



Relion® Protection and Control

615 series ANSI, RER620 Modbus Communication Protocol Manual



615 series



620 series

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Section 1 Introduction

1.1 This manual

The communication protocol manual describes a communication protocol supported by the IED. The manual concentrates on vendor-specific implementations.

1.2 Intended audience

This manual addresses the communication system engineer or system integrator responsible for pre-engineering and engineering for communication setup in a substation from an IED perspective.

The system engineer or system integrator must have a basic knowledge of communication in protection and control systems and thorough knowledge of the specific communication protocol.

1.3 Product documentation

1.3.1 Product documentation set

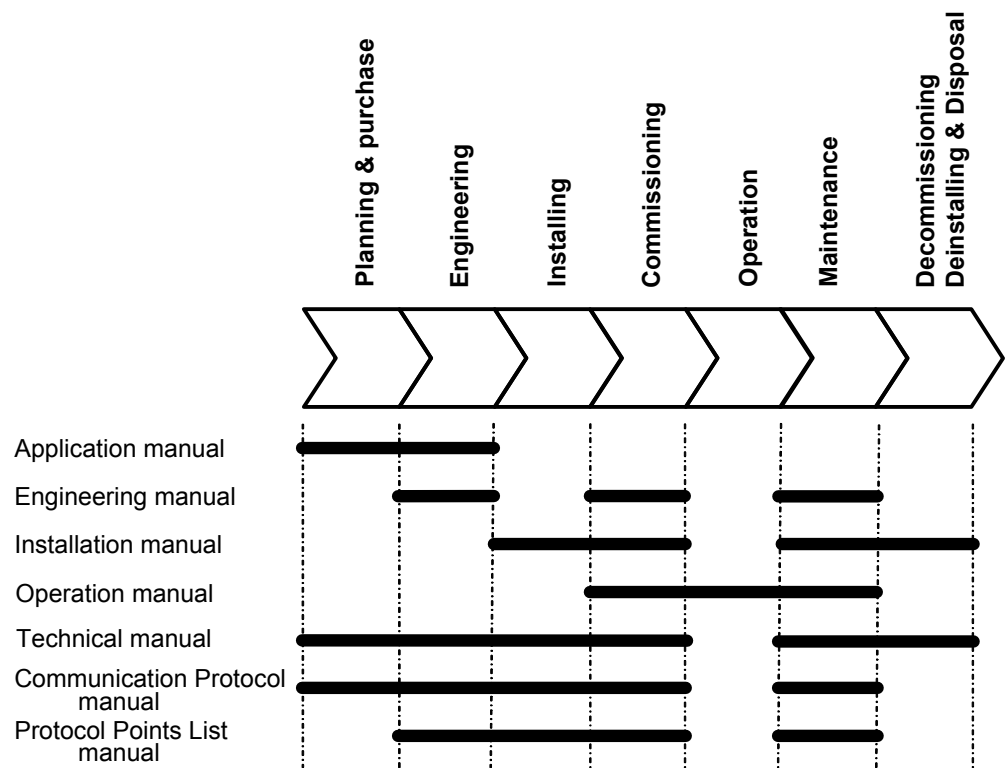


Figure 1: The intended use of manuals in different lifecycles

The engineering manual contains instructions on how to engineer the IEDs using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert IEDs to the project structure. The manual also recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 61850 and DNP3.

The installation manual contains instructions on how to install the IED. The manual provides procedures for mechanical and electrical installation. The chapters are organized in chronological order in which the IED should be installed.

The operation manual contains instructions on how to operate the IED once it has been commissioned. The manual provides instructions for monitoring, controlling and setting the IED. The manual also describes how to identify disturbances and how to view calculated and measured power grid data to determine the cause of a fault.

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data

sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

The communication protocol manual describes a communication protocol supported by the IED. The manual concentrates on vendor-specific implementations. The point list manual describes the outlook and properties of the data points specific to the IED. The manual should be used in conjunction with the corresponding communication protocol manual.

1.3.2 Document revision history

Document revision/date	Product series version	History
A/03/28/2008	1.0.1	First release
B/12/22/2008	1.1	Content updated to correspond to the product series version
C/01/20/2010	2.0	Content updated to correspond to the product series version
D/11/23/2010	615 series: 2.0 620 series: 1.0	Added information about 620 series
E/03/31/2011	615 series: 4.0 620 series: 1.0	Version updated for 615 series v4.0 ANSI release
F/10/31/2011	615 series: 4.0 620 series: 1.1	Version updated for 620 series v1.1 release
G/05/01/2015	615 series: 4.2 620 series: 2.0	Version updated for 615 series v4.2 and 620 series: 2.0 ANSI release



Download the latest documents from the ABB web site
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1.3.3 Related documentation

Product-specific point list manuals and other product series- and product-specific manuals can be downloaded from the ABB web site <http://www.abb.com/substationautomation>.

1.4 Symbols and conventions

1.4.1 Safety indication symbols



The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.



The information icon alerts the reader to important facts and conditions.






The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although warning hazards are related to personal injury, it should be understood that operation of damaged equipment could, under certain operational conditions, result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2

Manual conventions

Conventions used in IED manuals. A particular convention may not be used in this manual.

- Abbreviations and acronyms in this manual are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons, for example:
To navigate between the options, use  and .
- HMI menu paths are presented in bold, for example:
Select **Main menu > Settings**.
- LHMI messages are shown in Courier font, for example:
To save the changes in non-volatile memory, select `Yes` and press .
- Parameter names are shown in italics, for example:
The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks, for example:
The corresponding parameter values are “Enabled” and “Disabled”.
- IED input/output messages and monitored data names are shown in Courier font, for example:
When the function picks up, the `PICKUP` output is set to `TRUE`.
- Dimensions are provided both in inches and mm. If it is not specifically mentioned then the dimension is in mm.

Section 2 Modbus overview

2.1 Modbus standard

Modbus is a communication protocol developed by the Modicon company in the 1970's. Originally it was used for communication in PLCs and RTU devices. Later on the Modbus protocol has been used in a variety of different device applications. Today the Modbus protocol is mainly used over serial communication networks and Ethernet.

The Modbus serial communication and the Ethernet based Modbus TCP/IP communication in this IED follow the specifications maintained by Modbus Organization.



Modbus communication reference guides are downloadable from Technical Resources at www.modbus.org.

2.1.1 Serial communication

Modbus is a master-slave protocol when it is used over serial communication networks. This IED implements the slave side of the protocol. Depending on the chosen physical serial interface it is possible to build multidrop networks or point-to-point communication connections.

There can only be one Modbus master unit on a Modbus serial network. The Modbus master unit communicates with one Modbus slave unit at a time. Usually the master reads, or scans, data from the slaves cyclically. The master can also write data or give commands to the slave units. Each slave unit has a unique unit address. Thus, the master can identify the slave with which it communicates. The Modbus standard also defines the possibility for Master broadcast transmissions.

Modbus serial protocol uses two link modes: Modbus RTU and Modbus ASCII. Both modes are supported by this IED.

2.1.2 Ethernet communication

Modbus communication over Ethernet TCP/IP is of client-server type. This IED operates as a Modbus server.

Modbus TCP/IP connection is established when the Modbus client opens a TCP socket connection to the Modbus server. The socket port 502 on the TCP/IP stack is reserved for Modbus. If the connection request is accepted by the server, the client can start communicating with the server unit.

IEDs can usually accept several simultaneous Modbus TCP/IP client connections even though the number of connections is limited. It is possible to configure the IED to only accept socket connection requests from known client IP addresses.

2.1.3 Application data implementation

This IED is designed to operate with a wide range of different Modbus masters and clients. The Modbus memory map offers the possibility to view IED's internal process data in a simple I/O map style which is mainly aimed at PLC masters and other process automation devices. Time-tagged, chronological event lists and fault records can be read over the Modbus interface. These data are more suitable for SCADA type of Modbus masters.

The Modbus standard defines four main memory areas for mapping IED's process data. Due to its open nature, the Modbus standard does not define exactly what type of data should be mapped to each memory area. The Modbus mapping approach of the IED ensures that the same process data are readable from as many Modbus memory areas as possible. The users may then choose the memory areas that are most suitable for their Modbus master systems.

All Modbus data in the IEDs can be accessed using command functions belonging to Modbus conformance classes 0 and 1. This means that most master systems are able to communicate with the IED.

2.2 Terms and definitions

Modbus data appears in different memory areas in the Modbus device. The four most common areas are coils, digital input, input register and holding register. These are also referred to as 0X, 1X, 3X and 4X areas respectively.

Data within these four areas are addressed from 1 onwards. Modbus defines addressing in two ways: PLC addressing starts from address 1 and regular Modbus data addressing starts from 0. For example, a holding register at PLC address 234 can be referred to either as 4X register 234 or as 40234. The regular Modbus addressing, that is the PLC address decremented by one, is shown when analyzing the Modbus traffic on the physical network.

Listings and references to the Modbus data in this documentation follow the PLC addressing scheme. Refer also to the Modbus protocol standard documentation that can be found for free at www.modbus.org.

2.3 Documentation

The ANSI Modbus point list manuals cover all the 615/620 series variants.



A newer SW version of the same 615/620 series configuration may contain additional Modbus points.

Section 3 Vendor-specific implementation

3.1 Modbus link alternatives

Modbus communication is possible over the serial communication interface, over the Ethernet interface, or over both interfaces simultaneously.

3.1.1 Serial link

Modbus serial communication requires that the IED variant is equipped with a serial interface card at the slot X000. The serial interface card can contain one or two serial interfaces.

The Modbus link mode can be either Modbus RTU or Modbus ASCII.

Modbus serial communication can run on two separate serial ports simultaneously. The Modbus serial link characteristics can be different on the two ports. This applies also to the Modbus RTU and ASCII link modes and the unit address.



Documentation concerning the Modbus serial link messages and the Modbus standard can be obtained from www.modbus.org.

3.1.1.1 Modbus serial link parameters

Serial link setting parameters can be accessed with PST or via the LHMI path **Configuration > Communication > Modbus**.



In the LHMI parameter names end either with number 1 or with number 2. The numbers refer to two separate serial ports, that is the instances 1 and 2.

Address

Each serial link can be given a separate unit address.

End delay

The end of message delay, or timeout, is used only in the Modbus RTU link mode. According to the Modbus standard, an idle period of 3.5 characters, that is the time it takes to transmit 3.5 characters with the used baud rate, defines the end of a Modbus RTU frame in the RTU mode. This parameter can be given with the accuracy of one character. The default setting is three characters but the user can increase or decrease the value.



In a multidrop RS-485 Modbus network the unit may detect and receive response messages from other slave units. Thus, consider the minimum silent time between the response frame and the beginning of master's next request frame when setting the end delay in Modbus RTU mode.



This parameter has no meaning in the Modbus ASCII link mode.

Start delay

The intraframe delay on serial Modbus RTU link is defined as a silent interval of 3.5 characters. The delay is essential for Modbus devices to recognize the beginning and end of each RTU frame. If the end delay is decreased in this IED, the response messages may be transmitted too fast according to the link standard especially true with slower baud rates. The start delay parameter adds idle characters before the transmission, thus increasing the silent interval between the Modbus RTU link frames. The start delay default setting is four idle (silent) characters.



To set the timing properly, consider also how the other slave units in a multidrop RS-485 network detect the Modbus traffic between the master and this IED.

Serial port

It is possible to define which serial port is used for separate Modbus serial instances: COM1 or COM2. The serial communication instance is not active if this parameter is set to "Not in use."



If this protocol does not operate as expected, make sure that other serial protocols are not using the COM port as well.



Baud rate is defined on the serial driver side and are therefore located via the LHMI paths **Configuration > Communication > COM1** and **Configuration > Communication > COM2**.

3.1.1.2

Modbus serial diagnostic counters

Modbus Serial diagnostic counters can be viewed via the LHMI path **Monitoring > Communication > Modbus > Serial**.

Counters related to the possible Modbus serial instances 1...2 have the suffixes 1...2 (N). The counters show complete Modbus protocol link frames and Modbus errors. The serial communication drivers (COM1, COM2) maintain their own counters for lower level serial communication diagnostics.

Table 1: *Serial diagnostic counters*

Counter	Description
Received frames N	Total amount of received Modbus frames. For example, the Modbus frames that are addressed to this instance.
Transmitted frames N	Total amount of transmitted Modbus responses.
Cksm Err N	Total amount of detected Modbus checksum errors. The Modbus instance only calculates checksums of Modbus frames that contain a proper link address. All other incoming Modbus frames are discarded.
Transmitted Exc A N	Total amount of exception responses 1 and 2. These exception responses usually reveal configuration errors on the Modbus client side. Either the client uses a request function code which is not supported or the requested Modbus point(s) does not exist.
Transmitted Exc B N	Total amount of exception responses 3. These exceptions usually reveal the IED application level rejections. That is, the IED application rejects the request at this moment, under the current circumstances. The exception can also mean that the value in the Modbus write request is out of range.
Status N	Shows the value "True" if the serial instance is in use. This indicates that the Modbus client is connected and Modbus messages, which are addressed to the device, are received regularly at least with a 30 second interval or faster. In all other cases this value is "False". Resetting of all diagnostic counters in the instance N is done by writing value "True" into this same Status N object.

3.1.1.3

Character framing in different serial link modes

According to the Modbus standard, the character length in the Modbus RTU mode should be 11 bits and in Modbus ASCII mode 10 bits. It is possible to freely define the character parity: even, odd or no parity. No parity means that the bit length of the serial character is reduced by one. Thus, the character is compensated with an additional stop bit.

Table 2: *RTU characters*

Coding system	8-bit binary
Bits per character	1 start bit 8 data bits, the least significant bit is sent first 1 bit for even/odd parity; no bit if parity is not used 1 stop bit if parity is used; 2 stop bits if parity is not used

Table 3: *ASCII characters*

Coding system	Two ASCII characters representing a hexadecimal number
Bits per character	1 start bit 7 data bits, the least significant bit is sent first 1 bit for even/odd parity; no bit if parity is not used 1 stop bit if parity is used; 2 stop bits if parity is not used

3.1.2

TCP/IP link

The IED operates as a Modbus TCP/IP server. A Modbus TCP/IP client can establish a connection to the IED through the standardized TCP socket port 502.

The Modbus TCP/IP interface of the IED can be configured to accept several simultaneous Modbus client connections. It is possible to grant connections only to the predefined TCP/IP clients. The write authority of the Modbus TCP/IP client is configurable.



Modbus TCP usually shares the Ethernet connection with the other Ethernet based protocols of the IED. The number of Ethernet based clients that can be simultaneously connected to the IED is restricted.

3.1.2.1 TCP/IP interface configuration

The Modbus TCP/IP protocol uses the Ethernet interface. The general setup parameters of Ethernet, for example the IED's own IP address, are found via the LHMI path **Configuration > Communication > Ethernet**.

Client connections

The Modbus TCP/IP server accepts as many simultaneous client connections as defined with the *Max TCP/IP clients* parameter:

- The setting range for the parameter is 0...5.
- If the parameter value is zero, the Modbus TCP/IP server connection is not in use.
- The parameter works in conjunction with the parameters of a registered Modbus TCP/IP client.

When client X reconnects, the old connection of that client is disconnected and the new connection is accepted to avoid zombie clients. When the maximum number of clients are connected, a new connection request is handled as follows:

- If there are unregistered clients connected, the one with the longest silent period is disconnected and a new connection is accepted.
- If there are only registered clients connected, the new connection request is rejected.

It is possible to predefine the client or clients which are always granted Modbus TCP/IP connections by registering the clients' IP addresses. For example, if four concurrent connections are allowed and three of them are registered, they are seen as Client connection 1...Client connection 3. These three registered connections are then dedicated to certain clients only and the fourth connection is available to other clients.

Client IP addresses

There are five Modbus setting parameters for Modbus client IP addresses. The parameter value "0.0.0.0" indicates that the client IP address is not defined.

If there are, for example, four available TCP/IP connections defined and one of the connections is to be dedicated for a certain client X, enter the client X's IP address to the *Client IP1* parameter. The IP addresses of the Modbus clients 2...4 can be set to "0.0.0.0". The setting of the Modbus client5 IP address has no meaning in this example as the connection is not in use. In this example, the TCP/IP session 1 is dedicated to the client X which means that this registered client X is always able to connect to the IED. Unregistered clients can connect to sessions 2...4. However, an unregistered client connection request can be rejected if sessions 2...4 are already occupied. The write authority can also be assigned differently for registered TCP/IP clients.

Client's write authority

The registering of a Modbus client affects the client's write authority and the reading of latched Modbus data.

The *TCP write authority* parameter can be set to three different states:

- 0 = No write authority for any Modbus TCP/IP client
- 1 = Write authority only for registered Modbus TCP/IP clients
- 2 = Write authority for all Modbus TCP/IP clients

The possible blocking of write operation does not include the selection write operation that has to be done to read out Modbus event and fault record structures.

3.1.2.2

Modbus TCP/IP diagnostic counters

Modbus TCP/IP counters can be viewed via the LHMI path **Monitoring > Communication > Modbus > Ethernet**.

Counters related to the possible Modbus TCP/IP instances 1...5 have the suffixes 1...5 (N). The counters show the complete Modbus protocol link frames and Modbus errors. The Ethernet communication driver maintains its own counters for lower level communication diagnostics.

Table 4: *TCP/IP diagnostic counters*

Counter	Description
Received frames N	Total amount of received Modbus frames.
Transmitted frames N	Total amount of transmitted Modbus responses.
Transmitted Exc A N	Total amount of exception responses 1 and 2. These exception responses usually reveal configuration errors on the Modbus client's side.
Transmitted Exc B N	Total amount of exception responses 3. These exceptions reveal the IED application level rejections.
Status N	Shows the value "True" if the TCP/IP or serial instance is in use. This means that a Modbus client has connected to the TCP socket and Modbus TCP messages are received regularly at least with a 30 second interval or faster. In all other cases this value shows "False". Resetting of all diagnostic counters in the instance N is done by writing value "True" into this same Status N object.

The counters and status of an instance N are reset when the client makes a TCP socket disconnection or if the TCP socket connection keep alive times out.

The common (instance independent) Modbus TCP/IP diagnostic counters can be reset separately by writing the value 0 into them.

Table 5: *Common (instance independent) Modbus TCP/IP diagnostic counters*

Counter	Description
CnReject No sockets	The amount of connection requests that are rejected due to unavailable TCP sockets.
CnReject Not reg	The amount of connection requests that are rejected since the client is not registered.

3.2 Supported function codes

3.2.1 Application functions

Table 6: *Supported application functions*

Function code	Name	Description
01	Read coil status	Reads the status of discrete outputs.
02	Read digital input status	Reads the status of discrete inputs.
03	Read holding registers	Reads the contents of output registers.
04	Read input registers	Reads the contents of input registers.
05	Force single coil	Sets the status of a discrete output.
06	Preset single register	Sets the value of a holding register.
08	Diagnostics	Checks the communication system between the master and the slave.
15	Force multiple coils	Sets the status of multiple discrete outputs.
16	Preset multiple registers	Sets the value of multiple holding registers.
23	Read/write holding registers	Exchanges holding registers in one query.

3.2.2 Diagnostic functions

The diagnostic functions are only intended for serial communication. However, the serial diagnostic counters can be read, but not reset, via the Modbus TCP/IP interface. The serial line cannot be forced to the listen mode via the Modbus TCP/IP interface.

Table 7: *Supported diagnostic subfunctions*

Function code	Name	Description
00	Return query data	The data in the query data field is returned (looped back) in the response. The entire response is identical to the query.
01	Restart communication option	The slaves peripheral port is initialized and restarted and the communication event counters are cleared. Before this, a normal response will be sent provided that the port is not in the listen only mode. If the port is in the listen only mode, no response will be sent.
04	Force listen only mode	The slave is forced to enter the listen only mode for Modbus communication.
10	Clear counters and diagnostic register	All counters and the diagnostic register are cleared.

Function code	Name	Description
11	Return bus message count	The response returns the number of messages in the communication system detected by the slave since its last restart, clear counters operation and power up.
12	Return bus communication error count	The response returns the number of CRC errors encountered by the slave since its last restart, clear counters operation and power up.
13	Return bus exception error count	The response returns the number of Modbus exception responses sent by the slave since its last restart, clear counters operation and power up.
14	Return slave message count	The response returns the number of messages addressed to the slave or broadcast which the slave has processed since its last restart, clear counters operation or power up.
15	Return slave no response count	The response returns the number of messages addressed to the slave for which a response (neither a normal response nor an exception response) has not been sent since its last restart, clear counters operation or power up.
16	Return slave NACK response count	The number of messages addressed to the slave for which a negative acknowledgement response has been sent is returned in the response.
18	Return bus character overrun count	The response returns the number of messages addressed to the slave for which it has not been able to send a response due to a character overrun since its last restart, clear counters operation or power up.

3.2.3 Exception codes

Table 8: Supported exception codes

Function code	Name	Description
01	Illegal function	The slave does not support the requested function.
02	Illegal data address	The slave does not support the data address or the number of items in the query is incorrect.
03	Illegal data value	A value contained in the query data field is out of range.

3.3 Application data

3.3.1 Modbus data objects

The Modbus protocol in 615/620 series IEDs is built on top of the internal IEC 61850 data model. Thus, the Modbus application data objects, proprietary events and MCD bits are derived from IEC 61850 data objects and data set reporting. The 615/620 series IEDs have a predefined IEC 61850 data set configuration. In other words, it is predefined which internal data object changes the 615/620 series IEDs detect.

The available Modbus indications in the 615/620 series IEDs are generally selected from the IEC 61850 indications residing in data sets. Objects that do not reside in any data set are updated to the Modbus database slower. This concerns, for example, some measurand register values. Fast changes in these object values may not be detected or propagated to the Modbus database. However, the latest value of these objects is always found in the Modbus database. The DS column in the Modbus point list manual shows if the object resides in some data set as a default.



For a list of the available data objects, see the point list manual.

3.3.2 Modbus data implementation



The numeric register locations used in this section are for example purposes only. The genuine Modbus register locations are located in the IED's memory map.

The IED is internally modelled according to the IEC 61850 standard. The Modbus protocol is implemented on top of this model. However, all features of the IEC61850 data model are not available through the Modbus interface.

The Modbus protocol standard defines one bit digital data and 16 bit register data as the application data alternatives but it does not define exactly how the digital data and the register data should be used by the application. Instead, the choice of the usage is left to the IEDs implementation.

Change events and time synchronization

The Modbus standard does not define event reporting or time synchronization procedures. Proprietary solutions have been introduced in this IED to support these functionalities.

Control operations

The Modbus standard defines data types 0X for coils and 4X for holding registers to be used for control operations.

Depending on the controlled object, the control operations may be of direct-operate or select-before-operate type. Control operations include automatic checking for authorization, local and remote blockings and preventing simultaneous controlling by multiple clients.

Application data compatibility

This IED is designed to operate with a wide range of Modbus masters spanning from industrial PLCs to substation SCADA devices. The application solutions have been chosen to achieve the highest possible level of compatibility with these systems:

- Application data are readable in many different Modbus memory areas. Digital data are readable as bits or packed bits in registers.
- Both 16 and 32 bit register sizes are used for measurands.
- The proprietary Modbus event buffer can be read in many different ways. A master can continuously read and log change events in real time or, for example, read out the n latest events on demand.
- Change detect data can be used as an alternative to the event record reading to catch fast indication data transitions between the master scans.
- The Modbus fault record gives a summary of the captured analog quantities and protection stages picking up and possibly tripping during a fault.
- The addressing of the application data in the documentation and tools follows the so-called Modbus-PLC addressing principle where the base address 1 is used. The application data addressing in this IED spans only between the locations 1 and 9999.
- UDRs are not yet supported in ANSI IEDs.

3.3.3 Data mapping principles

Modbus data is organized sequentially. This is the most efficient organization method since the master normally scans the Modbus data in blocks.

3.3.3.1 Data in monitoring direction

All data in the monitoring direction is available through the 4X memory area. This includes the digital indication data which is also readable in the 1X and 0X areas.

All register structures are located in the 4X area.

The Modbus data may contain empty bits or registers within the sequential data areas. These bits and registers are intended for possible future expansion. Reading this data does

not result in any Modbus exception response. The value in these bits or registers is always zero.

3.3.3.2 One bit data mapping

All one bit data in the IED is readable either from the 0X or 1X memory area. The Modbus bit point addresses are similar regardless of the memory area. One bit data is also available in 4X register memory area as bit packed 16 bit registers. The bit locations follow a pattern similar to the 0X and 1X locations.

3.3.3.3 Data in control direction

IED controls, set points and acknowledgements are mapped to Modbus 0X data (coils). Coils can only be operated one by one.

Currently the ANSI implementation of controls via the Modbus protocol are restricted to the 4X registers map.

Some control bits are packed bits in the 4X control register structures. The 4X control structure contains a password which has to be given before starting control operations.

3.3.4 Digital input data

Indication signals related to protection applications often change rapidly. Thus, the Modbus master might not be able to detect all changes.

Momentary- and momentary change detect bits

In this IED, indications are presented as two adjacent Modbus bits in the Modbus memory map. The two bits represent the momentary position and the momentary change detect state of the indication.

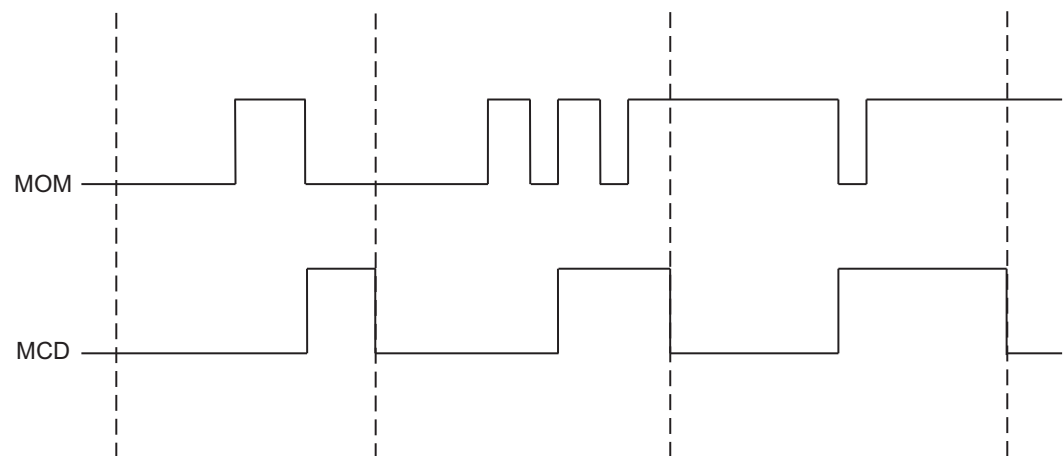


Figure 2: *Change detection bit*

If the momentary value of an indication bit has changed two times or more since the master last read it, the MCD bit is set to one. When the MCD bit has been read, it is reset to zero. Since indications usually are 1-active, it is easy to detect an indication activation by combining the MOM and MCD bits using a logical OR operation (MOM+MCD). The

momentary position bit and the MCD bit of a certain indication point always occur as pairs in the Modbus memory map.

Observe that the MCD bit states are client dependent. The MCD bit is only reset for the specific Modbus client that reads it. Thus, other Modbus clients may still receive value one from the same MCD bit when it is read.

MOM indication changes are captured in the IED's sequential Modbus event buffer. Additionally, the Modbus event buffer provides a time stamp and chronology of indication changes.

3.3.4.1 Multiple digital inputs mapping

Digital inputs related to two-bit DPC or DPS objects, for instance circuit breaker and disconnectors, have a multiple mapping in the Modbus address space. The objects' open and close bits are coded as MOM+MCD bit pair entities. The MCD bits reveals if the object has changed its position several times since the Modbus master last scanned it. In addition, the open and close bits are also coded using MOM values only, among with a fault bit. The fault bit is set to "1" when the object is in intermediate (00) or faulty (11) position.

Table 9: *Bit treatment*

Bits	Treatment
Close MOM	One 2 bit entity
Close MCD	
Open MOM	One 2 bit entity
Open MCD	
:	
Close MOM	One 1 bit entity
Open MOM	One 1 bit entity
Faulty position MOM	One 1 bit entity
:	

The MOM values are identical in each entity. The MCD bit is only reset if the MOM bit in the same entity is read.

3.3.5 Measurand registers

The Modbus measurands are located in the Modbus register area. The measurands are readable from 4X areas.

The formula for calculating the Modbus register value is:

$$\text{Modbus value} = (\text{IEC61850Value} \times \text{scaleFactor}) + \text{Offset} \quad (\text{Equation 1})$$

The range of the original IEC 61850 value can be seen in the Modbus memory map point list.

All frequently updated data are readable from a sequential data area. Additionally, there is a separate sequential data area for measurands and counters with a slow update rate.

3.3.5.1 Primary and per-unit values

Measurands originating from CT measurements can be obtained from the IED in two ways. They can be viewed either as primary values or as per-unit values.

The primary values are represented internally as decimal numbers. The primary units are [A] for current. The internal representation of the per-unit values is always 1.0 at nominal current. A typical range for a per-unit value is 0.00...40.00, that is 0 to 40 times nominal.



If the primary value representation is selected but no CT ratio parameters are configured in the IED, the Modbus values remain as per-unit values.

3.3.5.2 Register sizes

In most cases the measurands or counters are located in single 16 bit registers. The measurands are either unsigned or signed two's complement values while the counters are always unsigned values.

In some rare cases the measurands or counter values can be located in two consecutive registers, thus forming a single 32 bit integer value. The 32 bit value is always coded so that the high word part, that means the higher 16 bits, is located first in the lower register address. The low word part, that means the lower 16 bits, is then always in the next register address.

Register sizes and types are clearly stated in the Modbus memory map list.

3.3.5.3 Time of update

Some Modbus values may have a time structure attached to their values in the Modbus memory map. This is often the case with demand measurement values. The time structure shows the time when the value was last updated.

Table 10: *Time structure data*

Address	Register	Values	Comment
N	TimeStamp (Year,Month)		High byte:year, low byte:month
N+1	TimeStamp (Day,Hour)		High byte:day, low byte:hour
N+2	TimeStamp (Min,Sec)		High byte:min, low byte:seconds
N+3	TimeStamp (Milliseconds)		Word: milliseconds
N+4	Time quality	See the table about time quality register	

Table 11: *Time quality register*

Bit	Meaning	Values
15	Time format	0 = Local time
		1 = UTC time
14	Time source	0 = Internal (RTC)
		1 = Modbus stack
13	RTC not synchronized	0 = RTC synchronized
		1 = Not synchronized
12	RTC Failure	0 = RTC OK
		1 = RTC failure
11...0	Not used	0

3.3.6

Control operations

Refer to the Modbus control objects' memory map for the available control objects. Control operations are supported via the 4X registers.

The control objects in this IED are either single point or double point control objects.

Single point control object output types

Single point control objects can be either pulse outputs or persistent outputs.

The Modbus client can only write “1” to the pulse outputs. This write operation activates the control operation and there is no need for the Modbus client to ever write “0” to the object.

The Modbus client can write both “1” and “0” to the persistent outputs. Therefore, the persistent outputs have two defined levels: “0” and “1”.

Most of the outputs in this IED are pulse outputs.

Control operation modes

This IED supports two control models: direct-operate and select-before-operate. The single point control objects in this IED are of direct-operate type. The double point control objects can be configured either into the direct-operate or select-before-operate mode.



An output cannot support both direct-operate and select-before-operate modes at the same time.

The double point select-before-operate mode is usually used for the circuit breaker operations. It consists of four controllable objects:

- Select open
- Select close
- Cancel selection
- Operate (=execute) selection

Direct operate of a double point object consists of two controllable objects:

- Direct open (writing a “1” value opens the circuit breaker, writing a “0” value closes the circuit breaker)
- Direct close (writing a “1” value closes the circuit breaker, writing a “0” value opens the circuit breaker)



Direct operate of a double point object is always possible.
Select-before-operate control is possible if the controllable object's control model is set to “sbo-with-enhanced-security”.

3.3.6.1

Control functions

Only controls made through 4x register structures are supported in RE_615 ANSI. The circuit breaker can be operated via Modbus by using a function codes 06,16 or 23.

Only one control bit can be operated at a time when the 4X control structures are used.

Exception codes

Only a few exception code alternatives exist for the write coil and write register requests in Modbus:

- 01 = illegal function
- 02 = illegal address
- 03 = illegal value

The exception code 03 is also returned if a command operation is rejected due to the IED's other internal reasons. The client can find the code for the internal rejecting reason in the SSR6 register.

Internal control rejection reasons with coils may be, for example:

- The client has no write authority.
- The IED is in local state.
- The control operation is already reserved by another client and thus blocked.

If a positive acknowledgement is returned, the control command has been initiated by the IED.

3.3.6.2

Control operations through 4X register structures

The control outputs can be operated through the control structures in the 4X register area. This means that the control output is also located as a bit within the value and bit mask registers of the 4X control structure. Although usually less, there may be up to eight control structures defined in the IED.

The control structure operations can be controlled with passwords. As a default, no passwords exist for the structures. Any four character ASCII string can be used as a password. The password string “****” with four asterisks, that is ASCII code 42, indicates that a password is not used.

Table 12: *Single control structure*

Location	Meaning
4x Reg N	Execute register
4x Reg N+1	Password register 1 high, two ASCII characters
4x Reg N+2	Password register 2 low, two ASCII characters
4x Reg N+3	Control register
4x Reg N+4	Confirmation register

With the control operations the client must assemble the control structure register values and write them into the IED.

Execute register

Control step (select, execute or cancel) is executed when value “1” is written into this register.

Password register 1

If a password is defined, the two first ASCII characters of the four character password are written into this register: the first character into the higher byte and the second character into the lower byte of the register. If no password is defined for the control structure, this register is not checked by the IED.

Password register 2

If a password is defined, the two last ASCII characters of the four character password are written into this register: the third character into the higher byte and the fourth character into the lower byte of the register. If no password is defined for the control structure, this register is not checked by the IED.

Control register

Set the register bit corresponding to the output to the proper write value. For pulse type outputs the value is always “1”.

Confirmation register

Set the register bit corresponding to the object to be operated to “1”. All other bits must be set to zero.

Control structure register assembling order

The Modbus client can assemble all the control structure registers and write them in one multiple registers write function 16 request.

The Modbus client can also write the registers in several separate transactions or even one by one using registers write function 06. The execute register has to be written last and no more than 15 seconds may elapse between the separate register writes. The control structure operation will time out after 15 seconds after the last register write. The timeout between select and operate steps is fixed to 15 seconds regardless of the controllable object's configured timeout value.



If several clients are allowed to perform control operations simultaneously, this method should not be used by more than one of the multiple clients in question.

Exception codes

Only a few exception code alternatives exist for control structures:

- 01 = illegal function
- 02 = illegal address
- 03 = illegal value

The exception code 03 is also returned if a command operation is rejected due to the IED's other internal reasons. The client can find the code for the internal rejecting reason in the SSR6 register.

For example, the primary internal rejection reasons for control structure write operations may be that:

- The Modbus control structure write has timed out (15 sec).
- The client has no write authority.
- The IED is in the local state.
- The control operation is blocked, that means already reserved, by another client.

If a positive acknowledgement is returned, the control command has been initiated inside the IED.

3.3.6.3

Additional control operations

Secured and unsecured control operations

If the control command initiates an object that is internally defined to perform a secured control operation, the SSR6 register CmdState bits will show “Command In Progress” during the actual control operation. Once the command sequence is over, the SSR6 command state bits change to “Response Ready”. The contents of the SSR6 CmdResultCode can then be examined.

In unsecured operation mode, the positive confirmation response to a Modbus command request is based on the internal, IEC 61850 level, positive activation confirmation and not

on the command termination confirmation. In secured operation mode, the Modbus command response is always based on the termination confirmation.

The update of the SSR6 bits (sequence number + command state) is based on the termination confirmation in both operation modes. If a new control operation is issued by the client before the previous command has been concluded, that is before the SSR6 has been updated, the operation is rejected because the command operation still in progress.

Location of control structures

One or several control structures may be defined in the IED. If there are several control structures, they are located one after another in the Modbus 4X memory map. Refer to the IED's Modbus memory map for the actual locations of control structures.

3.3.7 System status registers

See Modbus ANSI point list manuals for specific register locations.

Table 13: *System status registers*

Register	Description	Address
SSR1	Device health	4xxxx + 1
SSR2	Device mode	4xxxx + 2
SSR3	Data available 1	4xxxx + 3
SSR4	Data available 2	4xxxx + 4
SSR5	Device alive counter	4xxxx + 5
SSR6	Last command result	4xxxx + 6

3.3.7.1 SSR1

The bits in SSR1 are common for all Modbus clients. The bits in SSR1 give an overview of the IEDs health. If a specific bit in this register is “1”, it signifies a warning or an error in the hardware entity in question.



More specific warning and error codes can be read from elsewhere in the Modbus memory. Refer to the Modbus memory map for these register locations.

Table 14: 16 bit SSR1 register

Bit	Meaning
0	Device global warning
1	Device global error
2	Slot 0 (X130) warning or error
3	Slot 1 (X120) warning or error
4	Slot 2 (X110) warning or error
5	Slot 3 (X100) warning or error
6	Slot 4 (X000) warning or error
7...15	0 = not used

3.3.7.2

SSR2

The bit values in SSR2 are common for all Modbus clients. The bits give an overview of the IED's mode. For example, bit 6 is activated if the IED's configured time synchronization source is lost.

Table 15: 16 bit SSR2 register

Bit	Meaning
0	Test mode (1= Device is set into test mode)
1	Local/Remote Off (0= On, 1= Off)
2	Local/Remote state (0= Remote, 1= Local, only relevant if Bit 1=0)
3...5	Active setting parameter setting group (bit 3 = LSB) 001 = Setting group 1 010 = Setting group 2 011 = Setting group 3 100 = Setting group 4
6	IED time synchronization failure (1 = Failure)
7	0 = not used
8	Last reset cause (1= Power reset)
9	Last reset cause (1= Watchdog reset)
10	Last reset cause (1= Warm reset)
11...15	0 = not used

3.3.7.3

SSR3

The bit values in the SSR3 register are Modbus client dependent.

Bits 0 and 1 are set to "1" as long as the client in question has not read out the available Modbus event or fault records.

Bit 4 is set to "1" if any momentary bit has been updated in the Modbus memory map. The bit is reset when the client reads the register.

Bit 5 is set to "1" if any MCD bit has been set in the Modbus memory map. The bit is reset when the client reads the register.

Bit 6 is set to "1" to indicate the device restart. The bit is reset when the client reads this register.

Bit 8 is set to “1” when an event record has been recorded. The bit is reset when the client writes the reset code 4 to the event record selection register.

Bit 9 is set to “1” when a fault record has been recorded. The bit is reset when the client writes the reset code 4 to the fault record selection register.

Table 16: 16 bit SSR3 register

Bit	Meaning
0	Unread event records available
1	Unread fault records available
2	0 = not used
3	0 = not used
4	Any MOM bit updated
5	Any indication MCD bit set
6	Device restart bit
7	0 = not used
8	Event record ready for reading
9	Fault record ready for reading
10...15	0 = not used

3.3.7.4

SSR4

The bit values in SSR4 are Modbus client dependent.

Bits 0...15 in the SSR4 registers correspond to different data categories in the regular Modbus memory map. Bit 0 corresponds to data category 1, bit 1 to data category 2 and so on.

If a bit is set to “1”, some data belonging to the category in question has changed since the client last scanned the register. The SSR4 bit or bits are cleared when the register is read.

The data category number for each Modbus data is shown in the Modbus memory map. The meaning of the category number is available in a separate table. If the data have not been assigned to any category, the data category number for that data is set to “0”.



See the point list manuals for data categories specific to ANSI IEDs.

Table 17: 16 bit SSR4 register

Bit	Meaning	Data category
0	Data in category 1 changed	1 = Physical inputs
1	Data in category 2 changed	1 = Protection function pickup/trip
2	Data in category 3 changed	1 = LED Alarm
3	Data in category 4 changed	1 = New disturbance record available
4	Data in category 5 changed	1 = New demand values
5	Data in category 6 changed	1 = New peak demand values
6	Data in category 7 changed	0
7	Data in category 8 changed	0
8	Data in category 9 changed	0
9	Data in category 10 changed	0
10	Data in category 11 changed	0
11	Data in category 12 changed	0
12	Data in category 13 changed	0
13	Data in category 14 changed	0
14	Data in category 15 changed	0
15	Data in category 16 changed	0

3.3.7.5

SSR5

SSR5 is a device alive counter. SSR5 simply counts upwards from 0 to 65535 and then starts over. The meaning of this register is to assure that the device is actually operating.

3.3.7.6

SSR6

SSR6 is a last command register. This client dependent SSR6 register shows the result of a specific client's last write attempt. This is especially useful if the exception code 03 appears or if the command initiates a secured control operation. The client will only see its own results, not the results of other clients. A client with no write authority will receive a 0x0000 value response when reading this register.

Table 18: 16 bit SSR6 register

ClientCmdSEQNo				Cmd State		Resp Type		CMDResultCode							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

ClientCmdSEQNo

Counts the client's control operations from 0000...1111, that is 0...15, and then starts over.

CmdState

00 = No write command has ever been issued by this client

01 = Command in progress

11 = Response Ready

RespType

01 = Unsecured control response

10 = Secured control response

11 = Modbus 03 exception response valid. CMDResultCode is in this case 0. The reason for the 03 exception is an invalid written value.

Table 19: CMDResultCode

Code	Meaning
0	OK
201	Device in local mode
202	Control operation reserved by another client
203	Select-timeout or Execute/Cancel without select
204	Control operation internally blocked
205	Control operation timed out
250	Other reason

3.3.8

Event records

The IED creates a Modbus event record when a momentary digital input bit changes its value. The IED then stores the changed Modbus bit location and value into the Modbus event record buffer. The event time tag is also stored into the record. The time tag includes a full time stamp from a year down to milliseconds.

The size of the IED's internal Modbus event record buffer is 500 events. The 500 latest events are at any time readable from the IED. When the Modbus event record buffer becomes full, the IED overwrites the oldest event records in the buffer.

Multiple clients support

Several Modbus clients can independently of one another read out Modbus event records from the IED. The Modbus event buffer keeps track of where in the event buffer the different clients are reading at the moment. Clients are identified either by the serial port from where the requests are issued or by the client's IP address in the TCP/IP network. Up to 25 different IP addresses are memorized by the IED.

Multiple events reading, backwards compatibility

The original 615/620 series event reading concept only allowed reading out one event structure at a time. In later 615/620 series IED versions this was extended to include up to 10 event structures at a time. Multiple event structures reading adds one Modbus register, "Num of event records in multiple event reading", that normally should contain the amount of event structures to be read. However, it is not necessary to write a "1" into this register if the client only wants to read one event at a time. This feature provides backwards compatibility with the original event reading concept.

3.3.8.1

Single event record structure

See Modbus ANSI point list manuals for specific event record structure mappings.

Table 20: *Event record structure*

Address	Register	Values	Comment
4xxxx + 1	Event selection	1...4 and -1...-499	Write register
4xxxx + 2	Sequence Number	0...65535	
4xxxx + 3	Unread records left	0...499	
4xxxx + 4	TimeStamp (Year,Month)		High byte:year, low byte:month
4xxxx + 5	TimeStamp (Day, Hour)		High byte:day, low byte:hour
4xxxx + 6	TimeStamp (Min, Sec)		High byte:min, low byte:second
4xxxx + 7	TimeStamp (Milliseconds)		Word: milliseconds (0...999)
4xxxx + 8	Event type		See separate description
4xxxx + 9	Data Object ID 1	0 or UID high word	See separate description
4xxxx + 10	Data Object ID 2	Modbus address or UID low word	
4xxxx + 11	Data Value	Modbus data value	Value into which object has changed
4xxxx + 12	Data Value		Additional data

The event record can have two different data object identification alternatives. The data object can be identified by the Modbus address on which the object resides or it can be identified by a unique id which is platform dependent.

The identification alternative is selected with the Modbus parameter *Event ID*.

3.3.8.2

Single event record reading

As long as there are unread Modbus events available for the Modbus client in question, bit 0 of Modbus SSR3 register remains “1”.

Events are read in two steps. First, the client writes a selection code to the Event selection register. The selection code defines the type of read operation that the client wants to perform. The selected event record is loaded by the IED into the following 11 registers. Second, the client reads out the 11 registers in one multiple register read operation.



Event records can be read by using two commands, function 5 for the write operation and function 6 for the read operation, or by using function 23 that includes write and read operations in the same transaction.



If event records are read by using two commands, the positive confirmation to the write select operation tells the client that an event record has been loaded for reading. Another way to detect the positive confirmation is by monitoring the state of SSR3 bit 8.

Selection code 1: Reading the oldest unread record

When writing the selection code 1, the IED first checks the client. If the client has read events before, the IED knows which internal event has been sent to this specific client during the last reading. The IED then loads the next event, that is the oldest unread event,

into the next 11 registers. If this is the first time the client reads events from the IED, the oldest event of the Modbus event buffer is loaded into the 11 event record registers.

Selection code 2: Reading the oldest stored record

Selection code 2 always forces the event reading to go back to the oldest event in the Modbus event buffer. The oldest event record is then loaded into the 11 event record registers. After the client has read out this record, the next record becomes the oldest unread. The client can continue with the selection code 1 by reading out the oldest unread event record again.

Selection code -1...-499

A negative selection code, that is a 16 bit two's complement value, defines how many records backwards from the newest event the event record reading is to be moved. For example, the ten latest events could be read out at any time by first selecting -10, reading out the event and then continuing with the selection code 1 to read out the nine additional event records. There can be 500 event records altogether.

Selection code 3: Resetting the event read pointer

The write selection 3 is not followed by a read operation. The selection 3 means that there are no unread records in the Modbus event buffer left for the client in question, that is, the buffer is cleared. The next new event that is logged into the Modbus event buffer becomes the first unread record for this specific client.

Selection code 4: Resetting SSR3 bit 8

The write selection 4 is not followed by a read operation. The selection code only resets the bit 8 in SSR3.



If event records are read by using two commands, the client can re-read the 11 event record registers as many times as it wants. As long as no new selection write operation is performed, the contents of the 11 event record registers are not changed.

3.3.8.3

Other event record registers

Sequence number

Every Modbus event record is given a sequence number. The sequence number runs from 1 to 65535 and then rolls over to 1 again. The client can check that the sequence numbers of the recorded data are sequential. During the event buffer overflow, the client can notice a jump in the sequence numbers when some event records are lost. The gap between the new and the previous sequence number reveals exactly how many event records have been lost.

Unread records left

This register shows how many unread event records still remain unread for the client in question at a particular moment.

Time stamp registers

Time stamp is either in local time or UTC time. The time stamp alternative is selected with a Modbus parameter.

Time stamp registers usually hold two data values in the high and low byte of the registers. High byte value = RegisterValue DIV 256, Low byte value = RegisterValue MOD 256. The Milliseconds register is an exception as it contains the milliseconds 0...999 coded as such.

Event type

This register contains information to interpret the event data correctly.

Table 21: Information contained by the 16 bit register

Bit	Meaning	Values	
15	Event time stamp format	0 = Local time	1 = UTC time
14	Time stamp source	0 = Internal application	1 = Modbus stack
13	Clock not synchronized	0 = Synchronized	1 = Time not synchronized
12	Clock failure	0 = Clock OK	1 = Clock failure
11	Reserved	0	
10	Reserved	0	
9	Reserved	0	
8	Data object ID type	0 = Modbus address	1 = UID data
7...0	Data value identification	00000000 = One bit indication 00000010 = Two bit indication 00000100... 00001010 = Integer value 11111111 = reserved	00000001 = ACD indication 00000011 = SEC indication+add data 00001001 = reserved 00001011...

Event time stamp format bit 15

Event time stamp format.

Event time stamp source bit 14

The time stamp can be generated by the IED application (accurate time) or by Modbus. If generated by Modbus, the change values are detected by the Modbus background scan task. Since there is a latency time between the value change and the time when Modbus detects the change, the time stamp is not accurate in this case.

Clock not synchronized bit 13

The quality information bit is set in the IED's real-time clock if the IED has not been synchronized.

Clock failure bit 12

The quality information bit is set in the IED's real-time clock if the clock has a severe failure. Do not rely on this time stamp.

Data object ID bit 8

The coding alternatives of the data object ID registers 1 and 2 are the Modbus address or UID. The coding alternatives cannot occur simultaneously in the IED but are selected and configured at the system setup phase. The default setting is “Modbus address”.

The UID code is 32 bits wide and occupies both registers. The word order is high/low. The UID code refers to the functional design of the IED platform in which the object resides. Shortly, it means that the UID code is equal in all the platform IEDs in which the same functional design and the same Modbus object is used.

Data value identification bits 5..0

Coding of the event data value is one bit, two bits or 32 bits. The coding depends on the IEC 61850 common data class, which is the origin of the Modbus data in question.

Table 22: *Modbus event value alternatives*

Object derived from IEC 61850 Class	Meaning	One Bit Data Value	Two Bit Data Value	32 bit Data Value
SPS	Single Point Status	X		
SPC	Single Point Status of a controllable object	X		
DPS	Dual Point Status		X	
DPC	Dual Point Status of a controllable object		X	
ACT	Trip status	X		
ACD	Start/Pick-up status	X		
INS/INC	Integer status			X

Table 23: *Interpretation of the one-bit data value*

Register 4xxx binary coded value	Meaning
xxxx.xxxx.xxxx.xxx0	Object in OFF position
xxxx.xxxx.xxxx.xxx1	Object in ON position

Table 24: *Interpretation of the two-bit data value*

Register 4xxx binary coded value	Meaning
xxxx.xxxx.xxxx.xx00	Object in intermediate position (changing)
xxxx.xxxx.xxxx.xx01	Object in ON (close) position
xxxx.xxxx.xxxx.xx10	Object in OFF (open) position
xxxx.xxxx.xxxx.xx11	Object in faulty position



In case of a DPS/DPC two-bit event value (Data value identification = 2), the data object ID registers always refer to the Modbus address or UID of the CLOSE momentary value bit.

Table 25: Interpretation of the integer status data value

Register address ¹	Meaning
4xxxx	Higher 16 bit part of the 32 bit integer value
4xxxx + 1	Lower 16 bit part of the 32 bit integer value

1. See Modbus ANSI point list manual for specific event record structure mappings.

Table 26: Interpretation of the ACD data

Register address ¹	Meaning
4xxxx	xxxx.xxxx.xxxx.xxx0 Object in OFF position
	xxxx.xxxx.xxxx.xxx1 Object in ON position
4xxxx + 1	xxxx.xxxx.xxxx.xx00 Start in unknown direction
	xxxx.xxxx.xxxx.xx01 Start in forward direction
	xxxx.xxxx.xxxx.xx10 Start in backwards direction
	xxxx.xxxx.xxxx.xx11 Start in both directions

1. See Modbus ANSI point list manual for specific event record structure mappings.

Table 27: Interpretation of the SEC data

Register address ¹	Meaning
4xxxx	xxxx.xxxx.xxxx.x000 Unknown security violation
	xxxx.xxxx.xxxx.x001 Critical security violation
	xxxx.xxxx.xxxx.x010 Major security violation
	xxxx.xxxx.xxxx.x011 Minor security violation
	xxxx.xxxx.xxxx.x100 Warning
4xxxx + 1	Security violations counter, 16 bits

1. See Modbus ANSI point list manual for specific event record structure mappings.

The original SEC cnt attribute is actually defined as a 32 bit counter. The Modbus event shows the least significant 16 bits of that counter (i.e., 0 - 65535).

3.3.8.4

Multiple event records reading

It is possible to read out up to 10 sequential event records in one event select/read transaction. The number of sequential event records to be returned for reading shall be written to the Num of records register in front of the selection register. This number can be written once or it can be rewritten for each select/read transaction. If this number is never written, only one event record is returned.

If the Modbus client requests multiple event records, the returned records should also be read out by the client. One record consists of 11 registers, two records of 22 registers and so on. The read length must thus be adjusted depending on the number of records requested.

The selection/read operation is otherwise exactly similar to the single-record read case. The next records to be returned always continues from the last record in the previous read operation.

Reading out more event records than are available in the internal event buffer

The requested amount of event records is always returned for reading. For example, if 10 event records are requested, but the IED only contains five event records, the last valid event record is repeated (duplicated) in the last five event records returned. The easiest way to detect the duplication is to check the sequence number of the event records. The sequence numbers remain similar to the duplicated event records.

Extended event record structure

Table 28: Extended event record structure with the maximum of 10 event records

Address ¹	Register	Values	Description
4xxx	Num of records	1...10	Write: Number of Event structures
4xxx + 1	Selection		Write: Selection code
4xxx + 2	Sequence Number 1		Event record 1
4xxx + 3	Unread records left 1		
4xxx + 4	TimeStamp 1		
4xxx + 5	TimeStamp 1		
4xxx + 6	TimeStamp 1		
4xxx + 7	TimeStamp 1		
4xxx + 8	Event Type 1		
4xxx + 9	Data Object Id 1_1		
4xxx + 10	Data Object Id 2_1		
4xxx + 11	Data Value 1		
4xxx + 12	Data Value 1		
4xxx + 13	Sequence Number 2		Event record 2
:	:	:	
4xxx + 23	Data Value 2		Event record 3
4xxx + 24	Sequence Number 3		
:	:	:	
4xxx + 34	Data Value 3		Event record 4
4xxx + 35	Sequence Number 4		
:	:	:	
4xxx + 45	Data Value 4		Event record 5
4xxx + 46	Sequence Number 5		
:	:	:	
4xxx + 56	Data Value 5		Event record 6
4xxx + 57	Sequence Number 6		
:	:	:	
4xxx + 67	Data Value 6		Event record 7
4xxx + 68	Sequence Number 7		
:	:	:	
4xxx + 78	Data Value 7		Event record 8
4xxx + 79	Sequence Number 8		
:	:	:	
4xxx + 89	Data Value 8		Event record 9
4xxx + 90	Sequence Number 9		
:	:	:	
4xxx + 100	Data Value 9		

Address ¹	Register	Values	Description
4xxx + 101	Sequence Number 10		Event record 10
4xxx + 102	Unread records left 10		
4xxx + 103	TimeStamp 10		
4xxx + 104	TimeStamp 10		
4xxx + 105	TimeStamp 10		
4xxx + 106	TimeStamp 10		
4xxx + 107	Event Type 10		
4xxx + 108	Data Object Id 1_10		
4xxx + 109	Data Object Id 2_10		
4xxx + 110	Data Value 10		
4xxx + 111	Data Value 10		

1. See Modbus ANSI point list manual for specific event record structure mapping.

3.3.9 Fault records

A fault record is created by the IED as a set of registrations during a detected fault period. The registration includes the selected peak values and the duration values of the protection stages, the time of recording, and the sequence number for the fault record.

The size of the IED's internal Modbus fault record buffer is 100 records. The 100 latest fault records are at any time readable from the IED. The Modbus fault record is Modbus dependent and the data organization and buffer size differ from the IED's initial system level registrations. When the Modbus fault record buffer becomes full, the IED overwrites the oldest records in the buffer.

Multiple clients support

Several Modbus clients can independently of one another read out the Modbus fault records from the IED. The Modbus fault record buffer keeps track of where in the buffer the different clients are reading at the moment. Clients are identified either by the serial port from where the requests are issued or by the client's IP address in the TCP/IP network.

3.3.9.1 Fault record structure

The IED's fault record structure consists of a fixed header part and an application data part. The application data part is always IED type specific. The whole fault record including the IED-specific application data part is found in the Modbus memory map section.

Table 29: Header part of the record structure

Address ¹	Register	Values	Comment
4xxxx	Fault record selection	1...4 and -1...-99	Write register
4xxxx + 1	Sequence Number	0...65535	
4xxxx + 2	Unread records left	0...99	
4xxxx + 3	TimeStamp (Year,Month)		High byte:year, low byte:month
4xxxx + 4	TimeStamp (Day, Hour)		High byte:day, low byte:hour
4xxxx + 5	TimeStamp (Min, Sec)		High byte:min, low byte:second
4xxxx + 6	TimeStamp (Milliseconds)		Word: milliseconds (0...999)
4xxxx + 7	Time quality		
4xxxx + 8	From this location onwards starts the Fault record application data.		

1. See Modbus ANSI point list manual for specific event record structure mapping.

Fault record application data part

The data in the application section are IED type dependent. The description of the data is found in the Modbus fault record section of the Modbus memory map.

Fault record reading

As long as there are unread fault records available for the Modbus client in question, bit 1 of the Modbus SSR3 register remains “1”.

The fault record reading is done in two steps. First, the client writes a selection code to the Fault record selection register. The selection code defines the type of read operation that the client wants to do. The selected fault record is loaded by the IED into the following N registers (4xxxx-NNNN). See Modbus ANSI point list manual for specific fault record structure mapping. Second, the client reads out these registers in one multiple register read operation.



The fault records can be read by using two commands, the function 5 for the write operation and the function 6 for the read operation, or by using the function 23 that includes write and read operations in the same transaction.



If the fault records are read by using two commands, the positive confirmation to the write select operation tells the client that a fault record has been loaded for reading. Another way to detect the positive confirmation is by monitoring the state of SSR3 bit 9.

Fault record structure length

Since the application data part is IED type dependent, the length of the fault record structures vary in different types of IEDs. A client can read out more Modbus registers than are actually coded in one structure when reading out the data structures. The maximum read amount is 80 Modbus registers. The additional trailing registers contain the

value 0. The Modbus protocol will give an exception response if the client tries to read out too few registers from the fault record structure.

Selection code 1: Reading the oldest unread record

When writing the selection code 1, the IED first checks the client. If the client has been reading fault records before, the IED knows which internal fault record has been sent to this specific client during the last reading. The IED then loads the next fault record, that is the oldest unread, into the registers following the selection register. If this is the first time the client reads fault records from the IED, the oldest fault record of the Modbus fault record buffer is given to the client.

Selection code 2: Reading the oldest stored record

The selection code 2 always forces the fault record reading to go back to the oldest fault record stored in the buffer. The oldest fault record is then loaded into the registers following the selection register. After the client has read out this record, the next record becomes the oldest unread. The client can continue by reading out the oldest unread fault records again with the selection code 1.

Selection code -1...-99

A negative selection code, that is a 16 bit two's complement value, defines how many records backwards from the newest fault record the reading is to be moved. For example, the ten latest fault records can be read out at any time by first selecting -10, reading out the record and then continuing with the selection code 1 to read out the nine additional records

Selection code 3: Resetting the fault record read pointer

The write selection code 3 is not followed by a read operation. The selection 3 means that there are no unread records in the Modbus fault record buffer left for the client in question, that is, the buffer is cleared. The next new fault record that is logged into the Modbus fault record buffer becomes the first unread record for this specific client.

Selection code 4: Resetting SSR3 bit 9

The write selection 4 is not followed by any read operation. The selection code only resets bit 9 in SSR3.



If the fault records are read by using two commands, the client can re-read the given fault record registers as many times as it wants. As long as no new selection write operation is performed, the contents of the fault record registers are not changed.

Other fault record registers

Sequence number

Every fault record is given a sequence number. The sequence number runs from 1 to 65535 and then rolls over to one again. The client can check that the sequence numbers of the recorded data are sequential. During the fault record buffer overflow the client can notice a jump in the sequence numbers when some fault records are lost. The gap between the new and the previous sequence number reveals exactly how many records have been lost.

Unread records Left

This register shows how many unread fault records still remain unread for the client in question at a particular moment.

Time stamp registers

The time stamp registers usually hold two data values in the high and low byte of the registers. High byte value = RegisterValue DIV 256, Low byte value = RegisterValue MOD 256. An exception is the milliseconds register which contains the milliseconds 0...999 coded as such. Time stamp also contains a time quality register.

Time quality

Table 30: Information contained by the 16 bit (bits 15..0) register

Bit	Meaning	Values	
15	Event time stamp format	0 = Local time	1 = UTC time
14	Time stamp source	0 = Internal application	1 = Modbus stack
13	Clock not synchronized	0 = Synchronized	1 = Time not synchronized
12	Clock failure	0 = Clock OK	1 = Clock failure
11...0	Reserved	0	

Event time stamp format bit 15

The time stamp format can be selected with a Modbus parameter via the LHMI or the parameter setting tool.

Event time stamp source bit 14

The time stamp can be generated by the IED application, that is accurate time, or by Modbus. If generated by Modbus, the change values are detected by the Modbus background scan task. Since there is a latency time between the value change and the time when Modbus detects the change, in this case the time stamp is not accurate.

Clock not synchronized bit 13

The quality information bit is set in the IED's real-time clock if the IED has not been synchronized.

Clock failure bit 12

The quality information bit is set in the IED's real-time clock if the clock has a severe failure. Do not rely on this time stamp.

3.3.10 Parameter setting group selection

The active parameter setting group can be changed by writing the new setting group number to 4X register. See Modbus ANSI point list manual for specific mapping. See the IED documentation for the number of available setting groups. Exception response 3 is given if the written value is out of range or the setting group changing is blocked.

3.3.11 Time synchronization

The real-time clock inside the IED runs in UTC time. However, the local time is also known by the IED through the time parameter settings. With Modbus the IED time can be viewed and set either in local time or UTC time.

Two identical time structures are available in the Modbus memory map: the IED's local time and the internal UTC time.

Time synchronization can be given either to the local time structure or to the UTC time structure.



The IED accepts Modbus time synchronization only if the *Synch source* setting is set to “Modbus”. The parameter can be set via the LHMI path **Configuration > Time > Synchronization > Synch source**.

3.3.11.1 Real-time clock structure

Table 31: Modbus real-time clock structure

Modbus address ¹		Register contents	Values
Local Time	UTC Time		
4xxxx	4xxxx + 19	Control register	0...2
4xxxx + 1	4xxxx + 10	Year	2000...9999
4xxxx + 2	4xxxx + 11	Month	1...12
4xxxx + 3	4xxxx + 12	Day	1...31
4xxxx + 4	4xxxx + 13	Hour	0...23
4xxxx + 5	4xxxx + 14	Minutes	0...59
4xxxx + 6	4xxxx + 15	Seconds	0...59
4xxxx + 7	4xxxx + 16	Milliseconds	0...999

1. See Modbus ANSI point list manual for specific event record structure mapping.

3.3.11.2 Writing to real-time structures

The Modbus time synchronization can be done in several ways. Over the serial interface, the host's synchronization write can be given with the Modbus broadcast address “0”. Thus, all IEDs in the same serial network can be synchronized at the same time.

Method 1: Synchronization in one step

The real-time clock structure registers should be written in one multiple registers preset request (function 16) by a Modbus TCP/IP client or by a serial interface master. The IED's Modbus address or the Modbus broadcast address can be used with the serial interface. If the clock is written in one step, the write value of the control register is not checked by the IED.

Method 2: Synchronization in three steps

1. The client reserves the time synchronization by writing value “1” to the control register. If necessary, check that the reservation value is zero at the beginning. If the time synchronization writing is already reserved by another client, the IED returns the exception response 03.
2. The client writes the time structure to the IED. This can be done in one transaction or alternatively each register can be written separately.
3. The client sets the clock by writing “2” into the control register. When the value “2” is written, the timesync registers are latched onto the IED's internal clock and the reservation of the control register is released.



The Modbus broadcast address cannot be used with the synchronization method 2.

There is an internal timeout for the clock setting. The time synchronization reservation is released if the clock is not set within two minutes. The client can abort the time synchronization at any time by writing “0” into the control register. In that case the real-time clock is not set at all.

Other Modbus clients can read the currently running real-time clock even if the time writing is reserved by another client.

3.3.12

Device information

The IED's device information can be read from the Modbus registers.



If the information data are in practice shorter, the trailing registers in the response are filled with the value “0”.

The Modbus device information is based on the IED's internal IEC 61850 device information model. All internal descriptions are coded as ASCII strings. The Modbus device information ASCII string includes the information from the IED:

- IED model (max. 12 characters)
- IED type (max. 6 characters)
- IED serial number (max. 12 characters)
- IED location information (max. 34 characters)
- CPU card SW and HW revision numbers

- HMI card SW and HW revision numbers
- Slot 0 (X130) card SW and HW revision numbers
- Slot 1 (X120) card SW and HW revision numbers
- Slot 2 (X110) card SW and HW revision numbers
- Slot 3 (X100) card SW and HW revision numbers
- Slot 4 (X000) card SW and HW revision numbers



The IED does not need to contain cards in all slots nor does a specific card need to include a CPU. The SW revision information is simply omitted from the information string.

3.3.12.1

ASCII character coding

Table 32: The 8 bit ASCII character coding in the Modbus registers

Modbus register	ASCII character
Register 1 High byte	= ASCII character 1
Register 1 Low byte	= ASCII character 2
Register 2 High byte	= ASCII character 3
:	:

3.3.12.2

ASCII string syntax

Syntax:

C(model;type;serialNo;location;swRev;hwRev)H(swRev;hwRev)0(swRev;hwRev)1(swRev;hwRev)2(swRev;hwRev)3(swRev;hwRev)4(swRev;hwRev)

- Parenthesis and semicolon ASCII characters are used as delimiters inside the string.
- Section C (. . .) contains IED information and CPU version information.
- Section H (. . .) contains version information of the local HMI card.
- Sections 0 (. . .) to 4 (. . .) contain version information of the additional HW cards (slots 0...4).
- If an additional card does not include any version information, it is signalled with a “-” (minus) character in the swRev field. If both swRev and hwRev are signalled with “-” signs, the card in question does not exist in the IED.



Example of an identification string could be:

C(REF615;FE01;1VHR123456R2;feeder
15.12;1.6;2.0)H(1.2;3.1)0(-;-)1(-;1.1)2(-;1.0)3(-
;1.1)4(-;2.0)

The data within the C section is restricted to certain maximum lengths. For example, the user definable IED location is here restricted to a maximum of 34 characters. If the IED location information on system level contains more characters, only the 34 first characters are displayed.

3.3.13 Reset time structure

The time and cause of the IED's last reset are stored into this structure. The reset time is taken directly from the IED's RTC at the startup. The clock might not be accurate and the data can be corrupted.

Table 33: *Reset time structure*

Address ¹	Register	Values	Comment
4xxx	TimeStamp (Year,Month)		High byte:year, low byte:month
4xxx + 1	TimeStamp (Day,Hour)		High byte:day, low byte:hour
4xxx + 2	TimeStamp (Min,Sec)		High byte:min, low byte:seconds
4xxx + 3	TimeStamp (Milliseconds)		Word: milliseconds
4xxx + 4	Time Quality	See Time quality table	
4xxx + 5	Cause of reset	1 = Power reset	
		2 = Watchdog reset	
		3 = Warm reset	

1. See Modbus ANSI point list manual for specific event record structure mapping.

Table 34: *Time quality*

Bit	Meaning	Values
15	Time format	0 = Local time
		1 = UTC time
14	Time source	0 = Internal (RTC)
13	RTC not synchronized	0 = RTC synchronized
		1 = Not synchronized
12	RTC Failure	0 = RTC OK
		1 = RTC failure
11...0	Not used	0

Section 4 Modbus parameters and diagnostics

4.1 Parameter list

The Modbus parameters can be accessed with PCM600 or via the LHMI path
Configuration > Communication > Modbus.

Table 35: MODBUS settings

Parameter	Values (Range)	Unit	Step	Default	Description
InOv	0=False 1=True			0=False	Modbus Internal Overflow: TRUE-System level overflow occurred (indication only)
Serial port 1	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for Serial interface 1
Parity 1	0=none 1=odd 2=even			2=even	Parity for Serial interface 1
Address 1	1...255			1	Modbus unit address on Serial interface 1
Link mode 1	1=RTU 2=ASCII			1=RTU	Modbus link mode on Serial interface 1
Start delay 1	0...20	char		4	Start frame delay in chars on Serial interface 1
End delay 1	0...20	char		3	End frame delay in chars on Serial interface 1
Serial port 2	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for Serial interface 2
Parity 2	0=none 1=odd 2=even			2=even	Parity for Serial interface 2
Address 2	1...255			2	Modbus unit address on Serial interface 2
Link mode 2	1=RTU 2=ASCII			1=RTU	Modbus link mode on Serial interface 2
Start delay 2	0...20			4	Start frame delay in chars on Serial interface 2
End delay 2	0...20			3	End frame delay in chars on Serial interface 2
MaxTCPClients	0...5			5	Maximum number of Modbus TCP/IP clients

Section 4

Modbus parameters and diagnostics

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Parameter	Values (Range)	Unit	Step	Default	Description
TCPWriteAuthority	0=No clients 1=Reg. clients 2=All clients			2=All clients	Write authority setting for Modbus TCP/IP clients
EventID	0=Address 1=UID			0=Address	Event ID selection
TimeFormat	0=UTC 1=Local			1=Local	Time format for Modbus time stamps
ClientIP1				000.000.000.000	Modbus Registered Client 1
ClientIP2				000.000.000.000	Modbus Registered Client 2
ClientIP3				000.000.000.000	Modbus Registered Client 3
ClientIP4				000.000.000.000	Modbus Registered Client 4
ClientIP5				000.000.000.000	Modbus Registered Client 5
CtlStructPWd1				****	Password for Modbus control struct 1 ¹ , 9, 17, 25...
CtlStructPWd2				****	Password for Modbus control struct 2, 10, 18, 26...
CtlStructPWd3				****	Password for Modbus control struct 3, 11, 19, 27...
CtlStructPWd4				****	Password for Modbus control struct 4, 12, 20, 28...
CtlStructPWd5				****	Password for Modbus control struct 5, 13, 21, 29...
CtlStructPWd6				****	Password for Modbus control struct 6, 14, 22, 30...
CtlStructPWd7				****	Password for Modbus control struct 7, 15, 23, 31...
CtlStructPWd8				****	Password for Modbus control struct 8, 16, 24, 32...
Internal Overflow	0=False 1=True			0=False	Modbus Internal Overflow: TRUE-System level overflow occurred (indication only)

1. The amount of available control structures may vary depending on the IED type.

4.2 Monitored data

The Modbus serial monitored data can be accessed with PST or via the LHMI path **Monitoring > Communication > Modbus > Serial**.

Table 36: *Modbus serial*

Parameter	Values (range)	Description
Received frames N ¹	0...2147483648	Received Modbus frames by instance N
Transmitted frames N	0...2147483648	Transmitted Modbus frames by instance N
Cksm Err N	0...2147483648	Checksum errors detected by instance N
Transmitted Exec A N	0...2147483648	Transmitted exception responses 1 and 2 by instance N
Transmitted Exec B N	0...2147483648	Transmitted exception responses 3 by instance N
Status N	True, False	Status of communication, instance N
		Reset of diagnostic counters instance N

1. N = instance number 1, 2...

The Modbus Ethernet monitored data can be accessed with PST or via the LHMI path **Monitoring > Communication > Modbus > Ethernet**.

Table 37: *Modbus TCP/IP*

Parameter	Values (range)	Description
Received frames N ¹	0...2147483648	Received Modbus frames by instance N
Transmitted frames N	0...2147483648	Transmitted Modbus frames by instance N
Transmitted Exec A N	0...2147483648	Transmitted exception responses 1 and 2 by instance N
Transmitted Exec B N	0...2147483648	Transmitted exception responses 3 by instance N.
Cn Rejects No socket	0...2147483648	Connection rejections due to no free sockets
Cn Rejects Not reg	0...2147483648	Connection rejections due to not registered client IP.
Status N	True, False	Status of communication, instance N
		Reset of diagnostic counters instance N

1. N = instance number 1, 2...

Section 5 Glossary

615/620 series	Series of numerical IEDs for basic, inexpensive and simple protection and supervision applications of utility substations, and industrial switchgear and equipment
ACD	Start/pickup status
ACT	Application Configuration Tool in PCM600; Trip status
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
CmdState	Command state
CPU	Central processing unit
CT	Current transformer
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
DPC	Double point control
DPS	Double point status
DS	Data set
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
HMI	Human-machine interface
HW	Hardware
IEC 61850	International standard for substation communication and modelling
IED	Intelligent electronic device
INS/INC	Integer status
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
LED	Light-emitting diode
LHMI	Local human-machine interface
LSB	Least significant bit

MCD	Momentary change detect
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
Modbus ASCII	Modbus link mode. Character length 10 bits.
Modbus memory map	Allocation of accessible protocol data
Modbus RTU	Modbus link mode. Character length 11 bits.
Modbus TCP/IP	Modbus RTU protocol which uses TCP/IP and Ethernet to carry data between devices
MOM	Momentary position
PCM600	Protection and Control IED Manager
PLC	Programmable logic controller
PST	Parameter Setting Tool in PCM600
RS-485	Serial link according to EIA standard RS485
RTC	Real-time clock
RTU	Remote terminal unit
SCADA	Supervision, control and data acquisition
SEC	Security violation
SPC	Single point status of a controllable object
SPS	Single point status
SSR1	System status register for device health
SSR2	System status register for device mode
SSR3	System status register for data available 1
SSR4	System status register for data available 2
SSR5	System status register for device alive counter
SSR6	System status register for last command result
SW	Software
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
UDR	User-definable register
UID	Unique ID
UTC	Coordinated universal time

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