Relion® Protection and Control

620 series
IEC 60870-5-103 Communication Protocol Manual

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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

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

The engineering guide provides information for IEC 61850 engineering of the protection IEDs with PCM600 and IET600. This guide concentrates especially on the configuration of GOOSE communication with these tools. The guide can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service. For more details on tool usage, see the PCM600 documentation.

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 other supported protocols.

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 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.

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.

1.3.2 Document revision history

Document revision/date	Product series version	History
A/2013-05-07	2.0	First release

Download the latest documents from the ABB Website http://www.abb.com/substationautomation.

1.3.3 Related documentation

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

1.4 Symbols and conventions

1.4.1 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 of 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 is necessary to understand that under certain operational conditions, operation of damaged equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Document conventions

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.
  To navigate between the options, use  and  .
- HMI menu paths are presented in bold.
  Select **Main menu/Settings**.
- WHMI menu names are presented in bold.
  Click **Information** in the WHMI menu structure.
- LHMI messages are shown in Courier font.
  To save the changes in non-volatile memory, select `Yes` and press  .
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.
  The corresponding parameter values are "On" and "Off".
- IED input/output messages and monitored data names are shown in Courier font.
  When the function starts, the `START` output is set to TRUE.

Section 2 IEC 60870-5-103 overview

2.1 IEC 60870-5-103 standard

IEC 60870-5-103 is defined as a companion standard for the informative element of protection equipment. While the official IEC 60870-5-103 standard dates back to 1997, the protocol has its roots in the VDEW6 communication protocol from the late 1980's. A VDEW6 device can be seen as a subset of an IEC 60870-5-103 device but not the opposite.

IEC 60870-5-103 defines communication for a serial, unbalanced link only. Communication speeds are defined as either 9600 or 19200 baud.

Standard documentation

This manual assumes that the reader has some basic knowledge of the IEC 60870-5-103 protocol and the standard IEC 60870 documents relating to the protocol.

Table 1: Standard IEC 60870 documents relating to IEC 60870-5-103

IEC 60870 document part	Description
5-1	Transmission frame formats
5-2	Link transmission procedures
5-3	General structure of application data
5-4	Definition and coding of application information elements
5-5	Basic application functions
5-6	Conformance testing guidelines
5-103	Companion standard for the informative interface of protection equipment.

The IEC 60870-5-1…6 parts are also used in communication protocols like IEC 60870-5-101 and IEC 60870-5-104.

Interoperability and interchangeability

An IEC 60870-5-103 device can be interoperable and interchangeable or only interoperable. Interoperability means that any required application data in the device, which can be coded into an IEC 60870-5-103 data type, can be mapped into the IEC 60870-5-103 address space. This data is recognized by any IEC 60870-5-103 master.

Interchangeability means supporting the application data (informative elements) whose semantics are pre-defined by the IEC 60870-5-103 standard. However, only a very limited set of application data informative elements has been defined by the

standard. It should also be noticed that these sets of data are mainly defined for a single-function protection IED. The 620 series IEDs in turn are multifunctional protection and control IEDs whose internal data model is based on the IEC 61850 standard.

Interoperability list

The standard requires the IEC 60870-5-103 device to provide an interoperability list, which actually is more an interchangeability list. See the point list manual for a complete list of all IEC 60870-5-103 data available in a specific IED..

Default data mapping principle

Whenever possible, process data is mapped into standard IEC 60780-1-103 function types and information numbers. When this is not possible, the process data is mapped into private function types and information numbers. General principle of the mapping is to keep all process data belonging to the same function design inside the same IEC 60870-5-103 function type definition. However, if this default mapping principle causes interoperability problems with older installations, every available IEC 60870-5-103 process data point can be freely remapped with PCM600. All the mapped data is not in use by default.

2.2 Documentation

Address information concerning IEC 60870-5-103 process data stated in this document is similar in all 620 series IEDs. The rest of the IEC 60870-5-103 application data are IED variant dependent.

A newer SW version of the same IED configuration may contain additional IEC 60870-5-103 points.

The IEC 60870-5-103 points list documentation of a certain IED configuration and SW version is available in addition to this document. It is essential to know the device type, configuration name and SW version to locate the correct IEC 60870-5-103 points listings.

Table 2: Example of IED information needed to locate the correct IEC 60870-5-103 points list

LHMI or WHMI path	IED information
Information/Product identifiers/Type	REF620
Information/Product identifiers/Configuration name	FE201
Information/Product identifiers/SW version	1.0

Section 3 Vendor-specific implementation

3.1 Product series implementation

IEC 60870-5-103 is specified for single function protective equipment with a limited set of process data. Some extensions are necessary for supporting the IEDs.

- Multiple protection functionality
- Objects with four valid positions such as circuit breakers or disconnectors
- Circuit breaker and disconnector control operations
- Class 1 event overflow handling

Since these features are not a part of the IEC 60870-5-103 standard, it is not likely that different vendors have implemented them in the same manner. However, it is guaranteed that the IEDs in this product series are equally implemented concerning these features. In addition of having product series-specific default settings for private function type and information number application data definitions, the user can reprogram these settings if required. The user can also affect the way in which Class 1 event overflows should be treated and reported.

ASDU type 2 data is generally supported. This means the generation of a fault number and a relative time stamp for protection related Class 1 events. Despite the default ASDU type settings it is possible for the user to configure either ASDU type 1 or 2 separately for each private Class 1 data.

Different Class 2 measurand value sets are selectable. All the standardized ASDU 3 (Meas I) and ASDU 9 (Meas II) sets can be selected. Additionally some IED-dependent private ASDU 9 frames are also provided. It is also possible for the user to freely define an own (private) Class 2 measurand set.

IEC 60870-5-103 disturbance files are supported. The IEC 60870-5-103 communication stack adapter contains a conversion functionality between the IED's native disturbance recorder files and the IEC 60870-5-103 specific disturbance recorder data and settings definitions.

3.2 Communication link

The IEC 60870-5-103 protocol can only operate on a serial communication link. The standard defines serial data characteristics.

Table 3: Serial data characteristics

Parameter	Value
Com speed	9600 or 19200 bauds
Data bits	8
Parity	Even
Start bits	1
Stop bits	1

Depending on the IED model and variant, the serial communication cards can host one or several serial channels. The IEC 60870-5-103 protocol can operate in up to two instances and therefore supporting two IEC 60870-5-103 masters in parallel. The two instances will share the same point configuration, but each instance has its own independent Class 1 event buffer. Instances can also have different Class 2 measurand frames. Separate link setting parameters exist for both instances. Setting parameters have the suffixes 1 or 2 depending on the instance.

3.2.1 Communication link setup

Serial communication link setup in the IED is divided between serial driver setup and protocol link setup. Serial drivers are related to the physical serial ports of the IED. If the IED has two physical ports, they are named COM1 and COM2. Setting parameters for COMn (n = 1 or 2) ports are found in **Configuration/ Communication/COMn**. The COMn setting parameters are protocol-independent and related to the physical link. The communication speed is set in the COMn parameters.

For the COM port parameter settings and hardware setup, see the technical manual.

The COM port connection type, optical ST or EIA-485 connection, star or loop topology, idle state (light on or light off) and the bias and bus termination are selected with the COM port jumpers.

Once the COMn port is configured, the next step is to attach the IEC 60870-5-103 protocol to the port. This is done by the setting parameters of the communication protocol in question. The IEC 60870-5-103 protocol setting parameters are located in **Configuration/Communication/IEC 60870-5-103**.

For example, Serial port 1 has to be set to COM2 and Address 1 to 25 to attach IEC 60870-5-103 instance 1 to the COM2 port and assign the link unit address to 25.

- Serial port 1 = COM2
- Address 1 = 25

The suffix 1 in a parameter name is related to instance 1. With the communication speed selection on COM2, these settings suffice to make the communication link operate.

3.2.2 Diagnostic counters

The IEC 60870-5-103 protocol diagnostic counters can be viewed via LHMI path **Monitoring/Communication/IEC 60870-5-103/Serial**. Counters related to the IEC 60870-5-103 link instances 1 and 2 have the suffixes (n) 1 and 2. The diagnostic counters show complete IEC 60870-5-103 link frames and link errors. The serial drivers (COMn) have their own diagnostic counters for lower-level serial communication errors. The COMn counters count all the messages on the serial line. It is possible to reset the diagnostic counters by setting the *Status value* to "True". When an IEC 60870-5-103 instance has never been polled by the master, the diagnostic counters belonging to the instance contain value -1. Counter value 0 in turn means that the instance is in use, but no messages have been detected after counter reset.

The diagnostic status indication automatically turns from "True" to "False" when there has not been any incoming IEC 60870-5-103 messages directed to the IED within 15 seconds. The status indication object is also visible in the IED's configurable application data and is used, for example, to lit a dedicated "Communication Error" LED on the front panel.

Table 4: Protocol diagnostic counters

Counter	Values (range)	Default	Description
Status 1	False = Communication inactive True = Communication active	False	Status (read) Reset diagnostic (write)
Received frames 1	-1...2147483646		Received frames
Checksum errors 1	-1...2147483646		Checksum errors
Transmitted frames 1	-1...2147483646		Transmitted frames
Status 2	False = Communication inactive True = Communication active	False	Status (read) Reset diagnostic (write)
Received frames 2	-1...2147483646		Received frames
Checksum errors 2	-1...2147483646		Checksum errors
Transmitted frames 2	-1...2147483646		Transmitted frames

3.3 IEC 60870-5-103 process data

3.3.1 IEC 60870-5-103 data objects

The IEC 60870-5-103 protocol in the IEDs is built on top of the internal IEC 61850 data model. Thus, the IEC 60870-5-103 application data objects and Class 1 events are derived from IEC 61850 data objects and data set reporting. The IEDs have a

predefined IEC 61850 data set configuration. In other words, it is predefined which internal data object changes the IEDs detect.

The available IEC 60870-5-103 Class 1 data objects in the IEDs are selected from the objects predefined in the IEC 61850 data sets. IEC 61850 data set reporting and IEC 60870-5-103 Class 1 event reporting are basically identical.

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

3.3.2 Indications

The IEC 60870-5-103 standard defines indications to be of ON/OFF type. The value coding for indications is always DPI, where only values 1 and 2 (binary 01 and 10) are used. Value 1 means OFF and value 2 means ON. Indications are assigned to IEC 60870-5-103 Class 1 data transactions.

Indications relate to general purpose signals or protection signals (start and trip). The standard defines two ASDU object types for indications: ASDU 1 and ASDU 2. ASDU 1 type is intended for general purpose objects and ASDU 2 type for protection objects.

The IEC 60870-5-103 standard was originally defined for protective equipment only. Therefore the standard does not include circuit breaker control and object definitions. For circuit breaker and disconnector position information the IEC 60870-5-103 DPI value is extended to include the values 0 and 3 (binary 00 and 11) also. These values represent the four-pole object’s intermediate and faulty positions.

3.3.2.1 ASDU 2 type fault number and relative time data

In addition to the absolute event time stamp, the ASDU 2 type requires that the message also contains a fault number and relative time data. However, these are not available in the IEC 61850 data model. Therefore, the IEC 60870-5-103 stack automatically creates a fault number, which is incremented each time the IED's internal IEC 61850 data attribute LD0.LEDPTRC1.Str.general (Start LED) is activated. Relative time is calculated from the time stamp of this same IEC 61850 data attribute. Relative time is represented as a 16 bit millisecond value which saturates to its maximum value 65535 ms if necessary.

3.3.2.2 Configuring of IEC 60870-5-103 indications

With PCM600 the user can re-configure the default IEC 60870-5-103 indication definitions.

- Add or remove existing indications
- Change function type/information number definition of indication
- Restore default function type/information number definition of indications

- Change GI assignment of indications
- Change ASDU type used by the indications
- Change the DPI value representation (four-pole objects only)
- Suppress falling edge Class 1 events (non-standard feature)

Changing the DPI value representation means that the DPI value only shows the standard defined ON and OFF values instead of four-pole values ON, OFF, INTERMEDIATE and FAULTY.

Table 5: Conversion rule for the DPI value representation

True object position	IEC 60870-5-103 value
CLOSED	ON
OPEN	OFF
INTERMEDIATE	ON
FAULTY	ON

Suppressing the falling edge, that is the OFF Class 1 events, is useful in some cases. For example, the Operate-OFF signals could often be omitted. This decreases the amount of Class 1 events and thus saves the bandwidth.

Suppressing the OFF event is an non-standard feature. The standard requires that every position change of a Class 1 object is reported.

3.3.2.3 Class 1 event overflow

The size of the Class 1 event buffer in the IED is 500 events. The IEC 60870-5-103 standard does not define any method of indicating Class 1 event buffer overflows. Instead, the standard suggests that the master performs a general interrogation integrity scan every 15 minutes (or more), in order to detect indications that have not been updated.

The IED contains a special overflow Class 1 ASDU 1 indication. The default setting of this overflow indication is FUN = 10, INF = 255. The FUN/INF definition can be changed if required. This object creates an ON event when the overflow occurs. It is also possible to take the overflow operation completely out of use and operate without any overflow indication as the IEC 60870-5-103 standard defines. The IEC 60870-5-103 instances can also be configured differently.

There are four setting parameters related to the IEC 60870-5-103 Class 1 overflow operation in the IED. The setting parameters are located via LHMI path **Configuration/Communication/IEC 60870-5-103** (parameter suffix n = 1 or 2, depending on the instance):

- *Class1OvInd n*: takes the overflow object into use. Settings: No indication, Both edges, Rising edge.
- *Class1OvFType n*: defines the Function Type (FUN) for the overflow indication.
- *Class1OvInfNo n*: defines the Information Number (INF) for the overflow indication.
- *Class1OvBackOff n*: defines how many events have to be emptied from the Class 1 event buffer until new ones are collected. Default setting is 500 (meaning the whole event buffer must be emptied).

The overflow operation preserves the oldest events in the buffer. The overflow Class 1 event is given the time stamp of the indication that first created the overflow situation. In other words, the indication event is lost and replaced with the Class 1 overflow event.

3.3.2.4 Chronology of Class 1 events

In some special cases it is possible that Class 1 events can be transmitted in a wrong chronological order. However, this never occurs for the same object and the time stamps for all Class 1 events are always correct. Reason for the disorder can be the filtering time of a physical digital input, or suppressing of the intermediate state of four-pole objects. Event detection time and reporting time are different in these cases.

3.3.2.5 Class 1 data message priorities

1. User command responses (highest priority)
2. Class 1 change events
3. Disturbance file transfer messages
4. General interrogation data responses (lowest priority)

Disturbance file transfer increases the overall response time for Class 1 change events on the IEC 60870-5-103 interface. The standard does not suggest any particular priority division between these two message types. It is therefore possible to configure the priority division between the Class 1 change events and disturbance file transfer messages. There are three possible priority levels:

- Ev High: Class 1 change events has higher priority.
- Ev/DR Equal: Priority is equal between the two message types.
- DR High: Disturbance file transfer has higher priority.

The setting parameter for the priority level is located via LHMI **Configuration/ Communication/IEC 60870-5-103/Class1Priority n**. Default level is Ev High.

3.3.2.6 LED objects

The user-definable LHMI LED object is also visible as IEC 60870-5-103 Class 1 data. In older IED versions, the LED object had only two positions: Off and Alarm

(red). The corresponding IEC 60870-5-103 Class1 LED data area shows DPI values off, “01” for Off and values on, “10” for Alarm.

In the new LED versions, the IED LED objects can be configured to use several options and colors. By default, the LED states are defined as Off, OK (green) and Alarm (red). However, the color definition for the OK and Alarm states can be configured.

Two IEC 60870-5-103 LED protocol data area alternatives are available depending on how the LEDs are used.

Example 1

If the LEDs are configured to show two positions, for example Off-OK or Off-Alarm, the LED object positions are visible in the digital input *LED area 1* with DPI values off “01” for Off and on “10” for OK or Alarm. This coding is the same as in the older IED versions.

Example 2

If LEDs are configured to show all three positions or the two positions OK-Alarm, *LED area 2* can be used. *LED area 2* data are by default configured to show all the three possible LED state values in the extended DPI data octet. This resembles the coding of double-pole objects. The possible values are “00” for None, “01” for OK and “11” for Alarm.

In case of a two-position “OK-Alarm” LED, the *LED area 2* data can be configured to show normal Off/On DPI-data using the double-point extended value to single-point value conversion. This means that the actual DPI LED values are converted as 00-to-10, 01-to-01, (10-to-10), 11-to-10. Thus, the LED state OK (“01”) is shown as value “01” (Off) and state Alarm (“11”) as value “10” (On).

LED Pos	LED area 1 DPI data	LED area 2 DPI data	Three states determination
Off	OFF	-	Area1 = Area2 = OFF
OK	ON	OFF	Area1 <> Area2
Alarm	ON	ON	Area1 = Area2 = ON

The two IEC 60870-5-103 LED areas are updated in parallel. LEDs can be configured individually. The most suitable IEC 60870-5-103 LED data object for each case can be chosen.

3.3.3 Controls

The IEC 60870-5-103 standard defines remote control of indications or control of objects without corresponding indication. Example of a controllable indication could be circuit breaker ON/OFF whose position can be monitored as a normal ASDU 1 indication, and which also can be controlled ON or OFF by the IEC

60870-5-103 client. Example of a control object without corresponding indication could be an acknowledge object, for example LED Reset.

According to the standard the remote control operations are performed using the ASDU 20 object type. Controllable indications usually can be controlled into two positions, ON or OFF. Acknowledge points can only be controlled ON. If the IED is in local mode, the remote CB controls are rejected.

3.3.3.1 Circuit breaker control model

Circuit breaker can only be controlled with DIRECT ON/OFF commands. This is due to the limitations in the IEC 60870-5-103 standard. In case the IED's internal (IEC 61850) circuit breaker control model is set to Select-Before-Operate, the IEC 60870-5-103 stack will internally emulate both SELECT and OPERATE commands toward the circuit breaker. To the IEC 60870-5-103 client the control operation always appears to be DIRECT.

3.3.3.2 Local, Remote, Station and Off states

The IED can be set to four different states: Local, Remote, Station or Off. CB controls from an IEC 60870-5-103 client are possible when the IED is in the Remote or Station state. When the IED is in the Local or Off state, the circuit breaker cannot be controlled via IEC 60870-5-103. The IEC 60870-5-103 mapping includes two ASDU1 ON or OFF points dealing with these states.

First, the classic Local or Remote ON or OFF indication, CTRL.LLN0. Loc, is the easiest signal to use on the client side. The indication shows "Local" when the IED is in the `Local or Off state and "Remote" when the IED is in the Remote or Station state. Basically, this object tells if control is possible from the IEC 60870-5-103 client at a particular moment. This object is sufficient for most users.

Second, the Remote or Station indication, CTRL.LLN0.LocRem. Station, is an extension of the Remote state of the first object.

The IED cannot distinguish if the IEC 60870-5-103 client is of the Station or Remote (NCC) type. However, it is possible to locally reject the control operations on the IEC 60870-5-103 client side based on this indication and information about the client type (NCC or Station).

3.3.3.3 Control operation rejections

The IEC 60870-5-103 standard does not take into account that the IED could have several remote client connections. It should be noticed that a remote control operation could also be rejected if another remote client is performing a control operation at the same time. The IED handles the remote command rejection in three different ways.

- Remote command to an existing object, while the IED is in Local mode or the IED is in Remote mode, but control operation is blocked for some reason

(Blocking reasons include simultaneous control being performed by another remote client):

- The command is accepted on link level (Link ACK)
- The command is rejected on application level (Negative response, COT=21)

- Remote command while the IED is still performing the previous command of the same client:
  - The command is rejected on link level (Link NAK, DFC=1)
- Remote command performed on a non-existing object:
  - The command is rejected on link level (Link NAK, DFC=0)

In the last two cases the DFC flag is used to distinguish the faults.

3.3.4 Measurands

Measurand object transmission is defined by the IEC 60870-5-103 standard. The standard does not define any method for transporting integer values like counters or enumeral objects.

Measurands are transmitted as a set of Class 2 data, referred to as a Class 2 measurands frame. According to the standard the coding of IEC 60870-5-103 measurand objects must be 13 bit signed values in the range of -1…+1.

When an IEC 60870-5-103 measurand, for example phase current, is scaled as 2.4, it means that the measurand value 1 corresponds to 2.4*In, measurand value 0.5 corresponds to 1.2*In, and so on. If the measurand value in this case exceeds 2.4*In, the IEC 60870-5-103 object value saturates at its maximum value and an overflow flag is set in the IEC 60870-5-103 object.

3.3.4.1 Class 2 measurands

The interchangeable part of the IEC 60870-5-103 standard defines that only five Class 2 measurands frames exist. Measurands transmitted in these five Class 2 frames relates to current and voltage values only. The allowed scale factors, actually meaning |max values| of per unit coded measurands, are 1.2 or 2.4. The IEDs support all five interchangeable Class 2 measurand frames defined by the standard.

Table 6: Interchangeable Class 2 measurand frames

FrameNo	ASDU	FUN[1)]	INF	Num of data	Data in the Class 2 frame
1	3	0	144	1	IL2
2	3	0	145	2	IL2, U12
3	3	0	146	4	IL2, U12, P3, Q3
4	3	0	147	2	Io, Uo
5	9	0	148	9	IL1, IL2, IL3, UL1, UL2, UL3, P3, Q3, f

1) FUN = 0 means that the Function type is coded as the Device function type which in turn is defined by the setting parameter **Configuration/Communication/IEC 60870-5-103/DevFunType n**.

3.3.4.2 Extended Class 2 measurand frames

IED-dependent frames 6 and 7

The IED also provides two private Class 2 frames that are IED type- and variant-dependent. These Class 2 frames are in the IED referred to by frame numbers 6 and 7. These Class 2 frames contain most of the transferable measurands produced by the IED in question. Frame 6 contains frequently changing updated values and frame 7 adds more, less frequently updated values, to the contents of frame 6.

See the product-specific point list manuals for detailed information concerning the contents of frames 6 and 7.

Contents of frames 6 and 7 are equal if no additional, less frequently updated values exist in the IED.

Table 7: Function type (FUN) and Information number (INF) definitions for frames 6 and 7

Frame	FUN	INF
Class 2 frame 6	10	236
Class 2 frame 7	10	237

User-definable Class 2 frame 0

As a third option, the user can freely compose an own private Class 2 frame using PCM600. The user can also configure the Function Type and Information Number for this user-definable Class 2 frame through the setting parameters *UsrFType n* and *UsrInfNo n* via LHMI path **Configuration/Communication/IEC 60870-5-103**. Default values are FUN = 10, INF = 230.

See the list of available measurands from the product-specific point list manuals.

3.3.4.3 Selection of Class 2 frame

The Class 2 frame is selected via LHMI path **Configuration/Communication/IEC 60870-5-103/Frame1InUse n**. The user can select between the user-defined frame 0, standard frames 1 to 5, or IED-dependent frames 6 and 7. Selection of frames 0 to 7 is possible even if the IED does not produce all the values required by the mentioned Class 2 frames. Values that are not available in the IED is set to 0 in the selected Class 2 data frame.

Using of several Class 2 frames simultaneously

Using several Class 2 frames simultaneously is not a standard feature. However, it is possible to define that the IED sends more than one Class 2 frame to the master. Actually up to four Class 2 frames can be defined. The additional Class 2 frame selections is defined in setting parameters *Frame2InUse n*, *Frame3InUse* and *Frame4InUse*. For example, if *Frame1InUse* is set to *"Private frame 6"* and *Frame2InUse* is set to *" User frame "*, the IED gives out Class 2 "Private frame 6" and Class 2 "User frame" responses to every second Class 2 poll made by the master.

3.3.4.4 Scaling of Class 2 measurands

All Class 2 measurands can be rescaled separately using PCM600. The scale value defines the highest value expressed by the IEC 60870-5-103 measurand. Values 1.2 and 2.4 are standard values but the IED can actually accept any value. For example, scale 4.0 for IL1 enlarges the measurand range to -4.0*In…+4.0*In. The IEC 60870-5-103 measurand value is always signed, regardless if the original value is a positive only value.

3.3.4.5 Unsupported analog values

The IEC 60870-5-103 protocol does not support the transmission of counters or integrated totals meaning cumulative values such as energy values. The IEC Technical Committee 57 has defined the companion standard IEC 60870-5-102 for this purpose.

3.3.5 Accessing non-protocol-mapped data

The IED application includes a number of general-purpose I/O data. By default, these data are mapped to this protocol. See the point list manual for the exact mappings.

The general-purpose objects can be connected to any internal object in the IED configuration application using the Application Configuration or Signal Matrix tool. This gives additional opportunities for the protocols.

Example 1

Due to security reasons, protocols do not contain mappings for the direct control of physical outputs. This way, the master cannot accidentally write a change to a physical output.

It is possible to connect general-purpose outputs to physical outputs using the Application Configuration tool. The general-purpose output can, be controlled also from the protocol.

Example 2

The legacy protocol default mappings are a selection of the most important signals produced by the IEC 61850-based IED applications. The manufacturer’s selection of important signals may not always serve every customer.

Any non-protocol-mapped internal signal can be freely connected to a general-purpose input object via the Application Configuration tool. This object can then be accessed by the legacy protocol as regular protocol application data.

Example 3

The basic IEC 61850 application model of the IED produces a great amount of information. In some cases, this is more than what is feasible to transport through a legacy protocol. Via the PCM600/Communication Management tools, unnecessary data objects can be excluded from the legacy protocol.

However, in some cases a better solution is to OR together several internal signals into one general signal. This OR output can be connected to a general-purpose input and accessed by the legacy protocol as regular protocol application data.

3.4 Other IEC 60870-5-103 data

3.4.1 Changing of parameter setting group

The IED supports remote changing of the used parameter setting group. The six possible setting groups in the IED are coded as objects Characteristic 1… Characteristic 6 using standard information numbers 23…28.

On the IED's native IEC 61850 model level the parameter setting group change object is also a setting parameter in itself, not a process object as is assumed in the IEC 60870-5-103 standard. Only process object updates get accurate time stamps from the IED system level. Consequence is that Class 1 event updates concerning changes in objects Characteristic 1…Characteristic 6 do not contain an accurate time stamp but rather a time stamp from when the change was noticed by the IEC 60870-5-103 stack.

In a normal case, any parameter setting change in the IED requires that the client first reserves the parameter setting rights, then changes the setting and finally stores the change. An exception to this is the *Parameter setting group change*

parameter. Writing remotely to this parameter automatically includes reservation and storing.

3.4.2 Device identification

3.4.2.1 Device function type

The IEC 60870-5-103 standard requires that an IED is identified as a certain Device type. The standard has only the following single functional device types:

- 128 distance protection
- 160 overcurrent protection device
- 176 transformer differential protection
- 192 line differential protection

Since the IEDs are multifunctional, the Device type is set to the private function type value 9 as default. However, if this definition would cause incompatibility with some client systems, the user can freely change the definition through the *DevFunType n* parameter located via LHMI path **Configuration/Communication/ IEC 60870-5-103/DevFunType n**.

3.4.2.2 Device identification code

The device identification information for the IED consists of three parts.

- Compatibility level (COL) = 2
- Eight character ASCII ID string
- Internal code = 4 octets

The ASCII string consists of eight characters, for example, 620FE201.

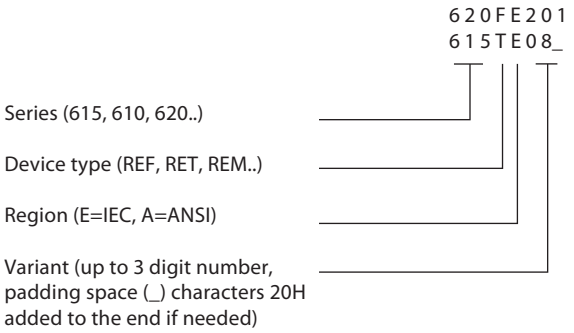

Figure 1: Examples of device identification codes

3.4.3 Time synchronization

Time synchronization over IEC 60870-5-103 is supported. This requires that the IED's global *Time Sychronization Source* parameter (in **Configuration/Time/Synchronization/Synch source**) is set to "IEC 60870-5-103" mode. If some other time synchronization source is configured for the IED, the IEC 60870-5-103 time synchronization messages will be rejected.

3.5 Disturbance recorder file transfer

The IED includes a functionality that converts the IED's natively captured disturbance file contents into IEC 60870-5-103 disturbance data. Disturbance files are also available as standard COMTRADE files through PCM600 or WHMI.

IEC 60870-5-103 disturbance recorder spontaneous Class 1 notification message (disturbance recorder file directory ASDU 23) can be enabled or disabled via the setting parameter *DR Notification n* located via LHMI path **Configuration/Communication/IEC 60870-5-103/DR Notification n**. The default setting is disabled. Purpose of this notification message is to inform the IEC 60870-5-103 client that the disturbance file directory has been updated. Usually this means that a new disturbance recording has been captured and stored by the system. If a disturbance recorder file transfer is not required from the IED, the notification is also unnecessary.

3.5.1 Disturbance recorder file directory (ASDU 23)

The disturbance recorder files IEC 60870-5-103 identification in the IED is a sequential 16 bit number starting from 1 at IED reset and is incremented for each new captured disturbance recorder file.

IEC 60870-5-103 standard defines the disturbance recorder file identification to be the fault number (FAN), which is the same number that will be generated by ASDU 2 Class 1 events during the same fault. The IED could theoretically capture several disturbance recorder files during the same fault, be triggered by a non-protection signal, triggered externally or triggered periodically. In this case the disturbance recorder file would not correspond to any particular fault detected by the IED.

The IEC 60870-5-103 directory information octet SOF, TP, TEST and OTEV bits are not supported by the IED's native disturbance recorder file system. These bits are therefore always set to 0. The TM bit is however supported.

The IEC 60870-5-103 disturbance recorder directory structure only allows up to eight disturbance recorder files to be available in the IED. If the IED's native

disturbance recorder file system contains more than eight disturbance recorder files, only the 8 latest files are accessible through IEC 60870-5-103 protocol.

The IEC 60870-5-103 disturbance recorder file directory can be requested by the client at any time. In addition, should the disturbance recorder file directory be sent spontaneously by the IED (through Class 1 report) to the client if the directory structure changes. A change in the directory structure normally means that a new disturbance recorder file has been captured and stored. It also could mean that a disturbance recorder file is deleted from the native disturbance recorder file system. Disturbance recorder files cannot be deleted by the IEC 60870-5-103 master. But the recorder file is deleted by the IED after it has been sent to the IEC 60870-5-103 master. according to the standard. Disturbance recorder files can also be deleted from PCM600, WHMI or LHMI.

3.5.2 Disturbance recorder channel identification

IEC 60870-5-103 defines channels (analog data) and tags (digital data) to be transferred from a disturbance recorder file. The IEC 60870-5-103 file transfer is random access, meaning that the client can select exactly what information to read from the file.

The standard defines the identification, ACC (actual channel), for eight channels, numbered 1...8. For example, when a client requests channel 1, it always means Phase current L1. The IED supports all the eight IEC 60870-5-103 standard channel numbers and in addition defines some private channel numbers. Private channel numbers starts from ACC 64 as is defined by the standard.

Table 8: Disturbance channel identification

ACC Number	Signal
1	Phase current IL1-A
2	Phase current IL2-A
3	Phase current IL3-A
4	Neutral current Io-A
5	Phase voltage U1-A or phase-to-phase voltage U12-A
6	Phase voltage U2-A or phase-to-phase voltage U23-A
7	Phase voltage U3-A or phase-to-phase voltage U31-A
8	Neutral voltage Uo-A
Private channel numbers	
64	Neutral current Io-B
65	Phase current IL1-B
66	Phase current IL2-B
67	Phase current IL3-B
68	Neutral voltage Uo-B
69	Phase voltage U1-B or phase-to-phase voltage U12-B
70	Phase voltage U2-B or phase-to-phase voltage U23-B
71	Phase voltage U3-B or phase-to-phase voltage U31-B

Disturbance recorder channels are the physical measurement inputs to the IED. It depends on the IED type if all the disturbance recorder channel signals are available or not. The IED may measure voltages either between phase and ground or between phases. The contents in ACC 5...8 and 69...71 are coupled directly to these voltage measurements.

The default setting of the native disturbance recorder supports the channels, meaning physical analog input channels, listed in table 8. Additional user-defined internal disturbance channels are not supported by IEC 60870-5-103. User-defined channels in the 60870-5-103 files appear as ACC=255 (unknown channel) and they cannot be read by the IEC 60870-5-103 master.

3.5.3 Disturbance recorder tags identification

According to the IEC 60870-5-103 standard the disturbance recorder tags (digital signals) are identified by the same function type/information number combination that corresponds to the signal in the normal IEC 60870-5-103 Class 1 event transfer. This rule is followed by the IED if the indication signal in question is solely connected to the disturbance recorder digital channel. If the signal, for example, is OR-ed together with other internal digital signals or if the signal is not present in the normal IEC 60870-5-103 Class 1 data, then the tag identification is always:

Function type = 5

Information number = disturbance recorder digital channel number

3.5.4 Disturbance recorder transfer

When the IEC 60870-5-103 client selects a disturbance recorder channel to be transferred, the corresponding disturbance recorder channel data is internally fetched from the IED's native disturbance recorder file, cached and converted into IEC 60870-5-103 format. This operation may take some time depending on the size of the disturbance recorder file.

Once an IEC 60870-5-103 disturbance recorder channel or tag transmission is in progress, it can be performed till the end, even if the native original disturbance recorder file simultaneously is deleted from the system. Unless the IEC 60870-5-103 master does not abort the transmission.

Disturbance recorder transfer verification

The IEC 60870-5-103 disturbance recorder file transfer implemented in the IED has been verified by a third party client software.

3.6 Non-standard features

The IEC 60870-5-103 protocol is defined for a single-function protection device with limited set of functionalities. Problem that arises in a multiple functionality IED are mainly related to the larger amount of Class 1 events typically generated during a fault. Modern multifunctional IEDs may create up to 20-40 times more events during a fault compared to single function devices that were the basis for the IEC 60870-5-103 standard. IEC 60870-5-103 has some limitations:

- The protocol is defined to be used on serial interfaces (max. allowed baud rate 19200 bauds).
- The protocol can only transfer one change event per Class 1 poll.
- Unbalanced communication: the master must poll all IEDs in the network cyclically which means that the master cannot remain polling out events from a certain IED for a very long time, since this degrades the overall response time from the whole substation.

The IED includes some possibilities to fasten up and optimize the IEC 60870-5-103 communication. However, it is necessary to verify that these features are accepted by the network and the IEC 60870-5-103 master used.

- Remove unnecessary Class 1 objects. Even if the IED can provide a lot of valuable information, it is not feasible to send everything on slower serial links.
- Remove falling edge events for selected Class 1 objects.
- Serial communication speed can be increased up to 115.2 kbauds. However, observe that all IED’s on a multidrop link must support the same communication speed.
- GI data optimization which means that not all data is sent as GI data in a GI cycle.

3.6.1 GI optimization

The master should initiate a GI always after the IED has reported a Class 1 event buffer overflow. The IED starts then to send GI data through the Class 1 event buffer. As the standard defines, new events always have higher send priority than GI data in the IED’s Class 1 buffer. The standard also defines that all data that are subject to GI is sent by the IED.

Optimization of GI data is a non-standard feature. As default the *Optimize GI n* parameter (located via LHMI path **Configuration/Communication/IEC 60870-5-103/GI Optimize n**) is set to "Standard behaviour", meaning that the GI cycle operates as defined by the standard. GI optimization strives to send less data to the master through the Class 1 report. The GI optimization in the IED is based on two facts:

- It is enough to send a certain Class 1 data once to the master after a GI initiation. This could be either the GI data report or a spontaneously updated

data report. In either case the master has the true position of the Class 1 data in its database.

- The IED also remembers which specific Class 1 data objects changes that has overflown. After the GI initiation only these marked Class 1 data objects are reported through the GI cycle.

Table 9: GI optimization alternatives

Parameter value	Description
Standard behaviour	No optimization.
Skip spontaneous	Enables the IED to not send GI data for those objects that already have been spontaneously updated by the IED (that is, sent as Class 1 events) after the initiation of a GI.
Only overflown	Enables the IED to send only the Class 1 data that it knows have overflown in the Class 1 buffer. The first GI cycle initiated after a master Reset CU or Reset FCB does not use this feature, that is, the IED keeps track of that it actually has reported a value at least once to the master since the last reset.
Combined	Combines the two optimization features explained above.

Section 4 IEC 60870-5-103 parameters and diagnostics

4.1 Parameter list

The IEC 60870-5-103 parameters can be accessed with PCM600 or via the LHMI path **Configuration/Communication/IEC 60870-5-103**.

Table 10: IEC 60870-5-103 settings

Parameter	Values (Range)	Unit	Step	Default	Description
Serial port 1	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for instance 1
Address 1	1...255			1	Unit address for instance 1
Start delay 1	0...20	char		4	Start frame delay in chars for instance 1
End delay 1	0...20	char		4	End frame delay in chars for instance 1
DevFunType 1	0...255			9	Device Function Type for instance 1
UsrFType 1	0...255			10	Function type for User Class 2 Frame for instance 1
UsrInfNo 1	0...255			230	Information Number for User Class2 Frame for instance 1
Class1Priority 1	0=Ev High 1=Ev/DR Equal 2=DR High			0=Ev High	Class 1 data sending priority relationship between Events and Disturbance Recorder data.
Frame1InUse 1	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			6=Private frame 6	Active Class2 Frame 1 for instance 1

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Frame2InUse 1	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			-1=Not in use	Active Class2 Frame 2 for instance 1
Frame3InUse 1	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			-1=Not in use	Active Class2 Frame 3 for instance 1
Frame4InUse 1	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			-1=Not in use	Active Class2 Frame 4 for instance 1
Class1OvInd 1	0=No indication 1=Both edges 2=Rising edge			2=Rising edge	Overflow Indication for instance 1
Class1OvFType 1	0...255			10	Function Type for Class 1 overflow indication for instance 1
Class1OvInfNo 1	0...255			255	Information Number for Class 1 overflow indication for instance 1
Class1OvBackOff 1	0...500			500	Backoff Range for Class1 buffer for instance 1
GI Optimize 1	0=Standard behaviour 1=Skip spontaneous 2=Only overflown 3=Combined			0=Standard behaviour	Optimize GI traffic for instance 1
DR Notification 1	0=Disabled 1=Enabled			0=Disabled	Disturbance Recorder spontaneous indications enabled/disabled

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Serial port 2	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for instance 2
Address 2	1...255			1	Unit address for instance 2
Start delay 2	0...20	char		4	Start frame delay in chars for instance 2
End delay 2	0...20	char		4	End frame delay in chars for instance 2
DevFunType 2	0...255			9	Device Function Type for instance 2
UsrFType 2	0...255			10	Function type for User Class 2 Frame for instance 2
UsrInfNo 2	0...255			230	Information Number for User Class2 Frame for instance 2
Class1Priority 2	0=Ev High 1=Ev/DR Equal 2=DR High			0=Ev High	Class 1 data sending priority relationship between Events and Disturbance Recorder data.
Frame1InUse 2	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			6=Private frame 6	Active Class2 Frame 1 for instance 2
Frame2InUse 2	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			-1=Not in use	Active Class2 Frame 2 for instance 2
Frame3InUse 2	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			-1=Not in use	Active Class2 Frame 3 for instance 2

Table continues on next page

Parameter	Values (Range)	Unit	Step	Default	Description
Frame4InUse 2	-1=Not in use 0=User frame 1=Standard frame 1 2=Standard frame 2 3=Standard frame 3 4=Standard frame 4 5=Standard frame 5 6=Private frame 6 7=Private frame 7			-1=Not in use	Active Class2 Frame 4 for instance 2
Class1OvInd 2	0=No indication 1=Both edges 2=Rising edge			2=Rising edge	Overflow Indication for instance 2
Class1OvFType 2	0...255			10	Function Type for Class 1 overflow indication for instance 2
Class1OvInfNo 2	0...255			255	Information Number for Class 1 overflow indication for instance 2
Class1OvBackOff 2	0...500			500	Backoff Range for Class1 buffer for instance 2
GI Optimize 2	0=Standard behaviour 1=Skip spontaneous 2=Only overflown 3=Combined			0=Standard behaviour	Optimize GI traffic for instance 2
DR Notification 2	0=Disabled 1=Enabled			0=Disabled	Disturbance Recorder spontaneous indications enabled/disabled

4.2 Monitored data

Table 11: Protocol diagnostic counters

Counter	Values (range)	Default	Description
Status 1	False = Communication inactive True = Communication active	False	Status (read) Reset diagnostic (write)
Received frames 1	-1...2147483646		Received frames
Checksum errors 1	-1...2147483646		Checksum errors
Transmitted frames 1	-1...2147483646		Transmitted frames
Status 2	False = Communication inactive True = Communication active	False	Status (read) Reset diagnostic (write)
Received frames 2	-1...2147483646		Received frames
Checksum errors 2	-1...2147483646		Checksum errors
Transmitted frames 2	-1...2147483646		Transmitted frames

Section 5 Glossary

620 series	Series of numerical IEDs for high-end protection and supervision applications of utility substations, and industrial switchgear and equipment
ASCII	American Standard Code for Information Interchange
ASDU	Application-layer service data unit
COMTRADE	Common format for transient data exchange for power systems. Defined by the IEEE Standard.
DPI	Double-point information
EMC	Electromagnetic compatibility
FAN	Fault number
FUN	Function type
GI	General interrogation
HMI	Human-machine interface
IEC	International Electrotechnical Commission
IEC 60870-5-101	Companion standard for basic telecontrol tasks
IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 60870-5-104	Network access for IEC 60870-5-101
IEC 61850	International standard for substation communication and modeling
IED	Intelligent electronic device
IET600	Integrated Engineering Toolbox in PCM600
INF	Information number
LED	Light-emitting diode
LHMI	Local human-machine interface
OTEV	Disturbance recording triggered from start bit
PCM600	Protection and Control IED Manager
Reset CU	Reset communication unit
Reset FCB	Reset flow control bit
SOF	Status of fault
SW	Software

TEST	Disturbance data recorded in test mode bit
TM	Disturbance data transmission in progress bit
TP	Disturbance data recorded with or without trip bit
VDEW6	Communication protocol standard for protection devices
WHMI	Web human-machine interface

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