

User's Guide

Soiling & Irradiance Measurement Using the RDE300 Series



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1 System Overview

1.1 Introduction

Soiling and Irradiance Measurement Systems with the RDE300 Series measurement and control unit collect critical data for evaluating PV array performance. The systems can be used at operating PV power plants and pre-construction site survey locations.

Each system uses one or two attached PV reference devices to perform measurements. Major applications include:

- **Irradiance Measurement:** Using a calibrated PV reference cell or reference module, the system produces accurate irradiance measurements that are well matched with the effective irradiance perceived by the user's PV array. Optional automated washing of the calibrated PV device ensures that the irradiance measurements are free of soiling artifacts.
- **Soiling Measurement:** Using a pair of PV devices, one clean and the other naturally soiled, the system measures power loss due to soiling. The system allows the user to choose a PV module identical to those in their PV array as their soiled reference module, ensuring that soiling measured by the system accurately represents soiling on the user's PV array. Optional automated washing of the clean reference device minimizes technician labor.

Accurate and reliable measurements are ensured by advanced features, including:

- **I-V Curve Measurement:** The system measures both short-circuit current and output power of PV modules from a complete I-V curve, ensuring accurate results even when soiling is spatially non-uniform.
- **Choice of Hold State:** In between measurements, the system holds PV reference modules at the user's choice of either open-circuit (typical for crystalline silicon modules) or short-circuit (typical for thin-film modules), minimizing PV module degradation.
- **Advanced Wash Unit:** The optional automated wash units not only provide an effective way to ensure clean irradiance measurements without technician labor, but also have advanced features for reliable operation, including:
 - Automatic dispensing of desired fluid amount using an integrated flow sensor
 - Diagnostic outputs that enable the user to log each wash event
 - Integrated heating system to allow deployment in cold climates that may include sub-freezing winter temperatures
- **Built-In Analysis:** The RDE's internal software analyzes all readings performed each day and produces filtered daily average values available on separate registers, reducing the need for post-processing of the data on the user's logging platform.

1.2 System Components

Major components of the system are illustrated in Figure 1-1.

The **RDE** is the Measurement and Control Unit for the entire system. This user guide addresses systems using the RDE300 Series. The series includes various models configured for different PV input ranges, number of PV inputs, power options, and other optional configurations. See Section 6.1 for more information.

PV1 and **PV2** are PV reference devices, which may be either reference cells or reference modules, depending on system configuration. Reference cells are supplied by Atonometrics for applicable system configurations; reference modules are typically user-provided.

The optional **Wash Unit** directs cleaning fluid through a **Spray Nozzle** for automatic cleaning of the PV1 device. See Section 6.4 for more information.

For **irradiance measurement**, only a single PV reference device (PV1) is required, and this device must be calibrated.

For **soiling measurement**, both PV1 and PV2 are required. PV1 is designated as the “clean” reference, and must be either automatically or manually cleaned. PV2 is designated as the “soiled” reference. The RDE compares the power output of PV2 to the expected power output given the irradiance measured on PV1 and uses this data to provide a soiling measurement.

The system components must be mounted on a user-supplied support structure.

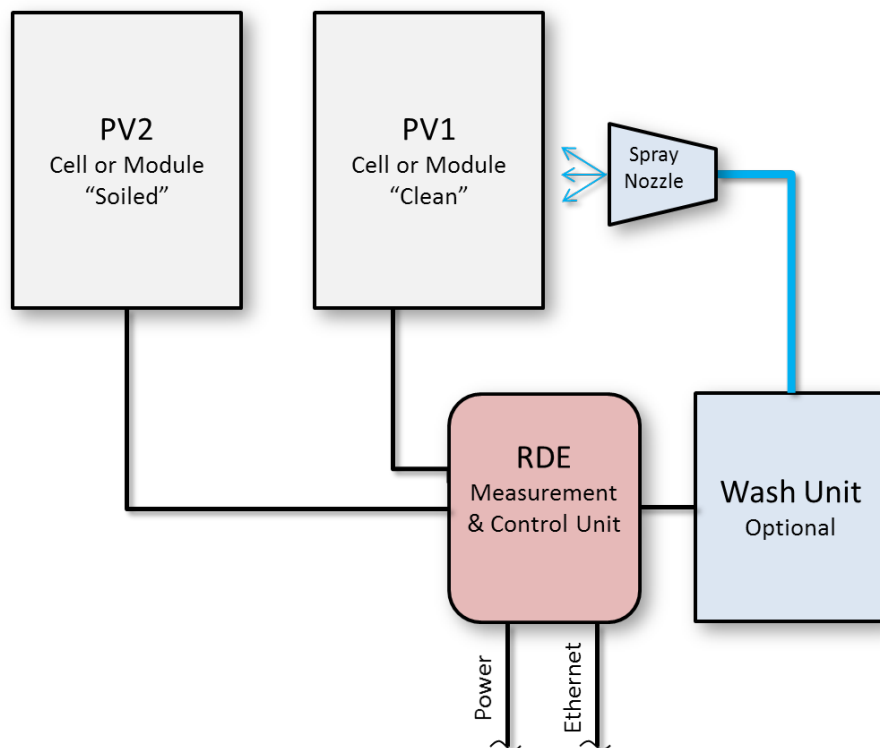


Figure 1-1: Major system components

For user applications requiring more than two PV device inputs, systems can be configured using multiple RDE300 Series measurement and control units, each of which supports up to two devices. To simplify installation with multiple RDEs, Atonometrics offers a **Hub** for power and Ethernet distribution. The user provides power and Ethernet input to the Hub and the Hub distributes power and Ethernet to connected RDE units as shown in Figure 1-2. See Section 6.2 for more information.

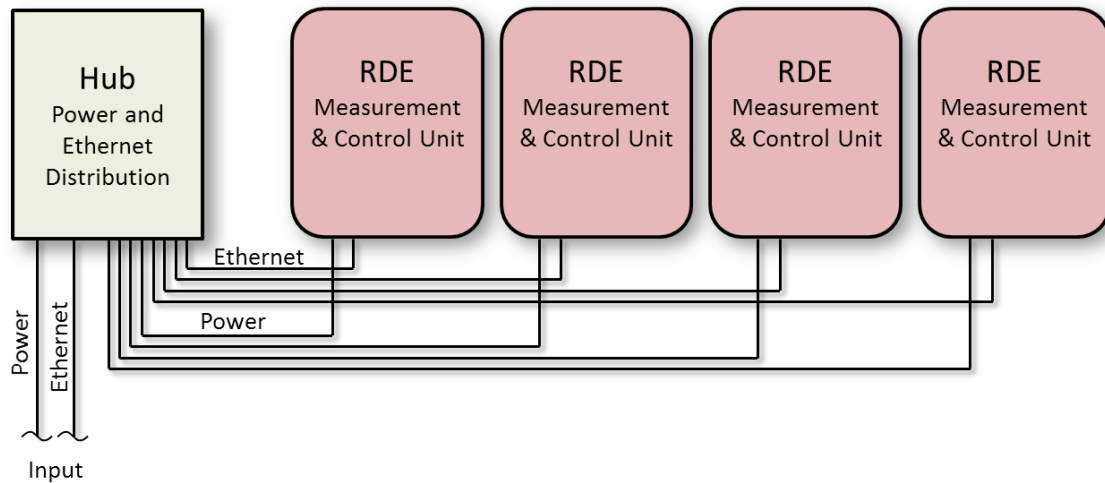


Figure 1-2: Multiple RDEs joined by Hub

1.3 Layout Guidelines

RDE and Hub:

- Mount the electronics enclosures (RDE and Hub) in a shaded location, if possible, such as directly underneath the PV modules.

Automatically Washed Reference Cell:

For proper system function, layout should be arranged to prevent fluid spray from inadvertently cleaning portions of the soiled PV reference module (PV2). Accordingly:

- If possible, mount the Reference Cell below PV2, as shown in Figure 1-3.
- If the Reference Cell is to be mounted to the side of PV2, position the cell at least 3 ft. from PV2. (When the cell is mounted at the end of a PV string, consider selecting an interior module, second from the end, to serve as PV2, rather than the end module, to more easily meet the 3 ft. spacing requirement.)
- Mount the Reference Cell with its cable facing down, preferably, or to the side, if required.
- For single-axis tracking systems, the Reference Cell mounting plate may be mounted to the tracking system torque tube.

Wash Unit:

- The Wash Unit must be mounted below the Reference Cell, for proper drainage of cleaning fluid.

Cable and Hose Lengths:

- RDE Module Leads: 84" (2.1 m)
- RTD Cable: 112" (2.8 m)
- RDE to Reference Cell Cable: 120" (3.0 m)
- Hose from Wash Unit to Ref Cell Nozzle: 96" (2.4 m)
- Wash Unit to RDE Cable: 96" (2.4 m)

For additional information, please request mechanical drawings and consultation from Atonometrics.

1.4 Example Installations

The photos in this section illustrate example installations. Note that the installations conform to the layout guidelines in Section 1.3.

1.4.1 With Automatically Washed Reference Cell

Standalone System

Figure 1-3 shows an example of a standalone system with an automatically washed reference cell as PV1 and a full-size PV module as PV2. Typical applications include pre-construction data gathering at planned solar power plant sites. The metal support structure would be user-provided.

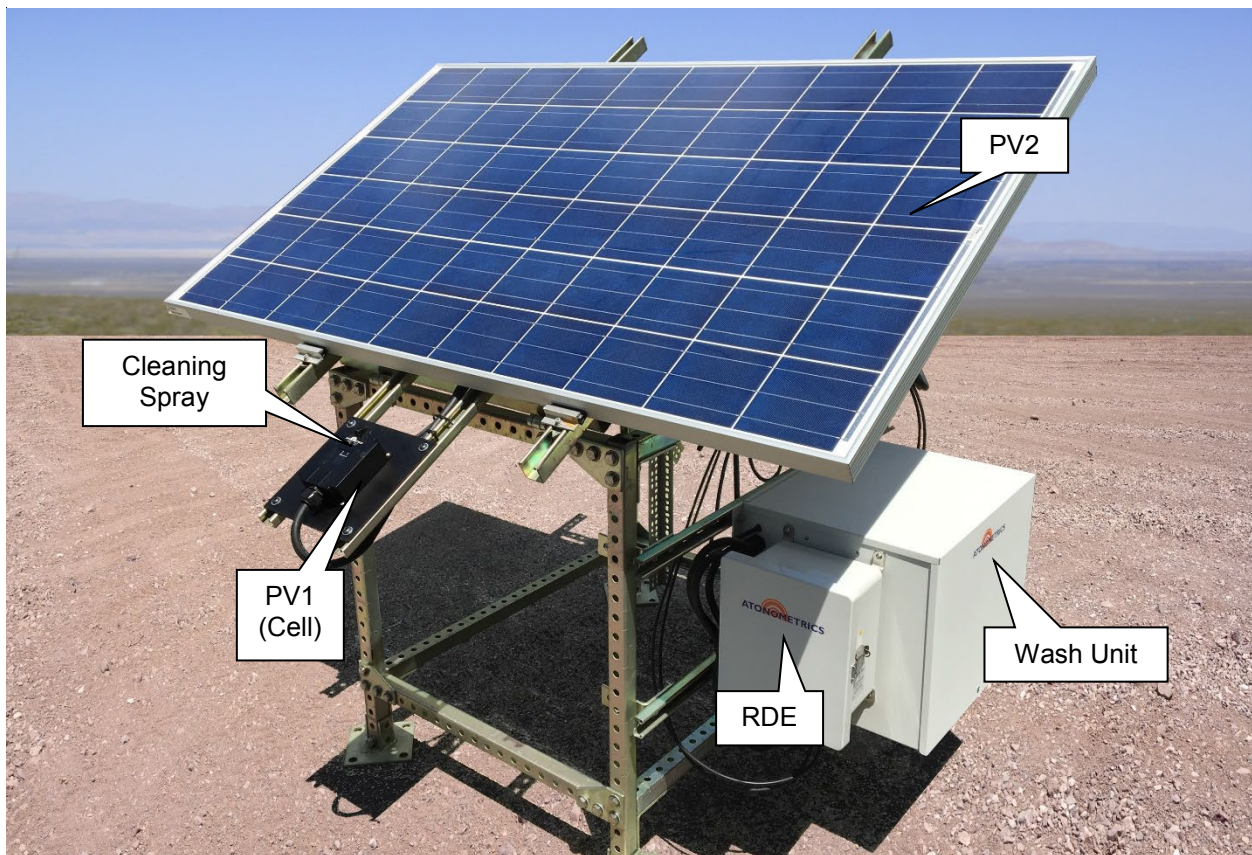


Figure 1-3: Example stand-alone installation

In Fixed-Tilt PV Array

Figure 1-4 shows an example installation in a fixed-tilt array. Note that the PV1 reference cell is mounted co-planar to the PV2 soiled module and is positioned below and away from the module to prevent the PV1 cleaning spray from inadvertently cleaning a portion of PV2.

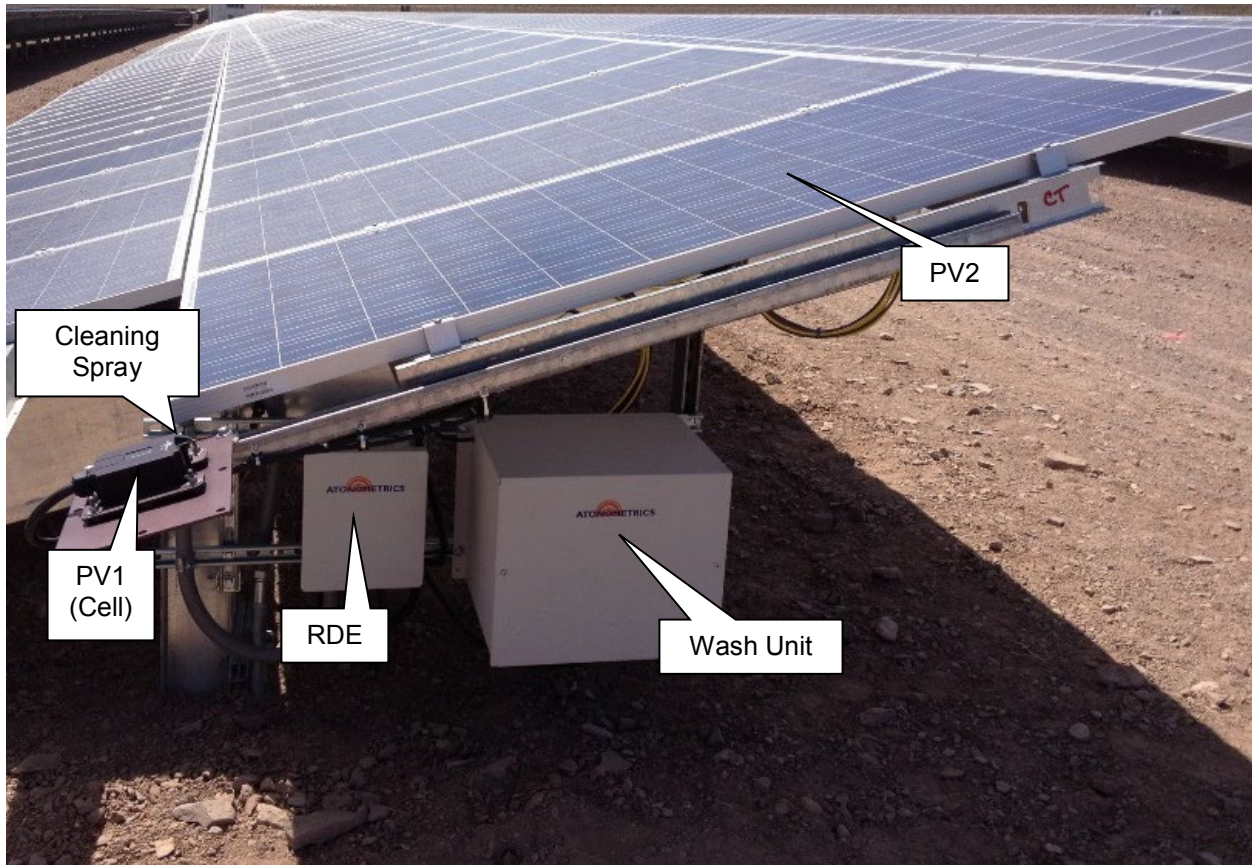


Figure 1-4: Example installation in fixed-tilt PV array

In Single-Axis Tracking Array

Figure 1-6 shows an example installation in a single-axis tracking array. Note that the PV1 reference cell is mounted on the tracking system torque tube, so that the PV1 device is maintained co-planar with PV2 throughout the day. Also note that an interior module is selected as PV2 to provide sufficient distance from the PV1 cleaning spray, and that the spray is directed away from the modules.

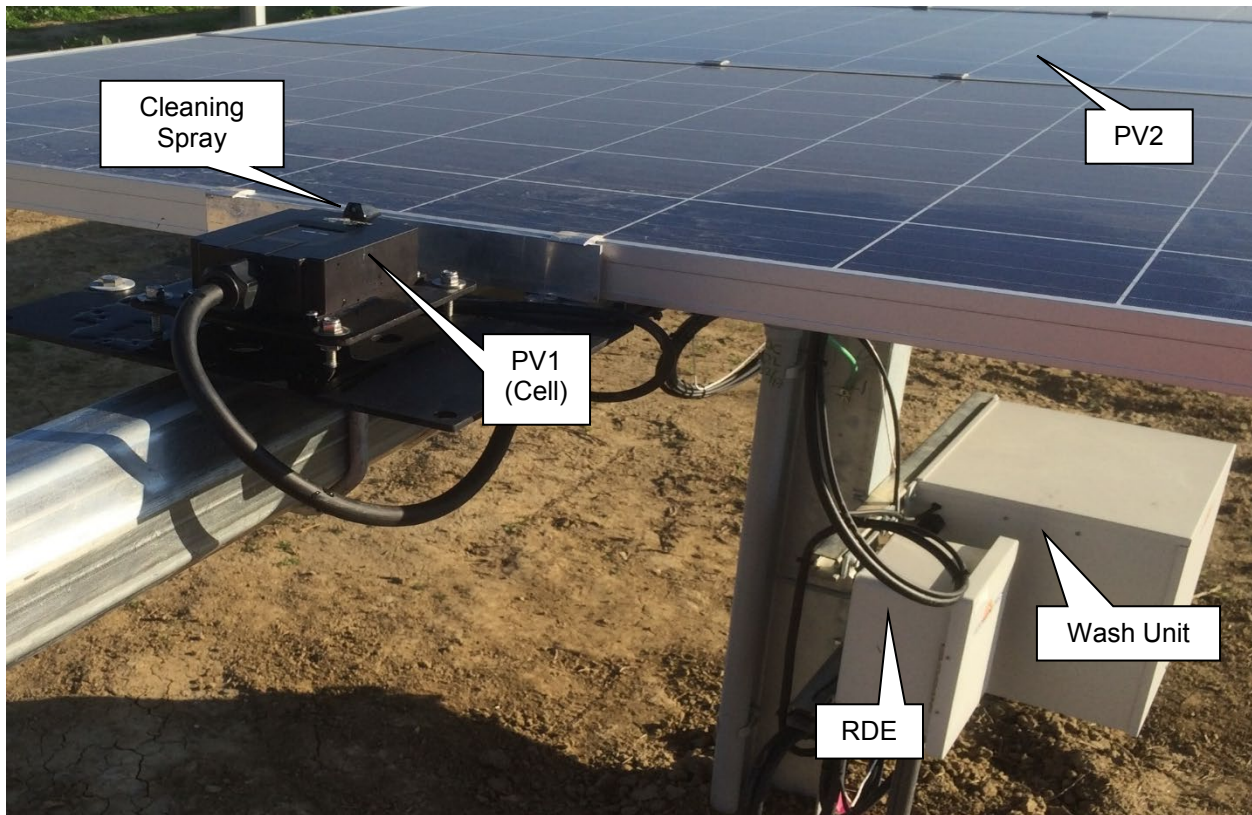


Figure 1-5: Example installation in single-axis tracking array

1.4.2 With Two Modules

Figure 1-6 shows an example installation without the automatic Wash Unit. In this example the Atonometrics system consists of an RDE300 unit with two inputs for PV modules. The PV1 module is manually washed by on-site personnel, and the PV2 module is allowed to collect soiling. (The RDE300 unit is mounted beneath the modules and is not visible in the photo.)



Figure 1-6: Example installation with two modules and manual washing

2 Theory of Operation

2.1 Irradiance Measurement

How Does the RDE Measure Irradiance?

The temperature-corrected short-circuit current of a clean PV device is proportional to irradiance. After measuring the PV device short-circuit current and temperature, the RDE determines irradiance using the following equation:

$$G = G_0 \cdot \frac{I_{sc} \cdot (1 - \alpha \cdot (T - T_0))}{I_{sc,0}} \quad (1)$$

Here I_{sc} is the measured short-circuit current and T is the measured PV device temperature. The other terms are constants for the device: $I_{sc,0}$ is the known short-circuit current at a reference condition (e.g. STC), T_0 is the temperature at the reference condition (e.g. 25 °C), G_0 is the reference condition irradiance (e.g. 1000 W/m²), and α is the temperature-coefficient of short-circuit current. These constants for each connected PV device are programmed into the RDE non-volatile memory.

What Calibration Is Required?

For accurate irradiance measurements, the PV device should be calibrated using a traceable reference.

For systems including an automatically washed Reference Cell, Atonometrics calibrates the cell at the factory and pre-programs the calibration constants into the RDE prior to shipment.

When using a PV module for irradiance measurement, there are several options for determining calibration constants. The user may send the module to Atonometrics for calibration. Alternatively the PV module may be calibrated on-site using the Atonometrics Field Calibration Unit, which is available separately.

For systems employing two devices, PV1 and PV2, typically only the PV1 device is used for irradiance measurement and must be calibrated. However, the RDE supports using both devices for irradiance if desired.

2.2 Soiling Measurement

What Is Soiling?

Soiling is the accumulation of dust, dirt, and other contaminants on the surfaces of PV modules, causing reduction of PV module output power.

How Does Soiling Affect PV Module Output?

Figure 2-1 illustrates how soiling affects PV module output. Consider a 72-cell crystalline silicon PV module as shown in the upper part of Figure 2-1. When the module is clean, it produces the

I-V and P-V curves shown by the solid lines in the graph in the lower part of the figure. If the module is uniformly soiled (as shown by the diagonal hatch marks across the entire module) to a level blocking 5% of the incident light, the short-circuit current, I_{sc} , and maximum power, P_{max} , each decrease by ~5%, as shown by the dashed lines in the graph. However, if in addition the module has non-uniform soiling consisting of a dirty strip across the bottom edge shading 10% of the bottom row of cells, as shown by the cross-hatched pattern on the diagram, the effect on the I-V and P-V curves is more complex, as shown by the dotted lines in the graph. The I_{sc} is not affected at all in this example, while the P_{max} is reduced by ~8.5% from the clean-state value. Therefore, it is important to measure the I-V curve and P_{max} value – as done by the RDE300 Series – to accurately measure this common type of soiling, rather than relying on short-circuit current reduction alone.

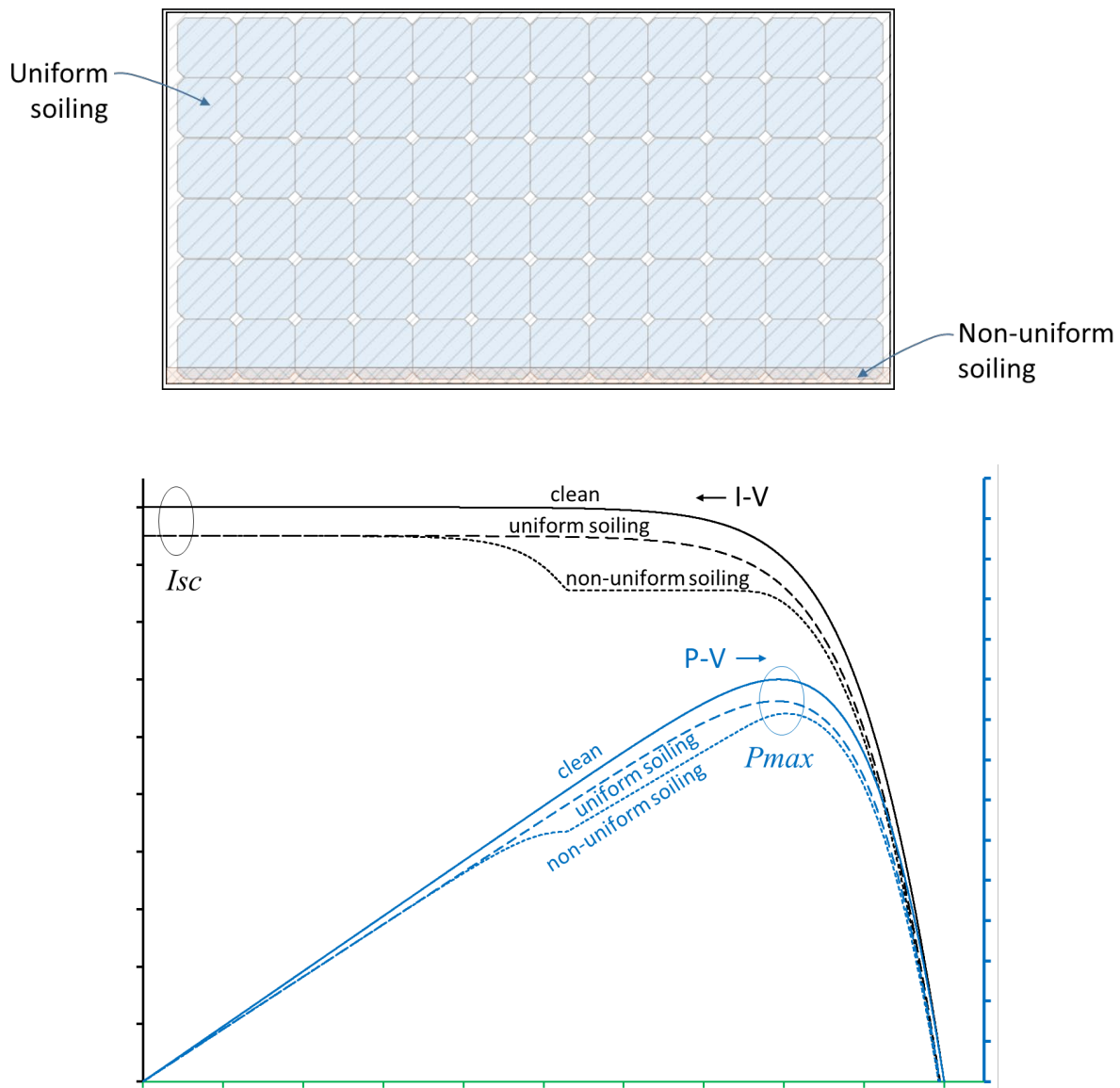


Figure 2-1: Illustration of soiled PV module and corresponding I-V & P-V curves

How Does The RDE Measure Soiling?

The RDE measures a complete I-V curve of the soiled module. It then calculates a soiling ratio metric. The soiling ratio SR is given by an equation of the form:

$$SR = \frac{\text{Measured Output}}{\text{Expected Output}} \quad (2)$$

The “expected output” is the output expected if the module is free of soiling, such that the above ratio should equal 1 when the module is clean.

The RDE provides several SR metrics.

One metric is the $SR^{I_{sc}}$ value which is based on the measured short-circuit current, calculated using the formula:

$$SR^{I_{sc}} = \frac{I_{sc}^{soiled}}{I_{sc,0}^{soiled} \cdot (1 + \alpha \cdot (T^{soiled} - T_0)) \cdot (G/G_0)} \quad (3)$$

Here I_{sc}^{soiled} and T^{soiled} are the measured short-circuit current and temperature of the soiled module, while $I_{sc,0}^{soiled}$, T_0 , α , and G_0 are calibration values defined in Section 2.1. G is the irradiance determined by the RDE300 from the clean PV reference device PV1 (cell or module) as defined in Section 2.1.

A second metric is the $SR^{P_{max}}$ metric based on the measured power, calculated using:

$$SR^{P_{max}} = \frac{P_{max}^{soiled}}{P_{max,0}^{soiled} \cdot (1 + \gamma \cdot (T^{soiled} - T_0)) \cdot (G/G_0)} \quad (4)$$

Here P_{max}^{soiled} is the measured maximum power of the soiled module, $P_{max,0}^{soiled}$ is the module's known maximum power at the reference condition, and γ is the temperature-coefficient of maximum power.

$SR^{I_{sc}}$ captures uniform soiling effects only, while $SR^{P_{max}}$ captures both uniform and non-uniform soiling. $SR^{P_{max}}$ is the value expected to track most closely with actual PV plant power loss due to soiling.

In addition to $SR^{I_{sc}}$ and $SR^{P_{max}}$, the RDE provides another soiling ratio metric denoted simply SR . (See register list, Table 12-1.) SR is calculated as a weighted average of $SR^{I_{sc}}$ and $SR^{P_{max}}$, constructed to be close to the $SR^{P_{max}}$ value. The calculation function weights the $SR^{P_{max}}$ value more heavily in the weighted-average as the difference between $SR^{P_{max}}$ and $SR^{I_{sc}}$ exceeds the measurement uncertainty.

What Calibration Is Required?

The constants of the soiled module defined in the previous section must be available. However, for soiling measurement, since the metrics are normalized, it is sufficient to take the module

constants from the module datasheet and then perform a final normalization in the field using the RDE, as described in Chapter 11.

How Are the Data Analyzed?

The RDE will be factory-configured to perform measurements once per minute. However, the minute-by-minute data will show significant variation throughout the day due to changing conditions, including sun angle, irradiance level, and especially the motion of clouds, which cause rapid fluctuations in the relative irradiance of the clean and soiled PV devices. Therefore, the minute data must be filtered and averaged to yield a single daily average value for each soiling ratio. The user may perform this filtering and averaging on their own logging platform. However, beginning with firmware version R3979 released October 2017, this daily averaging is also performed directly in the RDE firmware and provided on additional registers, eliminating the need for post-processing on the user's platform.

The RDE's internal analysis has the following features:

- **Time Window:** The RDE only reports soiling ratio readings that are performed within a user-settable number of hours before and after noon, e.g. ± 2 hours of noon or 10 AM to 2 PM local standard time. Readings outside the time window are ignored.
- **Irradiance Threshold:** The RDE only reports soiling ratio readings that are performed when the irradiance exceeds a user-settable threshold, e.g. 500 W/m². Readings below the threshold are ignored.
- **Filtered Average:** At the end of the time window for each day, the RDE performs a filtered irradiance-weighted average of all points recorded for the day. The average and standard deviation of all points is first computed and then points which are more than one standard deviation from the average are excluded. The final irradiance-weighted daily average is computed from the remaining points, using equation (5) below, provided that the number of remaining points exceeds a quality threshold. Note that the daily averages are reported by the RDE on separate registers than the minute data. See Section 12.3.

$$\langle SR \rangle_d = \frac{\sum SR \cdot G}{\sum G} \quad (5)$$

Example Data

Figure 2-2 shows example data from a four-day period and illustrates the analysis described above. The top two panels of the figure show the soiling ratio and irradiance measured by the RDE, while the bottom panel shows rain data collected by a separate instrument. In the top panel, green dots show minute data that pass the analysis filter, while red dots show minute data that are excluded. The soiling ratio readings are restricted to 10 AM to 2 PM and irradiance >500 W/m². At the end of each daily time window, the RDE computes a new updated value of the daily average soiling ratio value, shown by the thick black line. At the beginning of the plot, on the morning of June 9, the average soiling ratio is approximately 0.93, indicating 7% energy loss to soiling. At the end of the time window on June 9, the average soiling ratio is adjusted slightly downward based on the day's readings. On June 10, clouds arrive in the afternoon, as can be seen by the rapid irradiance fluctuations during this time in the middle panel of the figure. Note that during this time the soiling ratio readings are also fluctuating significantly as the clouds pass; however, these fluctuations are averaged out when the daily average is computed at the end of

the time window. Late in the day on June 10, rain arrives, as shown on the bottom panel of the figure, cleaning the PV devices. The soiling ratio minute data on June 11 are now close to 0.99, indicating reduced soiling loss. At the end of the time window on June 11, the daily average is updated to near 0.99 based on the day's readings. Another update on June 12 shows a small reduction in the soiling ratio as soil particles again accumulate.

Figure 2-3 shows a five-week period of the same data set. This larger time sequence shows a typical pattern, with the soiling ratio gradually decreasing from May 18 to June 10 at a rate of approximately 2% per week, a rapid increase in the soiling ratio with the rain on June 10, and then another period of continued decline in the soiling ratio. Note that the minute data show significant fluctuations on cloudy days compared to sunny days and that this variation is reduced by the RDE analysis described above. Also note that on June 5 no soiling ratio minute data are reported because irradiance was below threshold all day, and therefore the daily average is also not reported from the end of the time window on June 5 until the end of the next time window on June 6, when there are new valid data points. (However, beginning with software released May 2019, when there are not enough valid data points on a given day, the RDE will continue to report the soiling ratio based on the previous day's result.)

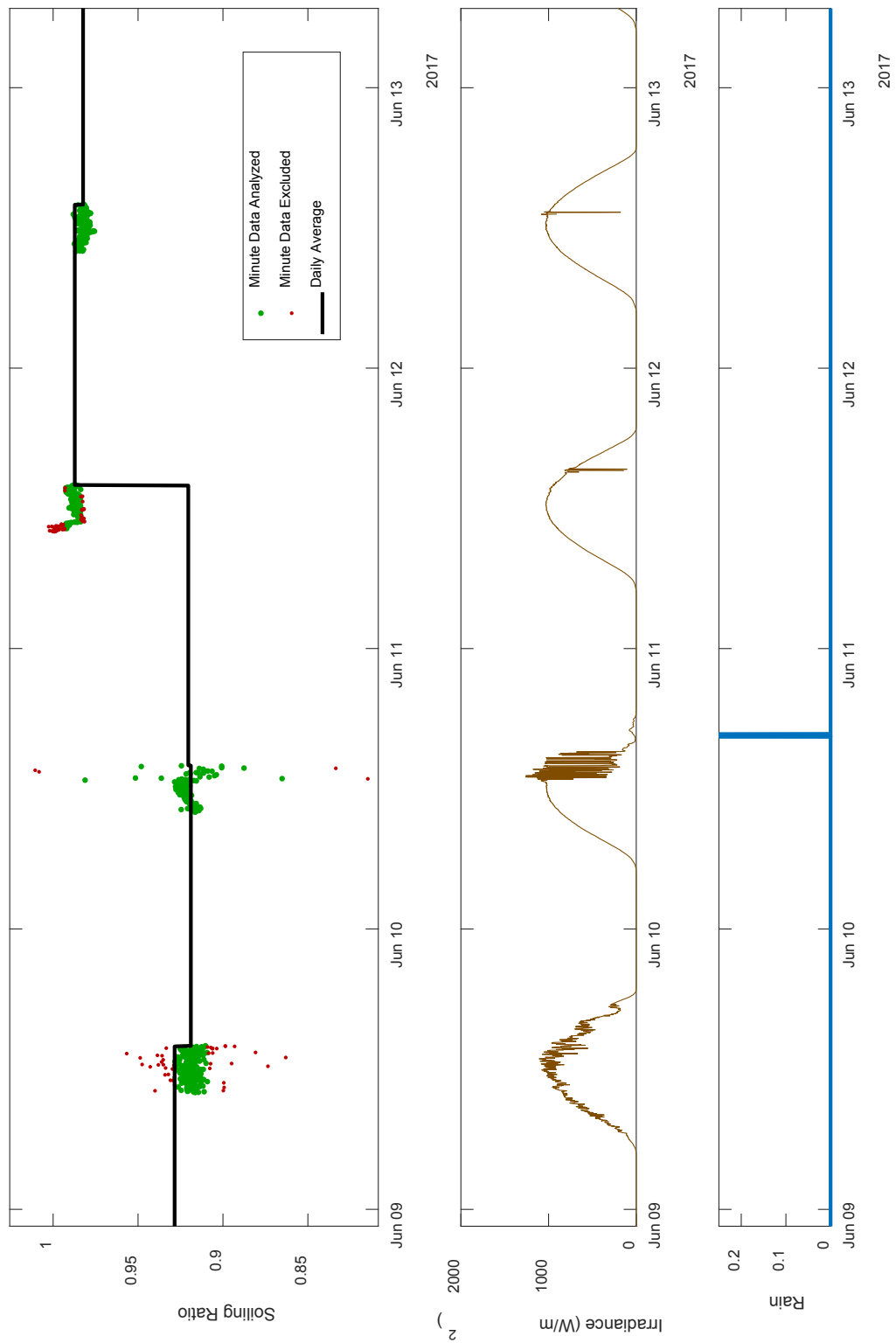


Figure 2-2: Example soiling data and reduction to daily average

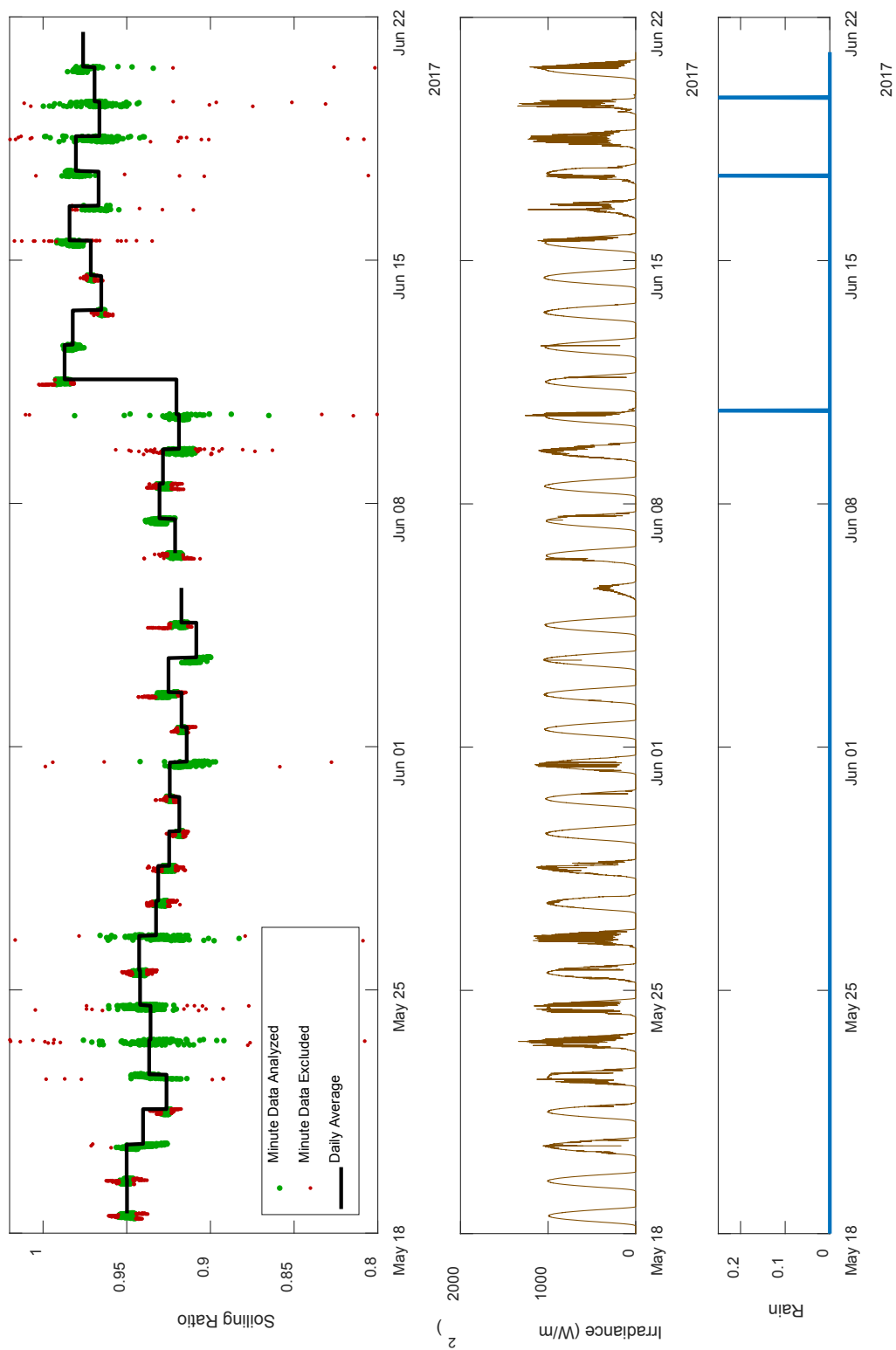


Figure 2-3: Example soiling data over five week period

For More Information and Training

Contact Atonometrics for more detailed information about theory of operation or guidance on usage of the system or data analysis. Atonometrics can provide Web-based tutorial and training sessions.

3 Safety

General Safety



WARNING: Follow directions: Operate this equipment only as directed in these instructions. Use for any other manner is not permitted, and may cause damage to the equipment or injury to personnel.

WARNING: Inspect before using: Inspect the equipment and note any damage or defects. The system should not be used if damaged or defective. All interconnecting wiring should be damage-free.

WARNING: Hazardous voltages: Hazardous voltages may be present inside electrical enclosures. Improper use of this equipment involves the risk of electric shock which could cause injury or death.

WARNING: Enclosures must be closed: The equipment may not be operated with any enclosure open except by qualified personnel in accordance with local codes.

WARNING: PV modules: Hazardous voltages may be present at connections to PV modules. These connections should be properly mated and secured during operation.

PV Module Safety



WARNING: Hazardous voltages: PV modules may produce hazardous voltages and currents when exposed to sunlight, and could create a lethal shock hazard during hours of daylight, including during periods of low light levels. The danger increases as modules are connected together in series and/or parallel. The following warnings pertain to single PV modules only. Strings of modules connected in series or parallel require additional safety precautions.

WARNING: Observe safety precautions: To avoid fire and/or injury due to ground fault and associated electrical hazards, observe all safety precautions listed.

WARNING: Do not unplug PV modules under load: Do not unplug PV module connections while under load. Do not disconnect the module connectors during daylight hours unless the module is in an open circuit condition or covered with an opaque material.

WARNING: Damaged wires: Repair or replace damaged wires immediately. Keep all array wiring out of reach of non-qualified personnel.

WARNING: Broken PV modules: Replace broken PV modules immediately.

WARNING: Ground faults: Repair any ground faults immediately.

WARNING: Safety glasses: Wear safety glasses (ANSI Z87.1-2003) and safety gloves when working on non-interconnected modules or systems.

WARNING: PV module instructions: Consult the user's guide for the PV module provided by the module manufacturer for additional safety instructions.

4 Quick Start Guide

System installation consists of the following steps:

- **Unpacking:**

- Unpack the system. See Chapter 4 for details.



- **Mechanical:**

- Note the system layout guidelines in Section 1.3.
- Set up the user-supplied support structure for the system components.
- Mount each of the system components to the support structure as directed in Chapter 6.
 - RDE units
 - PV1 Reference Device
 - PV2 Reference Device (if used)
 - Wash Unit (if included)



- If the system includes a Wash Unit, fill the Wash Tank with **distilled water only** (or distilled water plus winterizing additive) as directed in Section 6.4.

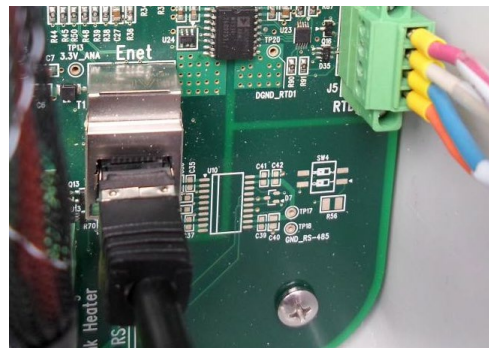


- For soiling measurement, **align the clean and soiled reference devices to within 0.5 degrees**, as directed in Chapter 7.

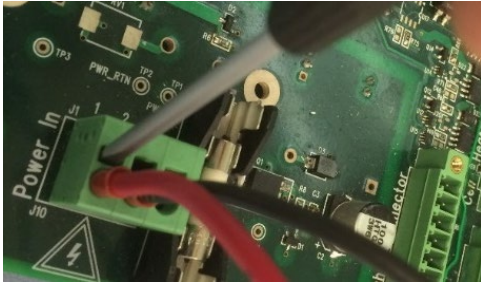


- **Electrical:**

- Install the Ethernet cable to the RDE. See Section 6.1 (and 6.2, if needed).



- Supply power to the RDE. See Section 6.1 (and 6.2, if needed). Refer to the wiring instructions on the door inside the enclosure.



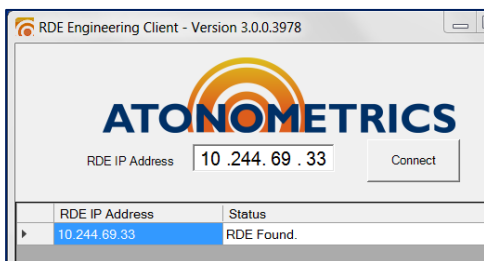
- Connect PV module electrical leads to the RDE as directed in Section 6.5.

- **Configuration:**

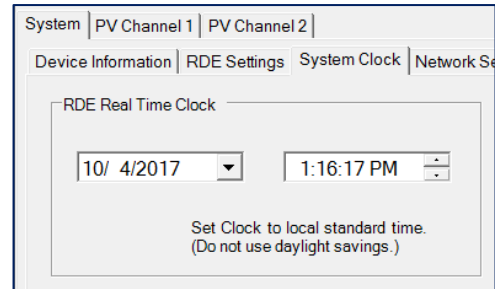
- Connect the RDE to the user's network and set up the network as directed in Chapter 8.
- Install** and run the RDE Engineering Client software to configure the RDE, as directed in Chapter 9.

****Download the software from:**

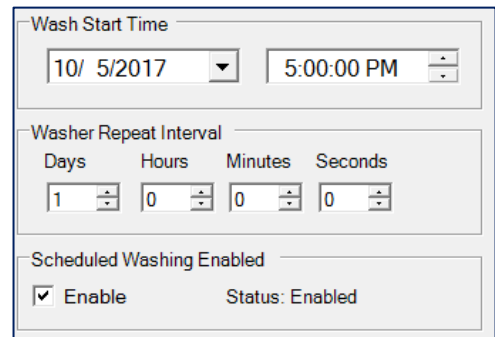
www.atonometrics.com



- Set the system clock to **local standard time (not daylight savings time)** at the site. See Section 9.4.3.



- Test the system as described in Chapter 10.
- **Enable the Wash Unit**, if equipped, and set the wash schedule. Atonometrics recommends daily wash at 5 PM.



- **Calibration:**

- Enter calibration or datasheet values for user-supplied PV devices.
- For soiling measurement, **clean the PV2 module and calibrate it per Chapter 11. Note: this procedure must be performed on a clear day between 10 AM and 2 PM.**

- **Data Acquisition Programming:**

- Program the user's data acquisition client software to read data from the RDE, using information provided in Chapter 12.

5 Unpacking the System

5.1 Systems with Automatically Washed Reference Cell

Figure 5-1 shows unpacking of a system including the automatically washed reference cell. The shipping box will contain the RDE, the Wash Unit, the Reference Cell, an RTD kit for the user's PV module, and associated cables and hoses.

Systems shipped after Q2 of 2017 will have the RDE and Reference Cell pre-mounted to the Wash Unit, as shown, for convenience in shipping, unpacking, and installation. The RDE may be left mounted to the Wash Unit; it is not necessary to remove it. However, once the system is installed at the site and the Wash Unit is mounted to the user's support structure, the Reference Cell should be disconnected from the Wash Unit and mounted in the appropriate location.

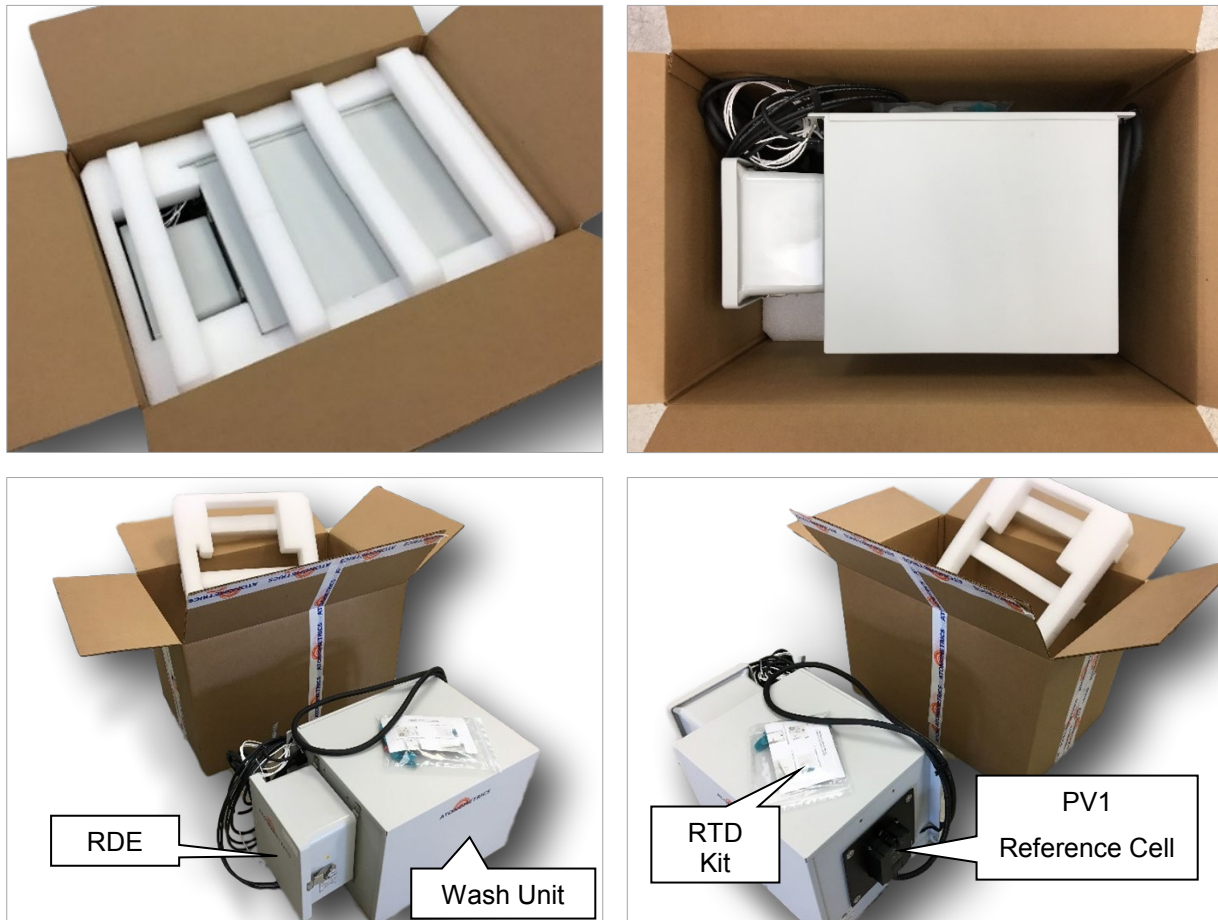


Figure 5-1: Unpacking a system with the automatically washed reference cell

5.2 Systems without Automatically Washed Reference Cell

Figure 5-2 shows unpacking a system for two modules, without the automatic Wash Unit. The shipping box will contain the RDE, two RTD kits, and associated cables. The RDE is to be connected to user-supplied PV modules for both PV1 and PV2 (as in Figure 1-6).



Figure 5-2: Unpacking a system for two modules without automatic washer

5.3 Other System Configurations

For details on packaging of other system configurations, including single-channel units, contact Atonometrics.

6 Hardware

6.1 RDE Measurement and Control Unit

6.1.1 Overview

The RDE is the Measurement and Control Unit for the system. It is housed in a NEMA 4 enclosure, shown in Figure 6-1. The RDE part number and serial number will be indicated on a label or badge on the enclosure exterior.

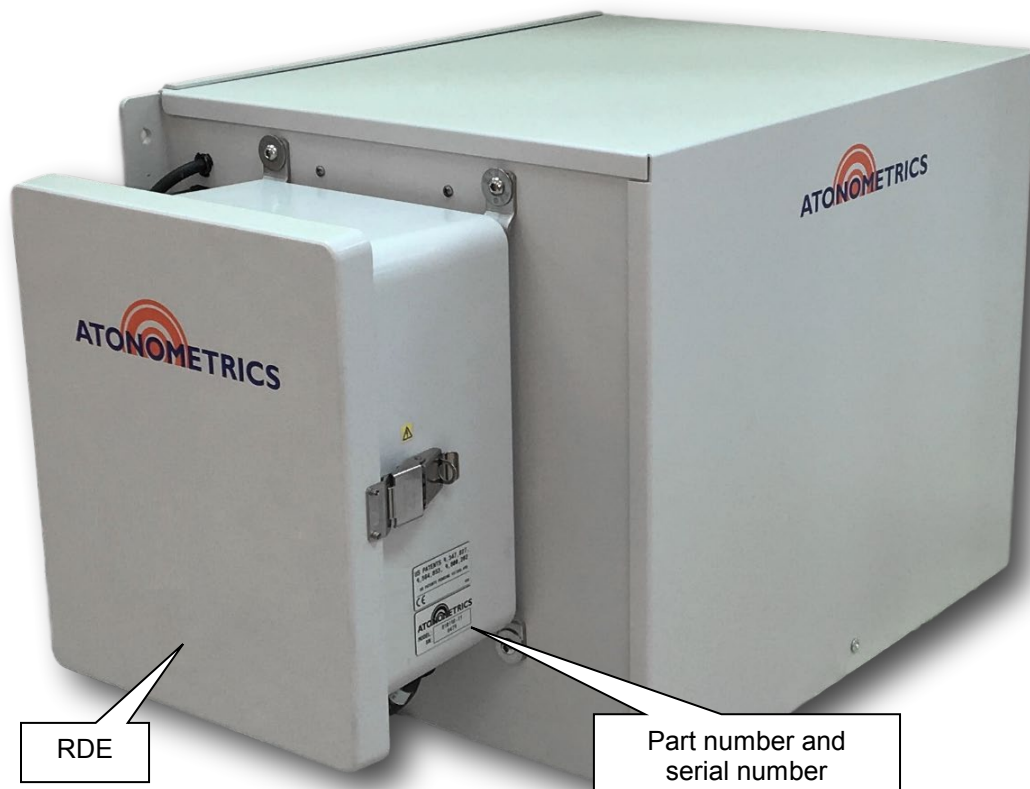


Figure 6-1: RDE enclosure

6.1.2 Part Numbers

Part numbers for the RDE300 Series are listed in Table 6-1. Refer to these part numbers when following instructions in this document. If your unit has PCB PN with an N suffix, I-V curves are disabled. For more detailed specifications or information on other part numbers or special configurations, contact Atonometrics.

Table 6-1: RDE300 Series part numbers

RDE Model	Description	Power	PCB PN	Assembly PN	Shipping Kit PN
<i>Obsolete models</i>					
RDE301	Washed Ref Cell + 1 Module Input (15A, 75V)	DC ⁽¹⁾	710335-01	810172-01	
RDE302	2 Module Inputs (15A, 75V)	DC ⁽²⁾	710335-02	810172-02	
RDE303	1 Module Input (15A, 75V)	DC ⁽²⁾	710335-03	810172-03	
RDE305	2 Module Inputs (5A, 250V)	DC ⁽²⁾	710335-05	810172-05	
<i>Current models</i>					
RDE351	Washed Ref Cell + 1 Module Input (15A, 75V)	DC ⁽¹⁾	710395-01	810198-01	910102-01
RDE352	2 Module Inputs (15A, 75V)	DC ⁽²⁾	710395-02	810198-02	910102-02
RDE353	1 Module Input (15A, 75V)	DC ⁽²⁾	710395-03	810198-03	910102-03
RDE354	Washed Ref Cell + 1 Module Input (5A, 250V)	DC ⁽¹⁾	710395-04	810198-04	910102-04
RDE355	2 Module Inputs (5A, 250V)	DC ⁽²⁾	710395-05	810198-05	910102-05
RDE356	1 Module Input (5A, 250V)	DC ⁽²⁾	710395-06	810198-06	910102-06
RDE357	Washed Ref Cell + 1 Module Input (10A, 125V)	DC ⁽¹⁾	710395-07	810198-07	910102-07
RDE358	2 Module Inputs (10A, 125V)	DC ⁽²⁾	710395-08	810198-08	910102-08
RDE359	1 Module Input (10A, 125V)	DC ⁽²⁾	710395-09	810198-09	910102-09
RDE360	Washed Ref Cell, Filtered for CdTe Matching, + 1 Module Input (5A, 250V)	DC ⁽¹⁾	710395-04	810198-10	910102-10
RDE361	Washed Ref Cell + 1 Module Input (15A, 75V)	AC ⁽³⁾	710395-11	810198-11	910102-11
RDE362	2 Module Inputs (15A, 75V)	AC ⁽⁴⁾	710395-12	810198-12	910102-12
RDE363	1 Module Input (15A, 75V)	AC ⁽⁴⁾	710395-13	810198-13	910102-13
RDE364	Washed Ref Cell + 1 Module Input (5A, 250V)	AC ⁽³⁾	710395-14	810198-14	910102-14
RDE365	2 Module Inputs (5A, 250V)	AC ⁽⁴⁾	710395-15	810198-15	910102-15
RDE366	1 Module Input (5A, 250V)	AC ⁽⁴⁾	710395-16	810198-16	910102-16
RDE367	Washed Ref Cell + 1 Module Input (10A, 125V)	AC ⁽³⁾	710395-17	810198-17	910102-17
RDE368	2 Module Inputs (10A, 125V)	AC ⁽⁴⁾	710395-18	810198-18	910102-18
RDE369	1 Module Input (10A, 125V)	AC ⁽⁴⁾	710395-19	810198-19	910102-19
RDE370	Washed Ref Cell, Filtered for CdTe Matching, + 1 Module Input (5A, 250V)	AC ⁽³⁾	710395-14	810198-20	910102-20

(1) 10-30 VDC, <90 W.

(2) 10-30 VDC, <7 W.

(3) 100-240 VAC, 50/60 Hz, <90 W.

(4) 100-240 VAC, 50/60 Hz, <7 W.

6.1.3 Mounting

If possible, install the RDE in a shaded location to minimize heating of the electronics.

6.1.3.1 Mounting to Wash Unit

If your system includes the optional Wash Unit and was shipped after Q2 of 2017, the RDE will be pre-mounted to the Wash Unit as shown in Figure 6-2. In this case it is only required to mount the Wash Unit to the user's support structure. See Section 6.4.2.

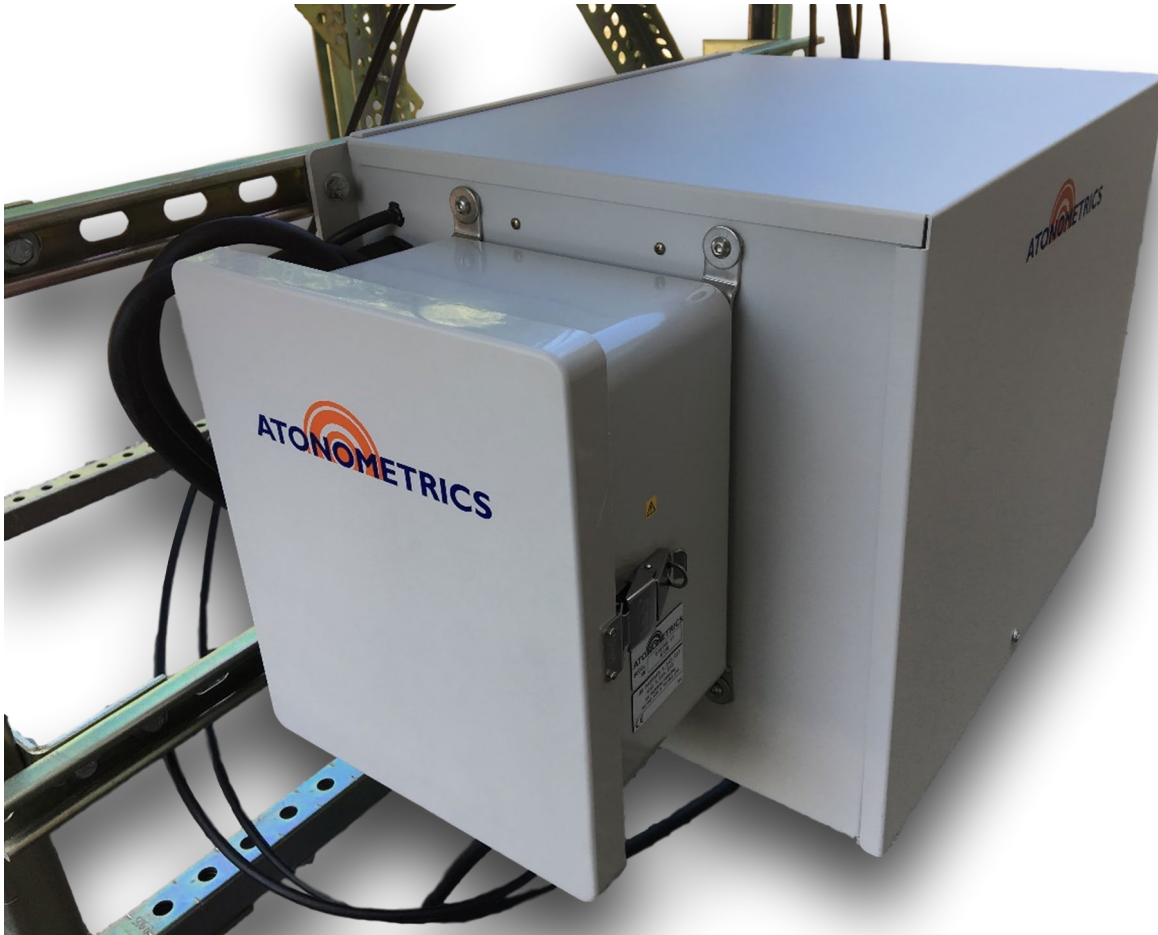


Figure 6-2: RDE mounted to Wash Unit

6.1.3.2 Mounting to User Support Structure

If your system does not include the Wash Unit, or you prefer to mount the RDE independently of the Wash Unit, mount the RDE to the user's support structure via the bracket tabs on the 4 corners of the RDE enclosure shown in Figure 6-3. Note:

- Use 5/16" or 8 mm bolts. (Mounting hardware is not supplied with the system.)
- The mounting holes for the RDE are 7.01" (178.05 mm) apart in the X-direction.
- The mounting holes for the RDE are 11.19" (284.23 mm) apart in the Y-direction.

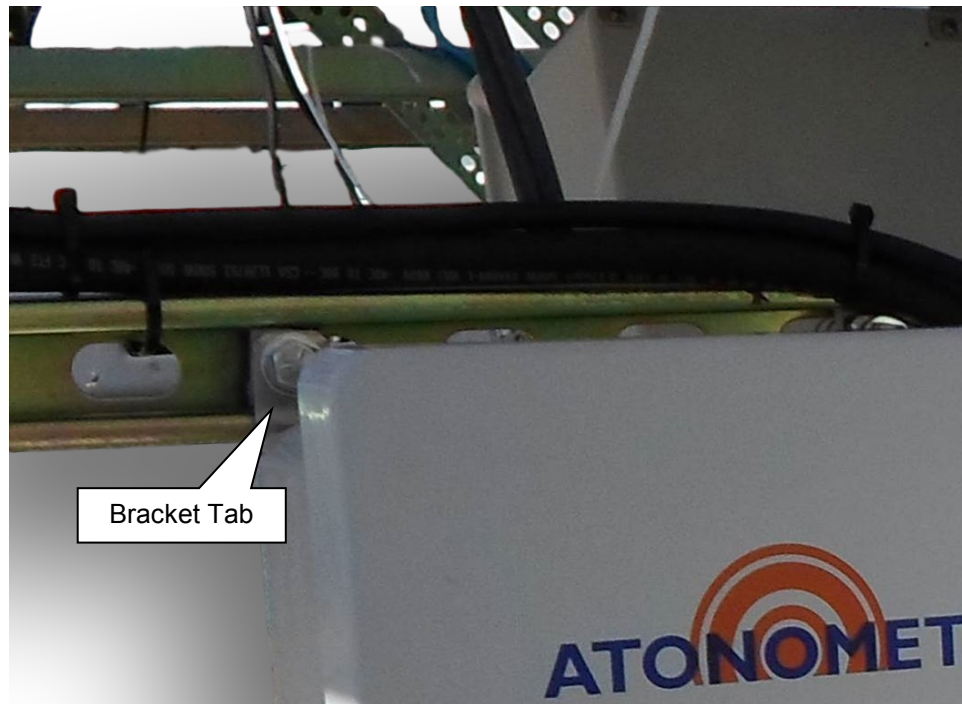


Figure 6-3: RDE enclosure mounting bracket tabs

6.1.4 Enclosure Interior

Figure 6-4 shows the interior of the RDE enclosure, including printed circuit board (PCB) and cable connections.

The number and type of cable penetrations on the enclosure will depend on system configuration and part number.

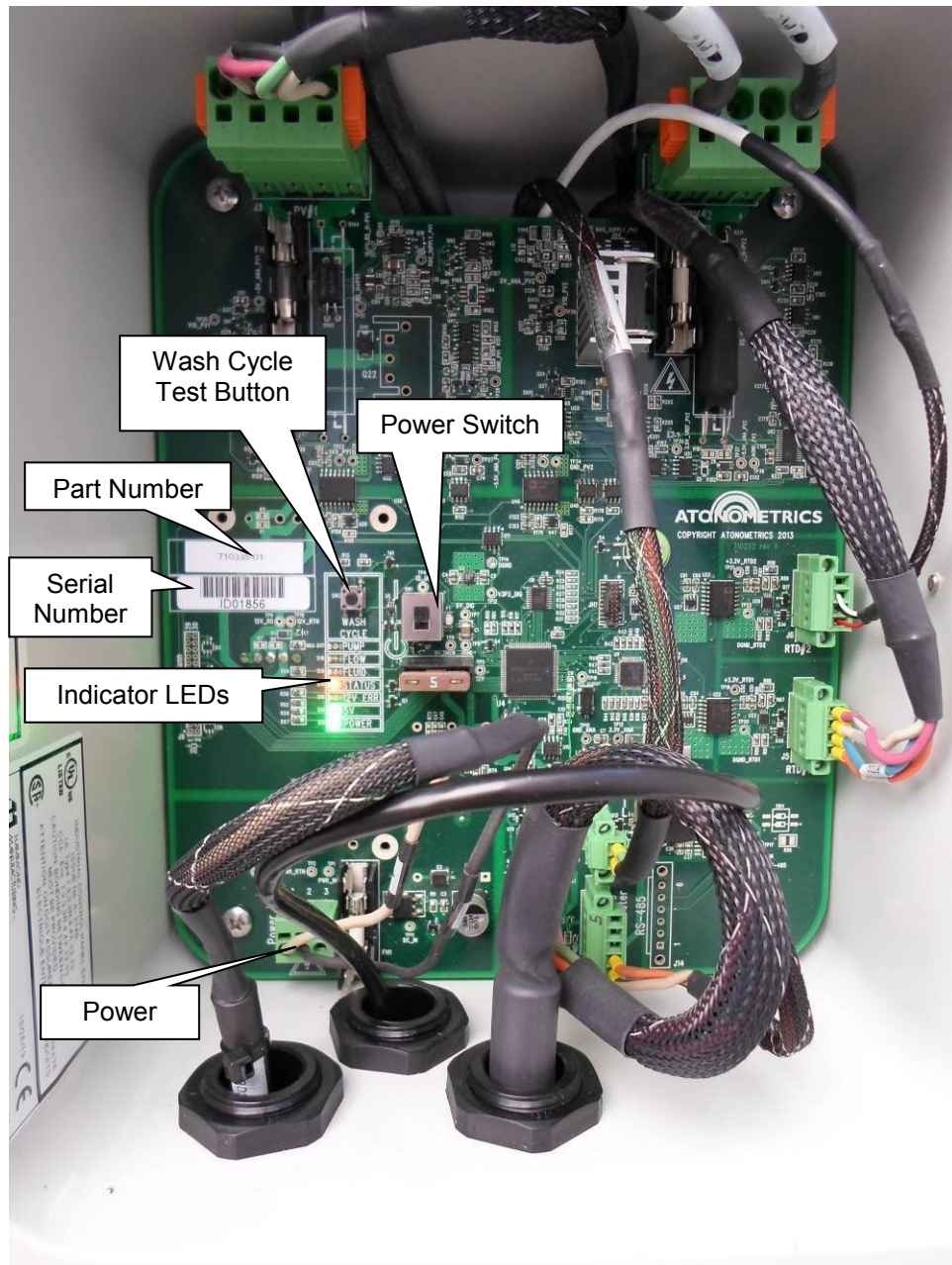


Figure 6-4: RDE enclosure interior showing PCB and cable connections

6.1.5 Part Number and Serial Number Label

The Part Number and Serial Number of the RDE PCB will be found on the lower left corner of the PCB, as shown in Figure 6-5. The serial number will normally begin with the prefix “ID”.

The numeric portions of the RDE PCB Part Number and Serial Number are also shown in the RDE Engineering Client on the Device Information screen, as shown in Figure 9-2.

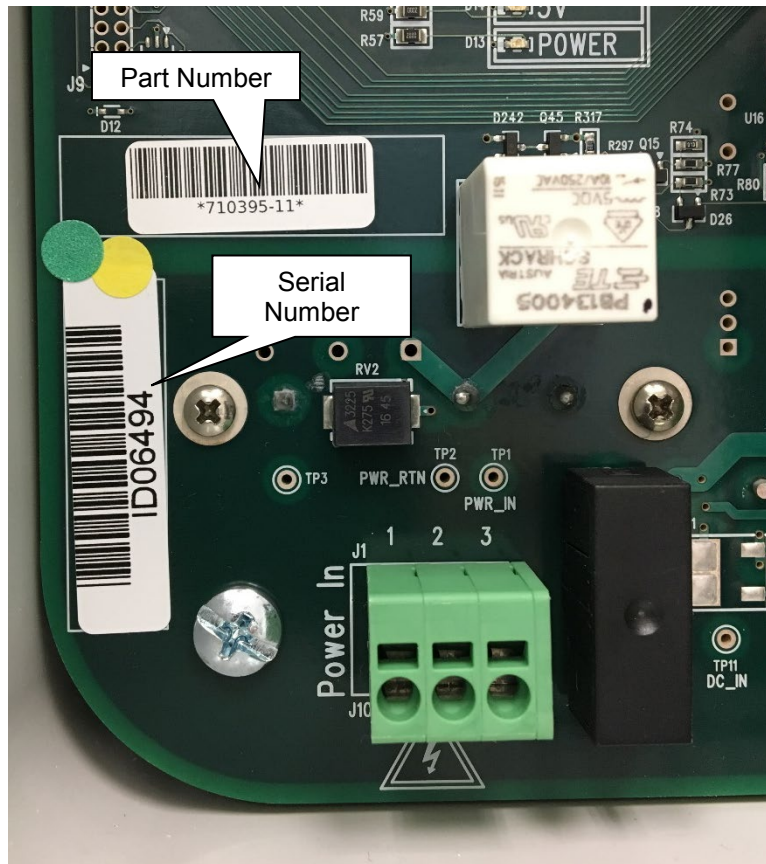


Figure 6-5: RDE PCB part number and serial number

6.1.6 Power

6.1.6.1 Power Requirements

The RDE must be supplied with power per Table 6-1. Other power configurations may be available. Contact Atonometrics for information.

Note: Power supplies must be sized to accommodate start-up currents, which could be 1-3x the indicated steady-state currents. For systems with automatic Wash Units, the listed power is the maximum power when pump and heaters are operating. Steady-state power is typically lower.

6.1.6.2 Power Hookup

WARNING: Qualified personnel only: Power wiring should be performed by qualified personnel only and in accordance with local codes.

WARNING: Hazardous voltages: Hazardous voltages may be present inside electrical enclosures. Improper use of this equipment involves the risk of electric shock and could cause injury or death.

Power is applied to the RDE at the J1 power connector in the lower left corner of the PCB. See Table 6-2 for terminal assignments.

Table 6-2: Terminal assignments of power connector J1

Power Type	J1 Connector Pin		
	1	2	3
10-30 VDC	Positive	Negative	
100-240 VAC	Line	Neutral	PE

To insert (or remove) wires from the J1 connector, press the tip of a 1/8" flat screwdriver into the slot above each terminal, as shown in Figure 6-6, to release the cable retention mechanism, while simultaneously inserting (or removing) the wire.

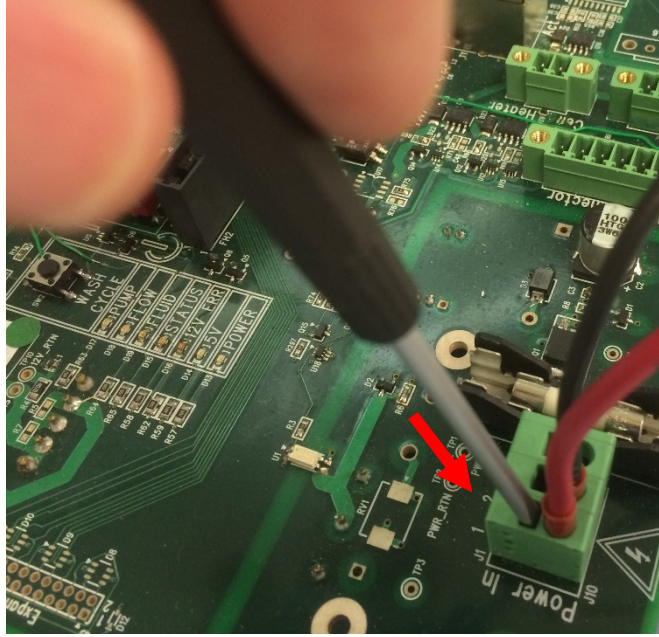


Figure 6-6: Inserting wires to the power connector J1

6.1.6.3 Power Hookup Notes

Note: In some cases the RDE will be supplied with the power cable pre-wired. Otherwise the user must supply and wire the power cable.

Note: If a user-supplied power cable is used, ensure that the cable size is compatible with the pre-supplied cable gland, or replace the cable gland with a compatible part. Failure to ensure compatibility may result in water penetration into the enclosure, which may cause equipment damage and/or electrical hazards. Contact Atonometrics for information if needed.

Note: For AC powered systems, the user should supply an external power disconnect box mounted near the RDE enclosure, in accordance with local codes.

Note: The “POWER” LED indicator on the board (Figure 6-4) will light whenever power is applied, even if the Power Switch is in the OFF state. The “5V” LED indicator will light when power is applied and the Power Switch is in the ON state.

6.1.7 Ethernet

An Ethernet cable is connected near the lower right corner of the PCB at the connector labeled “Enet”. See Figure 6-7.

In some cases the Ethernet cable will be pre-installed with the system.

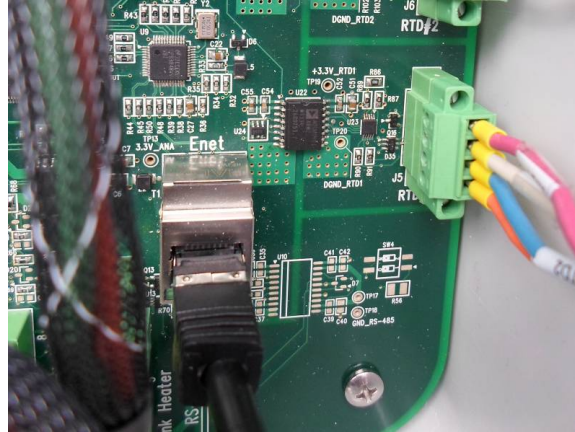


Figure 6-7: Ethernet connection

If the Ethernet cable is not pre-installed, note that when using the Atonometrics supplied cable gland for bringing a terminated Ethernet cable into the enclosure, the gland must be removed, disassembled, and reassembled around the Ethernet cable as shown in Figure 6-8.

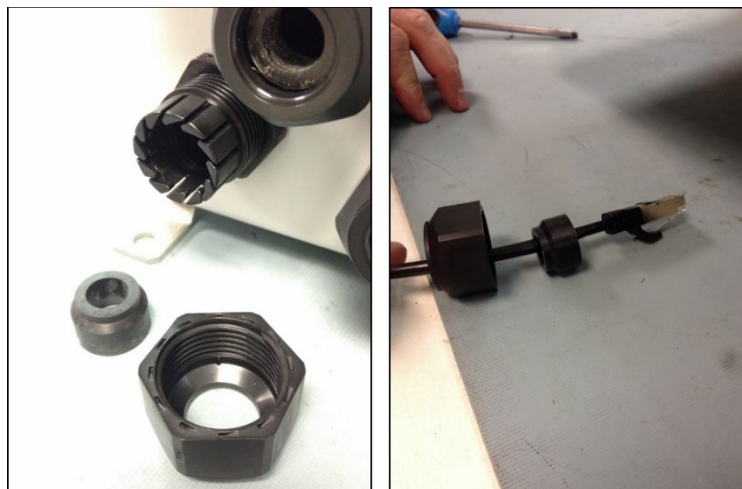


Figure 6-8: Installing an Ethernet cable in the supplied cable gland

Note: If a user-supplied Ethernet cable is used, ensure that the cable size is compatible with the pre-supplied cable gland, or replace the cable gland with a compatible part. Failure to ensure compatibility may result in water penetration into the enclosure. Contact Atonometrics for information if needed.

6.1.8 Power Switch

A power switch is located near the center of the PCB. See Figure 6-4.

Note: The “POWER” LED indicator on the board (see Figure 6-4) will light whenever power is applied, even if the Power Switch is in the OFF state. The “5V” LED indicator will light when power is applied and the Power Switch is in the ON state.

6.1.9 Indicator LEDs

Indicator LEDs (see Figure 6-4) are described in Table 6-3.

Table 6-3: Indicator LED descriptions

Indicator LED	Description
PUMP	Fluid pump is running.
FLUID	Fluid level in reservoir is low.
STATUS	Solid: status normal. Blinking: error condition, or no communication.
12V ERR	12V power fault.
5V	Power is ON.
POWER	Power is applied to the PCB.

6.1.10 Wash Cycle Test Button

Depressing the Wash Cycle test button (see Figure 6-4) causes the Wash Unit pump to run, allowing the Wash Unit to be tested.

Note: The Wash Cycle Test Button is only provided on DC-powered units. On AC-powered units (see Table 6-1) the button is omitted for safety, and the RDE Engineering Client software must be used to test the Wash Unit pump, as directed in Section 10.2.

WARNING: Qualified personnel only: When the equipment is powered, the electrical enclosure may only be accessed by qualified personnel and in accordance with local codes.

WARNING: Hazardous voltages: Hazardous voltages may be present inside the electrical enclosure. Improper use of this equipment involves the risk of electric shock and could cause injury or death.

6.1.11 Default IP Address DIP Switch

If the programmed IP address of the RDE is lost, communication may be re-established by temporarily setting the RDE to its factory-default IP address of 10.244.69.33. To do this use the following steps:

- Turn off power to the RDE.
- Set the SW3 DIP switch number 1 to the ON position (see Figure 6-9).
- Turn on power. Wait 30 seconds.
- Re-establish communication using the factory-default IP address (10.244.69.33).
- Reprogram the IP address.
- Turn off power.
- Set the SW3 DIP switch 1 back to the OFF position.
- Turn on power. The system will now use the new programmed IP address.

Note: Units shipped May 2019 and later (PCB ID06600 and up, see 6.1.5): When DIP switch 1 is placed in the ON position, both the orange Status LED and the green Flow LED will blink for up to 30 seconds. This indicates that the unit has entered default IP address mode. During the first 30 seconds, the unit will also be in bootload mode and will accept a firmware update using the factory default IP address. See section 9.7.

Note: Units shipped before May 2019 (PCB ID06599 and below, see 6.1.5): The default IP address DIP switch should not be used when updating firmware. See Section 9.7.

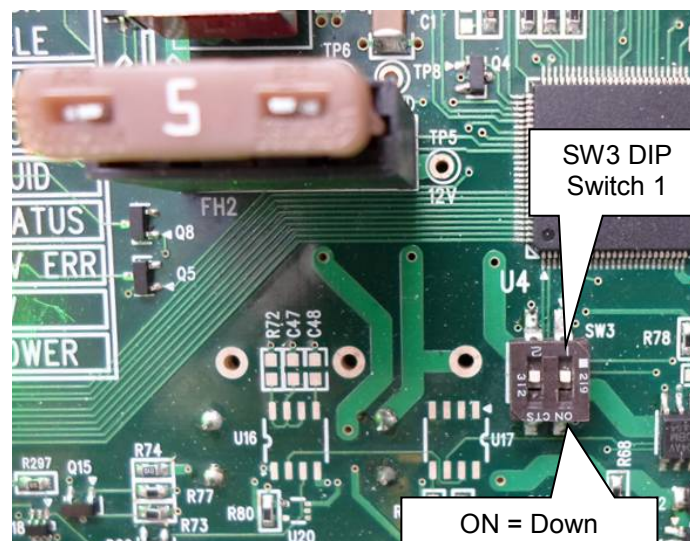


Figure 6-9: Default IP address DIP switch

6.1.12 Fuses

See Table 6-4 for fuse part numbers. Fuse holder reference designators are printed on the PCB next to each fuse.

Note: Before replacing any fuse, note the RDE PCB part number (see Figure 6-4) and select the correct fuse for the indicated part number.

Table 6-4: Fuse part numbers

Fuse Holder Reference Designator	Description	Atonometrics PCB Part Number	Atonometrics Fuse Part Number	Fuse Manufacturer Part Number
FH1	Power to RDE	710335-01, -04 710395-01, -04, -07	260052	Littelfuse 477012.MXP
		710335-02, -03, -05, -06 710395-02, -03, -05, -06, -08, -09, -11, -12, -13, -14, -15, -16, -17, -18, -19	260034	Cooper Bussman S506-1-R
FH2	12V to pump and heaters	710335-01, -04 710395-01, -04, -07, -11, -14, -17	260164	Littelfuse 164.6185.4502
FH3	PV1 Input (Reference Cell)	710335-01, -04 710395-01, -04, -07, -11, -14, -17	260034	Cooper Bussman S506-1-R
	PV1 Input (PV Module)	710335-02, -03 710395-02, -03, -12, -13	260049	Littelfuse 0477016.MXP
		710335-05, -06 710395-05, -06, -15, -16	260101	Littelfuse 0477005.MXP
		710395-08, -09, -18, -19	260168	Littelfuse 0477010.MXP
FH4	PV2 Input (PV Module)	710335-01, -02 710395-01, -02, -11, -12	260049	Littelfuse 0477016.MXP
		710335-04, -05 710395-04, -05, -14, -15	260101	Littelfuse 0477005.MXP
		710395-07, -08, -17, -18	260168	Littelfuse 0477010.MXP

6.1.13 Securing the Enclosure

After installing the RDE, close and latch the electrical enclosure. Use a locking mechanism to secure the enclosure and prevent access without a tool, in accordance with local codes.

WARNING: Enclosures must be closed: The equipment may not be operated with any enclosure open except by qualified personnel in accordance with local codes.

WARNING: Hazardous voltages: Hazardous voltages may be present inside electrical enclosures. Improper use of this equipment involves the risk of electric shock and could cause injury or death.

6.2 Power and Ethernet Distribution Hub

Systems using multiple RDEs may contain a power and Ethernet distribution Hub, as shown in Figure 1-2.

Hubs are configured according to specific customer needs and may have varying numbers of outputs, as well as varying internal fuse values and other customizations.

Figure 6-10 shows an example Hub, which is configured to support up to four RDE units. The left side of the figure shows the exterior of the Hub, which is housed in a NEMA 4 enclosure and has weather-tight cable glands for cable entry. Power and Ethernet cables (not shown) from the Hub to the individual RDE units may be supplied by Atonometrics, according to your purchase specifications, and may be pre-installed in the Hub. Internally, the Hub contains power distribution terminal blocks and an Ethernet switch, as shown on the right of Figure 6-10.



Figure 6-10: Example power and Ethernet distribution Hub

Wiring directions for each Hub are provided on a label on the inside of the Hub enclosure door. See Figure 6-11 for an example. Typically, cable outputs to the supported RDE units are pre-installed to the Hub by Atonometrics. In this case, general directions are as follows:

- Mount the Hub in its installation location using the bracket tabs on the rear of the Hub enclosure.
- Supply power and Ethernet to the Hub through a pair of cable glands and connect to the indicated terminals. Note that a large gland is used for Ethernet, and a small gland is used for Power. To install a terminated Ethernet cable in the supplied gland, the gland must be disassembled and reassembled around the cable; see Figure 6-8.
- Tighten the cable glands to ensure a good seal on each cable.
- Close and secure the Hub enclosure door.

- Bring the power and Ethernet output cables from the Hub to each RDE unit to be supported, and install as per Section 6.1.

Note: Cable glands supplied with the Hub are designed for a specific diameter of cable. Ensure that any cable used with the cable glands meets the gland's requirement, to prevent moisture penetration into the enclosure. If necessary, consult Atonometrics for details.

Note: Any unused output ports from the Hub must be capped. Remove the unused cable gland and cap the hole with a water-tight hole cover. In some cases hole covers will be pre-supplied by Atonometrics, depending on customer needs.

WARNING: Enclosures must be closed: the equipment may not be operated with any enclosure open except by qualified personnel in accordance with local codes.

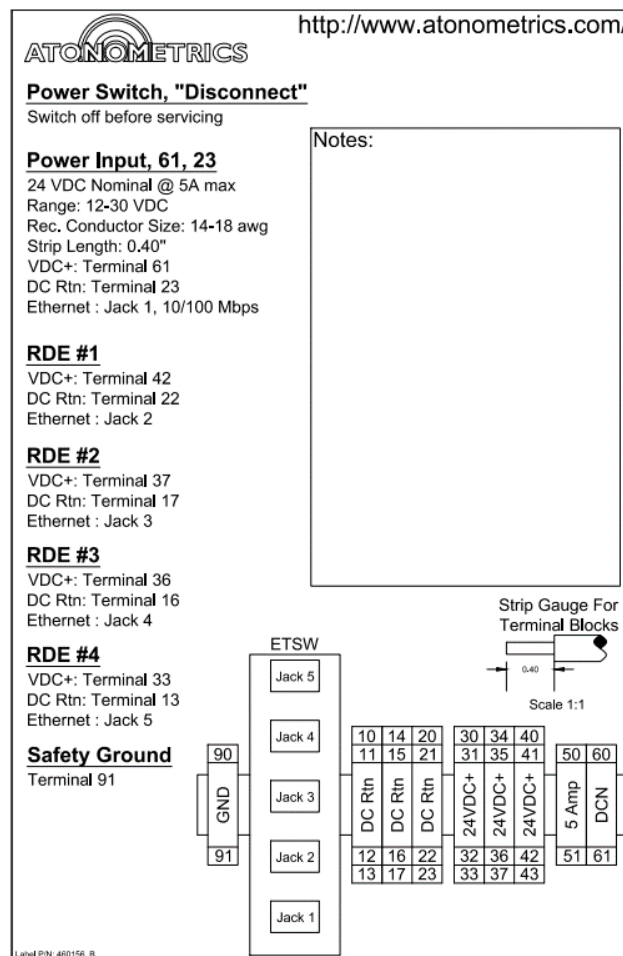


Figure 6-11: Example Hub wiring directions label inside enclosure door

6.3 Reference Cell

6.3.1 Overview

Some systems include the Atonometrics PV Reference Cell, shown in Figure 6-12, as one of the PV reference devices.

For use with the automatic Wash Unit, an integrated spray nozzle is included in the Reference Cell housing.

The included mounting plate allows the user to mount the Reference Cell onto the user's support structure. (Note: On systems shipped prior to Q2 of 2017 the mounting plate may consist of a dual-plate assembly.)

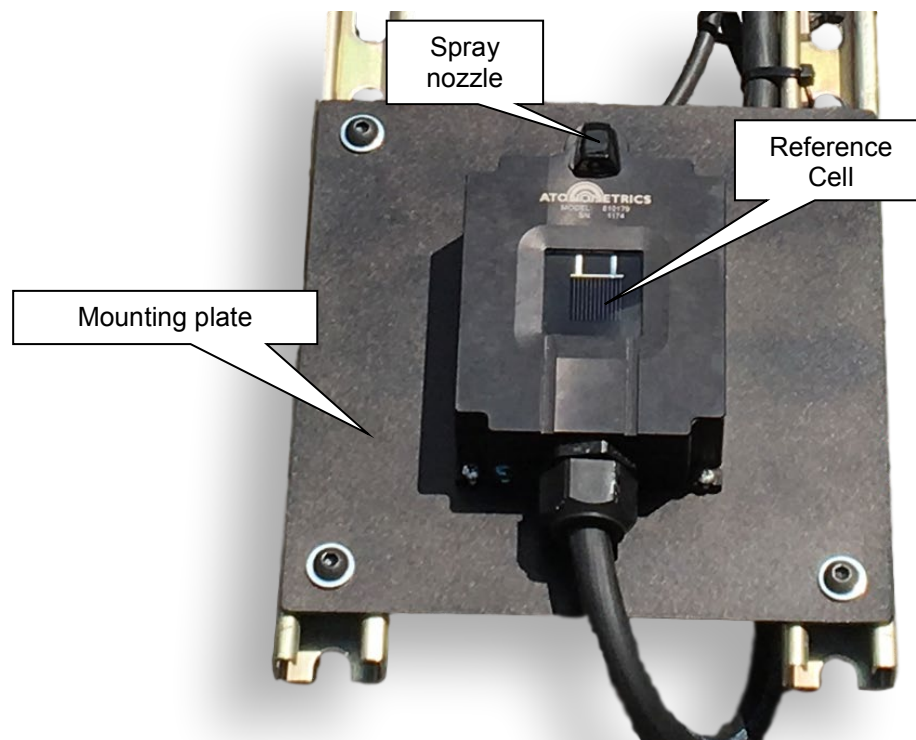


Figure 6-12: Atonometrics PV Reference Cell with spray nozzle and mounting plate

6.3.2 Mounting

On systems shipped after Q2 of 2017, the Reference Cell will be shipped mounted to the side of the Wash Unit, for convenience in shipping, unpacking, and installation. Once the Wash Unit is mounted to the support structure, the Reference Cell mounting plate must be removed from the Wash Unit, as shown in Figure 6-13, to complete installation.



Figure 6-13: Removing the Reference Cell assembly from the Wash Unit for installation

The Atonometrics-supplied mounting plate must be mounted on the support structure, for example as shown in Figure 6-14, using user-supplied hardware. Note:

- Use 5/16" or 8 mm bolts. (Mounting hardware is not supplied with the system.)
- The mounting holes are 7.50" (190.5 mm) apart in the X-direction.
- The mounting holes are 7.50" (190.5 mm) apart in the Y-direction.

Note: The Reference Cell must be mounted in a plane parallel to the PV modules. See Chapter 7 for alignment adjustment.

Note: For use in soiling measurement, the automatically washed Reference Cell assembly should be mounted in a position that will prevent water spray from cleaning or partially cleaning the nearby designated “soiled” reference module. Atonometrics recommends mounting the Reference Cell assembly at or below the bottom edge of the soiled reference module, or at least 3 ft. away from the soiled module if mounted to the side. See the example in Figure 6-14 as well as the layout guidelines in Section 1.3 and additional examples in Section 1.4.



Figure 6-14: Reference Cell assembly mounting location example

6.3.3 Electrical Connection

The Reference Cell includes a cable for connection to the RDE. The connection is typically pre-wired to the RDE upon shipment. If wiring information is needed, please contact Atonometrics.

6.3.4 Angle Adjustment

See Chapter 7 for details on angle adjustment of the Reference Cell.

6.4 Wash Unit

6.4.1 Overview

The optional Wash Unit, shown in Figure 6-15, contains a fluid reservoir and fluid delivery system for washing the clean PV reference device.

Systems shipped after Q2 of 2017 include the RDE pre-mounted to the Wash Unit, as shown in Figure 6-15. If desired, the RDE may be removed and mounted separately.

The Wash Unit is insulated and heated to prevent damage from fluid freezing in winter conditions.

The Wash Unit also contains a flow sensor to measure the fluid flow rate. This allows the desired fluid amount to be precisely dispensed at each wash and also allows detection of leaks, blockages, or other error conditions. The total measured flow volume dispensed at each wash is available as an output from the RDE, allowing the user to log the operation of the system. (Note: the flow sensor is supported in Wash Units shipped October 2015 or later.)

Note: The Wash Unit should not be stored in freezing conditions without application of power from the RDE.

Note: For some cold-climate applications Atonometrics recommends using environmentally friendly anti-freeze additives in the fluid reservoir. Contact Atonometrics for more information



Figure 6-15: Wash Unit with RDE

6.4.2 Mounting

Mount the Wash Unit to the user-supplied support structure using the mounting holes at the four corners of the Wash Unit. See Figure 6-16. Note:

- Use 5/16" or 8mm bolts. (Mounting hardware is not supplied with the system.)
- The mounting holes for the Washer are 19.68" (499.87mm) in the X-direction.
- The mounting holes for the RDE are 11.19" (284.23mm) in the Y-direction.

Note: The Wash Unit should be mounted below the elevation of the Reference Cell assembly, so that fluid will flow back from the Reference Cell assembly into the Wash Unit when the pump is turned off.

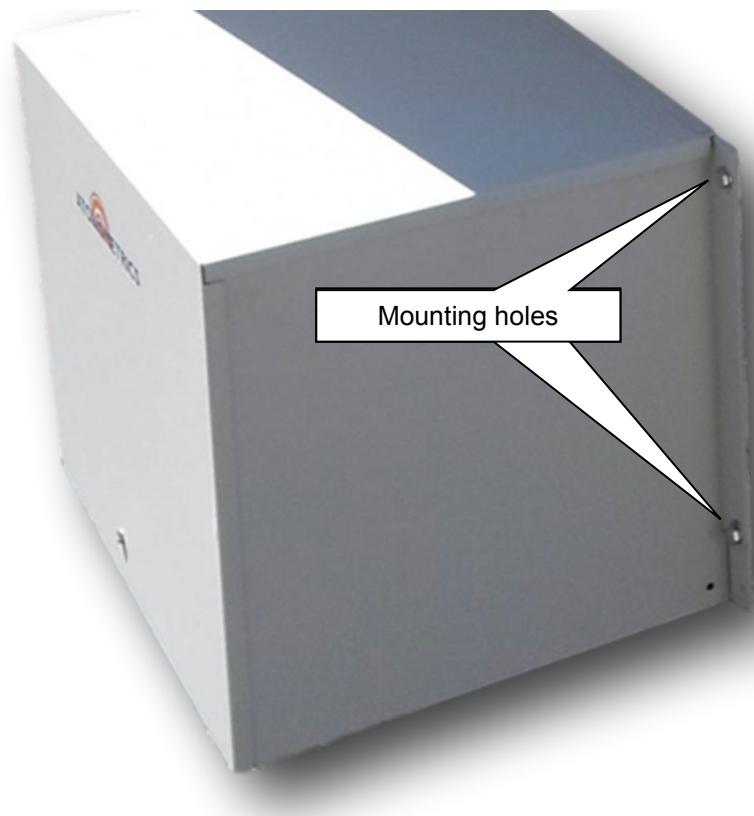


Figure 6-16: Wash Unit mounting

6.4.3 Electrical Connection

The Wash Unit is supplied with a cable for connection to the RDE. The cable is typically pre-wired upon shipment. If the cable is not pre-wired, connect it using the following steps:

- Remove power to the RDE from the power source, if present.
- Disconnect PV modules from the RDE, if connected.
- Open the RDE enclosure.
- Insert the Wash Unit cable through the designated cable gland on the RDE.
- Connect each wire of the cable to the designated terminal as indicated on the label inside the RDE enclosure door.
- Tighten the cable gland to prevent water penetration into the enclosure.

Note: There are two holes on the bottom flanges of the Wash Unit that can be used for a Protective Earth connection. To use, remove paint as required and use a 1/4" or M6 bolt for the electrical connection.

6.4.4 Filling the Wash Tank

6.4.4.1 Fluid

Note: For warm-weather climates with only moderate sub-freezing winter temperatures, use distilled water as the washing fluid. Distilled water is readily available at many local stores.

Note: For climates with extreme winter cold weather, Atonometrics recommends alternative fluids with lower freezing points. Contact Atonometrics for details.

Note: Do not use local tap water. Mineral deposits in the water may build up on the Reference Cell, causing stains that block light. See Figure 6-19. These can be cleaned with mineral deposit cleaners.

6.4.4.2 Accessing the Wash Tank

Access the wash tank using the following steps, illustrated in Figure 6-17:

- Use a #2 Phillips screwdriver to unlock the captive ¼ turn fastener
- Remove the Wash Unit housing cover by pulling out and slightly up.
- Remove the top insulation panel.
- Open the large round lid to the wash tank.



Figure 6-17: Accessing the wash tank

6.4.4.3 Filling the Tank

Pour the wash fluid directly into the tank, as shown in Figure 6-18.

Note: Use distilled water or Atonometrics specified fluids only. See Section 6.4.4.1.

Note: Take care not to spill fluid outside the wash tank. Wetness may compromise the thermal insulation effectiveness.



Figure 6-18: Filling the wash tank

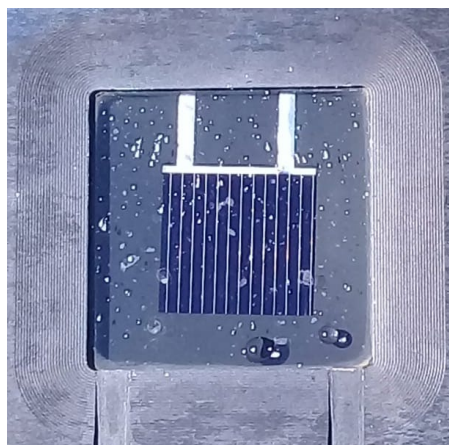


Figure 6-19: Example of mineral deposits (white spots) on Reference Cell

6.4.4.4 Closing the Wash Unit

See Figure 6-17 and follow steps in reverse to close the Wash Unit. Remember the following:

- Replace the lid to the wash tank.
- Replace the top insulation panel.
- Replace the Wash Unit enclosure cover.
- Lock the enclosure cover using the ¼ turn fastener.

6.4.5 Connecting the Fluid Hose

Wash fluid runs from the Wash Unit to the Reference Cell through a fluid delivery hose. The hose must be connected upon system installation.

Route the hose from Wash Unit to the Reference Cell observing the following requirements:

- Ensure that there are no significant dips in the hose where water could collect.
- Ensure that there are no sharp bends in the hose that would constrict flow.
- Run any extra length of hose along the support structure.
- Do not coil the hose.
- Do not shorten the hose.
- Secure the hose to the support structure with tie-wraps, but take care not to constrict the hose. See Figure 6-20.



Figure 6-20: Leave ties for hose loose, to avoid constricting flow

Attach the hose to the nozzle as follows, referring to Figure 6-21:

- Slide the hose through the hole in the mounting plate of the Reference Cell, with the pre-supplied hose clamp protruding through the mounting plate.
- Slide the hose onto the nozzle inlet.
- Place the hose clamp over the nozzle inlet using a pair of pliers to expand the spring clamp. Use your hand if necessary to guide the clamp onto the nozzle inlet.

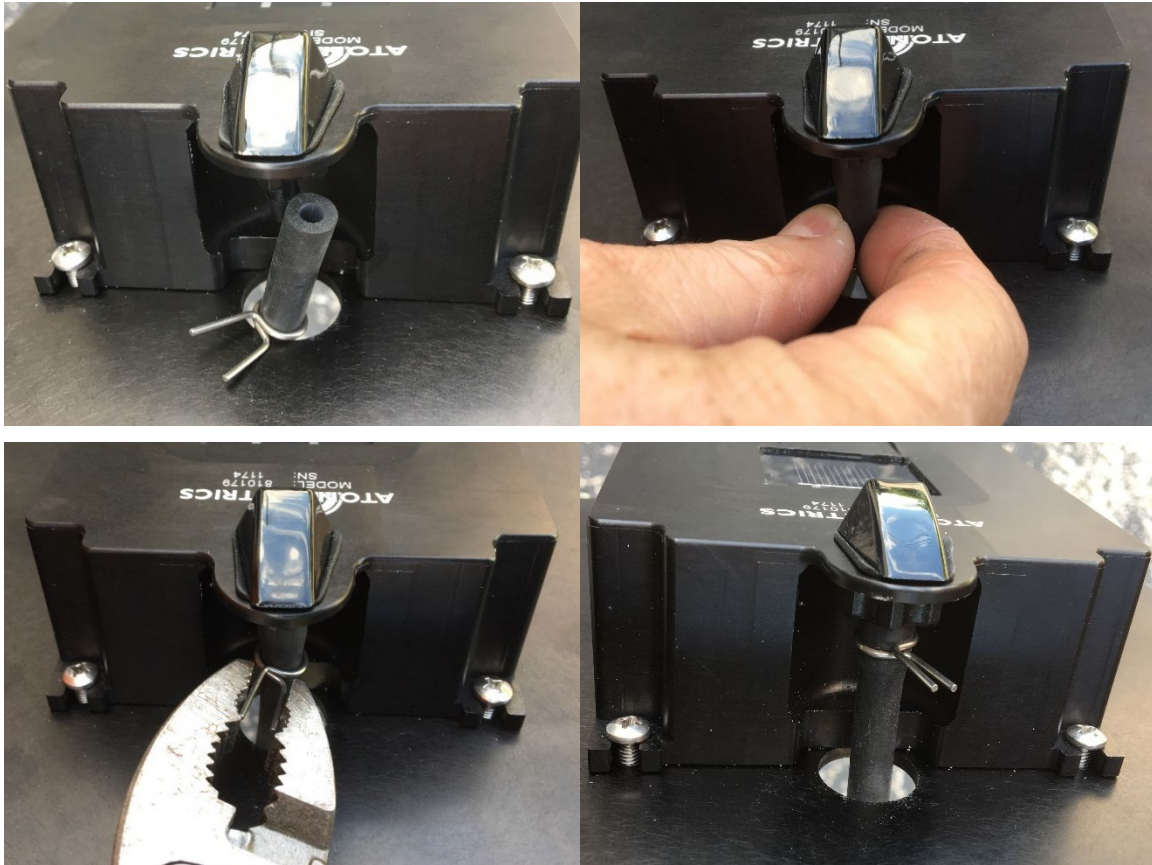


Figure 6-21: Connecting the fluid hose to the Reference Cell

6.5 Reference Modules

6.5.1 Overview

PV reference modules can be used for irradiance or soiling measurement.

6.5.2 Module Ratings

Standard RDE configurations are rated for reference modules up to 15 A / 75 V or 5 A / 250 V. (See Section 6.1.2). Other configurations may be available. Consult purchase specifications to determine the applicable rating.

6.5.3 Mounting

Support racks for PV reference modules are typically user-supplied. For recommendations on rack requirements, contact Atonometrics.

For soiling measurement, the clean and soiled reference devices should be aligned as discussed in Chapter 7. This may require shims or other adjustments. See Chapter 7 for details.

Note: When using a soiled reference module together with the automatically washed Reference Cell, observe layout guidelines in Section 1.3 to prevent inadvertent cleaning or partial cleaning of the soiled module by the cleaning spray.

6.5.4 Electrical Connections

The RDE includes PV module connection cables. MC4 connectors are standard. Connect these to the PV reference module leads after the module is mounted in position.

Note: Ensure that RDE power switch (see Figure 6-4) is in the OFF position when connecting or disconnecting PV modules.

6.5.5 RTD Attachment

The RDE includes an RTD for PV reference module temperature measurement. The RTD should be permanently applied to the back side of the reference module. A thermal epoxy kit (Atonometrics PN 810162) will be provided for attachment of the RTD. The kit includes an instruction document (Atonometrics PN 880031).

Note: Atonometrics recommends attaching the RTD near the center of the module, preferably centered on a cell.

7 Alignment of PV Reference Devices

7.1 Requirements

For soiling measurements, it is important that the clean and soiled PV reference devices be aligned properly. Observe the following requirements:

- Orient the PV1 and PV2 reference devices to face the same azimuth angle as the PV array at the site.
- Align the PV1 and PV2 reference devices so that they are co-planar to within 0.5 degrees.

7.2 Checking Azimuthal Orientation

To check the azimuthal orientation of the PV1 and PV2 reference devices, use a digital compass. Adjust the mounting structure as needed.

7.3 Checking Angular Alignment

To check the co-planarity of the reference devices, use a digital inclinometer with bubble levels, as illustrated in Figure 7-1 and Figure 7-2.

Note: The figures show a Reference Cell as the clean device, but a module could also be used, depending on the user's system configuration.

Check both the tilt angle (Figure 7-1) and cross-tilt angle (Figure 7-2).

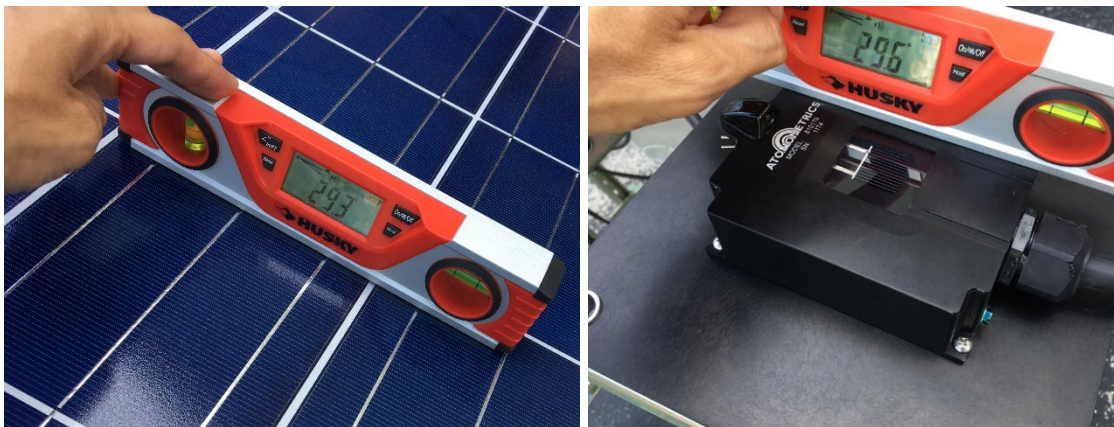


Figure 7-1: Comparing tilt angles of soiled (left) and clean (right) reference devices

Note: When checking the cross-tilt angle (Figure 7-2), use the bubble levels on the inclinometer to ensure that the inclinometer is oriented identically on the two devices.

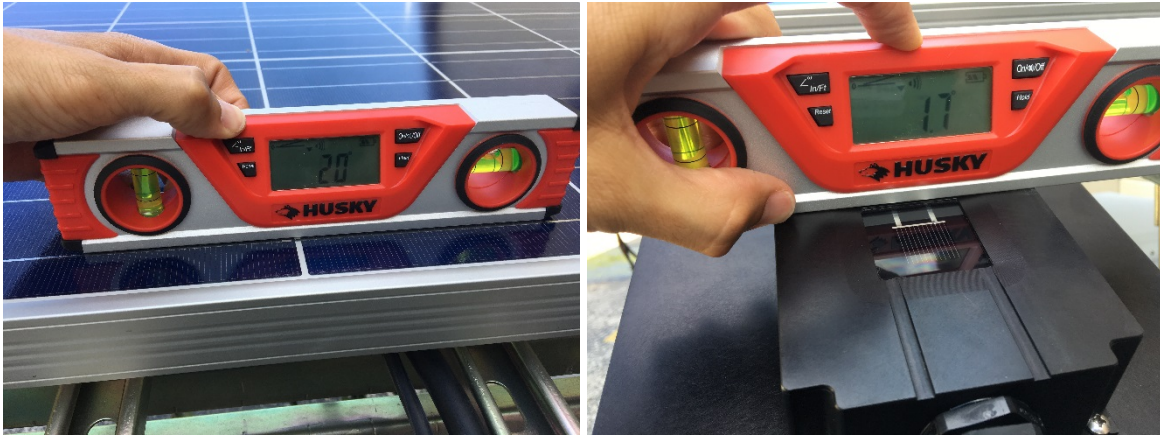


Figure 7-2: Comparing cross-tilt angles of soiled (left) and clean (right) reference devices

7.4 Adjusting Angular Alignment

If either of the angular differences between the clean and soiled devices is greater than 0.5 degrees, adjust the alignment of the clean device as directed below, and check the angles again.

7.4.1 Reference Module

If a reference module is used as the clean device, the adjustment mechanism depends on the user's mounting structure. Typically shims can be placed between the module frame and the support structure in order to elevate one side of the module.

7.4.2 Reference Cell

If the Atonometrics Reference Cell is used as the clean device, adjust the angle using the included washers as shims underneath the mounting holes to elevate one side of the Reference Cell. See Figure 7-3. (On systems shipped before Q2 of 2017, the angle may also be adjusted by moving nuts on one of the mounting plates.)

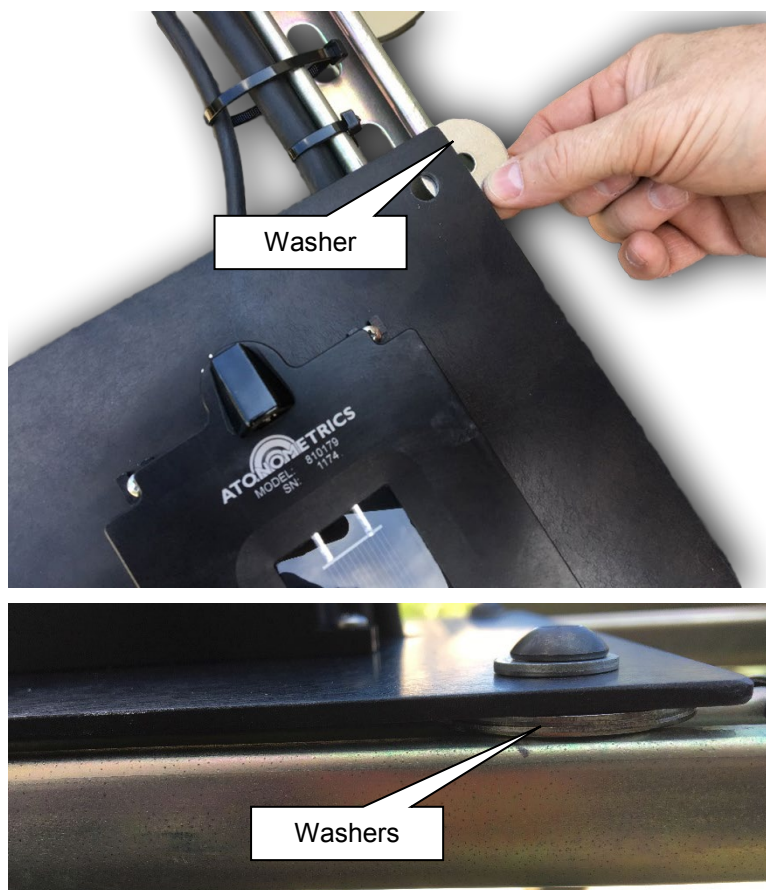


Figure 7-3: Adjusting the Reference Cell angle

8 Network Setup

8.1 Establishing Communication

The RDE is a host device and the polling device is its client. The client may be a PC, datalogger, PLC, or other device. Establishing communication to the RDE requires the following steps:

- Connect the client device to the RDE via the user's network, typically involving an intermediary Ethernet switch.
- Determine the current IP address of the RDE.
- Set the IP address of the client device to the same subnet as the RDE.
 - Example: if the RDE IP address is 10.244.69.33, the user client device must be set to 10.244.69.X, with X not equal to 33.

Once communication is established, the RDE IP address may be changed as desired by the user.

8.2 Changing the Client IP Address

Consult documentation for the client device to determine how to change its IP address.

For example, on a PC running Windows, the IP address is changed from the internet protocol item in the properties menu of the internet adapter, as illustrated in Figure 8-1. Consult Microsoft Windows documentation or other user guides for further details.

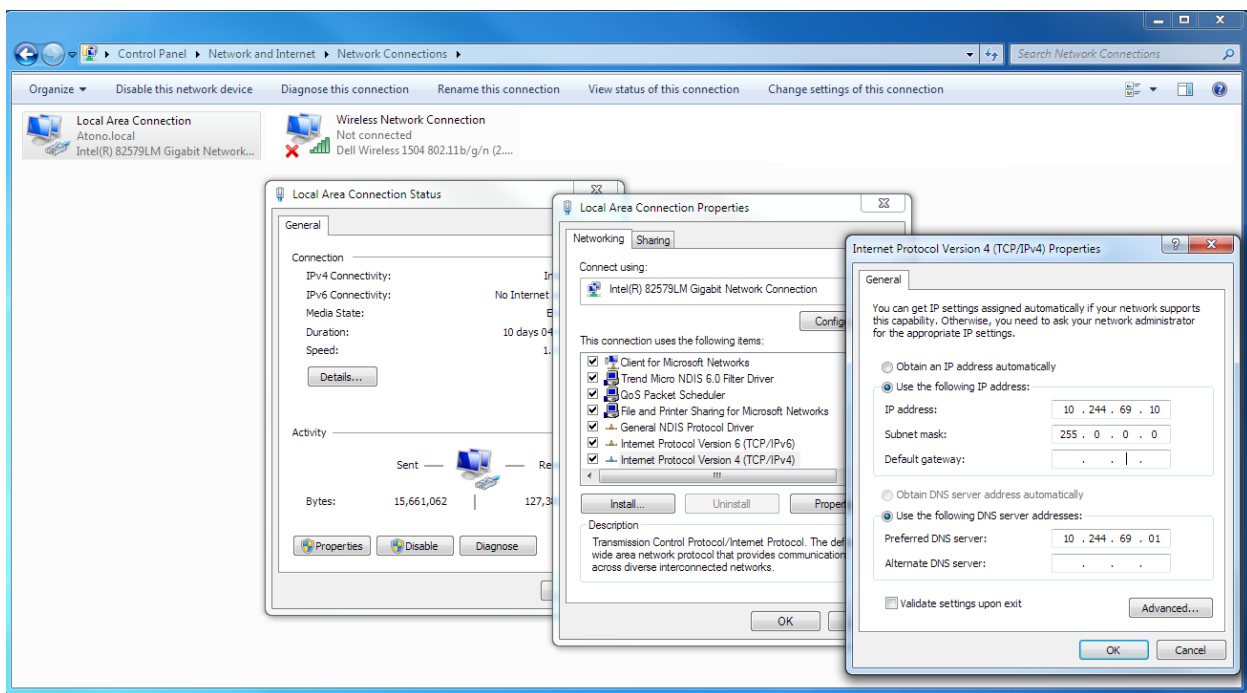


Figure 8-1: Setting IP address on Windows PC

8.3 RDE Default IP Address

The factory default IP address of the RDE is 10.244.69.33. Therefore, unless specified otherwise, the user PC must be set to the 10.244.69.X subnet when the RDE is first installed.

8.4 Changing the RDE IP Address

See Section 9.4.4.

8.5 Restoring RDE Factory Default IP Address

To restore the RDE to its factory default IP address, see section 6.1.11.

Note that the user-programmed IP address is maintained in the RDE memory. When the DIP switch is reverted to the OFF position and the power is cycled, the RDE will use the user-programmed address.

8.6 Network Ports and Firewall Information

The RDE uses the network ports listed in Table 8-1.

Table 8-1: RDE Network Ports

Port Number	Function
502	Modbus TCP
502, 503	Network discovery, UDP
69	Bootloading firmware updates, TFTP via TCP/UDP
n/a	Ping, via ICMP messaging

On client systems and PC's it may be necessary to open firewalls to permit communication via these ports. When using a cell modem with the RDE, the above ports should be forwarded.

Note: If some of the RDE's communication ports are enabled and others are blocked by a firewall on the user's system, the RDE may function but with some features disabled, including network discovery and bootloading.

9 RDE Engineering Client Software

9.1 About the Software

The RDE Engineering Client software (PN 500046-03) runs on a Windows system and allows the user to configure and test the RDE300 Series, as well as to perform maintenance and troubleshooting tasks under direction from Atonometrics.

This edition of the User Guide applies to RDE Engineering Client software PN 500046-03 version R3978 and later when used with RDE units running RDE300 series firmware PN 500044-03 version R3979 and later, both released October 2017.

PC requirements for the RDE Engineering Client include:

- Windows XP or higher
- At least one Ethernet network card
- At least 2 GB of RAM
- At least 100 MB of free space on the PC hard drive

To obtain the software, visit www.atonometrics.com or contact Atonometrics, and then run the installer provided.

Note that configuration parameters are stored in the file “RDE Engineering Application.exe.config” in the software application folder, but the user will not normally need to change these settings.

9.2 Launching the Software

Ensure that the PC is properly networked to the RDE, following instructions in Chapter 8.

Launch the application by executing the file “RDE Engineering Application.exe” or using a desktop shortcut.

9.3 Connection Dialog

When the software is launched, it will display a list of RDEs detected on the user's network, as shown below. To refresh the list, if needed, press "Search for RDEs".

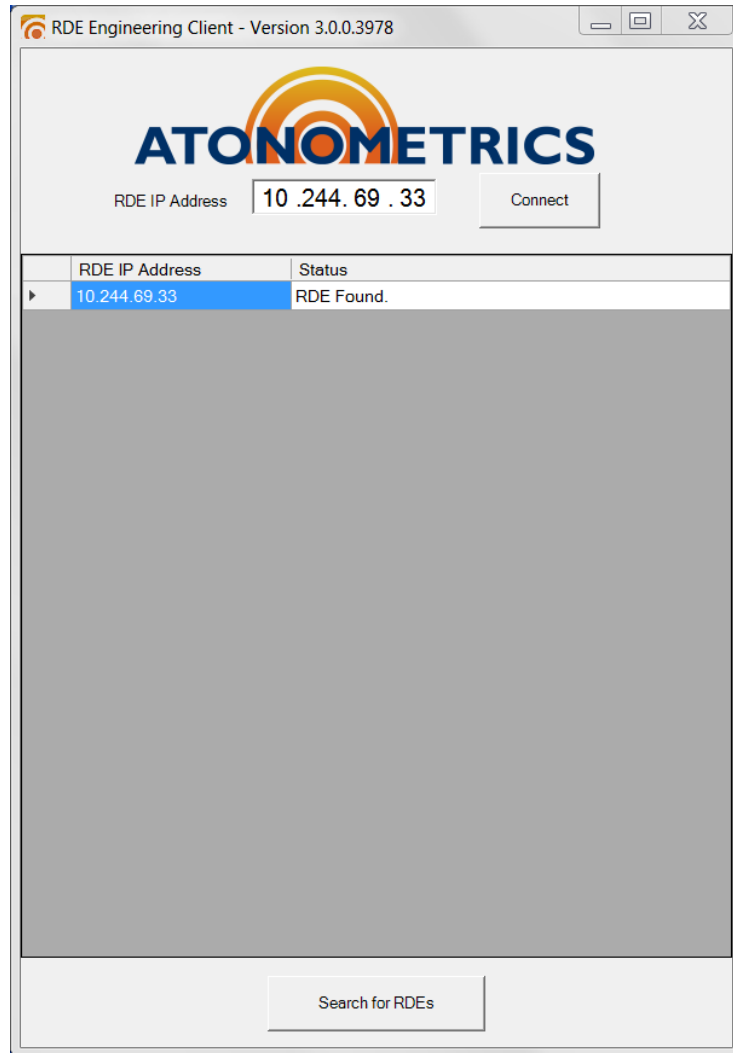


Figure 9-1: RDE network discovery and connection dialog

To connect, select the desired RDE based on its IP address and press "Connect". This will launch the main RDE Engineering Client dialog.

Note: Firmware versions R3787 and higher (beginning December 2015) support multiple simultaneous connections. This allows the RDE Engineering Client to connect to the RDE without disconnecting the user's datalogging system, for example. Earlier firmware versions permitted the RDE to connect to only one client at a time.

9.4 System Tab Group

9.4.1 Device Information Tab

The Device Information tab, shown below, displays key data for the connected RDE, including:

- Serial numbers
- Part numbers
- Firmware version
- Uptime

If necessary, press “Refresh” to reload data from the RDE onto the dialog.

The “Reset RDE” button causes the RDE firmware to reset and reload any programmed settings.

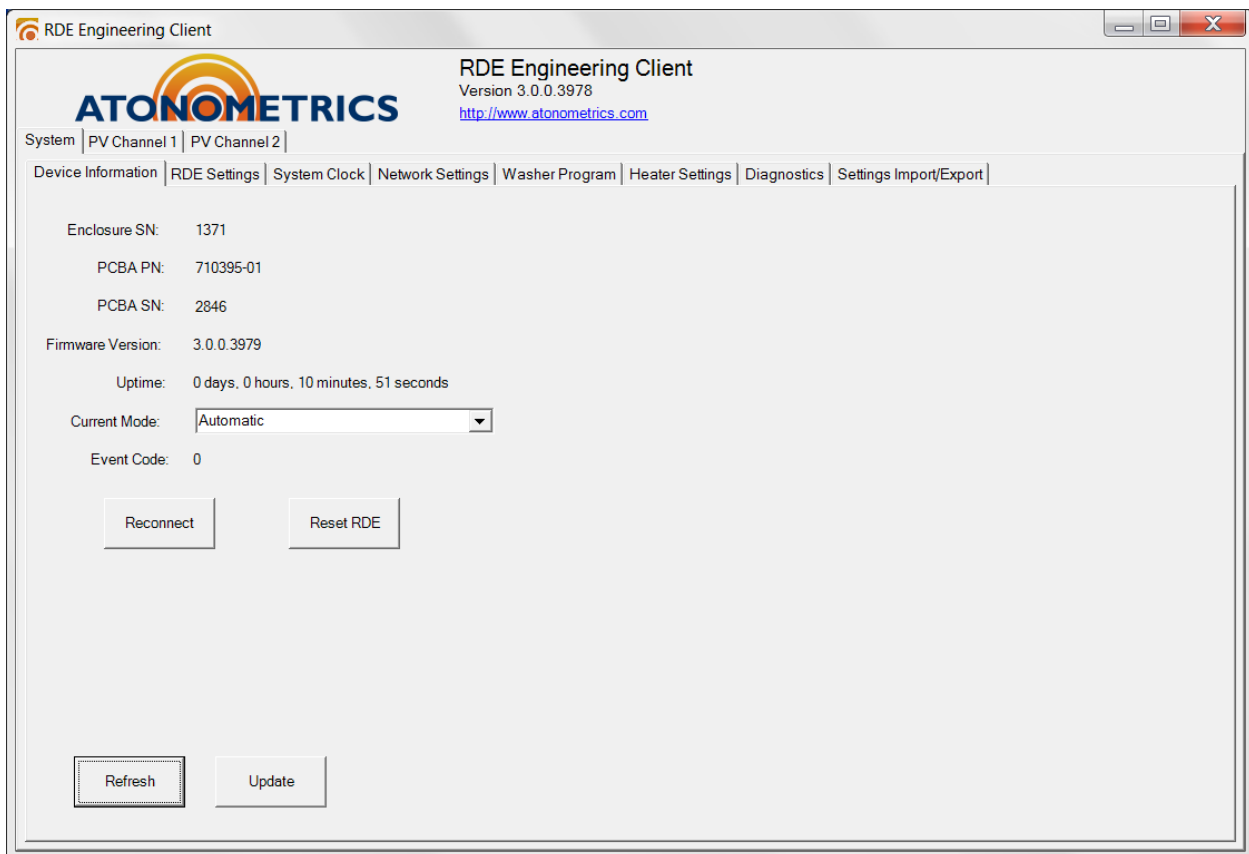


Figure 9-2: Device Information screen

9.4.2 RDE Settings Tab

The RDE Settings tab, shown below, displays settings on measurement timing and communication, including:

- Measurement Initiation:
 - Periodic: Measurements automatically performed once per Measurement Period.
 - Triggered: Measurement will be performed each time it is initiated by an “Initiate Measurements” command. (See Section 9.5.1 and Section 12.2.)
- Measurement Period: the time between measurement repetitions (Periodic mode) or the minimum allowed time between measurement initiations (Triggered mode).

These settings are normally pre-configured by Atonometrics for the user’s application. Editing the settings requires placing the software in advanced mode. (See 9.6.)

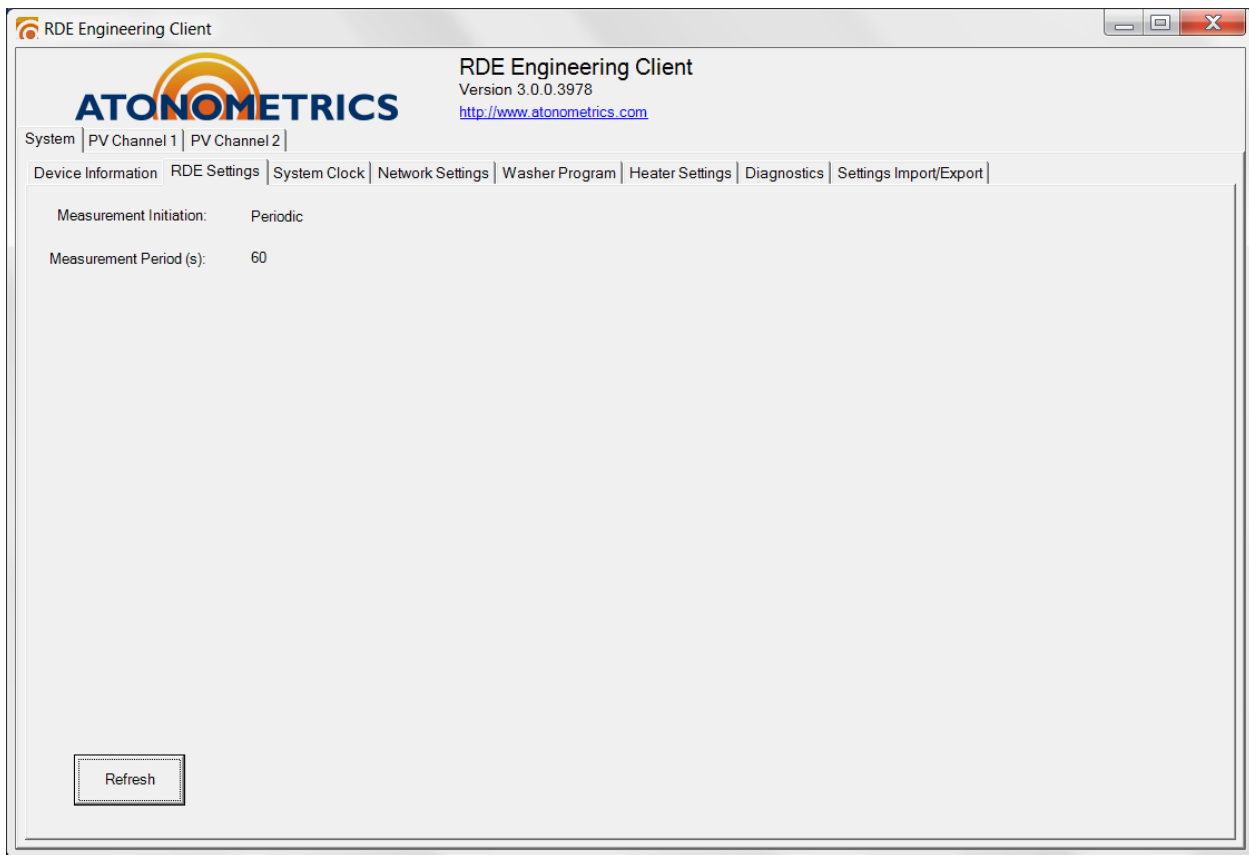


Figure 9-3: RDE Settings screen

9.4.3 System Clock Tab

Units in the RDE300 Series contain a battery-powered system clock for recording timestamps and scheduling events.

The clock date and time can be read from the System Clock tab in the System tab group.

To read the date and time from the RDE, press the “Refresh” button.

To set the RDE date and time:

- Change the date and time displayed on the dialog.
- Press “Update” to transfer the date and time to the RDE flash memory.
- Press “Refresh” to reload the settings from the RDE. Verify that the date and time are correct.

Note: Upon installation the date and time must be set to local **standard time (not daylight savings time)** at the site. Proper setting of the clock is critical for operation of the soiling analysis.

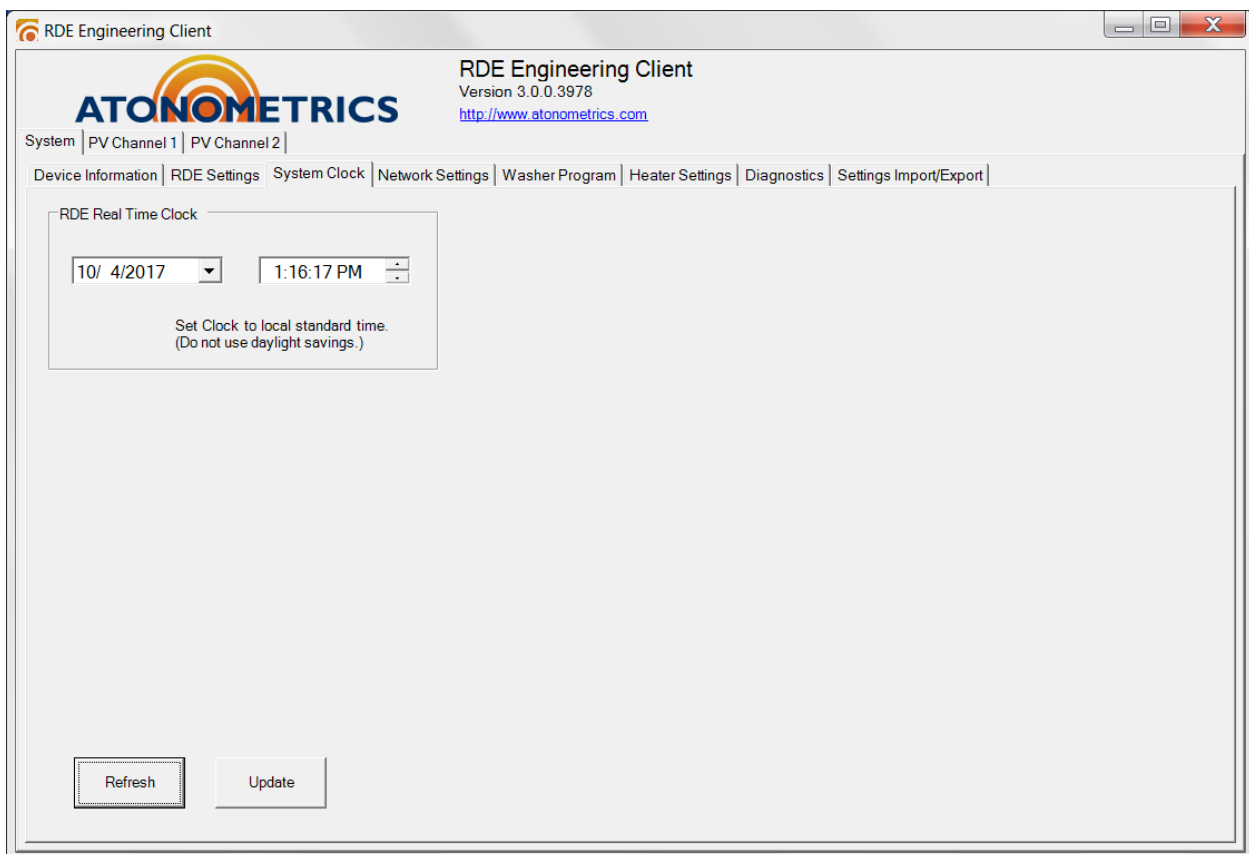


Figure 9-4: System Clock screen

9.4.4 Network Settings Tab

The Network Settings tab, shown below, allows the user to change the network settings of the RDE.

If necessary, press “Refresh” to load the network settings from the RDE to the dialog.

To change the network settings:

- Enter the new desired IP address, subnet mask, and default gateway.
- Press “Update” to transfer the new settings into the RDE flash memory.
- Press “Refresh” to reload the settings from the RDE. Verify that settings were written correctly.
- Cycle power to the RDE to make the new settings take effect. (Alternatively, reset the RDE from the reset button on the Device Information tab.)

Note: The RDE must be reset before new network settings take effect.

Note: After changing the RDE network settings, it may be necessary to reset the IP address of the user PC and re-launch the RDE Engineering Client to re-establish communication.

The screenshot shows the 'RDE Engineering Client' window. The title bar says 'RDE Engineering Client'. The main window has the 'ATONOMETRICS' logo on the left and 'RDE Engineering Client Version 3.0.0.3978' with the website 'http://www.atonometrics.com' on the right. Below the logo is a 'System' tab with 'PV Channel 1' and 'PV Channel 2' options. A horizontal menu bar contains 'Device Information', 'RDE Settings', 'System Clock', 'Network Settings' (which is selected), 'Washer Program', 'Heater Settings', 'Diagnostics', and 'Settings Import/Export'. The 'Network' section is expanded, showing three input fields: 'IP address' with '10.244.69.33', 'Subnet mask' with '255.255.255.0', and 'Default gateway' with '10.244.69.1'. Below this is the 'MAC Address' section with a single input field containing '00:50:C2:F7:C1:DB'. At the bottom left are two buttons: 'Refresh' and 'Update'.

Figure 9-5: Network Settings screen

9.4.5 Washer Program Tab

Some systems are configured to support an automatic Wash Unit to wash a Reference Cell or module. The Wash Unit schedule and settings are adjusted from the Washer Program tab. Two washing modes are supported:

- In **Timed Mode**, referring to Figure 9-6, the wash will start at the selected Wash Start Time and run for the number of seconds selected in Wash Time.
- In **Volume Mode**, referring to Figure 9-7, the wash will start at the selected Wash Start Time and run until the fluid amount dispensed equals the specified Wash Volume or the wash time exceeds the specified Wash Timeout parameter.

In both modes, the actual amount of fluid dispensed and the actual duration of the wash are recorded, along with the time the wash occurred. These are available as outputs from the RDE (see Section 12.3) to enable the user to log system operation, and are also visible on the Diagnostics tab of the RDE Engineering Client (see Section 9.4.7).

When the wash is complete, the Wash Start Time will be automatically incremented by the duration shown in the Washer Repeat Interval field.

Note: Atonometrics recommends a Wash Start Time of 5 pm local time at the site. This takes advantage of daytime high temperatures during winter months to avoid fluid freezing.

The screenshot shows the 'RDE Engineering Client' window with the 'Washer Program' tab selected. The interface includes the Atonometrics logo and version information (3.0.0.3978). The 'Washer Parameters' section is active, showing 'Mode' set to 'Timed' (selected with a radio button) and 'By Volume' (unselected). The 'Wash Time (s)' is set to 15.000. The 'Wash Start Time' is set to 10/ 5/2017 at 5:00:00 PM. The 'Washer Repeat Interval' is set to 1 Day, 0 Hours, 0 Minutes, and 0 Seconds. The 'Scheduled Washing Enabled' checkbox is checked, and the status is 'Enabled'. At the bottom, there are 'Refresh' and 'Update' buttons.

Figure 9-6: Washer Program screen, in Timed mode

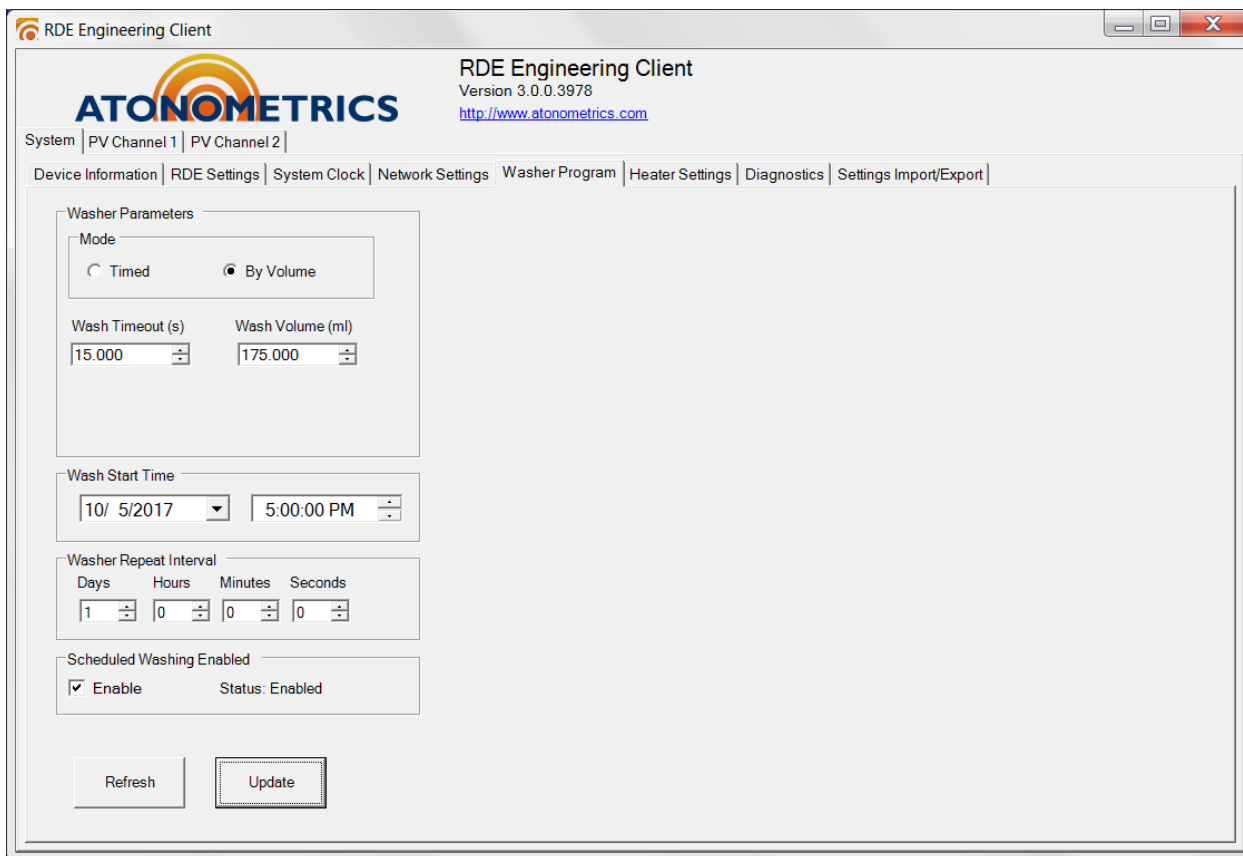


Figure 9-7: Washer Program screen, in Volume mode

To update any of the settings, change the value shown in the dialog and then press the “Update” button. Hit “Refresh” to reload the settings from the RDE to the client software, and confirm that the settings were properly programmed.

Note: Measurement of fluid flow rate and volume, as described above, require the flow sensor in the Wash Unit. The flow sensor is supported in Wash Units shipped October 2015 or later.

9.4.6 Heater Settings Tab

The Heater Settings tab, shown below, displays settings for the Tank Heater and Ref Cell Heater. The Tank Heater is designed to keep the wash fluid in the wash tank from freezing. The Ref Cell Heater is designed to keep the Ref Cell free of snow, ice, and frost.

Software settings include:

- Lower Limit: The temperature below which the heater will go to its maximum Duty Cycle.
- Upper Limit: The temperature above which the heater will turn off.
- Duty Cycle Limit: The maximum duty cycle for the heater when the temperature falls below the Lower Limit.

These settings are normally pre-configured by Atonometrics for the user's application. Editing the settings requires placing the software in advanced mode. (See 9.6.)

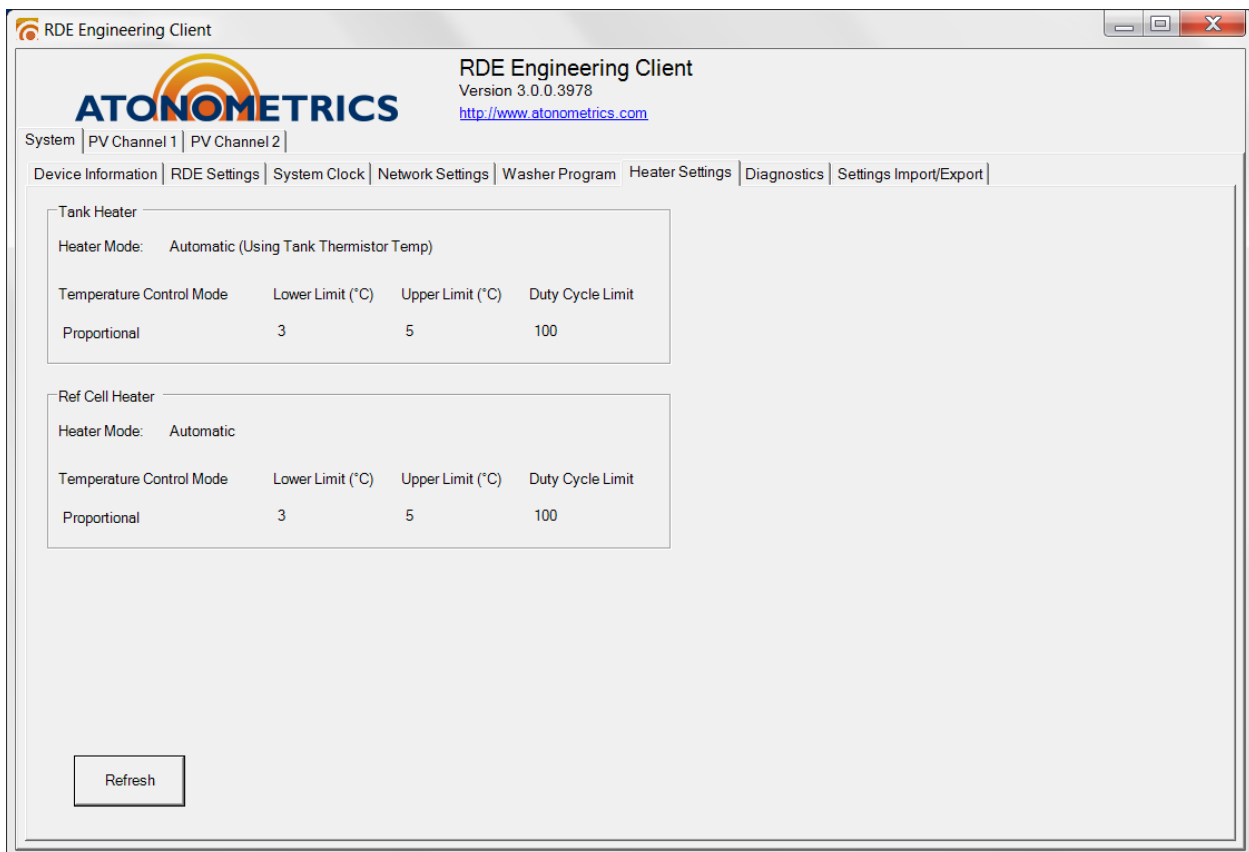
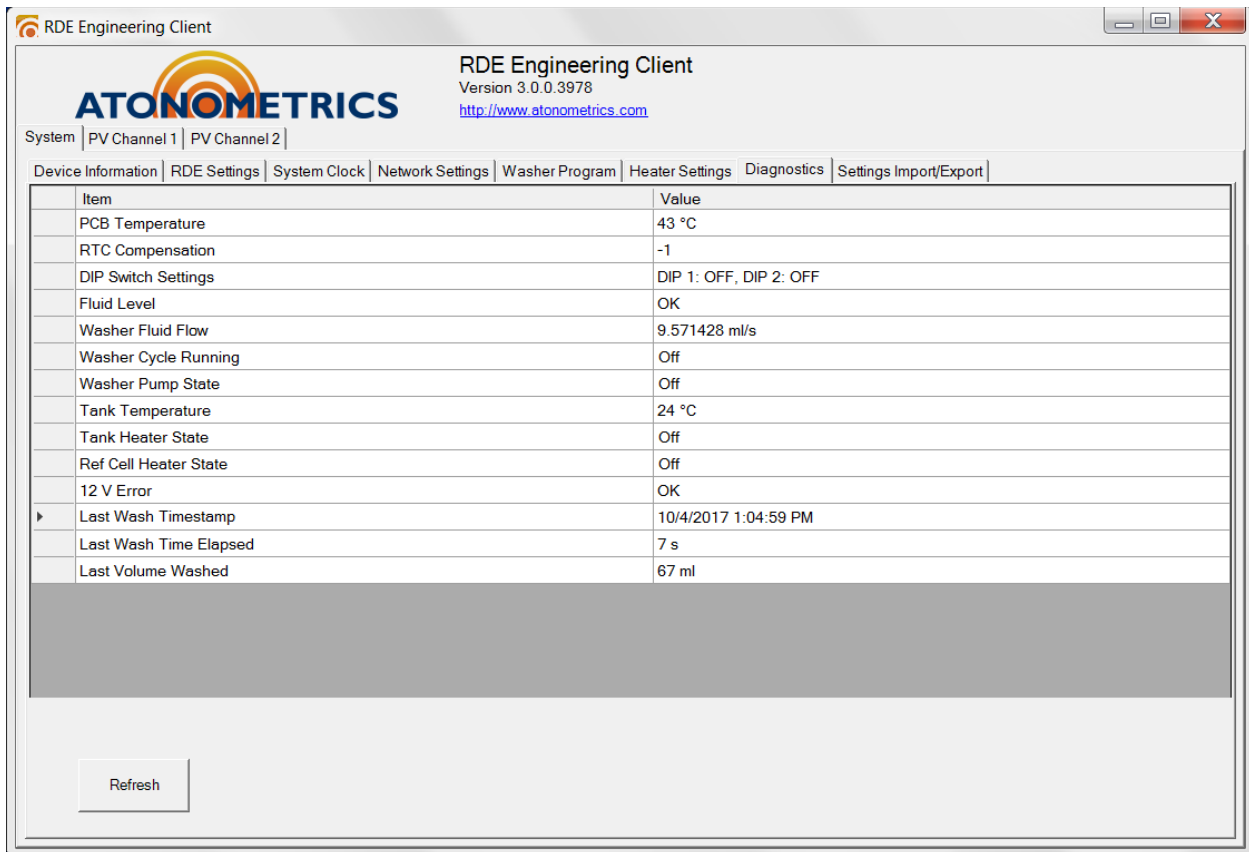


Figure 9-8: Heater Settings screen

9.4.7 Diagnostics Tab

The Diagnostics tab, shown below, displays status and diagnostic information for the RDE, including PCB temperature, DIP switch settings, wash tank fluid level, pump status, and heater status.



The screenshot shows the 'RDE Engineering Client' window with the 'Diagnostics' tab selected. The window title bar includes the RDE Engineering Client logo and version information. The main content area displays a table of diagnostic data. The table has two columns: 'Item' and 'Value'. The data includes PCB Temperature (43 °C), RTC Compensation (-1), DIP Switch Settings (DIP 1: OFF, DIP 2: OFF), Fluid Level (OK), Washer Fluid Flow (9.571428 ml/s), Washer Cycle Running (Off), Washer Pump State (Off), Tank Temperature (24 °C), Tank Heater State (Off), Ref Cell Heater State (Off), 12 V Error (OK), Last Wash Timestamp (10/4/2017 1:04:59 PM), Last Wash Time Elapsed (7 s), and Last Volume Washed (67 ml). A 'Refresh' button is located at the bottom left of the window.

Item	Value
PCB Temperature	43 °C
RTC Compensation	-1
DIP Switch Settings	DIP 1: OFF, DIP 2: OFF
Fluid Level	OK
Washer Fluid Flow	9.571428 ml/s
Washer Cycle Running	Off
Washer Pump State	Off
Tank Temperature	24 °C
Tank Heater State	Off
Ref Cell Heater State	Off
12 V Error	OK
▶ Last Wash Timestamp	10/4/2017 1:04:59 PM
Last Wash Time Elapsed	7 s
Last Volume Washed	67 ml

Refresh

Figure 9-9: Diagnostics screen

9.4.8 Settings Import/Export Tab

The Settings Import/Export tab, shown below, allows importing and exporting all RDE device settings to an XML file. This feature may be used to archive device settings and to communicate settings information with Atonometrics support staff.

Settings may be selected for export from among certain key groups, as indicated by the “Register Types to Export” checkboxes. To export all settings, select all groups.

Note: Settings may contain calibration constants and other device-specific data. Transferring settings from one RDE to another RDE or otherwise editing settings may overwrite critical data. Consult Atonometrics for guidance.

Register	PV Channel	Value
IP Address		10.244.69.33
Subnet Mask		255.255.255.0
Gateway		10.244.69.1
MAC Address		0:80:194:247:193:219
RTC Compensation		-1
RDE SN		1371
PCBA PN		710395-01
PCBA SN		2846
Firmware Version		3.0.0.3979
PCB Temperature Offset		0
Output Communication		0
Output Broadcast		0
IV Sweep Validation		0
Scheduled Washing Enabled		1
Scheduled Washing Start Second		0
Scheduled Washing Start Minute		0
Scheduled Washing Start Hour		17
Scheduled Washing Start Day		5
Scheduled Washing Start Month		10
Scheduled Washing Start Year		2017
Scheduled Washing Interval		86400

Figure 9-10: Settings Import/Export screen

9.5 PV Channel Tab Groups

The PV Channel 1 & PV Channel 2 tabs allow access to the measured data and configuration settings for each PV Channel.

9.5.1 Output Data Tab

To display the most recently read measurement values, press the “Refresh” button on the “Output Data” tab, as shown below.

Most systems are factory configured to Periodic Mode (see 9.4.2 and 12.2) in which the RDE runs automatically and new data are available once per Measurement Period (typically 1 minute). If instead the RDE is in Triggered mode, press the “Initiate Measurement” button to cause a measurement to be performed. (In Periodic Mode the Initiate Measurement button is ignored.)

For PV Channel 2, the data displayed include soiling ratio values. These are not displayed for PV Channel 1, which is designated the clean device.

Values displayed on the left are from the RDE’s last reading. Values displayed on the right are daily average values of soiling ratios. The averages are updated each day at the end of the soiling analysis time window (see Section 2.2 and Section 9.5.4). Therefore, before the end of the time window on a given day, the values displayed are from the previous day’s data.

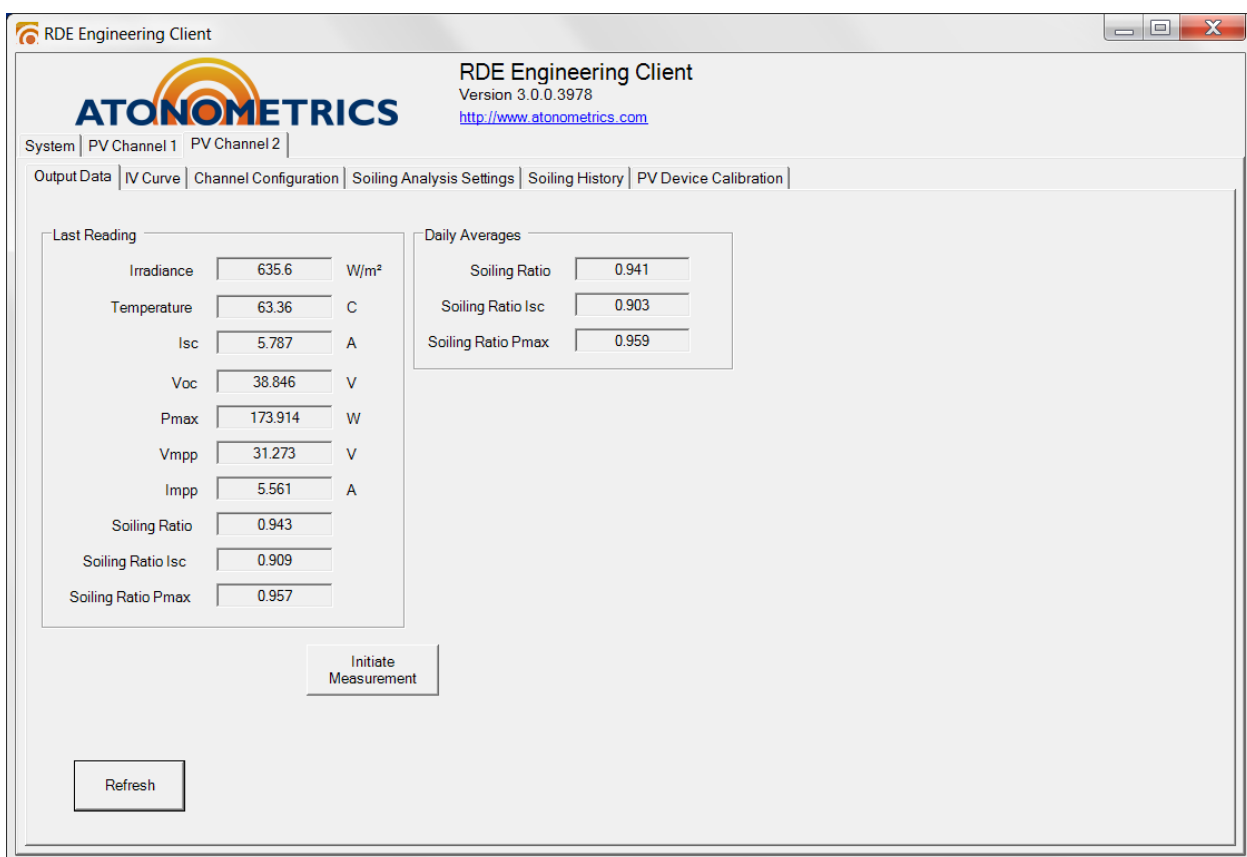


Figure 9-11: Output Data screen

9.5.2 IV Curve Tab

The IV Curve tab, shown below, displays the most recently read I-V curve data for the PV Channel.

Note: On systems with a part number having an “N” suffix, I-V sweeps are disabled.

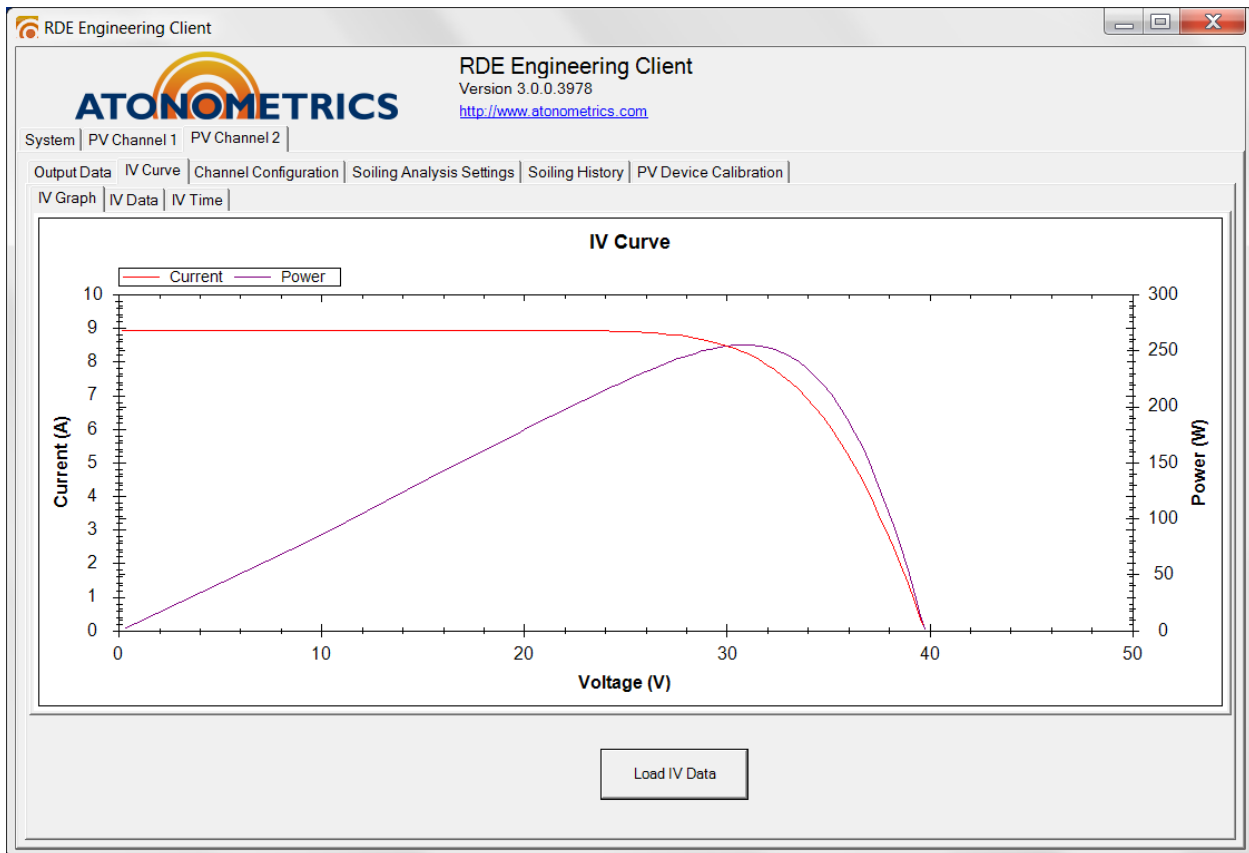


Figure 9-12: IV Curve screen

9.5.3 Channel Configuration Tab

The Channel Configuration tab, shown below, displays the configuration of the PV channel.

Key settings include:

- Enabling of IV Sweeps (Yes/No)
 - IV Sweeps must be enabled in order to measure the Pmax of the PV device.
- Selection of Hold State in between IV Sweeps (Isc/Voc)
 - Voc is selected for modules that could be damaged by continuous operation at short-circuit, such as crystalline silicon modules.
 - Isc is selected for modules that could be damaged by continuous operation at open circuit, such as some thin-film modules.
- Selection of PV Temperature Measurement Type
 - RTD: Temperature is measured from an RTD affixed to the back of the PV device.
 - Voc: Temperature is measured from the PV device open-circuit voltage (Voc). IV sweeps must be enabled. The user must also supply additional calibration data (see Section 9.5.6) to use this feature, introduced in firmware R3979 October 2017. The calibration data are typically available on module datasheets, but also often need device-specific calibration for accurate results. Note that in Voc temperature measurement mode, temperature measurements are provided only when irradiance is above a minimum configurable threshold of typically 50-100 W/m². Contact Atonometrics for more information.

The settings will typically be pre-configured by Atonometrics for the user's application. Editing the settings requires placing the software in advanced mode. (See 9.6.)

Note: On systems with a part number having an "N" suffix, I-V sweeps are disabled.

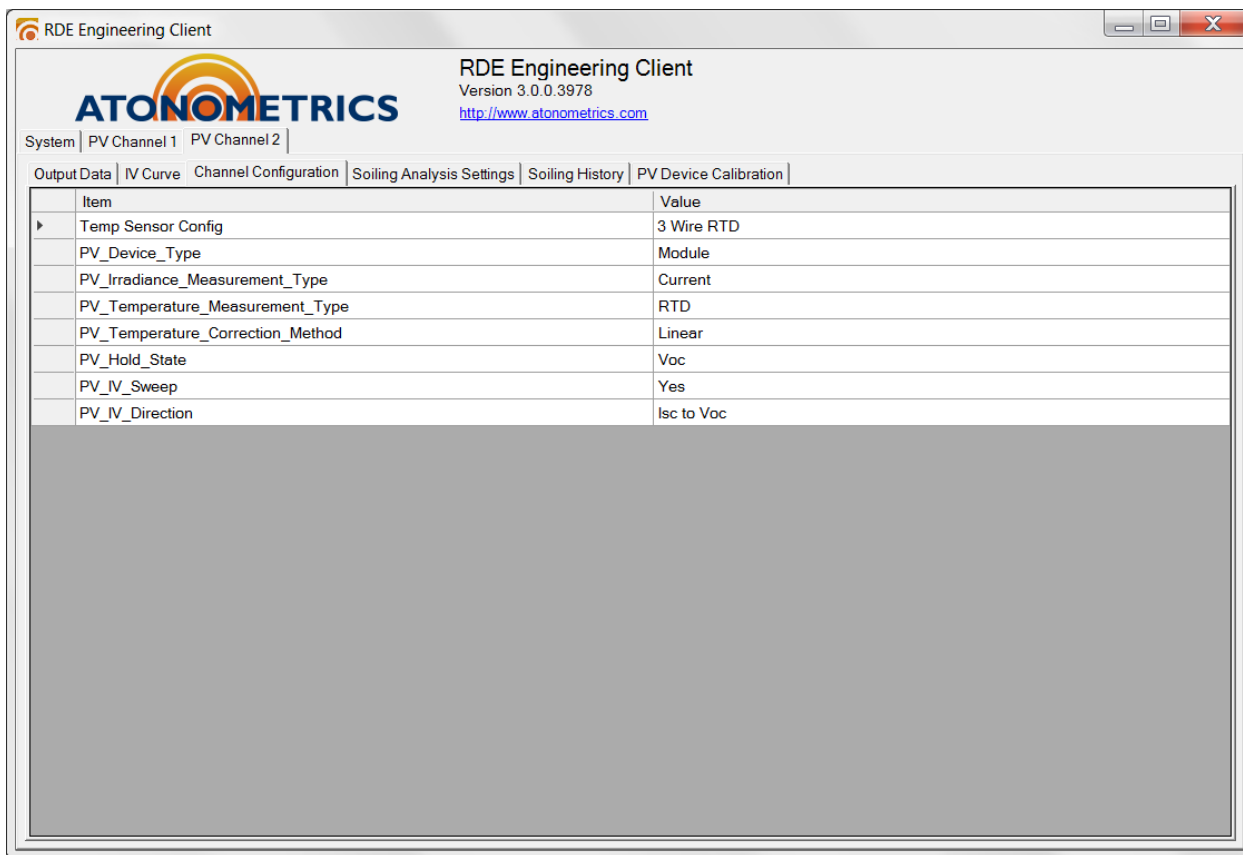


Figure 9-13: Channel Configuration screen

9.5.4 Soiling Analysis Settings Tab

The Soiling Analysis Settings tab, shown below, allows the user to set limits on conditions for the collection of soiling data. (See Section 2.2.) Settings function as follows:

- Min Irradiance: Minute-by-minute soiling ratio values will only be calculated when the irradiance measured on PV1 exceeds this threshold.
- Time Window: Minute-by-minute soiling ratio values will only be calculated during the number of hours before and after noon specified by this parameter. For example, +/-2 hours results in soiling ratio measurements being performed between 10 AM and 2 PM.

Note: Atonometrics recommends using the default settings of 500 W/m² and noon +/-2 hours.

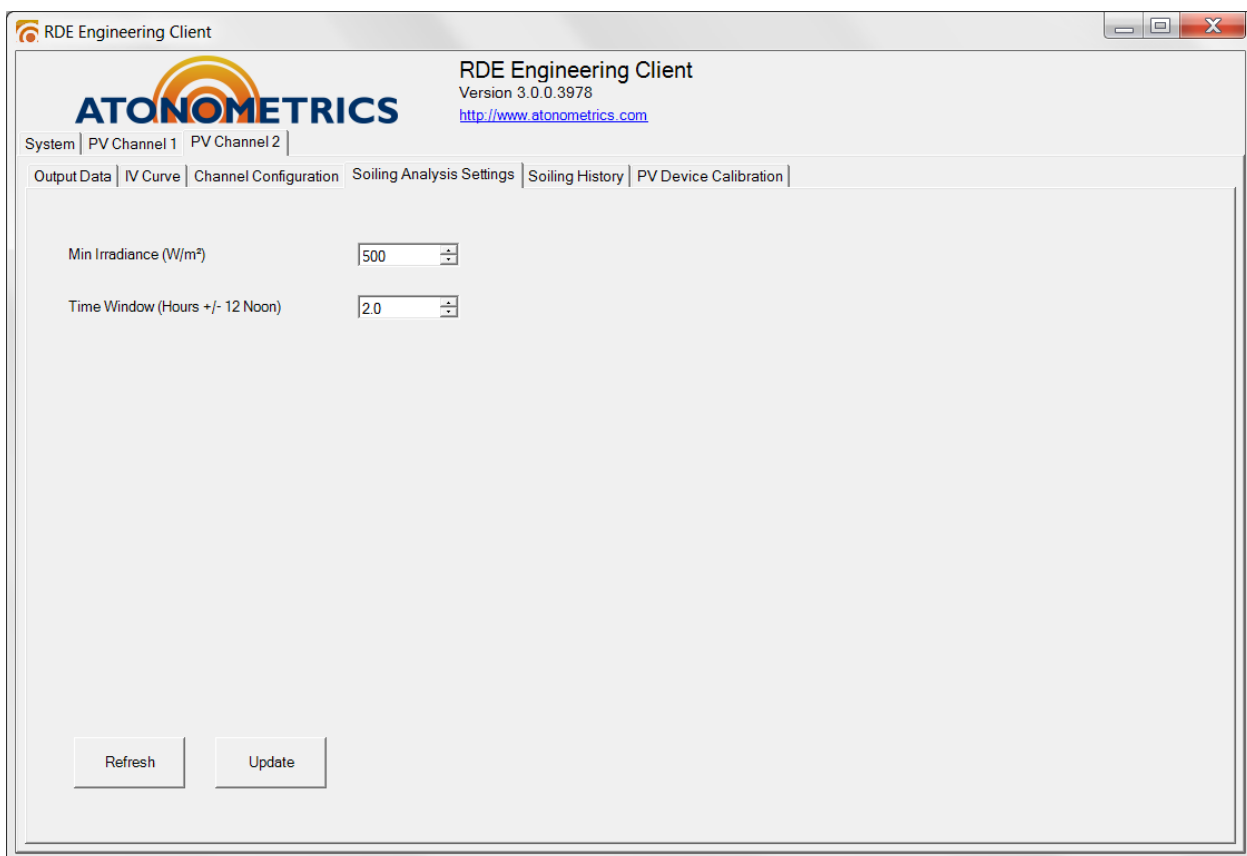


Figure 9-14: Soiling Analysis Settings screen

9.5.5 Soiling History Tab

The Soiling History tab, shown below, displays up to a one-year history of daily average soiling ratio values recorded by the RDE. To load the data for display, press the “Refresh” button.

In addition to the daily average soiling ratio values, the history table displays the number of data points that passed the soiling analysis settings filter requirements (see Section 9.5.4) and the average irradiance of these data points.

To export the data, highlight the desired cells, press Ctrl-C to copy to the clipboard, and use Ctrl-V to paste into a text file or spreadsheet.

Note that the RDE stores each day’s average results in a rolling one-year table; as new data are added, data from one year previous are overwritten.

To clear the history table, press the “Clear Soiling History” button.

Date	Soiling Ratio	Soiling Ratio Isc	Soiling Ratio Pmax	Irradiance	Datapoints
10/4/2017	0.984	0.984	0.985	867.2	134
10/3/2017	0.986	0.986	0.987	904.1	124
10/2/2017	0.988	0.988	0.990	1047.1	124
10/1/2017	0.990	0.990	0.992	972.1	135
9/30/2017	0.992	0.992	0.994	723.8	52
9/29/2017	0.947	0.947	0.916	923.9	83
9/28/2017	0.948	0.948	0.918	916.6	135
9/27/2017	0.951	0.951	0.921	1037.3	114
9/26/2017	0.952	0.952	0.923	921.4	133
9/25/2017	0.954	0.954	0.925	931.0	135
9/24/2017	0.955	0.955	0.927	921.5	95
9/23/2017	0.958	0.958	0.929	1008.8	157
9/22/2017	0.959	0.959	0.931	1022.9	120
9/21/2017	0.961	0.961	0.933	924.4	133
9/20/2017	0.963	0.963	0.936	912.5	146
9/19/2017	0.965	0.965	0.938	932.5	141
9/18/2017	0.967	0.967	0.939	996.7	93
9/17/2017	0.969	0.969	0.941	921.7	150
9/16/2017	0.971	0.971	0.943	974.1	123

Figure 9-15: Soiling History screen

9.5.6 PV Device Calibration Tab

The PV Device Calibration tab, shown below in Figure 9-16, displays the calibration data for the PV cell or module associated with the PV Channel.

These settings may be manually edited in advanced mode. (See Section 9.6.)

In addition, calibration files produced by an Atonometrics portable PV module calibration station (contact Atonometrics for information) can be downloaded to the RDE by pressing the “Download MCF file to RDE” button.

Note: The PV device calibration data are used for the irradiance and soiling ratio calculations described in Chapter 2, and must be entered correctly in order for the RDE calculations to be accurate. In some cases these data will be pre-programmed into the unit by Atonometrics, while in other cases the user must enter the data. Contact Atonometrics for guidance.

For soiling ratio determination, Isc Ref and Pmax Ref must be manually set for PV2, following the calibration procedure described in Chapter 11.

Parameter	Value
Module SN	123456789
Isc Ref (A)	8.925
Pmax Ref (W)	311.0
Irradiance Ref (W/m²)	1000.0
Temp Ref (°C)	25.0
Isc Temperature Coefficient (%/°C)	0.05
Pmax Temperature Coefficient (%/°C)	-0.41

Figure 9-16: PV Device Calibration screen

When Voc temperature measurement mode is enabled (see Section 9.5.3), the PV Device Calibration screen displays additional parameters, as shown in Figure 9-17. These parameters are typically found on module datasheets, but also may need module-specific calibration for accurate results.

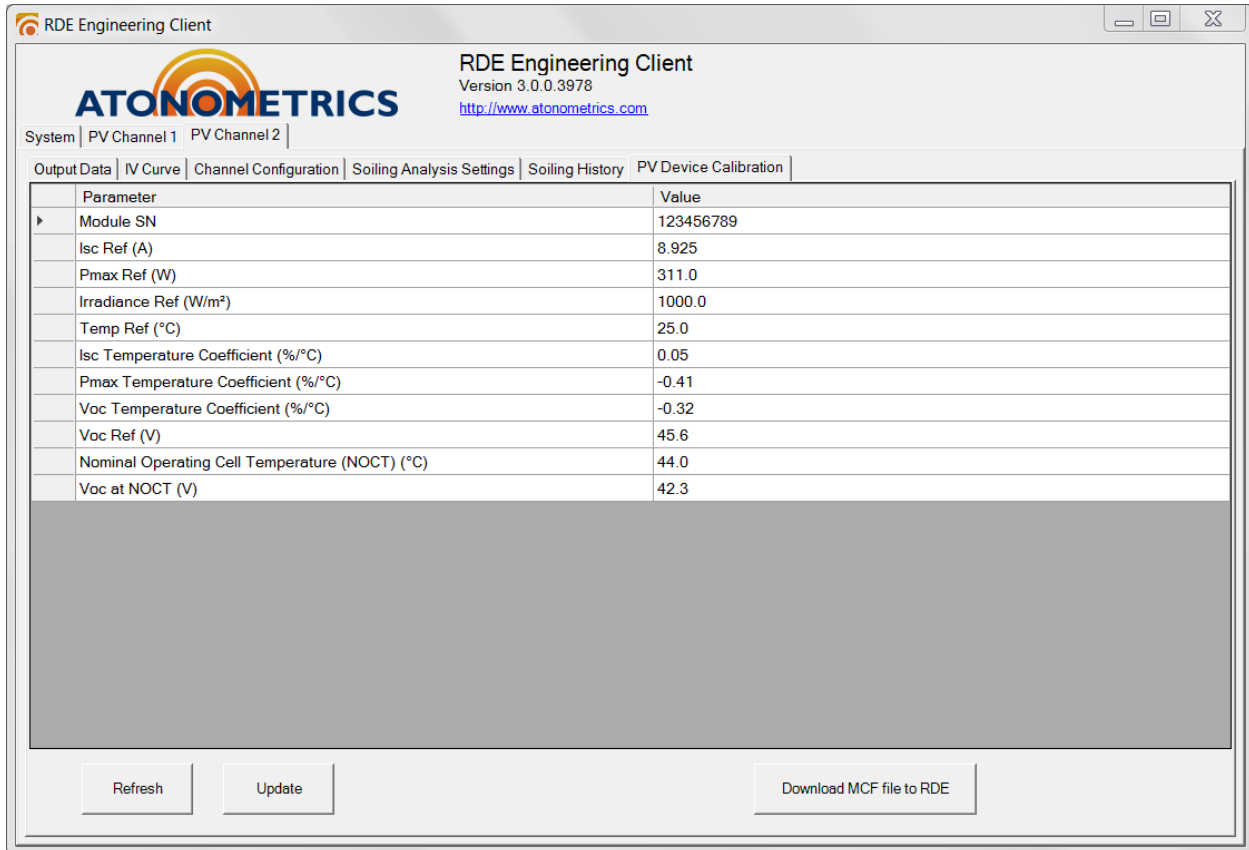


Figure 9-17: PV Device Calibration screen, with Voc temperature measurement enabled

9.6 Advanced Mode

Certain RDE settings can only be edited while running the software in an advanced mode.

To enter the advanced mode, double-click on the Atonometrics logo on the connect screen (see Figure 9-1) prior to connecting to the RDE, and accept the warning prompt.

Note: Incorrectly editing settings in advanced mode may negatively impact RDE operation.
Consult Atonometrics for guidance.

9.7 Updating Firmware

Users may update the RDE firmware when a new version is provided by Atonometrics.

Note: Obtain the latest firmware, along with the latest version of the RDE Engineering Client software and the latest version of this User Guide, from www.atonometrics.com.

Note: Caution: Incorrectly updating the RDE firmware may cause the device to become inoperative. Only update firmware as directed by Atonometrics.

Note: Units shipped May 2019 and later (PCB ID06600 and up, see 6.1.5): When the default IP address DIP switch (see 6.1.11) is placed in the ON position, both the orange Status LED and the green Flow LED will blink for up to 30 seconds. This indicates that the unit has entered default IP address mode. During the first 30 seconds, the unit will also be in bootloader mode and will accept a firmware update using the factory default IP address. This feature can be used to recover the unit if a previous firmware update attempt was interrupted or did not complete successfully.

Note: Units shipped before May 2019 (PCB ID06599 and below, see 6.1.5): The default IP address DIP switch (see 6.1.11) should not be used when updating firmware.

Note: Do not update firmware via a remote network. If the communication is interrupted or corrupted during the firmware update process, the RDE may become inoperative. Always update firmware using a local connection.

To update the firmware with a new release provided by Atonometrics, follow these steps:

- On your PC, disable Windows Firewall, or ensure that all ports listed in section 8.6 are enabled for RDE Engineering Client to communicate through the firewall.
- Connect to the RDE as indicated in Section 9.3, using a locally connected PC.
- Once connected to the RDE, enable the hidden firmware update dialog by simultaneously holding the CTRL and ALT keys while right-clicking with the mouse in the application window on the Atonometrics logo. A dialog labeled “Atonometrics Firmware Update” will appear, as shown below.

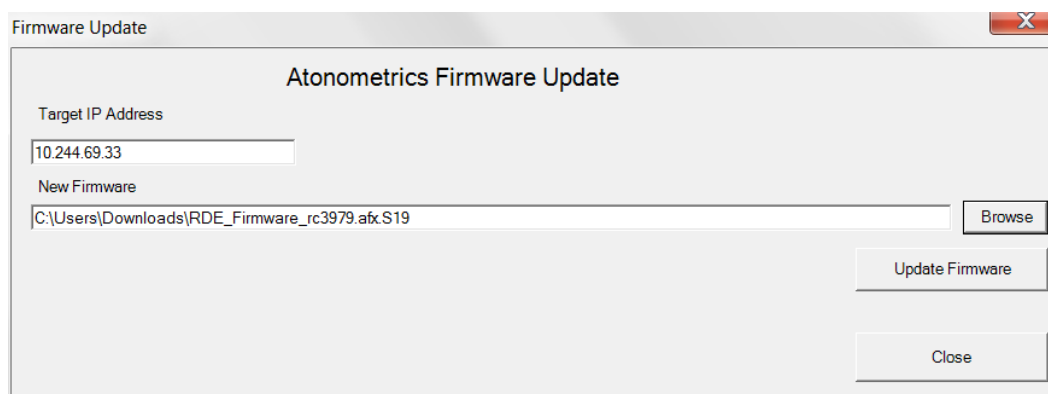


Figure 9-18: Firmware Update screen

- Press the “Browse” button and navigate to the location of the “.S19” file with the RDE firmware (PN 500044-03) provided by Atonometrics.
- Press the “Update Firmware” button to transfer the firmware file to the RDE, and verify if prompted. The firmware transfer process will begin and a progress bar will be displayed on the dialog as shown in Figure 9-19.
- While the RDE is in bootload mode awaiting firmware update, the orange Status and green Flow LEDs will blink (for systems with PCB ID06600 and up only, see 6.1.5).
- When the transfer is complete, a success message will be displayed, the dialog will be closed and the software will return to the connection screen.
- Reset power on the RDE device.
- To verify operation, reselect the RDE device from the software connection screen and connect to it again.

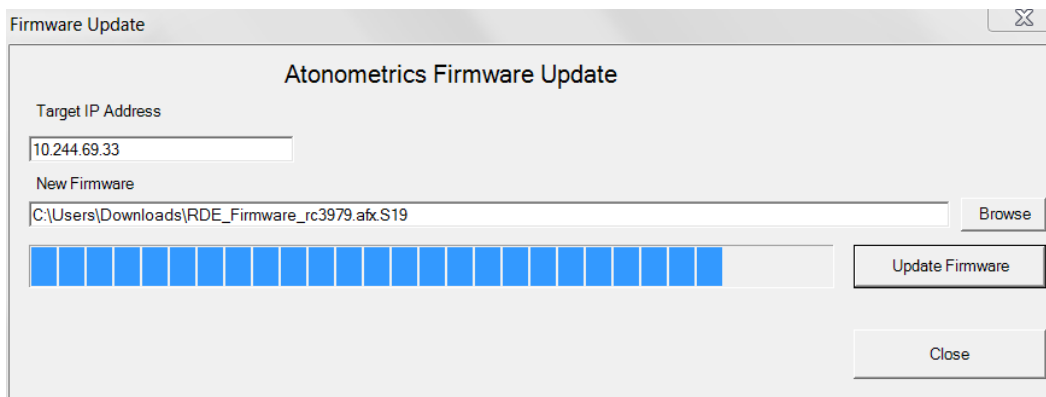


Figure 9-19: Firmware update progress bar

If the firmware update process is interrupted or is unsuccessful, follow these steps:

- Return to the connection screen of the RDE Engineering Client software
- Press Search for RDEs
- If the RDE is detected, a message indicating that it is running the Bootloader (firmware update program) will be displayed, as shown in Figure 9-20, along with the RDE IP address.
- Ensure that the client PC is operating on the same network subnet as the RDE.
- Select the RDE and double-click to connect.
- The firmware update dialog shown above will now be displayed, and the update process may now be performed again.
- If necessary, use the default IP address switch (see 6.1.11) to set the unit to its factory default IP address and force 30 seconds of bootload mode upon power up.

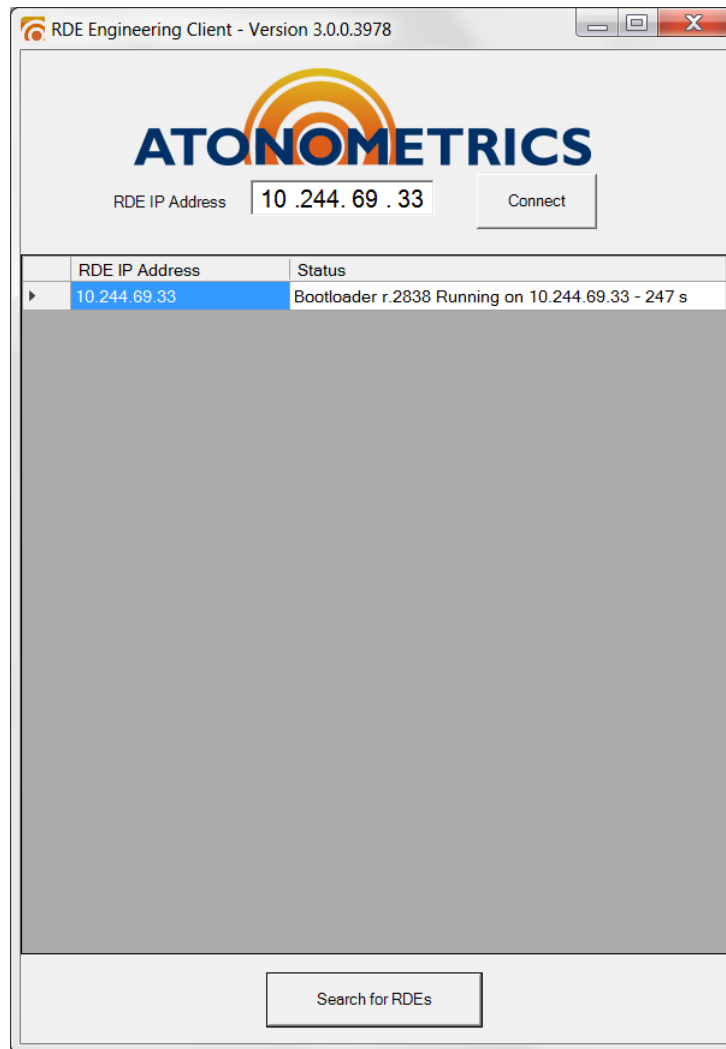


Figure 9-20: Connection screen detecting RDE in bootload state ready for firmware update

10 Testing the System

10.1 Testing the Measurements

To test the measurement system, use the RDE Engineering Client software outlined in Chapter 9. The RDE is typically configured by Atonometrics prior to shipment as appropriate for the user application, allowing valid measurements to be made as soon as the system components are connected and powered. However, if necessary, contact Atonometrics for support in configuring the RDE.

On each of the PV Channel Output Data tabs in the software (see Section 9.5.1), press “Refresh”. Confirm that the readings appear correct for current conditions of temperature and irradiance and for the user’s RDE configuration. (Note that soiling ratio values may not appear, depending on the time of day and irradiance during the test; see Section 9.5.4.)

10.2 Testing the Wash Unit

To test the Wash Unit, use the RDE Engineering Client to program the Wash Unit to run.

In the Washer Program tab of the software (see Section 9.4.5) set the program as listed in Table 10-1 and press “Update” to transfer settings to the RDE.

Wait until the Wash Unit begins to run. Then:

- Verify that wash fluid sprays out of the spray nozzle as shown in Figure 10-1.
- Verify that the spray is properly directed at the clean reference device.
- Ensure that there are no leaks or blockages in the fluid tubing.

Table 10-1: Washer Program settings for testing Wash Unit

Mode:	By Volume
Wash Timeout:	15 s
Wash Volume:	175 ml
Wash Start Time:	<i>Current date and time</i>
Washer Repeat Interval:	0 d, 0 h, 0 m, 30 s
Scheduled Washing Enabled:	Enabled

Once proper operation is verified, update the Washer Program settings as follows for normal operation:

Table 10-2: Recommended Washer Program settings for normal operation

Mode:	By Volume
Wash Timeout:	15 s
Wash Volume:	175 ml
Wash Start Time:	<i>Current date</i> , 5:00 PM
Washer Repeat Interval:	1 d, 0 h, 0 m, 0 s
Scheduled Washing Enabled:	Enabled

Note: Atonometrics recommends setting the Washer Program for daily wash at 5 PM. Late afternoon wash times are preferred to take advantage of daily high temperatures that help prevent freezing during winter operation.



Figure 10-1: Testing the Wash Unit

11 PV Module Calibration

11.1 Calibration for Irradiance Measurement

For **irradiance** measurement, the “clean” PV reference device in the PV1 channel must be calibrated against a suitable reference device in order to obtain accurate readings.

Often the system will use a calibrated Atonometrics-supplied PV Reference Cell as the PV1 device. In this case, irradiance measurement calibration constants are pre-programmed into the user’s RDE, and no further calibration is required by the user.

Atonometrics may also calibrate user-supplied modules and pre-program the values into the RDE. In other cases, contact Atonometrics for guidance.

11.2 Calibration for Soiling Measurement

For **soiling** measurement, the “soiled” PV module in the PV2 channel must be calibrated to match the PV1 device. This calibration ensures that no soiling losses will be detected when both PV1 and PV2 are clean.

This calibration is performed by the user, in the field, using either Method 1 or Method 2 below.

Method 1 is faster but requires visiting the RDE within 1-2 hours of noon.

Method 2 can be a bit more accurate, in particular for partly cloudy days, and can be initiated in the morning and then completed in the afternoon.

11.2.1 Method 1

1. **Select a clear day** for the measurements, when there are no clouds overhead near the position of the sun.
2. Perform the calibration **within 1-2 hours of solar noon** (local standard time, not daylight savings time) so that the sun will be at a high position in the sky. (Note: the measurements cannot be performed outside of the Soiling Analysis time window. See Section 9.5.4.)
3. **Thoroughly clean and dry** both PV1 and PV2 devices. **Confirm proper alignment** as directed in Chapter 7.
4. Launch the RDE Engineering Client software (see chapter 9). **Double-click on the Atonometrics icon** to enter advanced mode (see 9.6). Connect to the RDE.
5. From the PV Channel 2 \ PV Device Calibration tab, enter the default values of the PV2 device from the module datasheet and press Update. (Note: if PV1 data are not pre-programmed into the RDE by Atonometrics, also enter the datasheet or laboratory test values of PV1 into the corresponding PV Channel 1 \ PV Device Calibration tab. This is necessary only for user-supplied modules that are not calibrated by Atonometrics.)
6. **Wait 1 minute** (or the value of the programmed Measurement Period, typically 1 minute) to allow the measurements to update.

7. From the PV Channel 2 \ Output Data tab, **press “Refresh”** and **record the values** of the **Last Reading** for Soiling Ratio Isc and Soiling Ratio Pmax. (Note: if the system was disturbed during the measurement by shadows, clouds, etc., return to step 6.)

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<http://www.atonometrics.com>

System | PV Channel 1 | PV Channel 2 |

Output Data | IV Curve | Channel Configuration | Soiling Analysis Settings | Soiling History | PV Device Calibration |

Last Reading

Irradiance	635.6	W/m²
Temperature	63.36	C
Isc	5.787	A
Voc	38.846	V
Pmax	173.914	W
Vmpp	31.273	V
Impp	5.561	A
Soiling Ratio	0.943	
Soiling Ratio Isc	0.909	
Soiling Ratio Pmax	0.957	

Daily Averages

Soiling Ratio	0.941
Soiling Ratio Isc	0.903
Soiling Ratio Pmax	0.959

8. If the Soiling Ratio Isc and Soiling Ratio Pmax equal 1.00 ± 0.01 , the programmed calibration is adequate. The procedure is complete.
9. If the Soiling Ratio Isc or Soiling Ratio Pmax do not equal 1.00 ± 0.01 :
- From the PV Channel 2 \ PV Device Calibration tab:
 - Multiply** the Isc_Ref value by the Soiling Ratio Isc value recorded in step 7 and enter this new value into the Isc_Ref field.
 - Multiply** the Pmax_Ref value by the Soiling Ratio Pmax value recorded in step 7 and enter this new value into the Pmax_Ref field.
 - Press **“Update”** to transfer the calibration values to the RDE.

RDE Engineering Client

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RDE Engineering Client
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<http://www.atonometrics.com>

System | PV Channel 1 | PV Channel 2 |

Output Data | IV Curve | Channel Configuration | Soiling Analysis Settings | Soiling History | PV Device Calibration |

Parameter	Value
Module SN	123456789
Isc Ref (A)	8.925
Pmax Ref (W)	311.0
Irradiance Ref (W/m²)	1000.0
Temp Ref (°C)	25.0
Isc Temperature Coefficient (%/°C)	0.05
Pmax Temperature Coefficient (%/°C)	-0.41

10. Return to step 6 to verify.

11.2.2 Method 2

1. **Select a clear or slightly cloudy day** for the measurements.
2. Begin the calibration **in the morning before the start of the Soiling Analysis time window**. (Typically 10 AM on the RDE clock, local standard time, not daylight savings time; see Section 9.5.4.)
3. **Thoroughly clean and dry** both PV1 and PV2 devices. **Confirm proper alignment** as directed in Chapter 7.
4. Launch the RDE Engineering Client software (see chapter 9). **Double-click on the Atonometrics icon** to enter advanced mode (see 9.6). Connect to the RDE.
5. From the PV Channel 2 \ PV Device Calibration tab, enter the default values of the PV2 device from the module datasheet and press Update. (Note: if PV1 data are not pre-programmed into the RDE by Atonometrics, also enter the datasheet or laboratory test values of PV1 into the corresponding PV Channel 1 \ PV Device Calibration tab. This is necessary only for user-supplied modules that are not calibrated by Atonometrics.)
6. **Wait until after the end of the Soiling Analysis time window**. (Typically 2 PM on the RDE clock, local standard time, not daylight savings time; see Section 9.5.4.)
7. From the PV Channel 2 \ Output Data tab, **press “Refresh”** and **record the values** of the **Daily Averages** for Soiling Ratio Isc and Soiling Ratio Pmax.

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<http://www.atonometrics.com>

System | PV Channel 1 | PV Channel 2 |

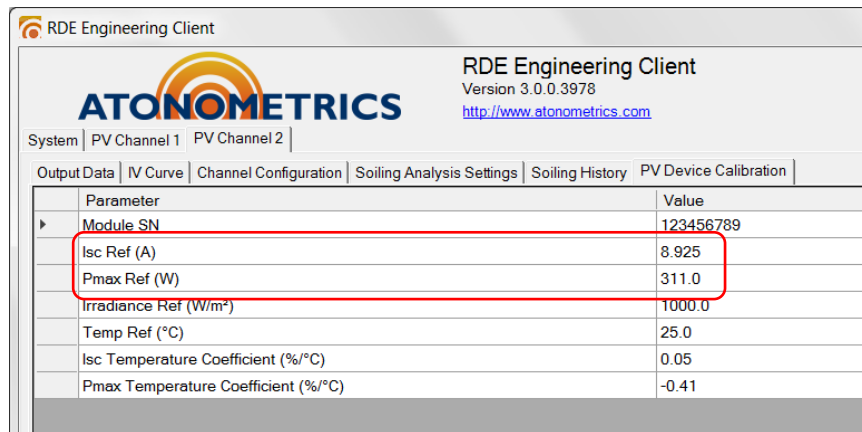
Output Data | IV Curve | Channel Configuration | Soiling Analysis Settings | Soiling History | PV Device Calibration |

Last Reading		
Irradiance	635.6	W/m²
Temperature	63.36	C
Isc	5.787	A
Voc	38.846	V
Pmax	173.914	W
Vmpp	31.273	V
Impp	5.561	A
Soiling Ratio	0.943	
Soiling Ratio Isc	0.909	
Soiling Ratio Pmax	0.957	

Daily Averages	
Soiling Ratio	0.941
Soiling Ratio Isc	0.903
Soiling Ratio Pmax	0.959

8. If the Daily Averages for Soiling Ratio Isc and Soiling Ratio Pmax equal 1.000 ± 0.005 , the programmed calibration is adequate. The procedure is complete.
9. If the Soiling Ratio Isc or Soiling Ratio Pmax do not equal 1.000 ± 0.005 :
 - a. From the PV Channel 2 \ PV Device Calibration tab:
 - i. **Multiply** the Isc_Ref value by the Daily Average Soiling Ratio Isc value recorded in step 7 and enter this new value into the Isc_Ref field.
 - ii. **Multiply** the Pmax_Ref value by the Daily Average Soiling Ratio Pmax value recorded in step 7 and enter this new value into the Pmax_Ref field.

- b. Press “**Update**” to transfer the calibration values to the RDE.



RDE Engineering Client

ATONOMETRICS

RDE Engineering Client
Version 3.0.0.3978
<http://www.atonometrics.com>

System | PV Channel 1 | PV Channel 2 |

Output Data | IV Curve | Channel Configuration | Soiling Analysis Settings | Soiling History | PV Device Calibration

Parameter	Value
Module SN	123456789
Isc Ref (A)	8.925
Pmax Ref (W)	311.0
Irradiance Ref (W/m²)	1000.0
Temp Ref (°C)	25.0
Isc Temperature Coefficient (%/°C)	0.05
Pmax Temperature Coefficient (%/°C)	-0.41

10. Check the system in 24 hours and **confirm** that the new Soiling Ratio Daily Averages displayed on the PV Channel 2 \ Output Data tab are close to 1.00 – provided that the PV2 device is still clean.

12 Programming Guide

12.1 Overview

This chapter provides information for setting up data logging, which is performed by the user's client software running remotely from the RDE.

The RDE units communicate via Ethernet using the Modbus TCP protocol.

Client software may include 3rd-party or user-developed software compatible with the Modbus TCP protocol, running on a data logger, PLC, PC, or SCADA system.

12.2 Measurement Timing

The RDE unit may be configured to run in either a **Periodic** or Triggered mode, as follows:

- In **Periodic** mode, the RDE continuously performs measurements at an interval specified in its configuration settings.
- In **Triggered** mode, the RDE waits to receive an Initiate Measurement command (register 8000 – see Section 12.3) prior to performing a measurement.

Regardless of the measurement mode, when polled with a read request to any of the data registers, the RDE responds with the most recently measured value for the requested register.

Configuration of the measurement timing mode is performed by Atonometrics prior to shipment. It may also be changed by the user in the field by using the RDE Engineering Client software. (See chapter 9.)

12.3 Register Table

Table 12-1 lists the registers available for the user's client software to read data from the RDE, as of firmware version R3979, released October 2017.

Each numbered register in the table is a 16 bit (2 byte) register.

Parameters requiring 4 bytes must be read from a sequential pair of registers, as indicated by the Register Start and End columns. For a 4-byte value with bytes in the order *ABCD*, from most to least significant, the first register reads out bytes *AB* and the second reads out bytes *CD*.

For clarification, see the packet examples in Section 12.6.

Note: On some user data acquisition devices, it is necessary to add 1 to all the register values shown in **Table 12-1** to determine the Modbus address. For an example, see section 12.4.

Table 12-1: RDE Modbus registers

Register Start	Register End	Parameter Name	Units	Data Format	Bytes	Read/Write	Description
PV Channel 1							
1000	1001	Irradiance	W/m ²	Float32 ⁽¹⁾	4	Read Only	The measured irradiance, which is calculated from the temperature-corrected short-circuit current (Isc) of the PV device, using internally stored calibration constants. See Chapter 2.
1002	1003	Isc	A	Float32 ⁽¹⁾	4	Read Only	The measured short-circuit current (Isc) of the PV device. This value is not temperature-corrected.
1004	1005	PV Temperature	°C	Float32 ⁽¹⁾	4	Read Only	The temperature of the PV device measured using the attached RTD or from the PV device open-circuit voltage (Voc).
1006	1007	Pmax	W	Float32 ⁽¹⁾	4	Read Only	The measured maximum power (Pmax) of the PV device. This value is not temperature-corrected. This function requires I-V curve sweep capability enabled. I-V sweeps are not performed on reference cells; when a reference cell is used, no value will be reported for Pmax.
PV Channel 2							
2000	2001	Irradiance	W/m ²	Float32 ⁽¹⁾	4	Read Only	See notes for PV Channel 1.
2002	2003	Isc	A	Float32 ⁽¹⁾	4	Read Only	See notes for PV Channel 1.
2004	2005	PV Temperature	°C	Float32 ⁽¹⁾	4	Read Only	See notes for PV Channel 1.
2006	2007	Pmax	W	Float32 ⁽¹⁾	4	Read Only	See notes for PV Channel 1.
2008	2009	Soiling Ratio	n/a	Float32 ⁽¹⁾	4	Read Only	The instantaneous soiling ratio of the PV device. The ratio is calculated from the device's temperature-corrected output as referenced to the irradiance measured by PV Channel 1, which must be kept clean. The value returned by this register is a weighted average of the soiling ratio Isc and soiling ratio Pmax. See Chapter 2.

Register Start	Register End	Parameter Name	Units	Data Format	Bytes	Read/Write	Description
2010	2011	Soiling Ratio Isc	n/a	Float32 ⁽¹⁾	4	Read Only	The instantaneous soiling ratio Isc (also known as Isc Index), the ratio of the temperature-corrected Isc of the PV Channel 2 device to its expected temperature-corrected Isc under clean conditions at the current irradiance measured by PV Channel 1. If the PV Channel 2 device is clean, the ratio should be close to 1.00. See Chapter 2.
2012	2013	Soiling Ratio Pmax	n/a	Float32 ⁽¹⁾	4	Read Only	The instantaneous soiling ratio Pmax (also known as Pmax Index), the ratio of the temperature-corrected Pmax of the PV Channel 2 device to its expected temperature-corrected Pmax under clean conditions at the current irradiance measured by PV Channel 1. If the PV Channel 2 device is clean, the ratio should be close to 1.00. See Chapter 2.
2022	2023	Soiling Ratio Daily Average	n/a	Float32 ⁽¹⁾	4	Read Only	The daily average value of the soiling ratio, updated each day at the end of the soiling analysis time window. This is the user's primary output for soiling ratio. See Chapter 2.
2024	2025	Soiling Ratio Isc Daily Average	n/a	Float32 ⁽¹⁾	4	Read Only	The daily average value of the soiling ratio Isc, updated each day at the end of the soiling analysis time window. This is the user's primary output for soiling ratio Isc. See Chapter 2.
2026	2027	Soiling Ratio Pmax Daily Average	n/a	Float32 ⁽¹⁾	4	Read Only	The daily average value of the soiling ratio Pmax, updated each day at the end of the soiling analysis time window. This is the user's primary output for soiling ratio Pmax. See Chapter 2.
2028	2029	Irradiance Daily Average	n/a	Float32 ⁽¹⁾	4	Read Only	The daily average value of the irradiance of points used in the soiling ratio averaging analyses, updated each day at the end of the soiling analysis time window. See Chapter 2.
2030	2030	Number of Datapoints in Daily Average	n/a	UInt16	2	Read Only	The number of datapoints used to calculate the most recent soiling ratio and irradiance daily averages. See Chapter 2. Use this parameter as a quality metric for the reported daily averages.
System							
8000	8000	Initiate Measurements	n/a	UInt16	2	Write Only	When the RDE is configured to Triggered mode, write a 1 to this register to initiate a measurement. Data will then become available for readout at the appropriate registers. In Periodic mode, this register does not need to be used.
8206	8207	Uptime	seconds	Float32 ⁽¹⁾	4	Read Only	Number of seconds since RDE started.
Wash Unit & Heaters (if equipped)							
8510	8511	Last Wash Timestamp	seconds	UInt32	4	Read Only	Time at which the last wash occurred. Log this value to maintain a record of wash events. Time is reported as Unix epoch referenced to the local clock time, i.e. in seconds since midnight on January 1, 1970. (To convert this value to a date in Excel, use the following function: "=((A1/60)/60)/24)+DATE(1970,1,1)" where A1 is the cell to be converted.)
8512	8513	Last Wash Time Elapsed	seconds	Float32 ⁽¹⁾	4	Read Only	Duration of last wash event, in seconds. Log this value to maintain a record of wash events.
8520	8520	Fluid Low	n/a	UInt16	2	Read Only	Status of fluid level in Wash Unit tank. 0 = Fluid Level OK; 1 = Fluid Level Low.
8522	8523	Last Wash Volume	ml	Float32 ⁽¹⁾	4	Read Only	Volume of fluid dispensed at last wash event. Log this value to maintain a record of wash events. (This measurement is based on the Wash Unit flow sensor, supported on units shipped October 2015 and later.)

Register Start	Register End	Parameter Name	Units	Data Format	Bytes	Read/Write	Description
8530	8530	Tank Heater State	n/a	UInt16	2	Read Only	Instantaneous status of heater for Wash Unit fluid tank. 0 = Off; 1 = On.
8531	8531	Reference Cell Heater State	n/a	UInt16	2	Read Only	Instantaneous status of heater in Reference Cell. 0 = Off; 1= On;
8540	8541	Tank Temperature	°C	Float32 ⁽¹⁾	4	Read Only	Temperature of fluid tank in the Wash Unit.

⁽¹⁾ Float32 denotes single-precision 32-bit floating point per IEEE 754.

12.4 Programming Example: Campbell Scientific CR1000

Campbell Scientific's CR1000 is a popular datalogger product. The code below shows an example of implementing datalogging from the RDE using the CR1000. The code polls typical parameters from both PV channels 1 and 2 as well as diagnostic data on the wash and heating functions.

Note that to use the CR1000 for Modbus TCP, a Campbell Scientific Ethernet adapter is required. Consult Campbell Scientific's documentation for further details on the CR1000.

```
'-- CR1000 Sample Code
'-- Reads PV1 & PV2 IV parameters, soiling ratios, and washer & heater parameters
'-----
'-- THIS CODE AND INFORMATION ARE PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND.

'----- Variables -----
Public SocketHandle
Public ModbusResult(11)
Dim Channel1(4) As Float
Dim Channel2(10) As Float
Dim NumberOfDataPointsInSRAvg As Long
Dim LastWashTimestamp As Long
Dim LastWashTimeElapsed As Float
Dim FluidLevel As Long
Dim LastWashVolume As Float
Dim TankTemperature As Float
Dim TankHeaterState As Long
Dim RefCellHeaterState As Long

'----- Aliases -----
Alias Channel1(1) = Irradiance
Alias Channel1(2) = PV1_Isc
Alias Channel1(3) = PV1_PVTemp
Alias Channel1(4) = PV1_Pmpp
Alias Channel2(1) = PV2_Isc
Alias Channel2(2) = PV2_PVTemp
Alias Channel2(3) = PV2_Pmpp
Alias Channel2(4) = SoilingRatio
Alias Channel2(5) = SoilingRatioIsc
Alias Channel2(6) = SoilingRatioPmax
Alias Channel2(7) = SRDailyAvg
Alias Channel2(8) = SRIscDailyAvg
Alias Channel2(9) = SRPmaxDailyAvg
Alias Channel2(10) = IrradianceDailyAvg

'----- Units -----
Units Irradiance = W/m^2
Units PV1_Isc = Amps
Units PV1_PVTemp = Deg_C
Units PV1_Pmpp = Watts
Units PV2_Isc = Amps
Units PV2_PVTemp = Deg_C
Units PV2_Pmpp = Watts
Units IrradianceDailyAvg = W/m^2
Units LastWashTimestamp = ((CELL/60)/60)/24+DATE(1970,1,1)
Units LastWashTimeElapsed = seconds
Units LastWashVolume = ml
Units TankTemperature = Deg_C

'----- Constants -----
ConstTable
    'IP_Address must match the IP address of the RDE
    Const IP_Address = "10.244.69.35"
    Const UInt16 = 65536
EndConstTable

'----- DataTable -----
DataTable (RDE300,1,-1)
    'set the time interval based on the datalogger's RTC
    DataInterval (0,1,min,10)
    Sample (1,Irradiance,Float)
    Sample (1,PV1_Isc,Float)
    Sample (1,PV1_Pmpp,Float)
    Sample (1,PV1_PVTemp,Float)
    Sample (1,PV2_Isc,Float)
    Sample (1,PV2_Pmpp,Float)
```



```

    Sample (1,PV2_PVTemp,Float)
    Sample (1,SoilingRatio,Float)
    Sample (1,SoilingRatioIsc,Float)
    Sample (1,SoilingRatioPmax,Float)
    Sample (1,SRDailyAvg,Float)
    Sample (1,SRIsCDailyAvg,Float)
    Sample (1,SRPmaxDailyAvg,Float)
    Sample (1,IrradianceDailyAvg,Float)
    Sample (1,NumberOfDataPointsInSRAvgs,Long)
EndTable

DataTable (RDE300_WashUnitDiag,1,-1)
    DataInterval (0,1,min,10)
    Sample (1,LastWashTimestamp,Long)
    Sample (1,LastWashTimeElapsed,Float)
    Sample (1,LastWashVolume,Float)
    Sample (1,(FluidLevel/UInt16),Long)
    FieldNames("FluidLevel:0=OK:1=LOW")
    Sample (1,(TankHeaterState/UInt16),Long)
    FieldNames("TankHeaterState:0=OFF:1=ON")
    Sample (1,TankTemperature,Float)
    Sample (1,(RefCellHeaterState/UInt16),Long)
    FieldNames("RefCellHeaterState:0=OFF:1=ON")
EndTable

'-- Scan once a minute
'-- Note that CRBasic uses 1-based indexing,
'-- Read Irradiance, PV1 Isc, PV1 Temp, & PV1 Pmax
'----(1000,1002,1004,1006)
'-- Read PV2 Isc, PV2 Temp, PV2 Pmax, Soiling Ratio, Soiling Ratio Isc, & Soiling Ratio Pmax
'----(2002,2004,2006,2008,2010,2012)
'-- Read PV2 Daily Averages of Soiling Ratio(SR) Avg, SR Isc Avg, SR Pmax Avg, Irradiance Avg
'----(2022,2024,2026,2028)
'-- Read PV2 Number of Datapoints in the Soiling Ratios Daily Average Calculations (2030)
'-- Read LastWashTimestamp (8510)
'---- This Is saved in Unix/Epoch time. To convert: (((CELL/60)/60)/24)+DATE(1970,1,1)
'-- Read LastWashTimeElapsed (8512)
'-- Read FluidLevel (8520)
'-- Read LastWashVolume (8522)
'-- Read TankTemperature (8540)
'-- Read TankHeaterState (8530)
'-- Read RefCellHeaterState (8531)

'Long statements that overrun the CRBasic Editor page width can be continued on
'the next line if the statement break includes a space and an underscore

BeginProg
    Scan (1,Min,0,0)
    'Open TCP connection to RDE at IP Address defined in ConstTable
    SocketHandle = TCPOpen(IP_Address,502,300,20)
    ModbusMaster (ModbusResult(1),SocketHandle,-9600,255,3,Channel1,1001,4,3,200,2)
    ModbusMaster (ModbusResult(2),SocketHandle,-9600,255,3,Channel2,2003,6,3,200,2)
    ModbusMaster (ModbusResult(3),SocketHandle,-9600,255,3,LastWashTimestamp,8511,1,3,200,2)
    ModbusMaster (ModbusResult(4),SocketHandle,-9600,255,3,LastWashTimeElapsed,8513,1,3, _
    200,2)
    ModbusMaster (ModbusResult(5),SocketHandle,-9600,255,3,FluidLevel,8521,1,3,200,2)
    ModbusMaster (ModbusResult(6),SocketHandle,-9600,255,3,LastWashVolume,8523,1,3,200,2)
    ModbusMaster (ModbusResult(7),SocketHandle,-9600,255,3,TankTemperature,8541,1,3,200,2)
    ModbusMaster (ModbusResult(8),SocketHandle,-9600,255,3,TankHeaterState,8531,1,3,200,2)
    ModbusMaster (ModbusResult(9),SocketHandle,-9600,255,3,RefCellHeaterState,8532,1,3, _
    200,2)
    ModbusMaster (ModbusResult(10),SocketHandle,-9600,255,3,Channel2(7),2023,4,3,200,2)
    ModbusMaster (ModbusResult(11),SocketHandle,-9600,255,3,NumberOfDataPointsInSRAvgs,2031,1,3,200,1)

    'Close TCP connection after each scan
    TCPClose(SocketHandle)

    'Call Data Table to store data to memory
    CallTable RDE300
    CallTable RDE300_WashUnitDiag

    NextScan
EndProg

```

12.5 Special Notes

12.5.1 Connections

Firmware versions R3787 and higher (beginning December 2015) support multiple simultaneous connections. For example, this allows the RDE Engineering Client to connect to the RDE without disconnecting from the user's datalogging system. Earlier firmware versions permitted the RDE to connect to only one client at a time; additional connection requests were ignored.

12.5.2 Timeouts

Communication timeouts on the client device should be set to 1 second or longer for communication with the RDE.

The RDE will close its connection to the client after 2 minutes of communication inactivity, in order to release unused connections.

Note: Atonometrics recommends that client software open the connection before each polling request and close it again afterwards. See example code in Section 12.4.

12.5.3 Outgoing Port Reuse

The RDE follows network practices which require client communication devices to change to a new outgoing port number each time they make a new connection. However, some communication devices may use an outdated network practice in which the outgoing port number is reused for each connection, causing their connection attempts to be rejected by the RDE. In some cases this problem may be resolved by upgrading to the latest firmware version of the client device. Check with your device vendor.

Note: Assignment of outgoing port numbers is normally handled by your operating system or other built-in system resource. Most users will not be affected by this issue.

12.6 Modbus Protocol Details

12.6.1 Specifications

For detailed information on Modbus TCP protocols, please reference the specifications published by Modbus.org available at the following links:

- http://modbus.org/docs/Modbus_Messaging_Implementation_Guide_V1_0b.pdf
- http://www.modbus.org/docs/Modbus_Application_Protocol_V1_1b.pdf

12.6.2 Packet Description

Registers may be read from the RDE using Modbus Function Code 04 “Read Input Registers.” The formats of the data packets for this function code are shown in Table 12-2 and Table 12-3

Table 12-2: Format of function code 04 request from client to RDE

Item	Length	Value	Purpose & Notes
Transaction identifier	2 bytes	Determined by Client	Message synchronization
Protocol Identifier	2 bytes	0x0000	0 for Modbus TCP
Length Field	2 bytes	Number of remaining bytes in this frame	
Unit Identifier	1 byte	Not applicable. RDE currently has only 1 unit.	Slave Address. 255 if not used.
Function Code	1 byte	0x04	
Starting Register	2 bytes		Register number to begin reading
Qty of Registers to Read	2 bytes		

Table 12-3: Format of function code 04 response from RDE to client

Item	Length	Value	Purpose & Notes
Transaction identifier	2 bytes	Matching Client value	Message synchronization
Protocol Identifier	2 bytes	0x0000	0 for Modbus TCP
Length Field	2 bytes	Number of remaining bytes in this frame	
Unit Identifier	1 byte	Matching Client value	Slave Address. 255 if not used.
Function Code	1 byte	0x04	
Byte Count	1 byte	Number of bytes N in remaining data	Not including this byte.
Data	N bytes		

13 Troubleshooting

13.1 Diagnosing Common Problems

Table 13-1 lists common problems along with recommended diagnosis steps and solutions.

Many of the common problems listed are communication issues. Many of those may be diagnosed using standard Windows operating system tools, such as “ping” requests. However, diagnosis of some problems may require capturing and analyzing network traffic. See Section 0 regarding use of the Wireshark network traffic analyzer software.

Troubleshooting may require opening the RDE electrical enclosure. Use caution.

WARNING: Hazardous voltages – qualified personnel only: Hazardous voltages may be present inside the electrical enclosure. When the equipment is powered and/or connected to PV modules, the electrical enclosure may only be accessed by qualified personnel and in accordance with local codes.

Table 13-1: Troubleshooting guide

Problem	Symptoms	Diagnosis	Root Causes	Solution
RDE is Off		Check RDE power indicator LED.	No power to RDE, or RDE in Off state.	Ensure power is supplied. Turn RDE On at internal switch. See Section 6.1.
Power Supply Voltage Incorrect		Use a multi-meter to confirm the power supply voltage.		
No Communication	The Status LED is blinking slowly.	Connect to the unit locally via a laptop PC. Verify it is operating correctly.	The RDE has timed out waiting for communication from your external client. External client is not operating correctly, is set to the wrong IP address, or is being blocked by a firewall.	Correct the problem with your client application or network.
Error State	The Status LED is blinking rapidly.	Connect to the unit and check error codes.	The system is configured incorrectly, or a measurement is out of range. Example: a thermocouple is disconnected.	Use the error code to determine the problem and then correct it. Request assistance from Atonometrics.
Bootload Mode	The orange Status LED and green Flow LED are blinking.		The system is in bootload mode awaiting a firmware update.	See section 9.7.

Problem	Symptoms	Diagnosis	Root Causes	Solution
RDE Not Connected to Network		Check network connection is plugged in at RDE. Check activity LEDs on RDE Ethernet jack. Ping RDE from Windows.	Cable disconnected or not connected to network properly.	Connect Ethernet cable to user network. Verify connection via ping.
Incorrect IP Address	User client cannot connect to RDE. RDE cannot be pinged at target IP address.	Ping RDE from Windows command line.	IP address not set properly by user to desired address.	Reset RDE IP address to factory default to re-establish communication and then re-program IP address. See page 40.
Duplicate IP Address	Cannot connect to RDE or connection is intermittent.	Turn off target RDE, ping target IP address to see if response from any other device.	RDE or another device set to same IP address.	Change devices to unique IP addresses.
Firewall blocking communication	Cannot connect to RDE or cannot discover RDE via RDE Engineering Client	Ping RDE from Windows command line.	Firewall blocking ports used by RDE for communication or discovery	Allow Atonometrics RDE ports through firewall. See Section 8.6. (Or disable firewall.)
TCP Connections Already Occupied	Can ping RDE, but cannot connect to RDE with any client software.	Use Wireshark to identify all client communications with RDE. Determine if multiple clients are connecting to or transmitting to RDE. Alternatively, create network consisting of only RDE and PC running Atonometrics software. Verify only one instance of any RDE client software is running, including user client software. Verify RDE connects to Atonometrics software under these conditions.	RDE's available TCP connections are in use by too many clients.	Limit number of clients accessing the RDE.
Client Polling Too Frequently	RDE connection is intermittent.	Use Wireshark to capture network traffic. Examine connection requests from client, and check frequency of polling.	Client software polling too frequently.	Correct settings in client software.
Client Timeout Too Short	RDE data reads intermittent.	Use Wireshark to capture network traffic. Examine whether RDE is responding to every request, but not always within client specific time window.	Client software timeout configuration too short.	Increase timeout to 1 second or greater.

Problem	Symptoms	Diagnosis	Root Causes	Solution
Client Reading Registers Improperly	RDE data nonexistent or incorrect.	Use Wireshark to capture network traffic. Examine data packets. Verify that client is sending correct Modbus function, start register, and register length.	Client software misconfigured for RDE.	Adjust client to working settings.
Duplicate MAC Addresses	Pinging RDEs is intermittent or does not work. User client connection to RDE is intermittent. User client cannot establish connection to RDE. User client can only connect to one RDE at a time.	After pinging RDE(s), type <code>arp -a</code> at Windows command prompt to see IP address to MAC address mapping. Watch out for duplicates. If possible, connect to one RDE at a time using RDE Engineering Client and check MAC addresses. Ensure no duplicates.	MAC addresses incorrectly reset by user.	Determine correct MAC address for RDE serial number by contacting Atonometrics. Clear Address Resolution Protocol cache of hosts that have attempted connection. On Windows, this is <code>arp -d</code> at the Windows command prompt.
Client Re-Using Outgoing Port Number	RDE connection is intermittent.	Use Wireshark to capture network traffic. Examine connection requests from client, and check port numbers for each successive connection. Port numbers should change for each connection request. Re-use is not permitted by RDE.	Client software using outdated network practices.	Upgrade or rewrite client software.
RDE in Bootload Mode	Cannot connect to RDE In RDE Eng. Client software the RDE displays message "Bootloader X Running" as in Figure 9-20	Check for "Bootloader X Running" message as in Figure 9-20. If needed, Ping RDE from Windows command line. Check TTL. If TTL is ~64, RDE is in normal mode. If TTL is ~128, RDE is in bootloader mode.	RDE is in bootloader mode, awaiting download of new firmware. Operation cannot continue until firmware is updated.	Follow firmware update process in Section 9.7.
Wash Pump Runs Briefly Then Stops	Wash pump runs for ~3 seconds but stops before timeout or specific fluid volume are reached.	Check fluid level in tank. Check for leaks or blockages in fluid lines.	Fluid flow rate detected too high or too low. Pump automatically disabled by software.	Fill tank. Resolve any leaks or blockages. Check zip ties around hose lines to ensure hose is not constricted. See Figure 6-20.

Problem	Symptoms	Diagnosis	Root Causes	Solution
Wash Pump Does Not Run	Wash pump is programmed to run but it does not.	<p>Check settings in RDE Engineering Client software.</p> <p>Confirm all cables to wash unit, including heater cable, are connected at RDE PCB and Wash Unit.</p> <p>Use Wash Cycle test button on RDE PCB (if equipped) to manually operate pump.</p> <p>Check “PUMP” and “12V ERR” LEDs when pump is supposed to be operating.</p> <p>Check fuse at FH2.</p>	<p>Washer Program settings are incorrect.</p> <p>One or more cables are disconnected.</p> <p>Wash unit temperature sensor is disconnected.</p> <p>Fuse at FH2 is blown.</p> <p>Power supply or pump circuit damaged.</p>	<p>Confirm settings in software.</p> <p>Confirm all cables connected.</p> <p>Confirm fuse is good.</p>
Dirty Deposits Build Up on Reference Cell	The Reference Cell appears dirty.	<p>Confirm the Wash Unit is enabled and scheduled for washing.</p> <p>Confirm the Wash Unit is operating correctly by performing a manual test. See 10.2.</p> <p>Confirm clean distilled water is used as the wash fluid, or distilled water with anti-freeze additive. See 6.4.4.1.</p>	<p>Wash Unit not programmed to run.</p> <p>Pump or fluid hose problem. Hose blocked.</p> <p>Using local tap water instead of distilled water.</p>	<p>Program the Wash Unit correctly.</p> <p>Fix any problems with hoses, e.g. blockages and constrictions from zip ties. See Figure 6-20.</p> <p>Use distilled water or other clean mineral-free fluid.</p>
No Soiling Ratio Data on Output Data Tab	The minute-by-minute soiling ratio results are not displayed.	<p>Check the Soiling Analysis Settings (see Section 9.5.4).</p> <p>Check the System Clock (see Section 9.4.3) and confirm it is set to local standard time (not daylight savings).</p>	<p>Current irradiance and/or time of day are not within the range allowed by Soiling Analysis Settings.</p>	<p>Correct any errors in Soiling Analysis Settings or System Clock.</p> <p>Try again when time and irradiance are in correct range.</p>

Problem	Symptoms	Diagnosis	Root Causes	Solution
Soiling Ratio Data Changing Significantly During Time Window	The minute-by-minute soiling ratio values logged by the user's logging system are observed to change significantly during the analysis time window each day.	<p>For changes that appear random, check whether these correspond to cloudy days with rapidly changing irradiance. (See Section 2.2.)</p> <p>For changes that appear repeatable, check the alignment of the PV devices. (See Chapter 7.)</p> <p>Misalignment of the PV devices causes relative differences in irradiance throughout the day, and can result in significant variations in soiling ratio.</p> <p>Check that the PV temperature measurement is accurate: check whether module RTD's are making good contact; check temperature values against any other known data. Poor temperature correction will cause soiling ratio errors.</p> <p>Check the PV device calibration data, especially temperature coefficients. (See Section 9.5.6.)</p>	<p>Clouds and rapidly changing irradiance.</p> <p>PV device misalignment.</p> <p>PV device temperature measurement errors.</p> <p>PV device calibration errors.</p>	<p>In case of clouds, no correction is needed.</p> <p>Correct any other errors found.</p>
Voc-Based Temperature Incorrect	Temperature values obtained in Voc-based temperature measurement mode appear incorrect.	Confirm PV device calibration data. (See Section 9.5.6.) Note that datasheet parameters may not be sufficient, and module-specific calibration values may be required.	Incorrect calibration data.	Correct the calibration data. This may require getting module-specific calibration values.
Event Code Displayed	Event Code displayed on Device Information tab	<p>Check Event Code Value:</p> <p>7: Default Ethernet Mode</p> <p>8: Communication Timeout</p> <p>16: Irradiance Out Of Range PV1</p> <p>17: Irradiance Out Of Range PV2</p> <p>32: Current Out Of Range PV1</p> <p>33: Current Out Of Range PV2</p> <p>64: Temperature Out Of Range PV1</p> <p>65: Temperature Out Of Range PV2</p> <p>128: Voltage Out Of Range PV1</p> <p>129: Voltage Out Of Range PV2</p> <p>201: Configuration Error PV1</p> <p>202: Configuration Error PV2</p> <p>300: Washer Min Flow Error</p> <p>301: Washer Max Flow Error</p>	<p>Default IP DIP switch is set.</p> <p>Bad configuration.</p> <p>Loose cables.</p> <p>Wrong modules.</p> <p>Washer leak.</p> <p>Tank low.</p>	Codes are typically intermittent not requiring intervention. However, if codes persist and the system is not functioning correctly, contact Atonometrics for guidance.

13.2 Network Packet Analyzer

Atonometrics recommends using Wireshark (www.wireshark.org) or a similar network packet analyzer as an aid to communications debugging, if necessary.

If Wireshark is installed on the same PC as the user's client software, then it will be able to listen to network traffic between the client software and the RDE.

If Wireshark is running on a different PC from the client software, then an intermediary device may be needed. One solution is to place an Ethernet hub between the Atonometrics RDE and the user's client device, and then connect the PC with the Wireshark software to the Ethernet hub. Note that a standard Ethernet switch may not function for this application; either an Ethernet hub or an Ethernet switch with port forwarding (to simulate a hub) is required. For further information or guidance, please contact Atonometrics.

Figure 13-1 shows an example of network traffic captured by Wireshark. In this example, a client application at 10.244.69.230 is communicating with an RDE at 10.244.69.33. Modbus queries from the client are matched by responses from the RDE. The details of each packet can be investigated in the window at the bottom of the screen. To interpret Modbus data packets, refer to Section 12.6.

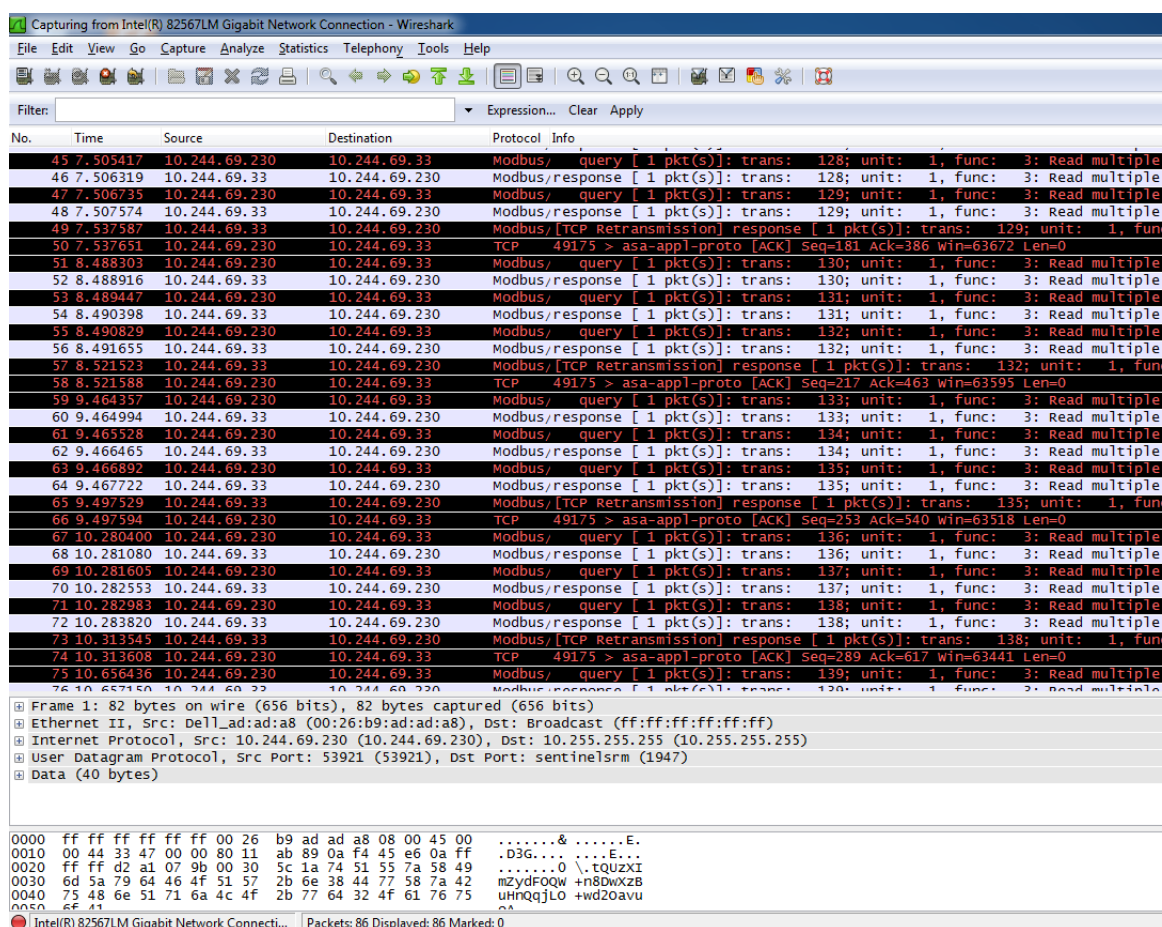


Figure 13-1: Example of Wireshark network traffic capture screen

14 Preventative Maintenance

For soiling measurements:

- Annually recalibrate the PV2 PV device, following the procedure in Chapter 11.
- Annually check the time on the RDE's internal clock and adjust if necessary. The time should be set to local standard time (not daylight savings time) at the site.

For systems including a Wash Unit:

- Routinely monitor for low fluid level in the wash tank and refill when needed.
 - Low fluid levels may be automatically detected from the user's client data acquisition system, using register 8520 (see Table 12-1). In this case the user may establish alarms from their data acquisition or SCADA system to notify operations and maintenance staff that fluid must be refilled.
 - Low fluid level can also be monitored from the RDE Engineering Client software on the Washer Diagnostics screen.
 - Low fluid level can also be monitored from the LED on the RDE PCB.
- Annually inspect the Wash Unit, as follows:
 - Inspect the inside of the tank and remove any debris, especially at the fluid inlet strainer.
 - Check inside the enclosure for leaks.
 - Check for degradation anywhere along the hose.
 - After filling the tank, run the wash pump and check for leaks or blockages anywhere along the fluid delivery system between the tank and the spray nozzle. The wash pump may be activated by pressing the Wash Cycle test button (see Section 6.1.10), if equipped, or by setting the Washer Program to immediately run the washer (see Section 10.2).

WARNING: Hazardous voltages – qualified personnel only: Hazardous voltages may be present inside the electrical enclosure. When the equipment is powered and/or connected to PV modules, the electrical enclosure may only be accessed by qualified personnel and in accordance with local codes.

Customer Support

For customer support, contact Atonometrics via email at info@atonometrics.com, or by phone at +1-512-377-6982. For more information, visit our web site at www.atonometrics.com.