PVI 50-100KW
SGI 225-500PE
SGI 500XT
SGI 500-750XTM
Commercial Inverters Communication Manual

Revision A

IMPORTANT SAFETY INSTRUCTIONS

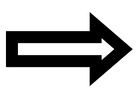
In this manual “inverter” or “inverters” refers to the Solectria inverter series: PVI 50-100KW, SGI 225-500PE, SGI 500XT, and SGI 500-750XTM, unless one of the specific models is noted.

This manual contains important topics relating to communications that shall be followed during installation and maintenance of the inverter.

To reduce the risk of electrical shock, and to ensure the safe installation and operation of the inverter, the following safety symbols are used to indicate dangerous conditions and important safety instructions:

WARNING: This indicates a fact or feature very important for the safety of the user and/or which can cause serious hardware damage if not applied appropriately.

Use extreme caution when performing this task.



NOTE: This indicates a feature that is important either for optimal and efficient use or optimal system operation.

EXAMPLE: This indicates an example.

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IMPORTANT SAFETY INSTRUCTIONS

- All electrical installations shall be performed in accordance with applicable local, state, and national codes.

  The inverter contains no user serviceable parts. Please contact Solectria Renewables or a Solectria Renewables authorized system installer for maintenance.
- Before installing or using the inverter, please read all instructions and caution markings in this manual, on the inverter, as well as on the PV modules.
- Connection of the inverter to the electric utility grid must be completed after receiving prior approval from the utility company and must only be performed by qualified personnel.
- PV modules produce dangerous electrical voltage and current when exposed to light and could create hazardous conditions. Completely cover the surface of all PV modules with an opaque material before wiring them or do not connect inter-module cables, PV source circuits, and/or PV output circuits under load.
- The inverter enclosure and disconnects must be locked (requiring a tool or key for access) for protection against risk of injury to persons. The enclosure includes a lockable handle and comes with a key. Keep the key in a safe location in case access to the cabinet is needed. A replacement key can be purchased from Solectria Renewables.

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PRESCRIPTIONS DE SECURITE IMPORTANTES

- Tous les travaux d'installation électrique doivent être exécutés en conformité aux normes électriques locales ainsi qu'à la norme nationale américaine et canadienne.
- Le PVI ne contient aucune pièce requérant un entretient effectué par l'utilisateur. Pour toute maintenance, veuillez consulter Solectria Renewables ou un installateur agrée par Solectria Renewables (les coordonnées de Solectria Renewables et des installateurs agrées sont indiquées sur le site web de Solectria Renewables: www.solectria.com.
- Avant d'installer ou d'utiliser le PVI veuillez lire toutes instructions et toutes les mises en garde présentes dans ce manuel, sur le PVI et sur les modules PV.
- Le raccordement du PVI au réseau électrique ne doit être effectuée qu'après avoir obtenu une entente d'interconnexion auprès de la compagnie locale de distribution électrique et uniquement par du personnel autorisé et qualifié.
- La surface de tous les capteurs PV doivent être recouverte entièrement d'un matériel opaque
- (noir) avant de procéder au câblage. Les capteurs PV exposés a la lumière produisent du courant électrique susceptible de créer une situation de risque.

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1. Introduction

Customers purchasing Solectria Renewables inverter systems have the option of collecting inverter data and events through two different methods. Data can be collected through SolrenView.com, Solectria Renewables' web-based solution (if monitoring option is purchased), or the data can be collected by a third party device using Modbus RTU protocol via the inverter's standard two wire RS-485 (officially called TIA-485-A) customer interface.

2. Modbus Serial Line Protocol

Modbus Serial Line protocol is a Master-Slave protocol. A Modbus serial network can contain only one Master and a maximum number of 16 commercial inverters. However, in practice this number is further reduced depending on the network length, local noise, and properties of the communication hardware utilized. The Master initiates all communications and the slave(s) responds only to the inquiries that contain their specific Slave ID. A slave will not transmit data without a request from the master and neither will it communicate with other slaves. Solectria's commercial inverters must be assigned a unique Slave ID between 1- 16. The Master/Slave protocol takes place at the 'Data Link' layer of the OSI model described in the next section.

2.1 Modbus and OSI Model

OSI Model was developed by International Organization for Standardization (ISO) to describe communications systems in terms of 7 abstract layers. The following table represents how Modbus serial communications stack fits into the OSI Model.

Layer	ISO/OSI Model	Modbus serial communications Stack
7	Application	Modbus Application Protocol (Client/Server)
6	Presentation	N/A
5	Session	N/A
4	Transport	N/A
3	Network	N/A
2	Data Link	Modbus Serial Line Protocol (Master/Slave Protocol) (Transmission Mode: RTU/ASCII)
1	Physical	RS-485

Table 1 : ISO/OSI Model and Modbus serial communications stack

2.2 Modbus Data Link Layer

The Modbus Data link layer contains two sub layers:

- The Master/Slave Protocol
- The transmission mode: Either RTU or ASCII mode.

A Modbus Master functions as a client that initiates requests to one or more Modbus Slaves, each functioning as a server. Modbus Slaves map each data point on one of the four primary Modbus data tables shown in Table 2:

Primary tables	Object type	Type of	Implemented at Solectria
Discrete Input	Single Bit	Read-Only	N
Coils	Single Bit	Read-Write	N
Input Registers	16-bit word	Read-Only	N
Holding Registers	16-bit word	Read-Write*	Y

* Note: Not all Holding Registers are writable.

Table 2 : Modbus Data Model

Modbus Serial Line PDU

The Modbus application layer defines a simple Protocol Data Unit (PDU) that contains the 'Function Code' and 'Data' fields. Address Field and CRC fields are further added for Modbus RTU transmission.

Address Field	Function Code	Data	CRC

Table 3: Modbus SERIAL LINE PDU

Address Field

When a master initiates a request to a particular slave, it addresses the slave by placing the slave address in the 'Address Field' of the message. When the slave responds, it puts its own Slave ID in the 'Address Field' of the message so that the master can identify which slave responded.

Function Code
The function code indicates to the slave what kind of function to perform. If the slave successfully performs the function then it echoes back the function code. In case of exceptions, the slave sets the high bit of the function code in its response (i.e. adds a value of 80h to the function code).

Fn	Description	Exception Code	Error Description
03h	Read holding registers	02h	Read not supported at 1+ registers
06h	Set single register	03h	Invalid set value
		02h	Write not supported at register
11h	Report Slave ID	No	Report slave ID
Xxh	Non-supported functions	01h	Function not supported

Table 4: Function codes supported by Solectria.

Data Field
The Data field contains the request parameters if it is sent by the master or the response parameters if it is sent by the slave.

Cyclical Redundancy Checking (CRC) Field

The Cyclical Redundancy Checking (CRC) is an error detecting technique to check the integrity of data. CRC field consists of two bytes. The transmitting device calculates the CRC of the message that it is about to send and places it in the CRC field of the PDU. The receiver then recalculates the CRC of the message that it received and compares it with the value in the CRC field of the message. If there’s a mismatch then the receiver throws a CRC error.

Solectria uses CRC-16 calculation intended to guarantee a distortion-proof data transfer between master and slave. In the serial data frame, the CRC span ranges from the slave address (byte index 0) to the last byte of message NOT including the CRC bytes.

Query-Response Cycle

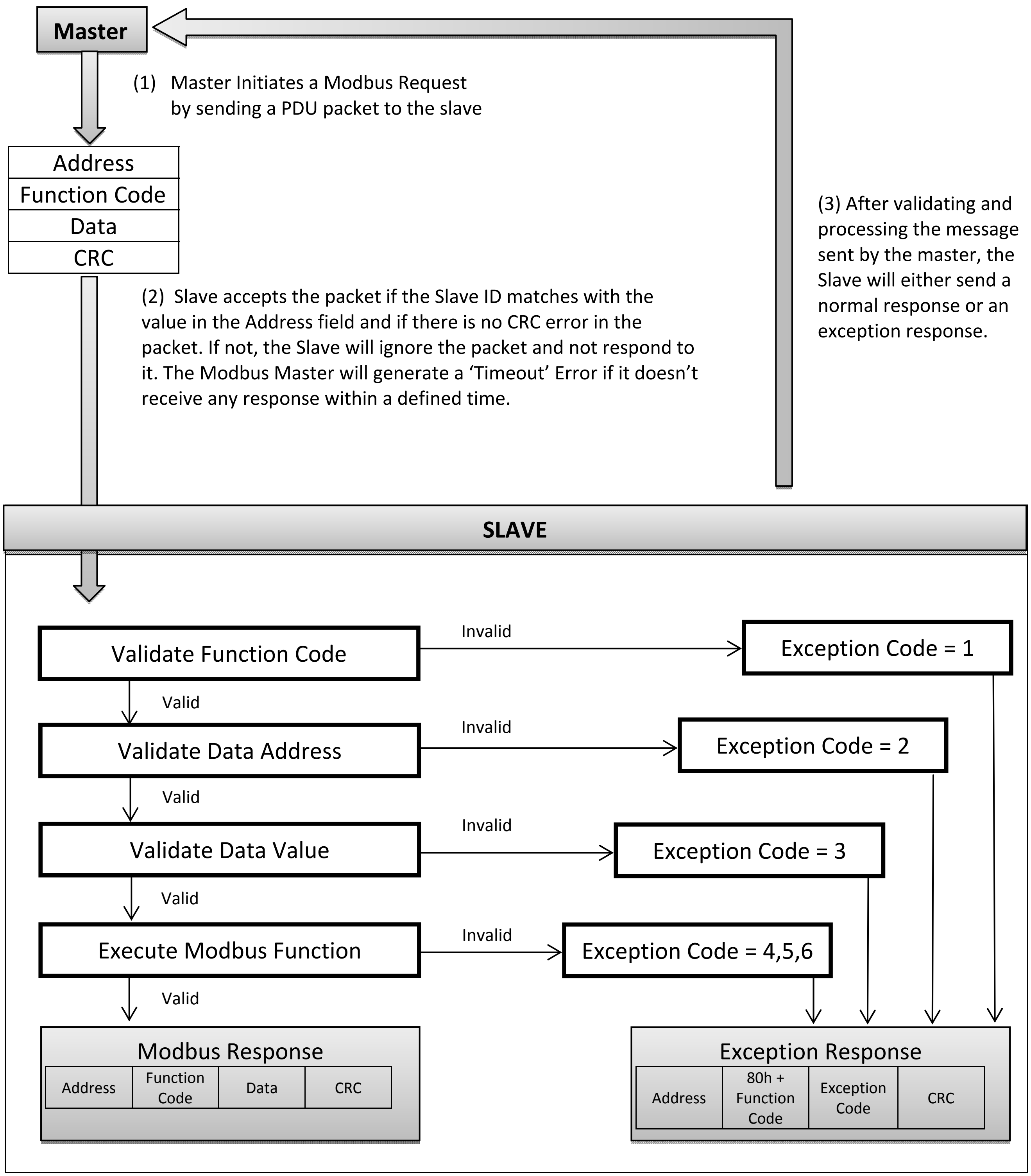

Figure 1: Query-Response cycle between the Master and a Slave

Query-Response Examples

The following examples use the abbreviations listed below-

MSB=Most Significant Byte ('high' byte); **LSB** =Least Significant Byte ('low' byte); **Sn=**Serial number; **CRC**=Cyclic Redundancy Check; **Fn**=Function; The term 'slave ID' may be interchanged with 'slave address', which is not to be confused with the address in 'parameter address' or 'register address'.

Function 03h – Read Holding Register

ID	03h	FIRST MSB	FIRST LSB	NUM MSB	NUM LSB	CRC LSB	CRC MSB

ID = inverter address, FIRST = starting register address, NUM = number of registers to read

Example read register 14 (0eh from Slave ID 1.

Byte Index	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Byte Data (Hex)	**01**	**03**	**00**	**0E**	**00**	**01**	**E5**	**C9**
Byte Data (Dec)	01	03	00	14	00	01	229	201
Byte Description	*ID*	*Fn*	*Register Start msb*	*Register Start lsb*	*Num Registers msb*	*Num Registers lsb*	*CRC lsb*	*CRC msb*

Response:

Byte Index	[0]	[1]	[2]	[3]	[4]	[5]	[6]
Byte Data (Hex)	**01**	**03**	**02**	**00**	**01**	**79**	**84**
Byte Data (Dec)	01	03	02	00	01	121	132
Byte Description	*ID*	*Fn*	*Num Bytes*	*Register Value msb*	*Register Value lsb*	*CRC lsb*	*CRC msb*

Function 06h – Set a Single Holding Register

ID	06h	ADDR MSB	ADDR LSB	VALUE MSB	VALUE LSB	CRC LSB	CRC MSB

ID = inverter address, ADDR = register address, VALUE = value to set register

In the event of an exception in the message, the slave will respond with an exception message instead.

Exception message format:

[0]	[1]	[2]	[6]	[7]
xxh	**80h+Fn**	**xxh**	**xxh**	**xxh**
ID	*Error*	*Exception*	*CRC*	*CRC*
	Code	*Code*	*lsb*	*msb*

Function 11h – Report Slave ID

ID	11h	CRC LSB	CRC MSB

ID = inverter address

Response:

[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]
xxh	11h	0Ch	*(ID)*		00h	00h	00h	00h	00h	xxh	xxh	xxh	xxh	xxh	xxh	xxh
ID	*Fn*	*Byte Count*	*Slave ID*	*Run Status*	*[.. Zero-filled ..]*					*Sn Year msb*	*Sn Year lsb*	*Sn Month*	*Sn Day*	*Sn Running Num*	*CRC lsb*	*CRC msb*

Transmission Mode – Modbus RTU

Modbus Serial communications can take place either in Modbus RTU mode or Modbus ASCII mode. **Solectria Renewables only uses Modbus RTU for the PVI 50-100KW, SGI 225-500PE, SGI 500XT and SGI 500-750XTM**. In Modbus RTU mode, each 8-bit byte contains two 4-bit hexadecimal characters. Modbus RTU is advantageous compared to ASCII because of its greater character density. Each message must be transmitted in a continuous stream.

Solectria Uses the following format for each byte in RTU mode:

Coding System: 8-bit binary, hexadecimal 0-9,A-F
Bits per Byte: 1 Start Bit
8 Data bits, least significant bit sent first
No bit for parity
1 Stop bit

Start	1	2	3	4	5	6	7	8	Stop

Table 5: Bit Sequence in RTU mode for one byte

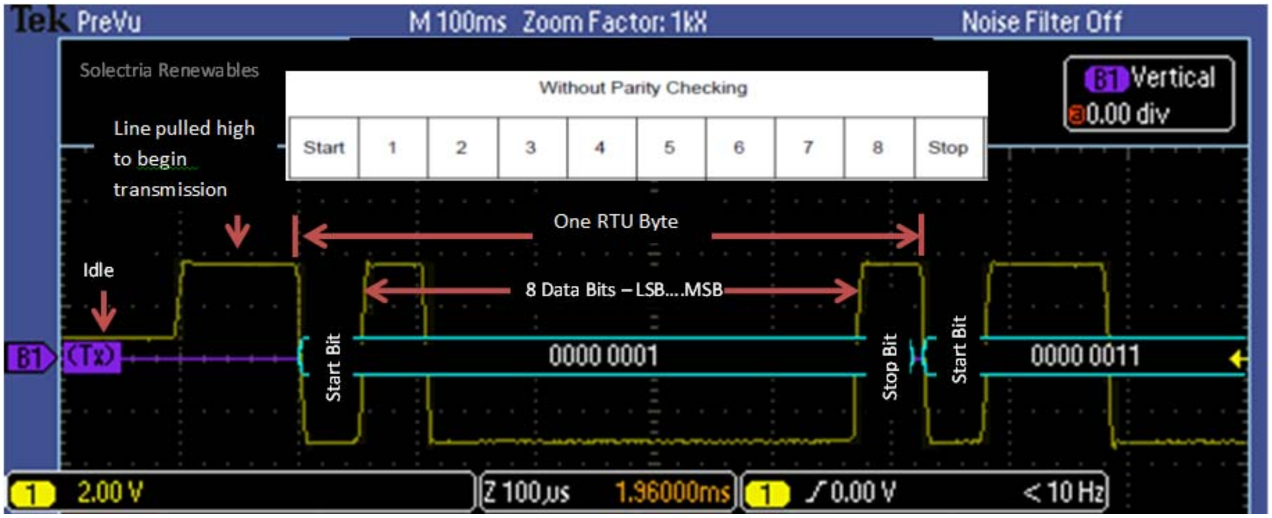

Figure 2: Modbus RTU message on an oscilloscope

In RTU mode, message frames should be separated by a silent interval of at least 3.5 character times. For 9600 baud rate, 3.5 character times is around 4ms. For 19200 baud rate, 3.5 character times is around 2ms.

Start	Address	Function	Data	CRC Check	End
Silent time > 3.5 Char time	1 byte	1 byte	N x bytes	2 bytes	Silent time > 3.5 char time

Table 6: Modbus Message RTU Framing

2.3 Physical Layer

RS-485 is a multi-drop serial communication standard that is frequently used in fieldbus networks. It features differential signaling on two communications wires, labeled (+) and (-). The differential signaling scheme provides a large degree of noise immunity, especially when twisted-pair wire is used. This enhances communication reliability.

The SolrenView RTU subsystem consists of a universal asynchronous receiver/transmitter (UART) device operating in asynchronous communication mode.

Baud Rate	9600*
Data Bits	8
Parity	None
Stop Bits	1
Mode	Half-Duplex
Framing	Modbus RTU

Table 7: SolrenView Modbus RTU Characteristics

Up to 125 registers can be polled with a timeout setting of at least 500ms.

* RS-485 serial port can be interfaced at 19200 baud, but will be susceptible to higher error rates under noisy conditions compared to 9600 baud rate.

3. SolrenView Device

The Solectria Commercial series of inverters contain an integrated SolrenView data acquisition device (DAQ). The SolrenView DAQ is often called the SolrenView Board. This device functions as both a HMI to configure, control and monitor the inverter; it also functions as a Modbus Slave RTU device that can be connected to a third party Master device.

SolrenView Contains the following Interfaces -

- **RS-485 Customer Interface:** SolrenView DAQ acts as a slave device on this interface. Multiple Commercial inverters can be daisy chained but communications performance may be compromised due to increased noise levels.
- **RS-485 Internal Interface:** SolrenView DAQ acts as a Master to the Inverter's DMGI. This connection is factory pre-wired and should not be altered.
- **Human-Machine Interface** (HMI) device consisting of a LCD and keypad, allow a human operator to configure, monitor and control various processes of the Inverter Control System.
- **Ethernet Interface:** The Ethernet interface is only used for Solectria's web-based solution if monitoring option is purchased. Modbus/TCP is not currently implemented on this interface.

If the SolrenView DAQ or inverter DMGI is not-operational (i.e. not powered) then data is not available to the Modbus Master. Please refer to Table 8 to determine the minimum conditions that must be met to power up SolrenView DAQ and inverter DMGI.

Inverter Models	AC Disconnect must be Closed	DC Disconnect must be Closed	Needs Sunlight?
PVI 50 - 100		Y	Y
SGI 225-500PE	Y	Y	Y
SGI 500XT	Y		

Table 8: Minimum Conditions to Power up SolrenView DAQ and Inverter DMGI

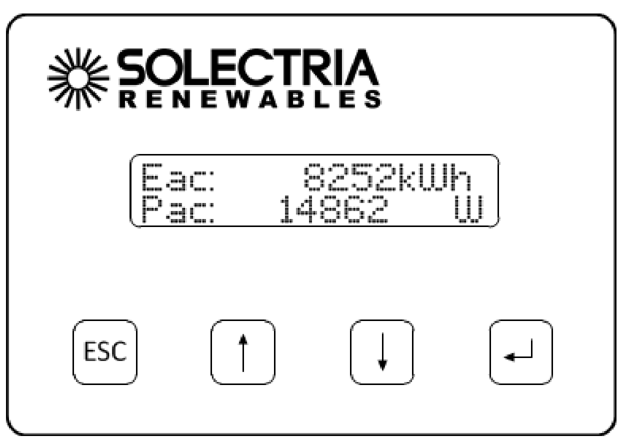

Figure 3: SolrenView HMI [Front]

The communications connections are on the back-side of the SolrenView HMI device and can only be accessed from inside the inverter. A third party Master and other slave(s) can be daisy chained to terminals A(+) and B(-) shown in figures 4 and 5.

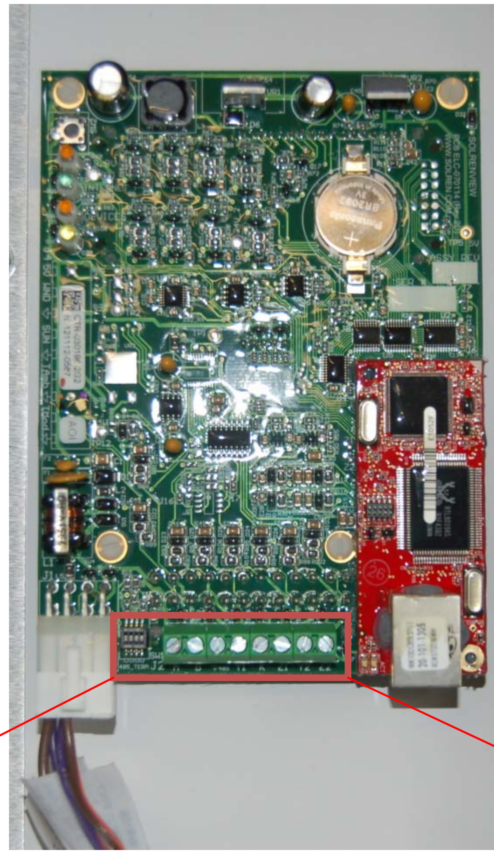

Figure 4: SolrenView DAQ [Back]

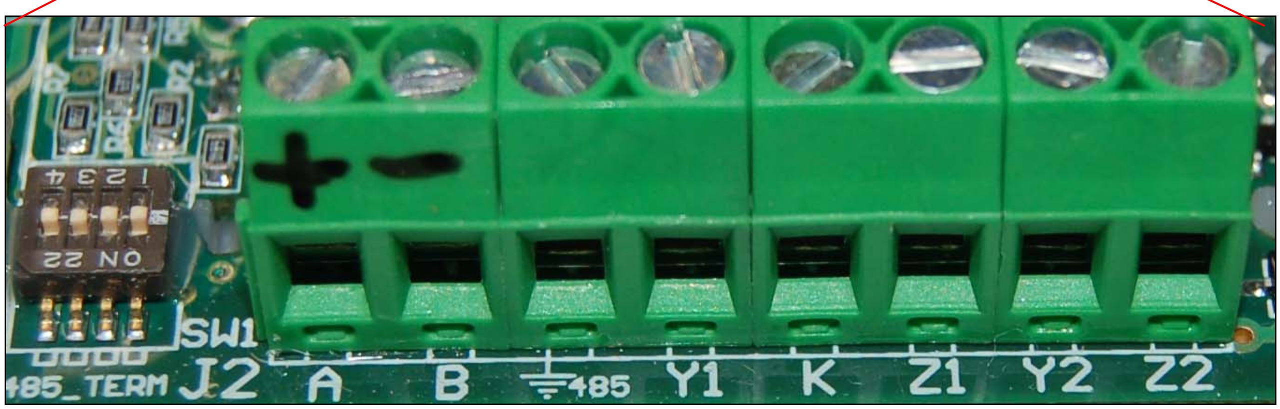

Figure 5: RS-485 Customer Interface terminal block in SolrenView.

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4. Guidelines for Proper Wiring of RS-485

Inverters cause electromagnetic noise due to switching of Insulated Gate Bipolar Transistors (IGBTs). Other sources of noise often exist in field installations that can disrupt communications. As RS-485 facilitates communications over relatively long distances of up to 4,000 ft (Solectria recommends limiting the distance to 1,000 ft), the RS-485 bus will be prone to transmission line effects that includes signal distortion caused by signal reflections. This section discusses important techniques that can be used for maximum noise rejection and minimizing transmission line effects.

4.1 Daisy Chaining

Multiple inverters can be connected together in a "daisy chain" pattern as shown in Figure 6. However, by adding each inverter in the daisy chain, the noise level on the RS-485 bus will increase. When daisy chaining multiple commercial inverters, RS-485 <u>isolated </u>repeaters are suggested to isolate the noise and boost RS-485 signals.

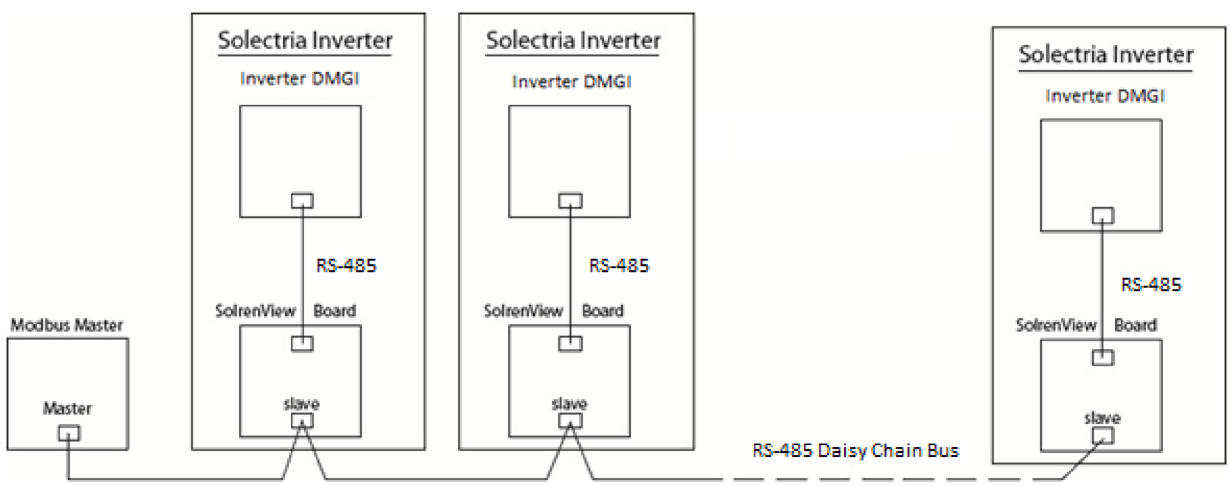

Figure 6: Overview of SolrenView's RS-485 connections in a daisy chain.
(Shown with external third-party master)

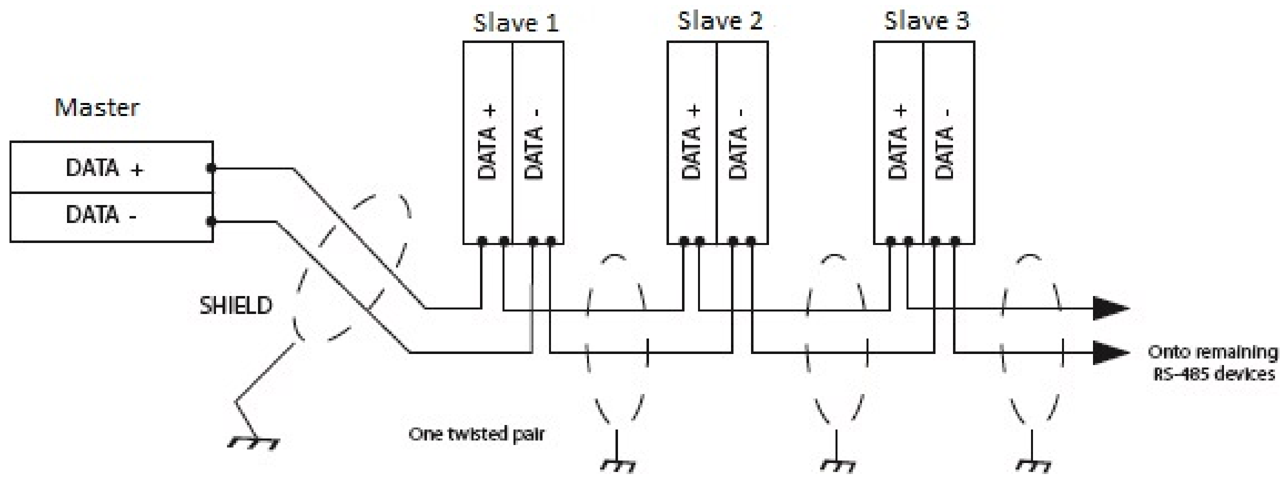

Figure 7: Master-Slave RS-485 connections to SolrenView's Slave Interface.

<u>RS-485 Pinouts</u>
As per RS-485 standard, 'A' terminal pertains to '-'inverting pin and 'B' pertains to '+' non-inverting pin. However, Solectria, in line with other transceiver manufactures, uses 'A' as '+' and 'B' as '-'. To daisy-chain devices, make point-to-point connection for each device on a RS-485 bus; connect (+) terminals to (+) terminals and (-) terminals to (-) terminals. If a device doesn't respond, there is no harm in reversing the lines to see if it communicates.

<u>Unique Modbus IDs</u>
Each commercial inverter in the daisy-chain must have a unique Modbus ID from 1-16 which can be set using the SolrenView HMI. If a Modbus Master in a RS-485 daisy chain network issues a request to multiple slaves that have the same Modbus IDs, then these slaves would step over each other when responding back to the Master. Consequently, the Master will see a garbled message and reject it.

Important Tips:

1. Only **<u>one</u>** Modbus Master can exist on a RS-485 daisy chain. Multiple Commercial inverters can be daisy chained but communications performance may be compromised due to increased noise levels. RS-485 isolated repeaters are suggested to isolate networks and boost RS-485 signals.
2. Inverter's Modbus ID can be set using the SolrenView HMI, which allows assignments from 1-16.
3. To daisy-chain devices, make point-to-point connection for each device on a RS-485 bus; connect (+) terminals to (+) terminals and (-) terminals to (-) terminals.
4. Avoid 'Star' and 'T' connection schemes (as shown in Figure 8 a,c,e) as they will cause unwanted signal reflections that can disrupt communication signals.

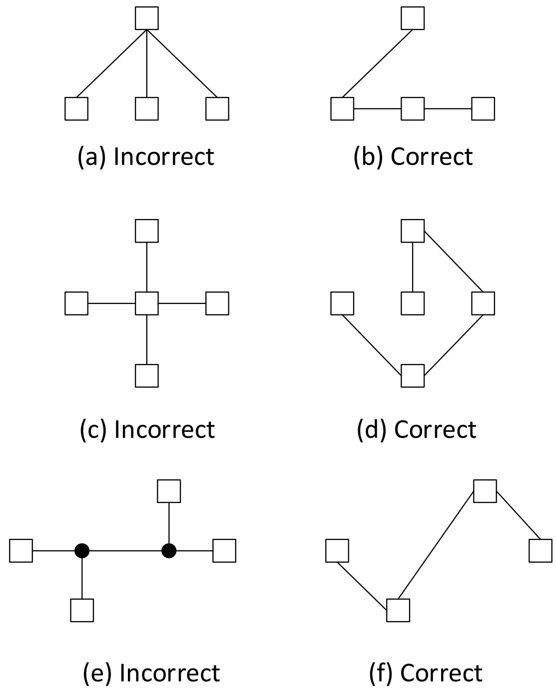

Figure 8: Correct and incorrect daisy-chain configurations.

5. Route a well twisted, shielded cable, away from sources of noise. If termination is necessary (see section on termination for details), terminate the ends of the cables to eliminate transmission reflections.
6. Limit the length of RS-485 daisy chain as much as possible to a maximum length of 1000 ft.

4.2 Importance of using twisted pair

Using a twisted pair, in which two data wires are twisted around one another, will reduce Electro-magnetic Interference (EMI) received from external sources.

Important Tips:

1. The higher the number of twists the cable has, the better it is. Use a cable that has at least one twist per inch. Wires that are twisted every inch have double the noise rejection compared to wires that are twisted every 4 inches. (IEEE 518-1982 Table 4 pg 96)

2. Connect Data+ and Data- to the same twisted pair.

4.3 Shielding

Effectively shielding the communications cable also plays a critical role in protecting the cable from external sources of EMI. Shield functions in two ways: shield reflects most of the electromagnetic energy and also picks up any EMI that penetrates its skin and drains this EMI to ground provided that the shield is terminated to ground. Typically, a bare wire known as 'drain wire' is used to drain any noise picked up by the shield.

For each cable segment, connect the drain wire to ground at one of the ends and keep the other end floating. Since multiple ground points will cause circulating currents, it is important to ensure that the shield is insulated at the unterminated end to prevent any inadvertent ground contact that will cause circulating currents.

Important Tips:

1. For each cable segment, connect the drain wire to ground at one of the ends and keep the other end floating.
2. A cable that uses foil shield to cover each twisted pair and an overall braided jacket will provide the best shielding. This scheme is referred to as double shielding.
3. Ensure that the shield is insulated at the unterminated end to prevent inadvertent contact to ground.
4. Don't use a cable that has extra wires that will not be used. Unused wires that are floating will act as antennas and pick up noise.

4.4 Cable Routing

In addition to using a twisted pair in a shielded cable, routing the communications cable in a separate metal conduit will further protect the cable from EMI. When routing through cable tray conduits, ensure that the communications cables are at least 18 inches away from power cables. If conduits are used, then ensure that the communications cables are at least 12 inches away from power cables (IEEE 518 -1982 Tables 8 and 9 pg. 103). If the communications cables have to be crossed with power cables, then do so abruptly at 90 degrees, avoiding close parallel runs.

Important Tips:

1. Keep the cables away from other sources of noise such as electrical motors, transformers, fluorescent lights, wireless transmitters, etc.
2. Communication cables should be separated by power cables by 12 inches if routed in conduits and 18 inches if routed in tray conduits.
3. If communications cables must cross power cables, then they should cross abruptly at 90 degrees.

4.5 Connections at the RS-485 Terminal

1. Minimize the untwisted and unshielded part of the wire when making terminal connections.
2. Stub Lines should be as short as possible. Long stubs add more capacitance and create impedance mismatches thereby causing reflections and disruptions to the signal in the RS-485 bus.
3. Always provide proper strain relief to wires.

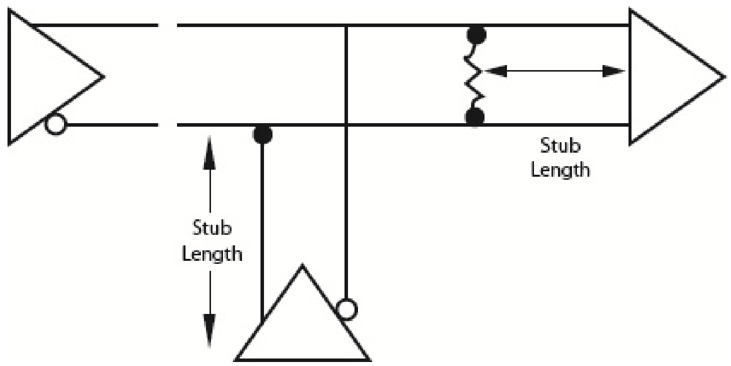

Figure 9: RS-485 Stub Length

4.6 Termination

When a signal propagates in a long unterminated RS-485 line, the signal will be reflected back from the unterminated ends. The signal may bounce back and forth from one end of the line to other but will eventually dampen down due to resistance in the wire. However, when the line is terminated at the source and at the end of the transmission line, then the signal gets fully absorbed by a termination resistor. Termination resistor ideally should match the characteristic impedance of the cable. Most twisted cables have impedance between 100-130 Ohms. Typically 120 Ohms is used for termination. Termination is usually not needed for low baud rates such as 9600 bps and 19200 bps since reflections are dampened out much before the middle of the bit that the UART samples.

While adding termination resistors reduces reflections on the line, there are some drawbacks that need to be considered. First, termination adds further load to the line consequently weakening the data signal. Second, adding termination will change the biasing requirements of the RS-485 bus. The decision as to whether or not to terminate is done on a site-by-site basis.

Important Tips:

1. Use the same type of cable for all RS-485 devices. Joining cables with different characteristic impedances may cause reflections.
2. Termination is usually not needed for 9600 and 19200 baud rate.
3. Typically 120 Ohms ($^1/_4$ W or $^1/_2$ W) is used for termination.

4. When termination is necessary, both ends of the RS-485 lines need to be terminated – i.e. the master and the last slave on the daisy chain should have terminations. Don't add any other terminations on the line.

4.7 Biasing RS-485 Bus

RS-485 transceivers interpret signals to be in high state when 'Data+' is 200mV above 'Data –' and interpret signals to be in low state when 'Data+' is 200mV below 'Data –'. Signals that are in between these limits are at an unknown state and can randomly be at a high or low state. Since RS-485 transceivers detect the start of a bit sequence only when transition occurs from high to low, it is necessary to bias the RS-485 bus to be in a high state when transceivers aren't active (idle condition). Moreover, properly biasing the RS-485 bus will allow more room for differential noise to exist without causing the RS-485 bus to switch states during idle condition.
RS-485 bus can be biased by placing a pull-up resistor between 'Data +' and voltage source and placing a pull down resistor between 'Data –'and ground. Values of the resistors should be chosen such that it causes 'Data+' to be at least 200mV above 'Data –'during idle condition. For more details on how to bias RS-485 bus please refer to Reference # 11.

Important Tips

1. 'Data +' should be above 'Data –'by at least 200mV during idle condition (use an oscilloscope with differential probe to look at the differential signal). If not, proper biasing must be provided.
2. Pull-up and Pull-down resistors should be chosen such that 'Data+' is at least 200mV above 'Data –'during idle condition.
3. Pull-up and Pull-down resistors should be of equal value for symmetrical loading of the driver.
4. Lowering the values of pull-up/pull-down resistors will increase biasing but at the cost of adding more load to the driver. As per RS-485 standard, the driver should provide minimum of +/- 1.5 V differential signal with a common-mode load of 375 Ohms, hence, the pull-up/pull-down resistors should be high enough to meet this standard.

5. References

1. *Modbus Application Protocol Specification V1.1b,* Modbus-IDA
   http://www.Modbus.org/docs/Modbus_Application_Protocol_V1_1b.pdf

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