Fracsun Modbus Documentation

January 23, 2023   **Revision F**

1.0   Introduction

This document is intended to provide the necessary information to connect the Fracsun soiling solution to an onsite SCADA system or datalogger via Modbus RS-485 protocol.

1.1 ARES and Wash Extension

The Fracsun soiling monitoring solution often encompasses two separate devices: ARES and the Wash Extension. Both devices are configurable as Modbus Slaves to transfer data into the onsite SCADA system via a Modbus RTU RS-485 connection.
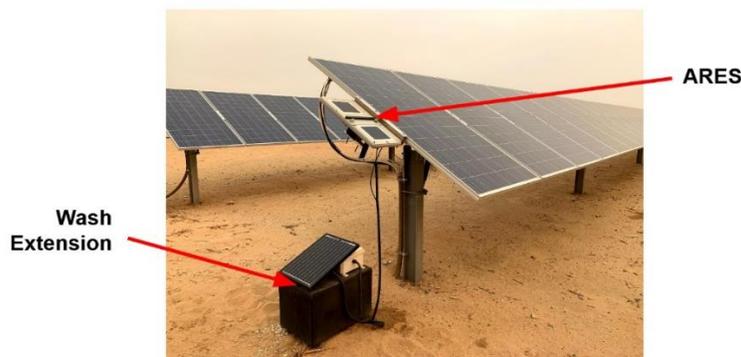
1.2 ARES Cellular-only and Modbus-only modes

In the default state, ARES is an IoT cellular-enabled device that automatically connects to the nearest cellular base station and outputs data to the Fracsun cloud. The customer can view the data on Fracsun Dashboard. The Fracsun Cloud also performs additional data processing. For example, the *daily* soiling loss and insolation values are calculated (filtered and weighted) as a cloud process.

ARES can also operate in Modbus-only mode for wired connections to dataloggers and SCADA systems, which is most likely the preferred connection method for customers reading this document. The cellular modem is turned off in this mode, which stops the flow of data to the Fracsun Cloud. This also means that the daily calculated data (daily soiling loss, insolation, and Wash Analysis) can no longer occur in Modbus-only mode because the Fracsun cloud process cannot run without the data.

In either mode, Fracsun has options to transfer soiling sensor data between the Fracsun Cloud and the data acquisition system (DAS). Please reach out for more information or read our API Documentation.

2.0   Modbus Information

2.1 Modbus commands

These commands are all according to the Modbus RTU protocols described in: 'Modbus® over serial line V1.02' and 'MODBUS application protocol V1.1b' available from the Modbus® organization (www.modbus.org). These commands can be tested using software tools, such as 'Modbus Poll' from www.modbustools.com.

The following commands are implemented:

Function	Description
0x03	Read Holding Register (Single or Multiple)
0x06	Write Single Register
0x16	Write Multiple Registers

2.2 RS-485 Configurations

The following slave addresses, baud rates and frame configurations are available on both ARES and Wash Extension devices:

Property	Acceptable Values
Slave Address	1 – 255 ARES: 42 (default) Wash Extension: 43 (default)
Baud Rate	1200, 2400, 4800, 9600, 14400, 19200 (default), and 38400.
Frame Configuration	8 data bits, Even parity, 1 stop bit (default) 8 data bits, None parity, 1 stop bit

2.3 Key Modbus Notes

- The address field uses the Protocol address with base 0, not the PLC Address with base 1.

- Treat all data types using Big-Endian format.

- The **Modbus data type** column refers to the data format of the Modbus register(s). In most Fracsun registers, that will be a unsigned 16-bit integer, signed 16-bit integer, or 32-bit unsigned integer. For example, if the Wash Power parameter reads 7521 as an unsigned 16-bit integer, after the scalar (100) is accounted for, the **final data type** would be a FLOAT value of 75.21 (7521 / 100 = 75.21).

3.0   Wiring

3.1 Wiring to a RS-485 Master Device

In its simplest form, ARES and Wash Extension devices are connected in parallel to the RS-485 master device. Internal 120Ω termination resistors are already installed in Fracsun devices, therefore are not required externally.

A 3m M12 cable is included inside the Wash Extension box, which is intended to connect between the ARES and the Wash Extension devices in the default cellular mode. When configured in Modbus mode, the RS-485 master needs to be connected to both Fracsun devices. These are a few potential connection methods:

3.1.1   Daisy chain (recommended)

In the daisy chain configuration, the RS-485 Master is connected to ARES, and ARES is connected to the Wash Extension.

On the ARES device, an M12 "T" or "Y" adapter (Phoenix Contact part # 1541186) is installed externally to support the pass-through (daisy-chain) style connection. A second M12 plug can also be added on the rear side of the ARES device and wired internally in the factory, for an added fee.

The included M12 cable can be used for the connection between ARES and Wash Extension, but an additional M12 to loose-end cable assembly (length of choice) must be purchased to connect ARES to the RS-485 Master.
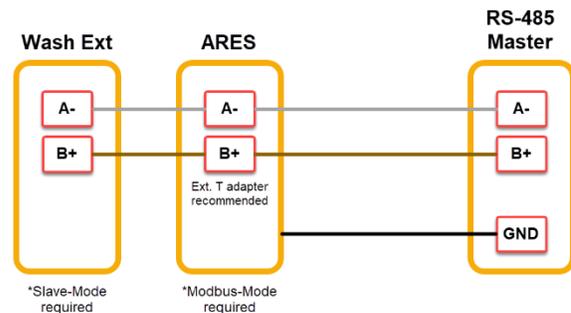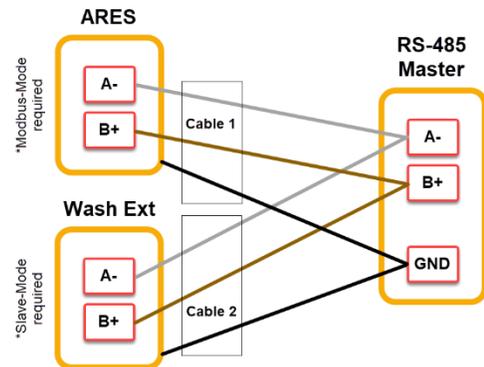
3.1.2   Two individual cables to each device

In this configuration:

- One cable is run between the RS-485 Master and ARES
- A second cable is run between the RS-485 Master and Wash Extension

Because two cables need to be run, this will connection method will typically cost more for parts and installation. The included M12 cable is not used with this connection method.

3.2 External power requirements in Modbus-only and Cellular-only modes

In the default Cellular-only mode, ARES and Wash Extension devices are solar-powered and do not require external power. However, in Modbus-only mode, *just the ARES device requires external power*. The Wash Extension can even provide power to ARES through the M12 connection. The table below summarizes the external power requirements for each device.

Device	Mode	Ext. power req'd?	Additional Notes
ARES	Cellular-only	No	Solar-powered when outside, but can also use voltage supply.
ARES	Modbus-only	**Yes**	12V from Wash Extension can power ARES, but can also use voltage supply.
Wash Extension	Master	No	Solar-powered when outside. Do not power with voltage supply.
Wash Extension	Slave	No	Solar-powered when outside. Do not power with voltage supply.

Note: On the Wash Extension, an external voltage supply cannot support the surge current from the pump, so it's not recommended to power the Wash Extension with any external voltage supply.

3.3 ARES voltage and current specifications

If a dedicated voltage supply is used to externally power the ARES device, use an appropriate power source with the following specifications, depending on the mode used.

Parameter	Min	Typical	Max	Unit	Mode
DC Input Voltage	11	12 / 24	30	V	All
Avg. Input Current @ **12 Vdc**	18	21	30	mA	Modbus-only
Peak Input Current @ **12 Vdc**	280	--	600	mA	Cellular (2G/3G)
Avg. Input Current @ **24 Vdc**	9	11	16	mA	Modbus-only
Peak Input Current @ **24 Vdc**	145	--	325	mA	Cellular (2G/3G)

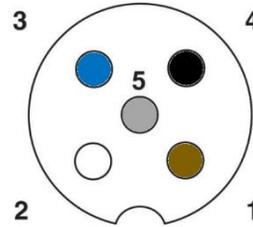## 3.5 ARES M12 connection diagram

3.5.1   ARES devices built 2021 and later

For installations utilizing Modbus-only mode (an external Modbus RTU connection) or Modbus + Cellular mode, use the M12 pinout diagram below to connect ARES to the RS-485 Master.

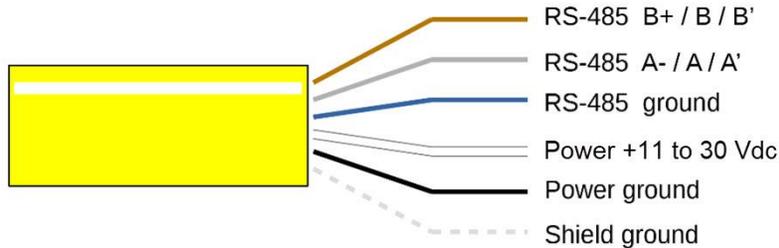| Wire		Connection description
1	Brown	Modbus RS-485 B+ / B / B'
5	Gray	Modbus RS-485 A- / A / A'
3	Blue	Modbus common / ground *
2	White	Power Input +11 to +30Vdc **
4	Black	Power common / ground
	Shield	Housing *

* Not a required connection.
** Absolute max power input voltage is 30 Vdc. *Do not exceed*.

Pin assignment for M12 socket (male)

M12 socket on rear of ARES device

RS-485 B+ / B / B'
RS-485 A- / A / A'
RS-485 ground
Power +11 to 30 Vdc
Power ground
Shield ground

M12 automation cable with loose-end wires purchased separately. Various lengths available.

## 3.6 Wash Extension M12 connection diagram

3.6.1   Wash Extension devices built 2021 and later

For installations utilizing Modbus-only mode, use the M12 pinout diagram below to connect to the RS-485 Master.

Wire		Connection description
1	Brown	Modbus RS-485 B+ / B / B'
5	Gray	Modbus RS-485 A- / A / A'
3	Blue	Modbus common / ground *
2	White	Power Output (12V battery) **
4	Black	Power common / ground **
	Shield	Housing *

* Not a required connection.
** Power pin tied to internal 12V battery. Do not inject power into these pins. These pins are disconnected by default.
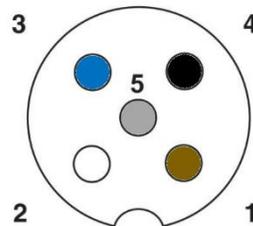
Pin assignment for M12 socket (male)


M12 socket on rear of ARES device

3.7 Enabling power pins on Wash Extension

If you would like to use the Wash Extension to externally power the ARES device (or another device with similar power draw), the positive and negative wires must be connected on the internal terminal block inside the Wash Extension. These pins are disconnected by default in the factory.


The included 5-pin M12 cable (3m) has enough pins to run both RS-485 and power between the Wash Extension and ARES.

Follow the steps below to reconnect the power pins.

1. Open the Wash Extension enclosure by removing the 4 screws from the corners.
2. Remove the cover from the enclosure.
3. Disconnect one of the battery terminals and unplug the solar panel *(very important)*
4. Locate the small 5-pin terminal block that connects to the M12 socket and unplug it from the PCB.
5. Locate the loose black and white wires that come from the M12 socket.
6. Strip approximately ¼" insulation from the black and white wires using a wire stripper.
7. Insert the black wire to the "G" pin and the white wire to the "Vo" pin on the terminal block. See picture for a wiring diagram.
8. Using a small flat-head screwdriver, gently turn the set screws in the clockwise direction to secure the wires inside the terminal block.
9. Reconnect the 5-pin terminal block to the plug on the PCB.
10. Reconnect the battery terminal and plug the solar panel back in.
11. Reinstall the cover and screws.
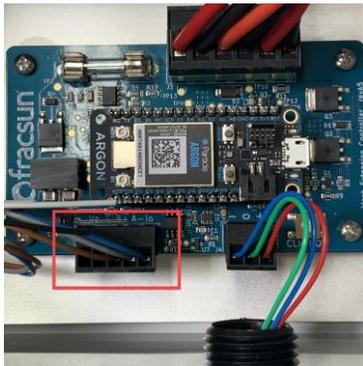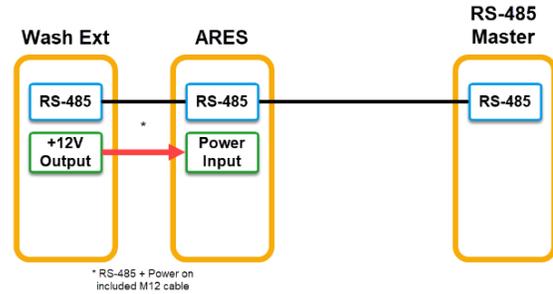
Locate the 5pin terminal block, which goes to the M12 socket.
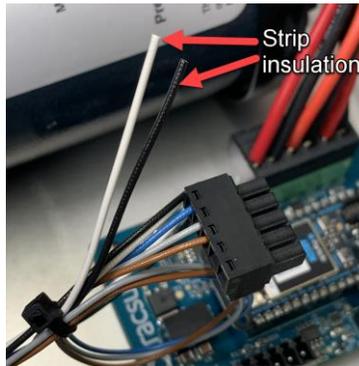
Strip the insulation on the black and white wires.
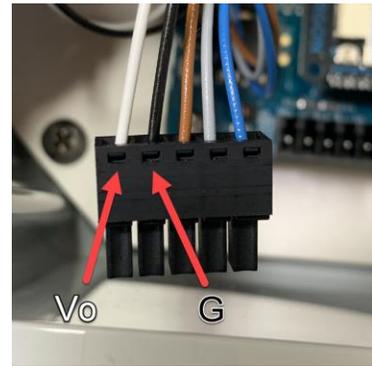
Insert the black and white wires into the terminal block and plug back in.

4.0   ARES device modes

Three different modes are available in the ARES device. Change the mode by writing to ARES Modbus register 44.

4.1 Cellular mode (default)

By default, the ARES device is configured as a self-powered and self-commissioning IoT cellular device. The device turns on, takes a few measurements, sends the data to the cloud, and then goes into a low-power sleep state to reduce battery power consumption. Any Modbus polling attempts during measurement or sleep states will almost always result in a timeout or missed poll. There is a very short ~3 second window in which a *single* poll attempt could be successful. Depending on the parameters, the window approximately occurs once every 2 - 5 minutes.

- Internal battery power is sufficient in this mode.

4.2 Modbus-only mode

When a more robust Modbus connection is required, a different mode (Modbus-only mode) can be enabled, but with the loss of the default cloud functions. Modbus-only mode will bypass the low-power sleep state and cellular cloud functions, but the microcontroller will always remain ON to be available for constant Modbus polling.

This mode is recommended for dataloggers, SCADA systems, and PV plants with NERC requirements.

- External power is required in this mode. The internal battery may not be sufficient in this mode.

4.3 Modbus+Cellular mode (experimental)

This is an experimental mode only. In this mode, the device will attempt to connect to a cellular tower at a predetermined time interval. During this connection, some data will be uploaded to the Fracsun cloud and will check for OTA firmware updates. The data can be used for Fracsun cloud processing.

- External power is required in this mode.

5.0 Configuring the ARES device modes and settings

The ARES device modes can be changed in a variety of ways including:

- A remote command can be issued over-the-air (OTA) through the Fracsun Web Portal. *ARES must be connected to cloud via cellular.*
- The Fracsun support team can remotely issue the command on your behalf. *ARES must be connected to cloud via cellular.*
- Write to the appropriate registers (see Modbus Mode and Apply Code parameters). *ARES must be connected to a Modbus RS-485 Master device (or a PC with Modbus Poll software).*
- Shipped preconfigured with a particular mode.
- Button press pattern on ARES main control PCB. *Not recommended, device must be opened. Reach out to Fracsun for instructions.*
- USB serial console command accessible from ARES PCB. *Not recommended, device must be opened. Reach out to Fracsun for instructions.*

5.1 Enabling Modbus-only mode remotely via Fracsun Dashboard

To change from Cellular-only to Modbus-only mode using this method, verify you have the following:

- DC power source (11 – 30 V) or device placed in direct sun for at least 1 hour
  - If using a DC power source, you need a M12 5pin A-coded female to loose-end cable
- Antenna fastened in with LTE or 3G signal
- Fracsun Dashboard access to the device

Follow the instructions below to enable Modbus-only mode:

1. Login to the Fracsun Portal and browse to the Device Data page.

   Note: If you don't see the Device Data page, you have a Staff type login and you must request this access from the Owner.

   Dashboard   Staff   Device Data   Account ▾

2. Locate the device in the list that you would like to change and click on the Edit button.

   ✚ Add New Device

   Note: If you don't see the device, you can add it with the "+ Add New Device" button.

3. Scroll down to the Configuration section of the device and click on the **Enable Modbus-Only** button. Click Yes if you are sure this is the device you want to modify.

   Enable Modbus-only Mode   ❓   **GO**

   Warning: Performing this action to a device at a plant will permanently turn off the internal cellular modem. This device cannot be reached until a technician is back on site.

## 5.2 Enabling Modbus-only mode via RS-485

To change from Cellular-only to Modbus-only mode using this method, verify you have the following:

- DC power source (11 – 30 V) or device placed in direct sun for at least 1 hour
- M12 5pin A-coded female to loose-end cable
- Antenna fastened in with LTE or 3G signal
- RS-485 to USB Adapter
- Computer with Modbus Poll or similar software

Follow the instructions below to enable Modbus-only mode:

1. Connect the M12 5pin female to loose-end cable between the ARES device and RS-485-to-USB adapter.
2. Power ARES using the DC power source (over the M12 cable) or by placing it in direct sun for at least 1 hour.
3. Connect the RS-486-to-USB adapter to a computer with Modbus Poll or similar software.
4. Open the Modbus polling software and perform a 0x16 (Write Multiple Registers) command *continuously* on register 43 (value: 1) and register 44 (value: 789) until a successful response is sent back.
   Note: Polling at 1 second intervals is recommended to catch the short ~3s available polling window.
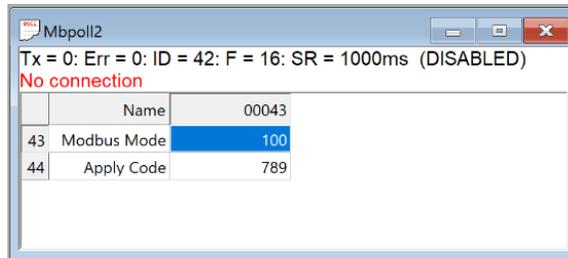

5. Once the ARES device has been polled successfully once, an automatic reset occurs and Modbus-only mode is turned on.
6. Turn off the continuously 0x16 Write Multiple Register command, otherwise the device will keep resetting.
7. You may now continuously poll at a frequency of 10 seconds or more from the RS-485 Master.

5.3 Configuring Slave Address, Baud Rate and Frame Config

To modify the default Modbus slave address, baud rate, or frame config settings, you must write to a specific set of registers using the Write Registers (0x16) operation while connected to the default configuration (19200, 8E1):

| Parameter Name	Register	Default Value	Notes
Slave Address	40	42	Slave address 42
Baud Rate	41	19200	
Frame Config	42	1	8 databits, Even parity, 1 stop bit
Modbus Mode	43	100	Modbus-only mode ON (should already be on)
Apply Code	44	456	"456" value must be written to enable Modbus configuration

For example, if you want to change slave address to 99, baud rate to 9600, and frame config to 8N1, the following registers must be written in a single operation:
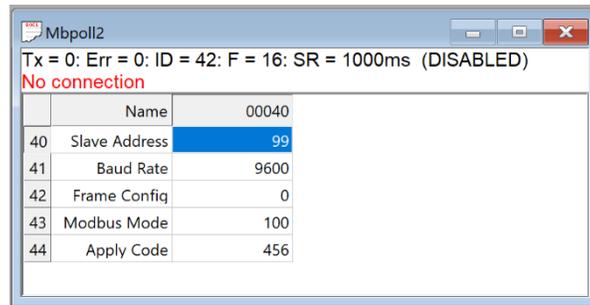
5.4 Enabling Cellular-only mode via RS-485

Enabling Cellular-only mode will turn the cellular modem back on and disable Modbus-only mode. This may be used to enable Cellular-only mode indefinitely or to temporarily enable for an OTA firmware update.

Perform a Write Register (0x16) operation *once* per the following example:
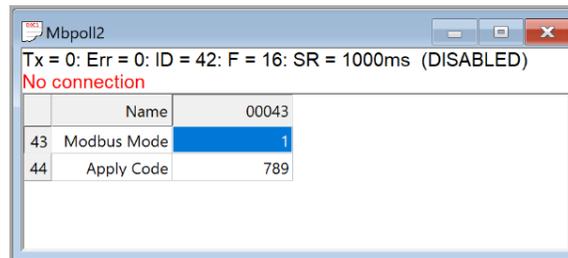
After a successful write, Cellular-only mode is enabled the device will start communicating with the Fracsun cloud, as long as an external antenna is connected and the SIM card is activated.

6.0 Wash Extension device modes and configuration

6.1 Modbus modes – Master/Slave

In the default mode, the Wash Extension functions as a Modbus Master (for a Fracsun-only connection). If connecting the Fracsun soiling monitoring system to an external Modbus RTU connection, the Wash Extension Modbus mode must be changed to function as a Modbus Slave. Changing this mode ensures that two Modbus Masters are not on the same RS-485 network.

6.2 Changing the Modbus Mode to SLAVE via USB

The mode, and other Modbus configurations, can be changed by interfacing a computer to the Wash Extension controller via the micro-USB connection on the board labeled "Xenon". With a few keypresses inside a serial console, the configuration can be performed. Follow the instructions below to change the Wash Extension to SLAVE-mode.
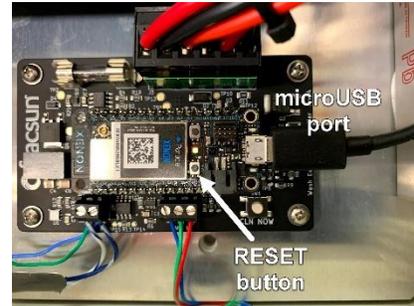
6.2.1 Windows Setup

1. On a Windows computer, download Tera Term VT serial terminal program.

2. Open the serial terminal program and enable the CR + LF option:

3. In Tera Term, go to Setup > Terminal. Under New-line - Transmit dropdown, select **CR+LF**.

4. Connect a microUSB cable between the Fracsun "Argon" board and a Windows 10+ computer.

5. In Tera Term, open a New Connection to the COM port associated with the Argon board. Often, it's displayed as "Argon Serial (COM#)".

   Note: *If the Argon Serial COM port is not visible, the Windows Particle USB Drivers might have to be installed. The default USB COM settings are: 9600 baud rate, 8 databits, NONE parity, and 1 stop bits.*

6. Once connected, the console will show all device logging information.

7. Press "m" *once* on your keyboard, wait up (up to 2 minutes) to access the Modbus menu in the console.

   Tip: *To eliminate any long wait times, press the Reset button on the Argon board and press the "m" key immediately after the COM port reconnects in Tera Term. The Modbus menu should appear a couple seconds later.*

8. Press "2" and then "y" to enable SLAVE mode.

9. If required, you can also change the slave address, baud rate, and frame configuration in this menu system. The default values are:

    a. Slave Address: 43
    b. Buad Rate: 19200
    c. Frame Configuration: 8 databits, EVEN parity, and 1 stop bit (8E1).

10. Type the "x" key or physically press the RESET button on the Argon board to start using Slave Mode.

6.3 Configuring the Wash Times

There are two methods to perform wash events on the Wash Extension:

6.3.1   Use the Wash Hour registers (time keeping required)

Using this method, wash events occur on the hour(s) configured in the Wash Hour registers. Up to 3 washes can be preconfigured. There is one caveat – the Unix (or Epoch) time must be written to the Wash Extension at a defined interval so that the device knows what time it is. There is no real time clock (RTC) to keep time during power-loss events, but the Wash Extension can keep time while powered, just not very accurately.

To write the Unix/epoch time, perform a 0x16 (Write Multiple Registers) command to registers 20-21 as an unsigned 32-bit integer.

The timezone must also be configured on the Wash Extension through register 13, but only has to be written once because the value is saved in EEPROM memory.

6.3.2   Use the Wash Now register (no time keeping)

Using this method, wash events only occur when the Wash Now register is written to. This method would be used if you prefer to write to this register using your own schedule or timer, or if you don't have the Unix / Epoch time available as a datapoint.

7.0   ARES Modbus Map (v33 and earlier)

Parameter name	Holding register	Modbus data type	R/W	Scalar	Final data type	Description
Irradiance (Clean)	0	UINT_16	R		UINT_16	Irradiance in W/m2 of the **Clean** reference cell. Is a temperature-compensated and post-calibrated value.
Irradiance (Soiled)	1	UINT_16	R		UINT_16	Irradiance in W/m2 of the **Soiled** reference cell. Is a temperature-compensated and post-calibrated value.
Shunt current (Clean)	2	UINT_16	R	100	FLOAT	Shunt (short-circuit) current of the **Clean** reference cell. Is not a temperature-compensated value.
Shunt current (Soiled)	3	UINT_16	R	100	FLOAT	Shunt (short-circuit) current of the **Soiled** reference cell. Is not a temperature-compensated value.
Soiling Loss	4	INT_16	R	100	FLOAT	Instantaneous Soiling Loss value in %. Computed as the percent difference between the Clean vs. Soiled irradiance (temp compensated).
Soiling Ratio	5	UINT_16	R	1000	FLOAT	Instantaneous Soiling Ratio value (no units). Computed per IEC 61724-1.
Calibration (Clean)	6	INT_16	R+W		INT_16	Calibration value of the **Clean** reference cell. Range is -30 to 30.
Calibration (Soiled)	7	INT_16	R+W		INT_16	Calibration value of the **Soiled** reference cell. Range is -30 to 30.
Temperature (cell)	8	INT_16	R	100	FLOAT	Temperature in degrees Celsius of the reference cell backsheet.
Temperature (interior)	9	INT_16	R	100	FLOAT	Temperature in degrees Celsius of the ARES interior (main PCB).
Battery Voltage	10	UINT_16	R	100	FLOAT	LTO battery voltage in Volts.
Soiling Loss Avg. (yesterday)	11	INT_16	R		FLOAT	Future update (2021) – not available yet. The daily average soiling loss value (%) from the previous day.
Cellular RSSI	12	INT_16	R		INT_16	Received Signal Strength Indicator in dBm from the last cell connection.
Slave address	40	UINT_16	R+W		UINT_16	Modbus slave address (1 – 255). Default is 42.
Baud Rate	41	UINT_16	R+W		UINT_16	Modbus baud rate. Acceptable rates are 1200, 2400, 4800, 9600, 14400, 19200, and 38400. Default is 19200.
Frame Config	42	UINT_16	R+W		UINT_16	Modbus frame configuration. Acceptable values are 0 and 4. 0 = 8 Databits, None Parity, 1 Stop Bit 4 = 8 Databits, Even Parity, 1 Stop Bit (default)
Modbus Mode	43	UINT_16	R+W		UINT_16	Modbus mode selection. Use the table below to select a mode: 1 = Cellular mode / intermittent Modbus (default mode) 100 = Modbus-only mode (cellular modem off) 200 = Modbus + Cellular mode (experimental)
Apply Code	44	UINT_16	R+W		UINT_16	Apply code that must be written *prior* to modifying Calibration values, Modbus config, or Modbus mode registers. 321 = Enable auto-calibration (recommended) 123 = Enable manual-calibration 456 = Enable Modbus configuration (Slave address, baud, frame) 789 = Enable Cellular/Modbus mode change This register automatically resets to 0 after any write operation to registers 6, 7, or 40-43.
Reset	45	UINT_16	R+W		UINT_16	Resets the device. Write 255 once to enable. Register is automatically reset to 0 upon reset.
Auto-Calibrate Result	46	UINT_16	R		UINT_16	The result of the auto-calibration process. 1 = Success, 2 = Failed during testing, 3 = Not enough sunlight to calibrate, 4 = No calibration reqd.
Night-Sleep Mode	48	UINT_16	R+W		UINT_16	Enables/disables night-sleep mode. When enabled, ARES will enter a deep sleep state during darkness. Acceptable values are: 0 = Disabled, 1 = Enabled

- The default SLAVE ID/address is: **42**. This address can be changed by writing to the slave address register.
- 1 minute scan rates are recommended. Scan rates less than 1 minute are not recommended.
- ARES takes a single soiling / irradiance measurement *once per minute*. Modbus polls are ignored during this short period.

8.0   Wash Extension Modbus Map

The default SLAVE ID/address is: **43**. The address can be changed via the microUSB cable. See instructions above.

Parameter Name	Address	Modbus Data type	R/W	Scalar	Final Data type	Description
Timezone	13	INT_16	R+W		INT_16	Current timezone (*required* for proper wash schedule). If negative, convert to an unsigned number. (**ex**: -7 timezone would convert to 65529). *This value is retained in flash memory. It only needs to be set once – new installs, during DST time changes, or changing station locations.*
Unix Time	20-21	UINT_32	R+W		UINT_32	The number of seconds that have elapsed since January 1, 1970 (midnight UTC/GMT). *Value is not retained in flash memory.* *Recommended to write every 3 hours for proper time keeping.*
Last Wash Time	40-41	UINT_32	R		UINT_32	Unix time value of the last wash event
Wash Power	42	UINT_16	R	100	FLOAT	Pump motor power (in watts) of the last wash event. Values between 50 – 85 W indicate a successful wash.
Temperature	43	INT_16	R	100	FLOAT	Temperature in degrees Celsius inside the Wash Extension enclosure.
Relative Humidity	44	UINT_16	R	100	FLOAT	Relative humidity (%) inside the Wash Extension enclosure. Can often detect rain events in dry/arid climates.
Battery Voltage	45	UINT_16	R	100	FLOAT	Lead-acid battery voltage in Volts.
Tank Level	46	UINT_16	R		UINT_16	Liquid level sensor output in Volts. 0 = presence of water, 3 = absence of water When the output switches from 0 to 3, this indicates approximately 8-10 weeks before the reservoir is empty.
Wash Temp Limit *	48	UINT_16	R+W		UINT_16	The temperature limit (in K) when washing is disabled. Default is 277 K (3.85 C, 38.9 F).
Wash Seconds *	49	UINT_16	R+W		UINT_16	The number of seconds to perform a wash for. Default is 5 seconds.
Wash Hour 1	50	UINT_16	R+W		UINT_16	Hour to initiate a wash event #1 (0-23). Default is 25 (no wash). *This value is retained in flash memory.*
Wash Hour 2	51	UINT_16	R+W		UINT_16	Hour to initiate a wash event #2 (0-23). Default is 25 (no wash). *This value is retained in flash memory.*
Wash Hour 3	52	UINT_16	R+W		UINT_16	Hour to initiate a wash event #3 (0-23). Default is 25 (no wash). *This value is retained in flash memory.*
Wash Now	53	UINT_16	R+W		UINT_16	Initiate a wash now. Write 255 once to enable. Register is automatically reset to 0 upon wash.

* Only available in Wash Extension v27 firmware and later.

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