Commonwealth Energy Biogas/PV Mini-Grid Renewable Resources Program

Making Renewables Part of an Affordable and Diverse Electric System in California

Contract No. 500-00-036

Data Acquisition System User Manual for Comprehensive Small PV System Comparison

Project 3.2 Building Integrated PV Testing and Evaluation Project

Task 3.2.2b (2) DAS Letter of Notification

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Data Acquisition System User Manual for Task 3.2.2b Comprehensive Small PV System Comparison

Commonwealth Biogas/PV Mini-Grid Renewable Resource Program[1]

Project 3.2 - Building Integrated PV Testing and Evaluation

1 Overview

The Comprehensive Small PV System Comparison (Task 3.2.2b) is intended to develop standardized PV system evaluation techniques and provide comparative data on systems relevant for Commonwealth Project 3.3 Building Integrated PV on Public Facilities. Under this phase of the project, three nominal 2kW systems have been installed on residential roof mock-ups at the PVUSA solar power facility near Davis, California. The three systems are samples of commercially available products that an energy provider might offer or homeowners might purchase. They represent a range of commonly-available module and inverter technologies used in grid-connected residential PV system configurations. A more complete discussion of Project 3.2, as well as access to real-time and historical data can be found in the PV System Evaluation Plan, which is available at www.pierminigrid.org/pubproject32.html.

A key aspect of this evaluation is the on-going monitoring of specific electrical operating parameters. The data acquisition system described in this document provides that capability.

1.1 Data Acquisition System

The Commonwealth/PIER Program Small PV Systems Data Acquisition System (DAS) is a collection of hardware and software that allows the status of the systems to be monitored and recorded for later analysis. A parallel evaluation project directed towards large systems includes a separate DAS sharing some of the features and components of this system and described in a separate document.

Three commercially available PV systems have been installed as part of the Comprehensive Small PV System Comparison::

- ✓ Sharp 2500
- ✓ Kyocera MyGen 2500
- ✓ Schott Applied Power SunRoof RS 2500

Each of these systems is intended to be self-contained, with a single inverter and an array of modules mounted on a composition shingle roof. The Sharp system includes an inverter with the relatively uncommon design feature of provision for simultaneously connecting and

[1] The Commonwealth program is funded in part by the California Energy Commission Public Interest Energy Research Program.

independently peak power tracking three different input arrays[2]. This feature is noted because of its impact on the DAS

1.2 This Manual

This manual is intended to provide a description of design and function of the Data Acquisition System hardware and software, to guide the user in the operation of the system, and to direct the operator as to where to find more information on its various components.

2 Hardware

The DAS hardware includes a datalogger-based (Campbell Scientific Model CR23X) monitoring subsystem for full monitoring of the three small systems and weather conditions. Table 1 shows the parameters monitored by the datalogger.

Table 1 Datalogger Monitored Parameters

Parameter	Comments
DC Voltage	One per array (four total, since one inverter has two separate arrays); measured at input to inverter
DC Current	One per array; measured at input to inverter
AC Voltage	One 120/240V split-phase measurement (measured as two 120Vrms phases)
AC Energy	One per inverter (three total); signal from pulse initiating watt-hour meters
Irradiance	One pyranometer (all arrays are oriented identically)
Wind Speed	Anemometer mounted on roof
Ambient Temperature	Thermistor in radiation shield mounted on roof
Array Temperature	Thermocouple mounted on back of one module in each array (three total)

Figure 1 shows the PV systems major components, and notes the parameters monitored.

Figure 2 shows a block diagram of the DAS subsystems and components. The site computer communicates via radio link to the datalogger and inverter-based monitoring subsystems.

[2] Note that most commonly-available inverters require that an array of "identical" modules are wired directly together, which can lead to reduced performance if the modules must be mounted on multiple roof orientations or if the array consists of a combination of different types of modules .

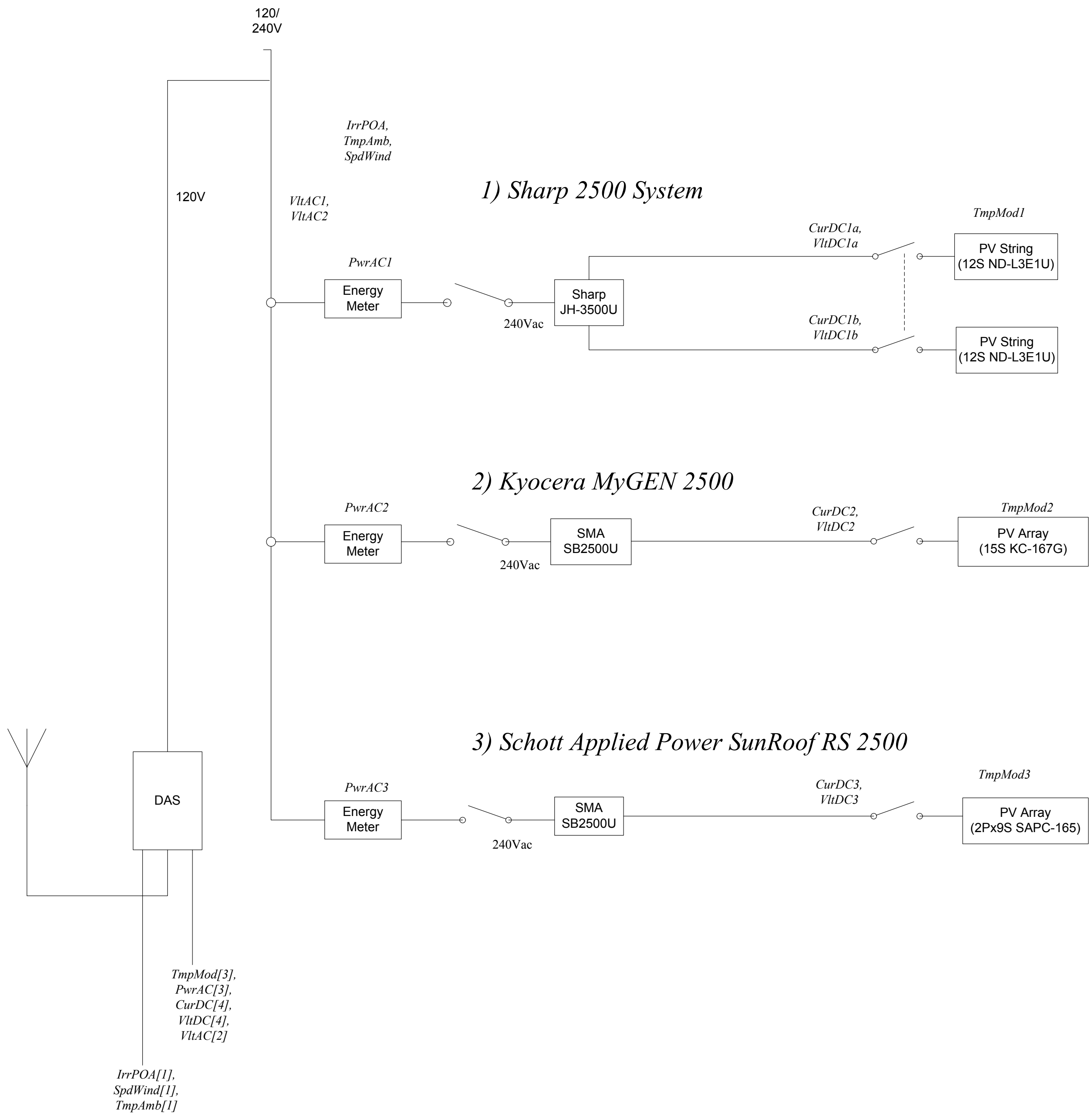

Figure 1. Small PV Systems Major Components

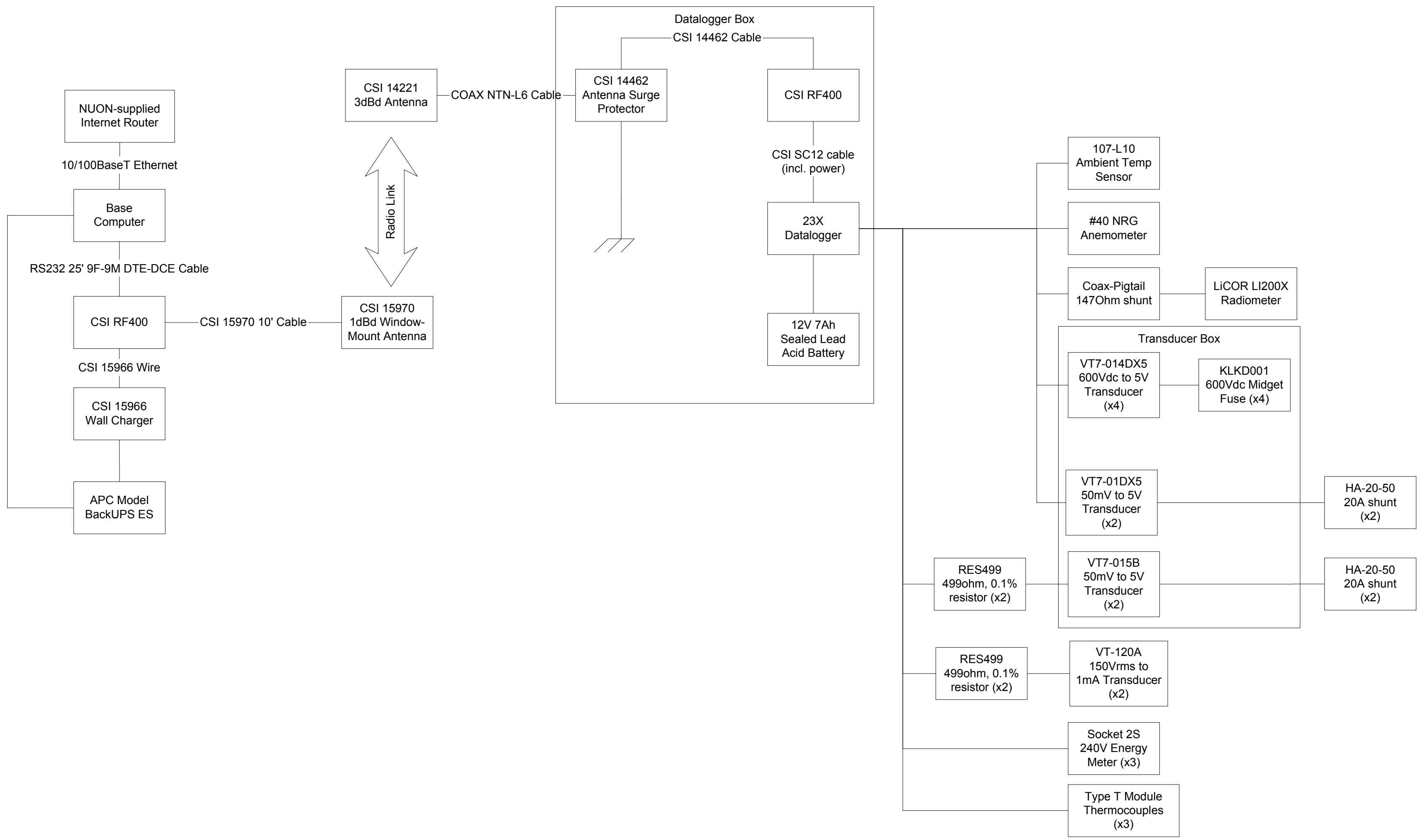

Figure 2. DAS Block Diagram

2.1 Datalogger Subsystem

The datalogger subsystem consists of a datalogger enclosure, transducer enclosure, weather sensors, antennas, and interconnection cabling. As shown in Figure 2, the datalogger communicates to the Site Computer via serial connection (COM1) with an RF400 digital radio link. The Datalogger and Transducer enclosures are located on the back of the roof mock-up structure. Figure 3 shows the Datalogger and Transducer enclosures, as well as the 480V-240V transformer, main ac disconnect, and power distribution enclosure. Ac power is connected to three energy meter enclosures about 50 feet to the right of the main ac disconnect. The 240V voltage level is monitored in the transducer cabinet with two separate 120Vrms voltage transducers, which are assumed to be 180 degrees out of phase. Dc voltage and current are measured for each system in the dc disconnect boxes on the inverter side of the disconnect. Transducers, including the pyranometer (irradiance), anemometer (wind speed) and thermocouples (ambient and array temperatures) are mounted close to the datalogger and produce signals that are routed directly to the datalogger. The datalogger is configured to monitor each channel once every five seconds and to store fifteen-minute averages of these channels as well as the maximum recorded wind speed.

Figure 3. Datalogger and Transducer Enclosures

Key datalogger subsystem components are identified in Table 2. Some transducers were reclaimed from existing unused PVUSA data acquisition systems. An in-situ, end-to-end calibration was performed to verify the accuracy of all ac and dc measurements

Table 2. Datalogger Subsystem Major Components and Transducers

Device	Manufacturer	Model	Location	Source
Datalogger	Campbell Scientific	CR23X	DAS Enclosure	Reclaimed
Communications Radio	Campbell Scientific	RF400	DAS Enclosure, I&C Building	Campbell Scientific
AC Voltage Transducer	Ohio Semitronics	VT-120A	Transducer Enclosure	Reclaimed
DC Voltage Transducer	Ohio Semitronics	VT7-014DX5	Transducer Enclosure	Reclaimed
DC Voltage Isolator (for Current Shunt)	Ohio Semitronics	VT7-01DX5	Transducer Enclosure	Reclaimed
DC Voltage Isolator (for Current Shunt)	Ohio Semitronics	VT7-015B	Transducer Enclosure	OSI
Current Shunt	Empro	HA-20-50	DC Disconnect Enclosures	Empro
Pyranometer	LI COR	LI-200SA	Rooftop (one, for common array orientation)	LI-COR
Anemometer	NRG	#40	Rooftop	Reclaimed
Ambient Temp Sensor/Radiation Shield	Campbell Scientific	Model 107 / Model 41301	Rooftop	Reclaimed
AC Energy (Pulse initiating meter)	ABB	A1D Alpha Meter	Next to AC disconnects	Austin International

2.1.1 Documentation

Documentation for the individual datalogger subsystem components is supplied in a mixture of paper and electronic forms. Documentation of the CR23X datalogger is only available in hard-copy form. Spec sheets and manuals for DAS components supplied by Endecon are in electronic form and may be found in the `C:\EndeconDAS\Documentation\` directory of the Site Computer.

Drawings and terminal connection tables are stored in the files described in Table 3.

Table 3. List of Datalogger Subsystem Drawings and Terminations Tables

Filename	Description	File Type
SmDASWHDiagrams.vsd	Overview diagrams of DAS	Visio Drawing
Sm_das_terminations.xls	Tables identifying connection points for the DAS box (2 worksheets), and Transducer box (2 worksheets).	Excel Workbook

3 Software

Software for the DAS running on the Site Computer consists of Campbell Scientific LoggerNet for retrieving data from the Datalogger, plus ancillary utilities to facilitate data transfer. The sequence of data movements and processing are shown in Figure 4.

Software within the Campbell datalogger `(C:\EndeconDAS\23X\SmPIER.CSI)` controls its behavior, determines which inputs to sample, how often to sample them, what calibration coefficients to apply, and how often to generate averages. The various sensors connected to the Campbell datalogger are sampled every 5 seconds, and the data placed in internal memory (Input Locations). Input Locations are available to the local LoggerNet numeric and graphical display functions. In addition each value is accumulated for statistical operations within the datalogger. Every 15 minutes, the datalogger stores accumulated results (averages and maximums) in a non-volatile circular buffer. The operation of the datalogger during loss of utility power is supported for a few days by an external lead-acid battery, but stored data is kept in non-volatile flash memory and will be retrievable even after sampling ceases when the battery is discharged. Note that during such power loss, none of the PV systems will operate nor will those transducers that require ac power to operate (ac and dc voltage and current, ac energy), so the only useful information would be from the weather instrumentation.

Real time display update rates available to the local user are limited mostly by the “sampling rate” that is set to 5 seconds.

Long-term data trends are extracted from the “averaged” data stream from the CSI “final storage”. The LoggerNet data software is configured to download data 30 seconds after the quarter-hour and triggers a script to transmit the newly recorded data to the Central Database. A single file containing uploaded data is maintained by LoggerNet on the Site Computer, and is left undisturbed by the transfer of new data to Endecon Engineering. This file `(C:\EndeconDAS\CSIData\SMPIER_23X_1.DAT)` can serve as a temporary backup for data transmitted to the Central Database.

Data transfer from the Site Computer to the Central Database is accomplished using standard e-mail techniques. Email was selected due to its low impact on Internet firewalls and inherent support for data buffering.

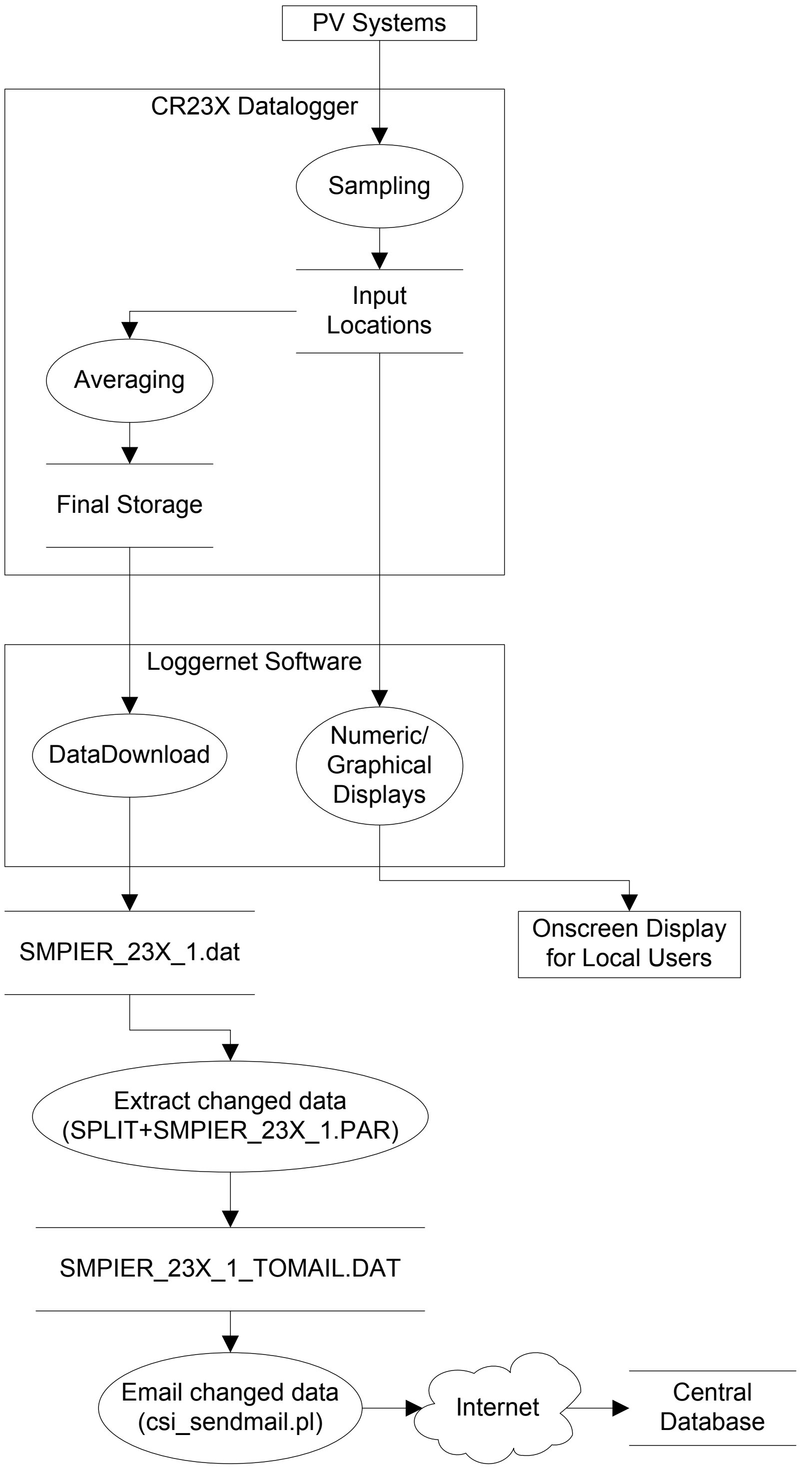

Figure 4 Data Flow Diagram

Data received by the Central Database computer are used to compute performance measures. This computer forwards results to the web site for display. Real-time data updates for remote users on the Commonwealth Mini-Grid Program website are implemented by tapping into these "averaged" data.   Update rate for that display is currently 4 times an hour with a delay of about three minutes after the quarter-hour.

3.1 LoggerNet Software

Campbell Scientific LoggerNet[3] is actually a combination of programs used to configure their dataloggers, review current readings, and record data. LoggerNet comes with an extensive manual covering these features ("Loggernet21.pdf" in the `C:\EndeconDAS\Documentation\Software\` directory of the Site Computer), so this discussion will only cover the configuration used in this system.

The LoggerNet software should be running at all times on the Site Computer, to insure that data are transferred from the datalogger to the computer hard disk, and to relay recent readings to Endecon for processing and uploading to the project web site in a timely manner.

3.1.1 Viewing Real-time Data

Real-time data may be monitored numerically or graphically through the LoggerNet Communication window. To initiate real-time monitoring, go to the LoggerNet main window titled "Datalogger Support Software" and click the "Connect" button to activate the communication window.

The communication window may or may not automatically connect when it is opened, depending on whether it was "connected" when the window was last closed. If it does not automatically begin to update the "Station" clock display, confirm that the correct station is selected (in the current configuration, there is only one station, labeled "CR23X1") and click the "Connect" button to initiate communication.

Once communication is enabled, the primary display is #1, so click the "Data Displays"/"Numeric 1…" button. Note that the screen will update a few seconds after the channels are updated in the datalogger, which occurs once every 5 seconds.

The real-time display may be left active indefinitely so long as status logging is disabled (otherwise the disk would fill with unnecessary information about the success or failure of every communication with the datalogger). If the disk seems active while real time display is active, go to the Status window of LoggerNet and use the "Edit"/"Log Settings…" menu to disable logging to disk. These options may get enabled if someone is troubleshooting datalogger communications and forgets to disable them.

3.1.2 Overview of Datalogging Automation

LoggerNet data collection automation is configured in the Setup window. The contents of the right portion of this window change when different items are selected in the "datalogger network" configuration pane on the left portion of the window. For this project, the CR23X_1

[3] Note: LoggerNet was recently introduced as a replacement for Campbell's traditional PC208W software

datalogger is the key configuration item. Also, the "Tasks…" button on the Setup window opens the Task Master window used to configure what action happens when data are collected.

To support web data reporting, data are collected every 15 minutes (schedule tab), Final Storage Area 1 must be enabled (Final Storage Area 1 tab) to append CSV data to `C:\EndeconDAS\CSIData\SMPIER_23X_1.dat`, and the Task Master "To_Mail" task attached to the SmDAS datalogger should be configured to activate the csi_sendmail.pl script (File Name = "`C:\Perl\bin\perl.exe`", Command Line Options = "`c:/EndeconDAS/bin/csi_sendmail.pl`", and Working Directory = "`c:/EndeconDAS/mailctl/`").

It is also recommended to maintain clock synchronization between the datalogger and the computer (Clock tab), assuming internet clock synchronization for the PC is enabled (using AboutTime).

3.1.3 Viewing Logged Data

Because the data collection schedule causes LoggerNet to open the file `C:\EndeconDAS\CSIData\SMPIER_23X_1.dat` every 15 minutes, care should be taken to look at the time to make sure it is not near a 15-minute download interval before accessing the file. To minimize the amount of time you might conflict with LoggerNet, copy the file to a temporary file with a .CSV filename extension and open that file with Excel.

No templates for viewing logged data locally are included on the DAS computer graphically at this time. Plotted data will be available for the duration of the PIER project on the PIER PV evaluation data website (http://pierminigrid.showdata.org).

3.2 Data Emailing Script for LoggerNet Data

As noted above, data transfer to the central database computer is accomplished using e-mail. The `csi_sendmail` script (`C:\EndeconDAS\bin\csi_sendmail.pl)` is invoked by LoggerNet each time new data is added to the `C:\EndeconDAS\CSIData\SMPIER_23X_1.dat` data file to send the newly added data records to the central database computer for analysis, archiving, and forwarding to the project web server. The script is written in Perl, so ActiveState Perl (http://www.activestate.com/) has been installed for the script to run. The script may be edited with any text editor (such as Notepad). Certain "library packages" (MIME::Lite and Net::SMTP) have also been downloaded from the Comprehensive Perl Archive Network (CPAN) using the Perl Package Manager and installed to support the the `csi_sendmail.pl` script.

The script includes certain variable definitions that may need to be updated if the processing or network environment changes. They are located just after the "Main (top-level) processing statements" comment banner. The smtpserver and fromaddress variables will have to be set to work with an appropriate SMTP server. The local file and directory-specific variables would only need to be edited (in a copy of this script) if another email destination is desired.

The `csi_sendmail` script performs the following tasks:

The LoggerNet SPLITR program is invoked by the script to extract the most recently-downloaded data. The PAR file (`C:/EndeconDAS/mailctrl/SMPIER_23X_1.PAR`) created by SPLITW is referred to and modified by SPLITR to keep track of which data has been downloaded. Therefore, the script saves both the updated and the old versions of the PAR file, leaving the old version in place until after the data are successfully emailed, and only then replacing the last version with the updated version.

Emailing requires outbound access to the Internet. If internet access is only available at specific times, the script will run, fail, and start over with the same PAR file, and extract the same data values plus any newly collected data the next time it runs. This feature provides a level of data continuity assurance in the central database with a minimum of manual intervention.

4 References

The following manuals are provided

Table 4. Supporting Documentation

Item	Location
Campbell 23X Datalogger Manual	Hardcopy; existing copy from PVUSA documentation
Campbell Scientific LoggerNet Manual	`C:\EndeconDAS\Documentation\Software\Loggernet21.pdf`
Perl “Manual” pages	Start Menu / Programs / ActiveState Perl / Documentation

Many Campbell Scientific manuals are available at their web site
http://www.campbellsci.com/manuals.html