codeplex.com/*) provides the server-side software for both the concentrator and historian

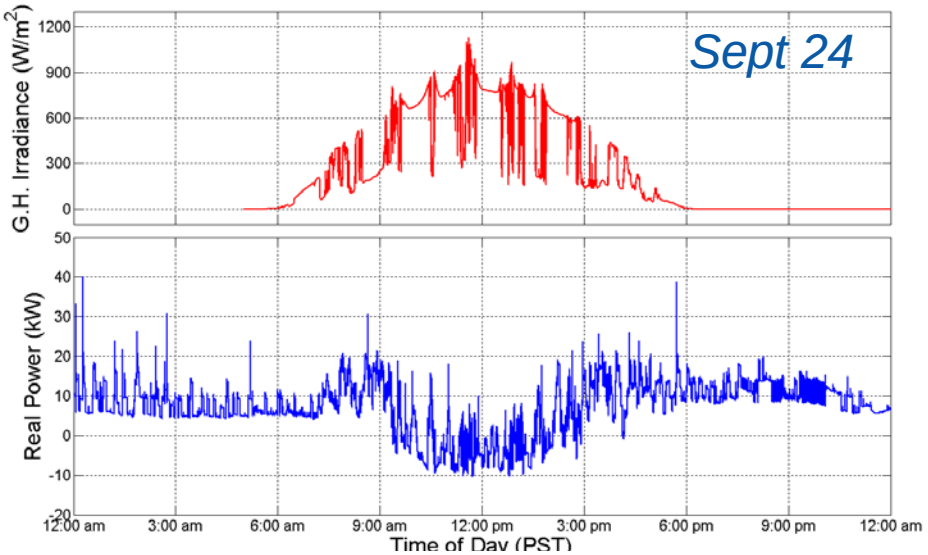


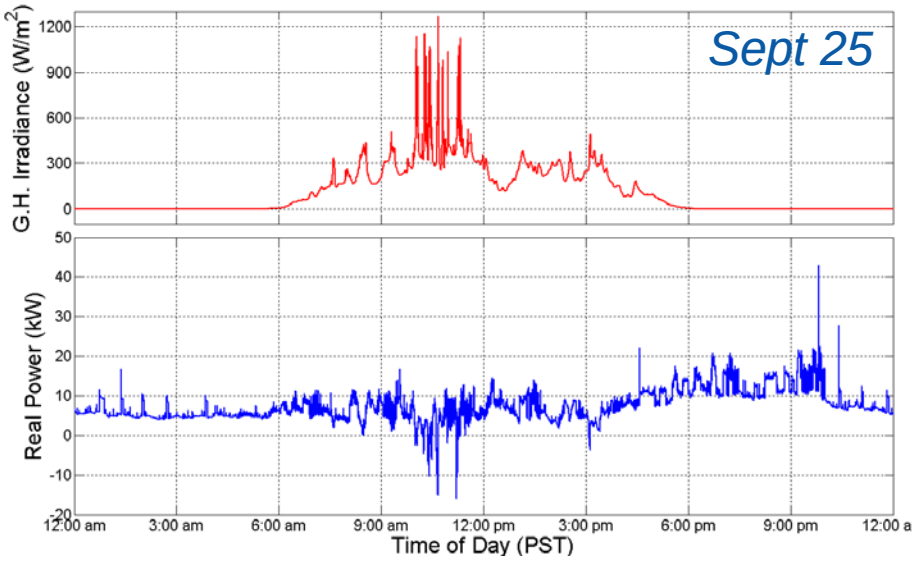
Solar Irradiance Measurements

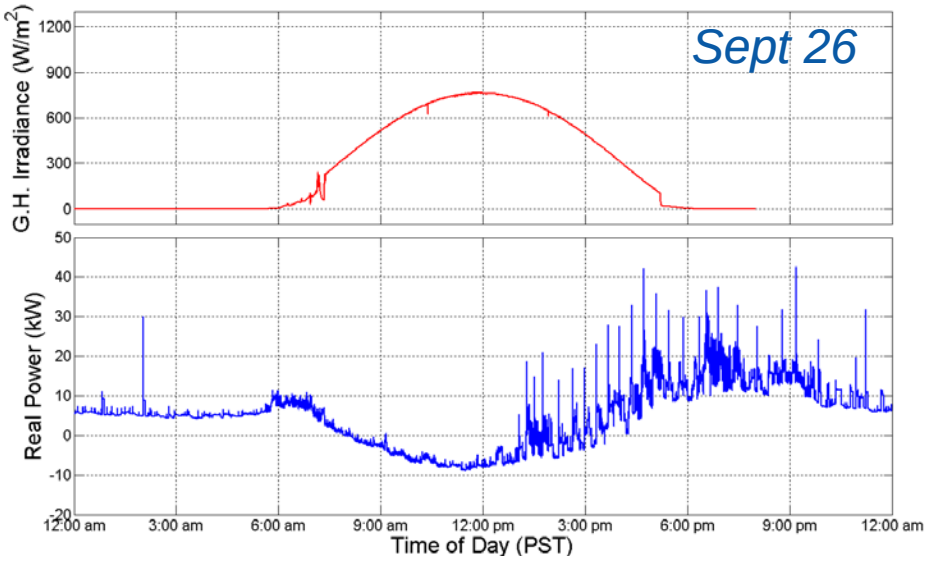
- This data collection network is focused on irradiance measurement
- Individual stations are solar powered and equipped for cellular communication
- Once fielded the units begin collecting global horizontal measurements at data rates up to once per second
- Data is passed to the central servers at NREL in a batch process

Collected Data – PV Production

- The red traces on these plots are global horizontal Irradiance measurements Taken from a MIDC tower in the Anatolia Neighborhood
- Blue traces are power flow through a transformer serving 10 houses, each with about 2kW of installed rooftop PV
- These plots represent three consecutive days, one cloudy, one sunny and one with intermittent cloud cover

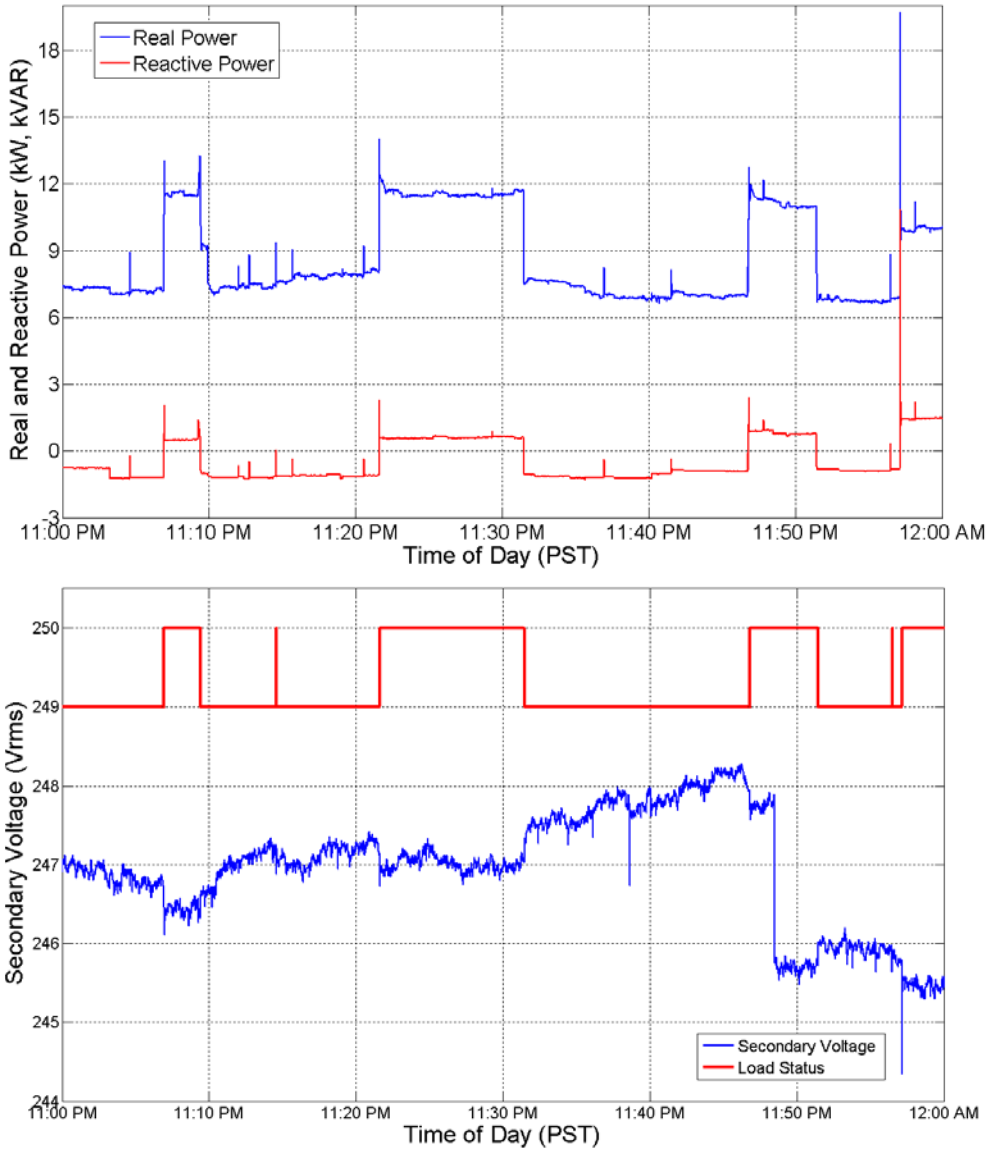






Collected Data – Observed Load Characteristics

- Upper plot is measured P and Q at a transformer serving 10 houses in Anatolia
- A load is observed switching on then off throughout the time span
- This load is about 5 kW and is observed all over the system at all times of day, most likely AC
- This switching effect is also apparent in the voltage measurements on the bottom plot



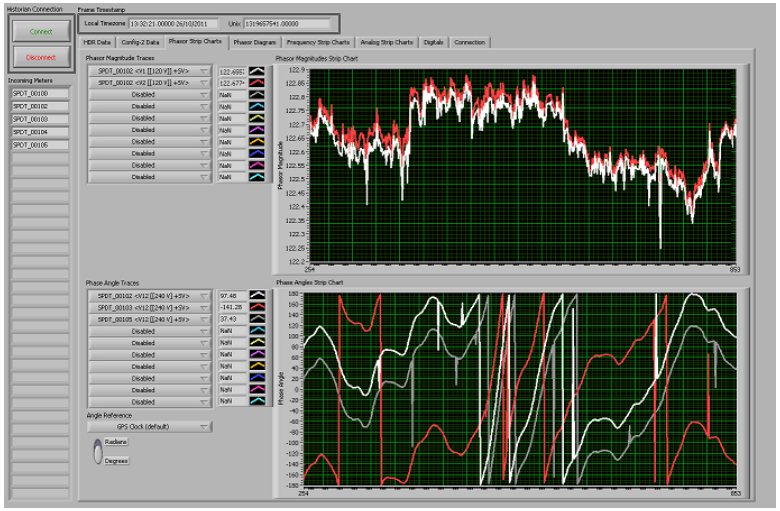
Data Visualization

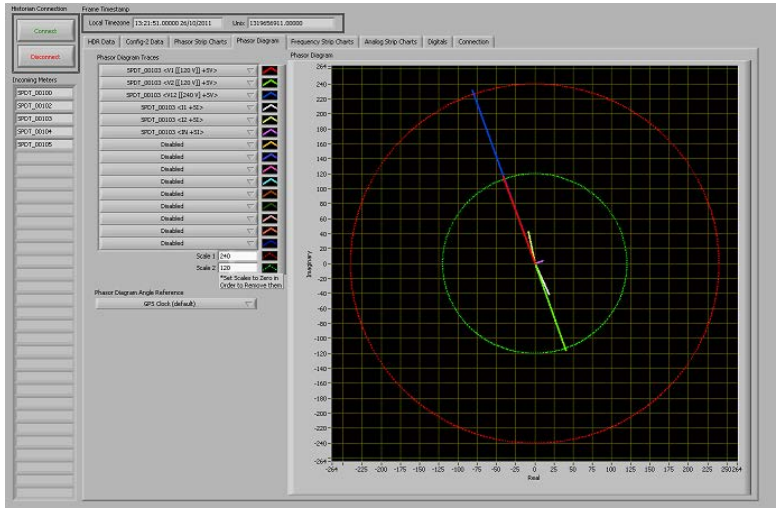
-Live data is displayed in Google Earth

-Accessible to internet connected users with the proper credentials

Strip Chart Displays

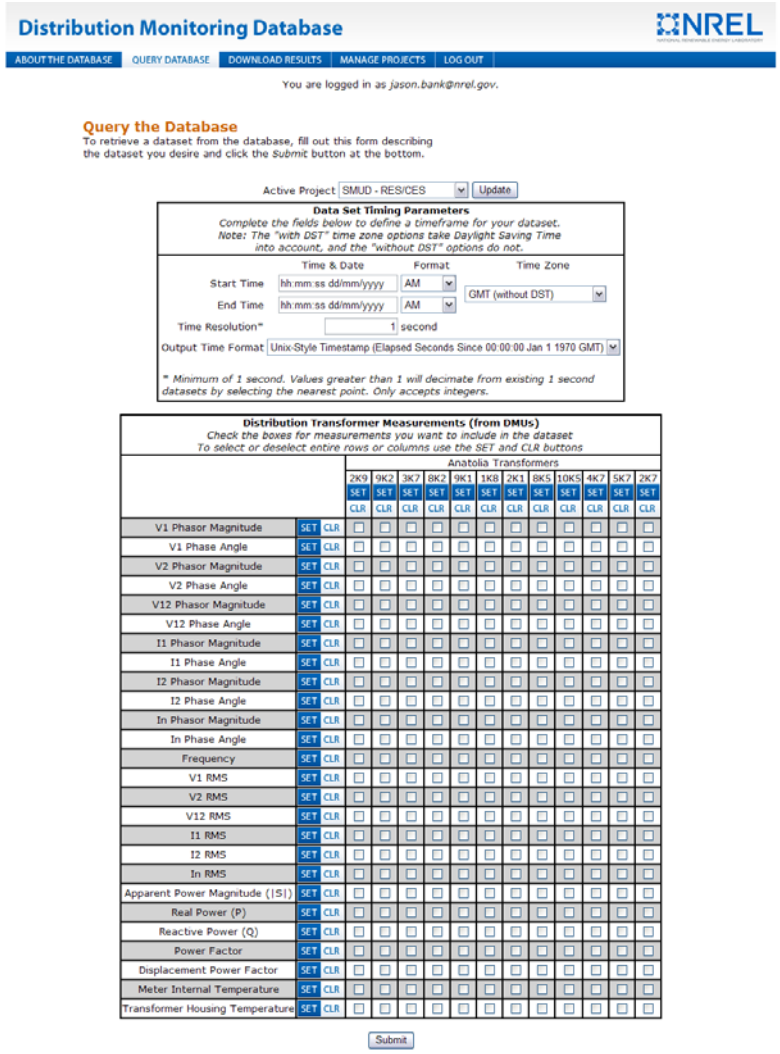
- A strip chart based display has also been developed for this live data
- This interface uses the IEEE C37.118 protocol to connect directly to data historian
- The data is presented in a series of strip charts and phasor diagram
- The user can select individual channels for display on the charts, building up customized live displays
- This package is capable of communicating directly to any IEEE C37.118 compliant device





Data Access

- Access to the data sets are granted to project members via a website (username/password authentication)
- With a form based tool a user can request a specific data set
- The website then pulls the required data from the database and returns a delimited text file



Distribution Monitoring Database

NREL

ABOUT THE DATABASE | QUERY DATABASE | DOWNLOAD RESULTS | MANAGE PROJECTS | LOG OUT

You are logged in as jason.bank@nrel.gov.

Query the Database

To retrieve a dataset from the database, fill out this form describing the dataset you desire and click the *Submit* button at the bottom.

Active Project: SMUD - RES/CES [Update]

Data Set Timing Parameters

Complete the fields below to define a timeframe for your dataset.
Note: The "with DST" time zone options take Daylight Saving Time into account, and the "without DST" options do not.

	Time & Date	Format	Time Zone
Start Time	hh:mm:ss dd/mm/yyyy	AM	GMT (without DST)
End Time	hh:mm:ss dd/mm/yyyy	AM	
Time Resolution*	1	second	
Output Time Format	Unix-Style Timestamp (Elapsed Seconds Since 00:00:00 Jan 1 1970 GMT)		

** Minimum of 1 second. Values greater than 1 will decimate from existing 1 second datasets by selecting the nearest point. Only accepts integers.*

Distribution Transformer Measurements (from DMUs)

Check the boxes for measurements you want to include in the dataset
To select or deselect entire rows or columns use the SET and CLR buttons

			Anatolia Transformers										
			2K9	9K2	3K7	8K2	9K1	1K8	2K1	8K5	10K5	4K7	5K7	2K7
			SET	SET	SET	SET	SET	SET	SET	SET	SET	SET	SET	SET
			CLR	CLR	CLR	CLR	CLR	CLR	CLR	CLR	CLR	CLR	CLR	CLR
V1 Phasor Magnitude	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V1 Phase Angle	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V2 Phasor Magnitude	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V2 Phase Angle	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V12 Phasor Magnitude	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V12 Phase Angle	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I1 Phasor Magnitude	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I1 Phase Angle	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I2 Phasor Magnitude	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I2 Phase Angle	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
In Phasor Magnitude	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
In Phase Angle	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Frequency	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V1 RMS	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V2 RMS	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
V12 RMS	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I1 RMS	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
I2 RMS	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
In RMS	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Apparent Power Magnitude (|S|)	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Real Power (P)	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Reactive Power (Q)	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Power Factor	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Displacement Power Factor	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Meter Internal Temperature	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Transformer Housing Temperature	SET	CLR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

[Submit]

Continuing Work

- Further deployment of meters into other distribution circuits
  - SCE High Pen Study
  - CPS Bluewing
- Development of other meter models for additional metering locations and reduced hardware cost
  - DFR-style triggered waveform capture
  - More complete support for Harmonics and THD
  - FTP store and forward version (trades real-time for reliability, higher measurement rates and ease of communications)
- Integration of other, data sets into data retrieval website
  - Utility SCADA data
  - Household level and Smart Meter Data
  - Solar and weather measurements
- Refinement and addition of features to Visualizations
- Integration of other sources into visualizations, including results from simulation and modeling

Integration of Simulation and Modeling

- The communications to the Google Earth and Strip chart displays have an open architecture which allows for easy integration of other data sources
- This would include data sets generated by simulation and modeling packages
- On going work includes the integration of the DEW distribution system modeling package so that simulation results can be incorporated and displayed along with the live data
- DEW can also receive the live data feeds as input to its solver, allowing it to fill in the missing points on the map