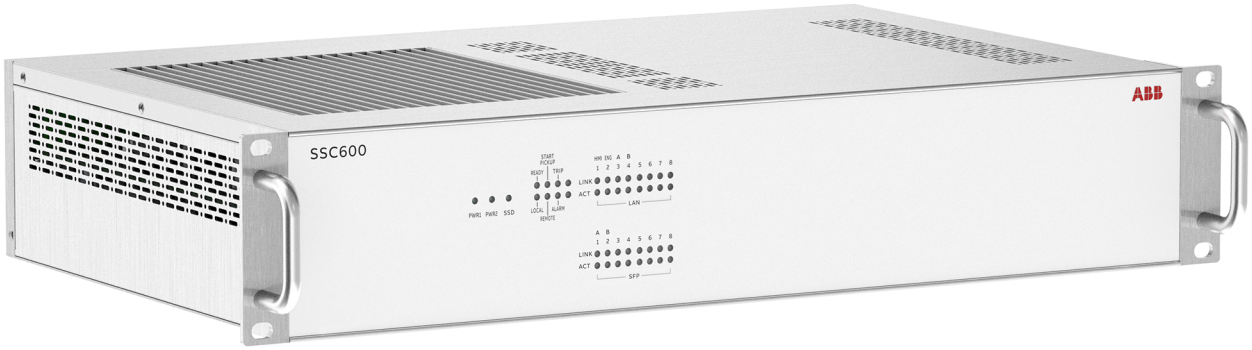
RELION® PROTECTION AND CONTROL

SSC600 and SSC600 SW

DNP3 Communication Protocol Manual



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- RoHS Directive 2011/65/EU
- RoHS Directive (EU) 2015/863 amending Annex II

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- Electrical Equipment (Safety) Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

These conformities are the result of tests conducted by the third-party testing in accordance with the product standard EN / BS EN 60255-26 for the EMC directive / regulation, and with the product standards EN / BS EN 60255-1 and EN / BS EN 60255-27 for the low voltage directive / safety regulation.

The product is designed in accordance with the international standards of the IEC 60255 series.

Contents

1 Introduction

1.1 This manual

The communication protocol manual describes a communication protocol supported by the protection relay. 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 the communication setup in a substation from a protection relay's 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

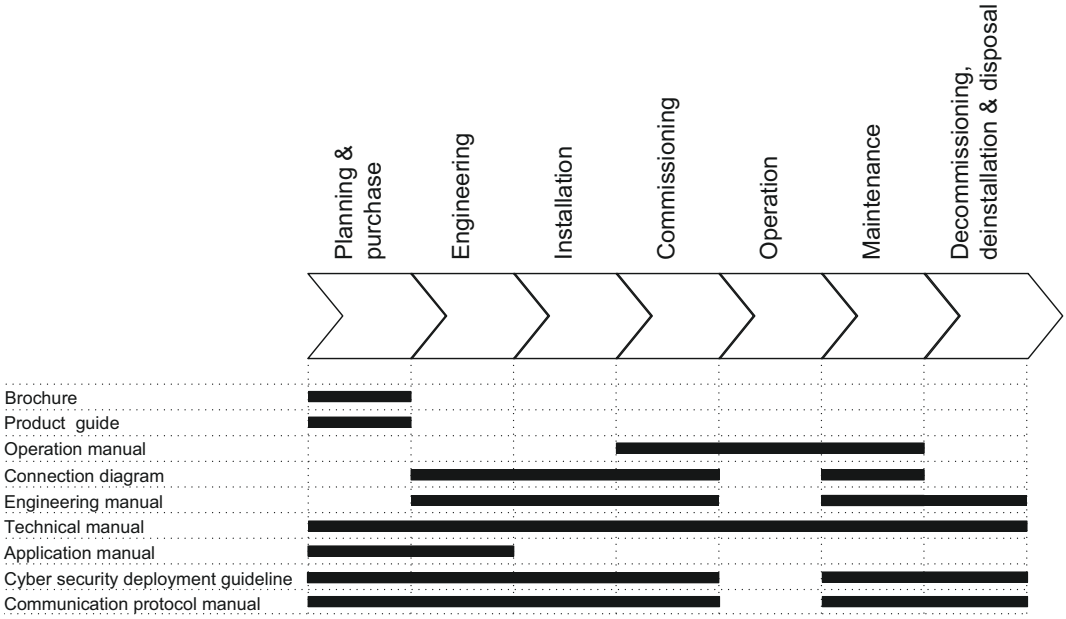

Figure 1: The intended use of documents during the product life cycle

Product series- and product-specific manuals can be downloaded from the ABB Web site.

1.3.2 Document revision history

Document revision/date	Product release	History
A/2024-12-13	1.5	First release

1.3.3 Related documentation

Download the latest documents from the ABB Web site *www.abb.com/medium-voltage*.

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 are spelled out in the glossary. The glossary also contains definitions of important terms.
- Menu paths are presented in bold.

  Select **Main menu** > **Settings**.
- 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".
- Input/output messages and monitored data names are shown in Courier font.

  When the function starts, the START output is set to TRUE.
- Values of quantities are expressed with a number and an SI unit. The corresponding imperial units may be given in parentheses.
- This document assumes that the parameter setting visibility is "Advanced".

2 DNP3 overview

2.1 DNP3 standard

The DNP3 protocol was developed by Westronic based on the early versions of the IEC 60870-5 standard telecontrol protocol specifications. Now the protocol specification is controlled by the DNP3 Users Group at *http://www.dnp.org*.

The ISO/OSI based model supported by this protocol specifies physical, data link and application layers only. This reduced protocol stack is referred to as EPA. However, to support advanced RTU functions and messages larger than the maximum frame length as defined by the IEC document 60870-5-1, the DNP3 data link is intended to be used with a transport pseudo-layer. As a minimum, this transport layer implements message assembly and disassembly services.

3 Vendor-specific implementation

3.1 Protocol server instances

The word "client" refers to the protocol master. The protection relay is referred to as "server" or a slave device.

The protection relay can communicate with several protocol clients simultaneously. Furthermore, it is possible to configure the protection relay to provide different protocol data and data outlook for different clients. A protocol server communication entity which is configured to operate with a specific master or client is called an instance.

There are three server instance scenarios.

1. One client - One protocol instance - One protocol mapping. The protection relay is intended to operate toward one protocol client. The default protocol data mapping or data outlook can be modified freely.
2. Several clients - Several protocol instances - One protocol mapping. The protection relay is intended to operate toward several protocol clients. All the clients are able to access the same data or similar data outlook. The default protocol mapping or data outlook can be modified freely.
3. Several clients - Several protocol instances - Several protocol mappings. The protection relay is intended to operate toward several protocol clients. Some or all the clients may access protocol data in a different manner, so several protocol mappings derived from the default protocol mapping need to be prepared.

3.1.1 Connection to clients

In the relay it is possible to activate up to five protocol server instances, each represented by a separate function block in the relay configuration. The five blocks are named DNPLPRT1...5. For each connected client, a protocol instance has to be activated by dragging the function block into the relay configuration. When the function block is active, its setting and monitoring parameters are visible in the HMI.

Figure 2: Function block

The protection relay restricts communication clients to five, regardless of the protocols to which the clients belong. This includes the MMS clients and other communication protocol clients. The available five DNP3 instances may be freely

activated. However, it is recommended to activate the instances in numerical order. For example, instance 1 is to be used if there is only one client connection and instances 1 and 2 when there are two clients.

First setup and configuration upload

Dragging the protocol instance function block into the relay configuration is only the first step of the protocol activation. When a protocol instance is added for the first time, it is inactive by default, meaning that it has not been assigned to a physical link port. Neither has any DNP3 data point configuration been loaded for the instance. Next step is to do these setups.

3.1.2 Protocol server attachment to a client

After its activation, an instance should be attached to the intended client.

In case of a TCP client, the instance must be first attached to the physical Ethernet port. If there are several TCP client connections, the protection relay must be able to distinguish between the clients. There are two setting parameters in an instance.

- *Client IP*: When the client makes the TCP connection, its IP address is checked. This instance is given to the client with this IP address. It is also possible to use the address “0.0.0.0” if no client IP address is to be defined. In this case, the client's IP address is ignored.
- *TCP port*: This parameter can be used in conjunction with the *Client IP* setting, thus allowing only a certain IP address at a specific TCP socket port number.

3.1.3 Several identical client connections

If several clients access the same protocol data, the client connections must still be kept apart. Also, the number of each instance used for each client must be noted so that if there are problems with the communication, the line diagnostic data for instances follows the same instance number rule.

In case of a sequential event data transaction and a TCP client connection, it is essential that a reconnecting client is given back the same instance to which it was attached before disconnecting. This way, the event reading resumes from the point where the client left off, provided that no event overflow has occurred while the client was absent. If multiple client connections are used, they must be distinguished by using the *Client IP* and *TCP port* parameters.

3.1.4 Protocol data mapping to server instances

There are two different types of data mappings for the protocol. The mappings are identified and numbered, starting from one. This number is not related to the protocol instance number.

In PCM600, it is necessary to always define the mappings to be edited or viewed.

Each protocol instance has the setting parameter *Mapping select*, which defines the protocol mappings to be used by this instance. Several protocol instances can use the same mapping. By default, the *Mapping select* parameter for all the instances is set to use the mapping number one.

Changing the mapping selection will cause the individual instance to restart.

3.2 Link modes

DNP3 can be configured to operate in Ethernet mode. The operation mode is configured with the *Port* parameter.

3.2.1 TCP/IP mode

The DNP3 TCP/IP link mode is supported by the protection relay.

The protection relay listens for a connection from a DNP3 client on the port specified by the user. The default values for the TCP port number range from 20000...20004 depending on the instance number. A different port can be selected with the *TCP Port* parameter.

3.2.2 UDP modes

UDP mode can be activated by the *Port* -parameter setting. One UDP mode is supported, "Ethernet TCP+UDP".

"Ethernet TCP+UDP" mode can be used in TCP mode with additional possibility to accept UDP broadcast messages. The relay does not send any UDP responses. In TCP+UDP mode an active TCP client connection is required to accept UDP broadcast messages from that client. UDP broadcast messages should have DNP3 broadcast address from 0xfffd to 0xffff, to reach multiple relays with the same broadcast command. The relay accepts UDP broadcast messages from the port defined for the TCP communication.

3.3 Communication setup

3.3.1 Communication modes

DNP3 communication can be set up in two alternative modes.

- Polled mode, also called “polled report by exception”. In this mode the DNP3 client always initiates the transaction with a read or write request to the DNP3 server. The server must reply with a response message.
- Unsolicited mode, called also “Unsolicited reporting mode”. In this mode the DNP3 server may spontaneously send changed class events to the client. The client can make additional read or write requests to the server.

By default, DNP3 operates in polled mode. Unsolicited reporting mode can be activated with the *UR mode* parameter.

3.3.2 DNP3 layer acknowledgements, retries and timeouts

It is possible to set up acknowledgements on both DNP3 link layer and application layer. The settings should be equal on both the client and the server sides of the communication. The timeouts must be set so that the other side has enough time to prepare a positive acknowledgement. If an acknowledgement is received after the configured timeout, it is discarded.

Confirmations, retries and timeouts can be configured via parameters.

- **Configuration** > **Communication** > **Protocols** > **DNP3.0 (n)** > **Data link confirm**
- **Configuration** > **Communication** > **Protocols** > **DNP3.0 (n)** > **Data link confirm TO**
- **Configuration** > **Communication** > **Protocols** > **DNP3.0 (n)** > **Data link retries**
- **Configuration** > **Communication** > **Protocols** > **DNP3.0 (n)** > **App layer confirm**
- **Configuration** > **Communication** > **Protocols** > **DNP3.0 (n)** > **App confirm TO**

DNP3 link layer acknowledgements should not be used in TCP/IP link mode, since the DNP3 message transport (link) is then encapsulated and secured by the Ethernet protocol.

The application layer acknowledgements also cover the link layer acknowledgements. This means that if the application message was successfully delivered, then the link layer must also have been successful. Furthermore, it is easier to perform a whole application layer retransmission rather than link layer retransmissions. Otherwise, the application layer timeout must be prepared to cover all the timeouts and retransmissions performed by the link layer.

3.3.3 Polled mode

In the polled mode the client station initiates a connection and polls periodically for static data (Class 0), and events (Class 1/2/3) from the server. Data must be polled frequently enough to prevent event overflow. If event overflow takes place, this is indicated in the IIN bits in the response message. This means that events have been lost.

3.3.4 Unsolicited reporting mode

The unsolicited mode can be enabled in the relay by the *UR mode* parameter. The operating principle is that the server sends event data spontaneously to the client. When the unsolicited mode has been activated by the setting parameter, the client station must activate UR reporting by *Enable unsolicited* Application function (20). After activation the server begins sending Class 1/2/3 events spontaneously.

The client must acknowledge the unsolicited events reported by the server to ensure the communication is fully operative. If the server does not receive acknowledgement in time, defined by the *UR TO* and *App confirm TO* parameters, it does a count of resends defined by the parameter *UR retries*. If the client station does not send acknowledgement during the count of retries, the server goes to offline mode. This means that spontaneous events are not sent for a period of time. The length of this period is defined by the parameter *UR offline interval*, (default 15 minutes). If the server should not go to offline mode, limitless retries can be achieved by setting the *UR retries* to “65535”.

Class event reporting can be buffered in the unsolicited mode by setting the Class buffer [x=1...3] dependent parameters *UR Class x Min event* and *UR Class x TO*. The event parameter UR Class x Min defines how many events must be buffered in the device before unsolicited report is sent out. The UR Class x TO parameter defines the minimum waiting time the device buffers events before sending them out after an event occurs. These parameters are useful for controlling the flow of events from the device and combining them into bigger reports.

Legacy master UR provides compatibility to some older DNP3 clients. When disabled, the server follows the DNP3 standard, sending its first unsolicited message after a connection has been established following relay reboot. The client is expected to send the Enable/Disable Unsolicited messages command to the relay. When *Legacy master UR* is enabled, the relay does not send the initial unsolicited message. Unsolicited responses are sent without the need of the Enable Unsolicited command. The client still needs to open a connection for the server to start sending unsolicited messages.

3.3.4.1 DNP3 link layer keep-alive timeout vs. UR confirmation timeouts and retransmissions

The DNP3 server's configured link keep-alive timer is reset every time a valid DNP3 client frame is received. The DNP3 client frame could be a client request or the client's confirmation to an unsolicited response message. If a link keep-alive timeout happens in the server, then the server will make some DNP3 link status requests*) to the client, and if no responses are received, then the server will consider the client lost.

If, before the keep-alive timeout happens, the DNP3 server's configured application layer retransmissions are exhausted, then the server could**)enter OFFLINE state.

***) Settings involved are:**

Data link confirm	= This setting is only relevant for variable DNP3 link frames (=application data frames). Link confirmations could then be omitted, since the application confirmation will also cover these. For fixed frame DNP3 request (f.ex. "Request DNP3 Link Status") link confirmations are always used.
Data link confirm TO	= Timeout for the confirmation.
Data link retries	= How many times the request is repeated.

****) Settings involved are:**

App layer confirm	= Application layer confirmations are always automatically enabled for all event (polled- or UR) transmissions. This setting then rather concerns all other application message types.
App confirm TO	= Timeout for the application confirmation.
UR retries	= How many retransmissions are done for a UR telegram.
UR TO	= This value is added to the configured *App confirm TO* value. And the sum is the time we wait for a confirmation to a UR telegram.

Table continues on the next page

Reason for this construction is to avoid possible UR re-collisions, by setting this value differently in each server.

UR offline interval = After the UR retries has been done, the server could enter an OFF-LINE state for the amount of minutes defined by this setting. During the OFFLINE time no UR transmissions are done. If this setting is 0, then the server never enters this state, and instead immediately starts all over with the UR retries.

It is recommended to set the *UR offline interval* =0 and let the *Link keep-alive* timeout happen instead of OFFLINE when the client has disappeared.

Also. Do not in this case use DNP3 link confirmations for application messages. Rely here only on application confirmations. This is done in the server by setting *Data Link Confirm* =Never. Of course, also the DNP3 client should not request data link confirmations from the server when doing application data requests.

3.3.5 Communication supervision and diagnostics

3.3.5.1 Communication supervision status

The DNP3 protocol provides a link to a keep-alive mechanism which can be used in Ethernet (TCP/IP) communication mode. When the client has successfully established connection to the protection relay, keep-alive messages are sent periodically by the client or protection relay, depending on which one has a lower keep-alive interval setting. Keep-alive timer is also restarted by any normal DNP3 frame, so keep-alive messages are only being transmitted after a longer idle time between frames. In the protection relay, the keep-alive timeout can be set with the *Link keep-alive (seconds)* parameter.

Default value “0” means that no keep-alive messages are sent by the protection relay. Keep-alive requests sent by the client are still responded to. If a keep-alive message is not responded to, the connection is considered broken. In case of TCP/IP connection the protection relay closes the associated TCP socket connection, and a new connection must be initiated by the client.

The DNP3 link status (True/False) is updated in the Monitoring data Status, which can also be used in Application Configuration in PCM600 for additional logic connection, for example, to a LED. DNP3 link status exists separately for each DNP3 protocol instance. True (value 1) means that the connection is active. False (value 0) means the connection has timed out. The status can be found via **Application Configuration** > **[Main Application]** > **Protocols** > **DNPLPRT** > **Monitoring** > **Status**.

In Application Configuration, the DNP3 protocol instance is represented by a function block DNPLPRTn, where n is the protocol instance number 1…5.

Use of TCP/IP connection keep-alive timeout only

When the DNP3 link keep-alive mechanism is not used in TCP/IP case, the Ethernet stack TCP socket keep-alive mechanism is still in use. If there is a TCP socket keep-alive timeout, the protection relay closes the associated TCP socket connection and updates the DNP3 link status.

3.3.5.2 Diagnostic communication counters

The diagnostic communication counters dependent on protocol instance n are provided in the protection relay. These counters can be accessed via **Application Configuration** > **[Main Application]** > **Protocols** > **DNPLPRT** > **Monitoring**.

Table 1: Diagnostic communication counters

Diagnostic counter	Description
Received frames	Total amount of received DNP3 frames
Transmitted frames	Total amount of transmitted DNP3 frames
Physical errors	Total amount of physical layer errors noticed
Link errors	Total amount of link layer errors noticed

Table continues on the next page

Diagnostic counter	Description
Transport errors	Total amount of transport layer errors noticed
Mapping errors	Total amount of protocol mapping errors noticed
Status	Shows the value "True" if the TCP/IP or serial instance is active. This means that a DNP3 client has connected to the TCP socket and DNP3 messages are received regularly at least within
Reset counters	True = Reset all diagnostic counters

For non-activated instances n, no communication diagnostic values are shown by the HMI. Diagnostic counter values are initially set to “-1” to indicate that no messages have yet been processed by the active instance. As soon as a message is received or transmitted, the counters initialize to “0”.

3.4 Data objects

3.4.1 Readable data objects

DNP3 data objects in the protection relay are all unmapped by default. Using Communication Management in PCM600, the objects can be freely added into the DNP3 memory map.

The available DNP3 data objects are taken (mapped) entirely from the native IEC 61850 application data available in the protection relay.

The DNP3 point configuration can be completed only after the protection relay's application configuration has been created.

- If a function block is removed from the configuration, the DNP3 objects belonging to the function block are automatically deleted from the DNP3 point list. If the points were mapped to DNP3 object addresses, the mapping contains gaps. However, those can be modified with Communication Management in PCM600.
- If a function block is added, the DNP3 points from this function block appear by default as unmapped in Communication Management.

3.4.2 Event classes

DNP3 objects that are not of “Static-only” type can be assigned by Communication Management in PCM600 into DNP3 event classes 1...3. Event buffering is defined per DNP3 object type and not by DNP3 event class.

Different DNP3 object types are often assigned to different DNP3 event classes.This has no consequence if the client performs class polling simultaneously to all three classes. Outstation still responds to the events in chronological order. However, there are some advantages.

- The event buffering is handled by DNP3 object type, but a possible event overflow signal is in turn given from the DNP3 event class. If a class only contains a particular object type, the overflow occurs for that DNP3 object type.
- In unsolicited reporting mode, the controlling station enables the outstation event classes that are subject to spontaneous event reporting. One or some of the event classes could then be left disabled.

3.4.3 Writable data objects

Writable objects belong to object types 10 (binary outputs) and 40 (analog outputs). Outputs are controlled through the control relay output block or analog output block commands. From the DNP3 output objects, the commands are propagated further to the native IEC 61850 control objects.

3.4.3.1 Control relay output block parameters

Controlling of the native IEC 61850 objects differs from the way that an RTU control operation is defined by DNP3. In DNP3 standard, it is assumed that the controlling station decides the control type (pulse or persistent), pulse lengths and possible pulse trains (number of pulses). These control parameters are given to the RTU outstation in the CROB command. In the IEC 61850 standard, the same parameters and few additional parameters are configured as properties of the control objects. The control command issued to the control object is only a trigger. In a protection relay, the control object knows how to perform the physical control operation.

In CROB data, the given pulse type and pulse length values are ignored by the outstation. The only data that is checked by the outstation is the direction (ON or OFF). If the IEC 61850 data object is of persistent type, OFF is also possible. When controlling a double-pole IEC 61850 data object, the direction information is used.

DNP3 protocol stack only accepts the standard combinations of OpType/TCC fields. This means in practice only specific combinations are supported, and the rest of the combinations are discarded and "not supported" return value is responded. *Table 2* describes the operation direction for the combinations.

Table 2:

TCC	OpType	DPC	SPC
NULL	PulseOn	Close	1
NULL	LatchOn	Close	1
NULL	LatchOff	Trip	0
Close	PulseOn	Close	1
Trip	PulseOn	Trip	0

3.4.3.2 Direct operate and select before operate

Both direct-operate and select-before-operate DNP3 control functions are supported for binary outputs.

In the native IED IEC 61850 data, these control operation differences are referred to as the control model. The control model is in turn configured as a property of the control object. Thus, an IEC 61850 control object can be either in “Direct” or “SBO” mode. This is applicable for double-point control objects. Single-point control

objects in the protection relay always work in “Direct” mode. Depending on the control model setting of the native IEC 61850 control object, various DNP3 control functions can be performed.

Table 3: Available control models

IEC 61850 control model	Supported DNP3 control function
Direct	Direct only
SBO	Direct or SBO

When making a DNP3 direct command to an SBO configured object, the desired behavior can be defined in Communication Management. In case the direct control mode property is set to “Always allowed”, the DNP3 stack automatically performs the two needed commands to the native control object. Direct control is always allowed. In case the direct control mode property is set to “Control model”, the DNP3 control command must follow the native IEC 61850 objects' control model. SBO control must be used in the SBO mode.

The DNP3 stack has a protocol-dependent parameter setting for the timeout between Select and Operate commands. The default value is "10 seconds" but it can be changed via *CROB select timeout* parameter. Also, the native control object has a configured timeout for the SBO operation. Since the control object may also be available for Local (manual) control, a longer timeout is often required. The DNP3 timeout should be set lower than the native control object's timeout.

3.4.3.3 Command blockings

According to the DNP3 standard, an outstation is considered to have the states “Local” or “Remote”. The IEC 61850 IED in turn can be in “Local”, “Station”, “Remote”, “Off”, or “All” state. A DNP3 controlling station can perform control operations in “Station”, “Remote”, and “All” protection relay states. However, it is the controlled protection relay's application in the outstation that rejects or accepts control operations based on the control allowance states and not the DNP3 protocol stack. In an RTU (non-intelligent outstation) application, the DNP3 stack rejects the commands.

3.4.4 Data object mapping

As the relay is a freely configurable device, almost all internal IEC 61850 data objects can be mapped to DNP3. The internal native IEC 61850 objects have been assigned with potential (empty) DNP3 mappings according to the general rules based on IEC 61850 common data classes (CDC).

The following data is unmapped: the Beh and Mod attributes of every logical node and some redundant data objects within the generic function blocks.

[1] Configurable with the Communication Management tool

Table 4: Mapping rules

Common Data Class	Description	Attribute [1]	DNP3 data type
SPS	Singe point status	stVal	BI data
SPC	Controllable single point status	stVal	BI data
		Oper.ctlVal	BO data
DPC	Controllable double point status	stVal [2]	Double Point and AI data
		Oper.ctlVal	BO data
ACD	Protection activation detection (Start)	general	BO data
		dirGeneral	AI data
		phsA	BI data
		phsB	BI data
		phsC	BI data
		neut	BI data
ACT	Protection activation (Operate)	general	BI data
		phsA	BI data
		phsB	BI data
		phsC	BI data
		neut	BI data
INS	Integer value	stVal	AI data
INC	Controllable integer value	stVal	AI data
		Oper.ctlVal [3]	AO or set of BO data
ENS	Enumeral value	stVal	AI data
ENC	Controllable enumeral value	stVal [4]	AI data or set of BI data
		Oper.ctlVal [3]	AO or set of BO data
MV	Measurement value	mag.f	AI data
		instMag.f	
CMV	Complex meas value	instCVal.mag.f	AI data
		cVal.mag.f	
DEL	Phase-to-phase measurements	phsAB.instCVal.mag.f	AI data
		phsAB.cVal.mag.f	AI data
		phsBC.instCVal.mag.f	AI data
		phsBC.cVal.mag.f	AI data
		phsCA.instCVal.mag.f	AI data
		phsCA.cVal.mag.f	AI data

Table continues on the next page

[1] A data object need not contain all data attributes that are listed for the object class in question.
[2] Switchgear position data is available as either Double Point or AI data for backward compatibility.
[3] AO data is supported. In some cases, there is also an alternative BO mapping for this kind of objects.
[4] AI data is supported. In some cases, there is also an alternative set of BI data mapping for this kind of objects.

Common Data Class	Description	Attribute [1]	DNP3 data type
WYE	Phase-to-ground measurements (filtered)	phsA.instCVal.mag.f	AI data
		phsA.cVal.mag.f	AI data
		phsB.instCVal.mag.f	AI data
		phsB.cVal.mag.f	AI data
		phsC.instCVal.mag.f	AI data
		phsC.cVal.mag.f	AI data
		neut.instCVal.mag.f	AI data
		neut.cVal.mag.f	AI data
		net.instCVal.mag.f	AI data
		net.cVal.mag.f	AI data
		res.instCVal.mag.f	AI data
		res.cVal.mag.f	AI data
SEQ	Sequence of components	c1.instCVal.mag.f	AI data
		c1.instCVal.ang.f	AI data
		c2.instCVal.mag.f	AI data
		c2.instCVal.ang.f	AI data
		c3.instCVal.mag.f	AI data
		c3.instCVal.ang.f	AI data
BCR	Binary counter	actVal	Counter data
ISC	Integer controlled step position	valWTr.posVal	AI data
BCS	Binary controlled step position	valWTr.posVal	AI data
		Oper.ctlVal	AO data

3.4.5 Update rate of analog and indication protocol data

Prioritized datapoint changes are detected immediately, other datapoints are polled at a 100ms interval. Detected changes are buffered and sent out by the DNP3 communica-tion stack every second.

3.5 Standard data object types

3.5.1 Binary inputs

DNP3 object type 1, binary input objects are derived from IEC 61850 data object's boolean type attributes, mainly from data classes SPS, SPC, ACD and ACT. Also, a few binary input objects have been converted from enumeral INS and INC classes (ENS and ENC classes in Edition 2).

[1] A data object need not contain all data attributes that are listed for the object class in question.

The circuit breaker and disconnector double point data objects, containing open and close bits, also exist in the DNP3 map as normal single binary input alternatives. These are intended for DNP3 controlling stations that do not support the double bit input DNP3 data type alternative (Object group 3).

DNP3 object type 2, binary input change events can buffer up to 32768 events. When the buffer becomes full, the new events are discarded until more space is available in the event buffer.

Binary inputs which are not of “Static-Only” type can be assigned to any DNP3 event class. Furthermore, it is possible to invert the signals, if necessary, for example, generic input data.

The default variation for all binary input values can be set with the *Default Var Obj 01* parameter.

3.5.2 Double point inputs

Double Bit input (object type 3) is supported by the protection relay. Double point objects are derived from the protection relay's internal data class DPC, that is, circuit breaker and disconnector position data. An alternative DNP3 analog input data always exists for the double point data. If the DNP3 client does not support object type 3, the analog input is the only other alternative for representing the double point value in one DNP3 data object.

The size of the DNP3 Double Bit input event buffer is 32768.

3.5.3 Analog inputs

DNP3 analog input data (Object type 30) is mainly derived from the protection relay’s IEC 61850 measurand object classes MV and CMV. Since the MV and CMV source values are of float32 type, the default setting for the default variation of DNP3 analog data is float32.

If needed, the default variation can be changed to integer 16- or 32-bit types. In such a case, re-scaling of the original data has to be applied.

There are four scaling options associated with analog input reporting.

- None: The value is presented as it is. None of the configured values in Communication Management columns Min Source Value, Max Source Value, Min Dest Value and Max Dest Value has any effect.
- Multiplication: The process value is multiplied by a constant. An offset is added producing the reported value. In Communication Management the constant is found in the Max Dest Value column and the offset in the Min Dest Value column.
- Division: The process value is divided by a constant. An offset is added by producing the reported value. In Communication Management the constant is found in the Max Dest Value column and the offset in the Min Dest Value column.
- Ratio: The four configured values *Min Source Value*, *Max Source Value*, *Min Dest Value* and *Max Dest Value* are all used. With ratio scaling it is possible to define a new linear scaling (including possible offset) and to set value limits for the measurand.

Consider this example:

- The source value (SourceValue) range of a secondary current value is defined as 0.00…60.00 x In
- In = 500 A and we want to present the DNP3 value in primary Amperes.
- Furthermore, we want not to show any DNP3 value larger than 4.00 x In, meaning that all source values larger than this saturate at 4.00 x In (= 4 x 500 A).

Table 5: Ratio scaling

Setting	Value
Min Source Value	0
Max Source Value	4
Min Dest Value	0
Max Dest Value	2000

The reported DNP3 value can be expressed as:

$$(SourceValue - MinSourceValue) \cdot \left(\frac{(MaxDestValue - MinDestValue)}{(MaxSourceValue - MinSourceValue)} \right) + MinDestValue$$

(Equation 1)

Some DNP3 analog input points, such as CT or VT measurement values, support primary and secondary scaling. This selection can be done in PCM600 by selecting either "Primary value" or "Secondary value" for *Representation*. If the analog input object does not support primary and secondary scaling, the selection has no effect.

3.5.3.1 DNP3 analog input change events

The DNP3 analog input event buffer size is 32768.

AI events arriving from the IEC 61850 level to the DNP3 stack are always changed values. The sampling rate and deadband can be modified for the DNP3 AI points through Communication Management in PCM600.

- If a DNP3 analog input points' additional *Deadband* value is set to "0.0", the IED system analog events are propagated as such through the DNP3 protocol.
- The sampling rate of the DNP3 AI value can also be reduced through the points' *Deadband Time* setting. This means that the events are transmitted less frequently. If *Deadband Time* is, for example, set to "2", analog events are produced less frequently than every two seconds from the DNP3 AI object.

3.5.4 Counter objects

DNP3 counter objects (object type 20) are derived from the relay's IEC 61850 object class BCR. For each counter, there is also a frozen counter value available for reading as object type 21.

There are two types of counters in the relay.

- BCR class is an integrated totals type counter, typically used for energy values.
- INC class counters are operational counters, for example, circuit breaker control counters.

It is possible to freeze and reset the DNP3 counters in this relay. However, the original BCR counters are also reset. Resetting counters is done by triggering the protection application specific trigger point, hence all counters related to specific protection application instance are reset when a single counter is reset. Another method is to read the cumulative values and not reset the counters.

The DNP3 Counter, and Frozen Counter event buffer size is 32768.

3.5.5 Binary outputs and control relay output block

DNP3 binary outputs (Object group 10) are cross-coupled with the protection relay's IEC 61850 control data classes SPC and DPC. The DNP3 stack automatically handles the conversion between the two protocols' control models.

DNP3 control is never done directly to the binary outputs but rather indirectly using the Control Relay Output Block (CROB) function. The CROB function contains some additional information regarding the control sequence, for example, pulse length and number of control pulses. These parameters are intended for RTU type (non-intelligent) DNP3 devices. However, in this protection relay, all the required control parameters are already configured properties of the control object. Therefore, most control parameters given in the DNP3 CROB command are ignored by the protection relay. Only the control direction is noticed. Most single point objects, like resets and acknowledgements, can only be controlled using ON. However, there may also be single point objects that have two states, ON or OFF. Double-point objects may be controlled using ON or OFF.

3.5.5.1 Control modes

All DNP3 binary outputs support direct control at any time. Double-point objects (circuit breakers and disconnectors) also support select-before-operate controls, provided that the native IEC 61850 control objects are in SBO control model mode. A double-point control is represented with one binary output point on DNP3 even if there are two separate control relay outputs (open and close) from the protection relay.

3.5.5.2 Accessing of physical outputs

Unlike an RTU device, the protection relay's physical output relays cannot be controlled directly with remote communication. However, this can be done using generic control points and dedicated Application Configuration application connections.

3.5.5.3 Control feedback

When the binary output values are read from the protection relay, the returned value is OFF. However, some IIN information like ONLINE/OFFLINE may be relevant if for example a DPC object is non-controllable at that time due to internal restrictions like local mode. While controlling an object, the final status change of the object should be verified from the corresponding binary input object, if available.

In case of double-point control, the IEC 61850 standard defines a value attribute named *stSeld* to be always available for the control object. In case of SBO, this value shows if the control object is selected, for example, by another controlling source.

This value is found in the DNP3 memory map as a regular DNP3 binary input. The *stSeld* value goes on (“1”) and off (“0”) during a control operation and is always held in true state (“1”) by the protection relay until the control operation is terminated.

In case of a long-lasting control operation, for example, a motor-controlled disconnector, the *stSeld* value can stay true for several seconds after the control operation is acknowledged and started. A new control operation cannot be started by the protection relay until the previous one has finished.

3.5.6 Analog outputs

Analog outputs are cross-referenced to the .Oper.ctlVal attribute of the protection relay's object class INC, controllable integer. If the INC object is readable, the .stVal attribute of the object is mapped to DNP3 AI data.

The protection relay platform contains a few controllable analog objects, for example, parameter setting group selection and tap changer control All analog objects are of integer type. The values do not have to be scaled.

The Analog Output Block DNP3 object group (41) is used for writing to a DNP3 analog output. Analog output can be also read from the protection relay, as object group 40. Reading an analog output returns the last written value to the object.

Class events are generated for changed Analog Output values. The DNP3 Analog Output event buffer size is 32768.

3.6 Fault records

Fault record data objects contain registered values captured simultaneously by the relay's protection at the moment of a fault. The fault record objects internally belong to IEC 61850 logical node FLTRFRC1.

Reading fault records with DNP3 is not supported. To read fault records use Web HMI or PCM600.

4 DNP3 parameters

4.1 Link and application layer parameters

The DNP3 parameters can be accessed with PCM600 or WHMI via **Application Configuration** > **[Main Application]** > **Protocols** > **DNPLPRT(n)**.

Some parameters are not visible in the “Basic” setting visibility mode. To view all parameters, use “Advanced” setting visibility mode in Parameter Setting in PCM600 and HMI.

DNP3 parameters, *Operation* and *TCP Port*, will cause all the DNP3 instances to restart. Other settings will cause the specific instance to restart.

4.1.1 DNP3.0 Settings

Table 6: Non group settings

Parameter	Values (Range)	Unit	Step	Default	Description
Operation	1=on 5=off			5=off	Operation Off / On
Port	3=Ethernet - TCP 1 4=Ethernet TCP+UDP 1			3=Ethernet - TCP 1	Communication interface selection
Unit address	0...65519		1	1	DNP unit address
Master address	0...65519		1	3	DNP master and UR address
Mapping select	1...2		1	1	Mapping select
ClientIP				0.0.0.0	IP address of client
TCP port	20000...65535		1	20000	TCP Port used on ethernet communication
Client control authority	0=No clients 1=Reg. clients 2=All clients			2=All clients	0=no client controls allowed; 1=Controls allowed by registered clients; 2=Controls allowed by all clients
Link keep-alive	0...1000000	s	1	0	Link keep-alive interval for DNP
Validate master addr	1=Disable 2=Enable			1=Disable	Validate master address on receive
Self address	1=Disable 2=Enable			2=Enable	Support self address query function
Time format	0=UTC 1=Local			1=Local	UTC or local. Coordinate with master.

Table continues on the next page

Parameter	Values (Range)	Unit	Step	Default	Description
CROB select time-out	1...65535	s	1	10	Control Relay Output Block select timeout
Data link confirm	0=Never 1=Only Multiframe 2=Always			0=Never	Data link confirm mode
Data link confirm TO	100...65535	ms	1	3000	Data link confirm timeout
Data link retries	0...65535		1	3	Data link retries count
Data link Rx to Tx delay	0...255	ms	1	0	Turnaround transmission delay
App layer confirm	1=Disable 2=Enable			1=Disable	Application layer confirm mode
App/UR confirm TO	100...65535	ms	1	5000	Application layer confirm and UR timeout
App layer fragment	256...2048	bytes	1	2048	Application layer fragment size
UR mode	1=Disable 2=Enable			1=Disable	Unsolicited responses mode
UR retries	0...65535		1	3	Unsolicited retries before switching to UR offline mode
UR TO	0...65535	ms	1	5000	Additional delay kept after App/UR confirm TO before sending new unsolicited retry
UR offline interval	0...65535	min	1	15	Unsolicited offline interval
UR Class 1 Min events	0...999		1	2	Min number of class 1 events to generate UR
UR Class 1 TO	0...65535	ms	1	50	Max holding time for class 1 events to generate UR
UR Class 2 Min events	0...999		1	2	Min number of class 2 events to generate UR
UR Class 2 TO	0...65535	ms	1	50	Max holding time for class 2 events to generate UR
UR Class 3 Min events	0...999		1	2	Min number of class 3 events to generate UR
UR Class 3 TO	0...65535	ms	1	50	Max holding time for class 3 events to generate UR
Legacy master UR	1=Disable 2=Enable			1=Disable	Legacy DNP master unsolicited mode support. When enabled relay does not send initial unsolicited message.
Default Var Obj 01	1=1:BI 2=2:BI&status			1=1:BI	1=BI; 2=BI with status.
Default Var Obj 02	1=1:BI event 2=2:BI event&time			2=2:BI event&time	1=BI event; 2=BI event with time.
Default Var Obj 03	1=1:DBI			1=1:DBI	1=DBI; 2=DBI with status.

Table continues on the next page

Parameter	Values (Range)	Unit	Step	Default	Description
	2=2:DBI&status				
Default Var Obj 04	1=1:DBI event 2=2:DBI event&time			2=2:DBI event&time	1=DBI event; 2=DBI event with time.
Default Var Obj 20	1=1:32bit Cnt 2=2:16bit Cnt 5=5:32bit Cnt no-flag 6=6:16bit Cnt no-flag			2=2:16bit Cnt	1=32-bit counter; 2=16-bit counter; 5=32-bit counter without flag; 6=16-bit counter without flag.
Default Var Obj 21	1=1:32bit FrzCnt 2=2:16bit FrzCnt 5=5:32bit FrzCnt&time 6=6:16bit FrzCnt&time 9=9:32bit FrzCnt noflag 10=10:16bit FrzCnt noflag			6=6:16bit FrzCnt&time	1=32-bit frz counter; 2=16-bit frz counter; 5=32-bit frz counter with time; 6=16-bit frz counter with time; 9=32-bit frz counter without flag;10=16-bit frz counter without flag.
Default Var Obj 22	1=1:32bit Cnt evt 2=2:16bit Cnt evt 5=5:32bit Cnt evt&time 6=6:16bit Cnt evt&time			6=6:16bit Cnt evt&time	1=32-bit counter event; 2=16-bit counter event; 5=32-bit counter event with time; 6=16-bit counter event with time.
Default Var Obj 23	1=1:32bit FrzCnt evt 2=2:16bit FrzCnt evt 5=5:32bit FrzCnt evt&time 6=6:16bit FrzCnt evt&time			6=6:16bit FrzCnt evt&time	1=32-bit frz counter event; 2=16-bit frz counter event; 5=32-bit frz counter event with time; 6=16-bit frz counter event with time.
Default Var Obj 30	1=1:32bit AI 2=2:16bit AI 3=3:32bit AI noflag 4=4:16bit AI noflag 5=5:AI float 6=6:AI double			5=5:AI float	1=32-bit AI; 2=16-bit AI; 3=32-bit AI without flag; 4=16-bit AI without flag; 5=AI float; 6=AI double.
Default Var Obj 32	1=1:32bit AI evt 2=2:16bit AI evt 3=3:32bit AI evt&time 4=4:16bit AI evt&time 5=5: float AI evt 6=6:double AI evt 7=7:float AI evt&time 8=8:double AI evt&time			7=7:float AI evt&time	1=32-bit AI event; 2=16-bit AI event; 3=32-bit AI event with time; 4=16-bit AI event with time; 5=float AI event; 6=double AI event; 7=float AI event with time; 8=double AI event with time.
Default Var Obj 40	1=1:32bit AO 2=2:16bit AO 3=3:AO float			2=2:16bit AO	1=32-bit AO; 2=16-bit AO; 3=AO float; 4=AO double.

Table continues on the next page

Parameter	Values (Range)	Unit	Step	Default	Description
	4=4:AO double				
Default Var Obj 42	1=1:32bit AO evt 2=2:16bit AO evt 3=3:32bit AO evt&time 4=4:16bit AO evt&time 5=5:float AO evt 6=6:double AO evt 7=7:float AO evt&time 8=8:double AO evt&time			4=4:16bit AO evt&time	1=32-bit AO event; 2=16-bit AO event; 3=32-bit AO event with time; 4=16-bit AO event with time; 5=float AO event; 6=double AO event; 7=float AO event with time; 8=double AO event with time.

4.2 Monitored data, general

4.2.1 DNP 3.0 Monitored data

Table 7: Monitored data

Name	Type	Values (Range)	Unit	Description
Reset counters	BOOLEAN	0=False 1=True		Reset counters
Received frames	INT32	-1...2147483646		Received frames
Transmitted frames	INT32	-1...2147483646		Transmitted frames
Physical errors	INT32	-1...2147483646		Physical layer errors
Link errors	INT32	-1...2147483646		Link layer errors
Transport errors	INT32	-1...2147483646		Transport layer errors
Mapping errors	INT32	-1...2147483646		Mapping errors

5 Glossary

ACD	Start/pickup status
ACT	1. Application configuration tool in PCM600 2. Trip status in IEC 61850
AI	Analog input
Beh	Behavior
BI	Binary input
BO	Binary output
CROB	Control relay output block
Data set	The content basis for reporting and logging containing references to the data and data attribute values.
DIP switch	A set of on-off switches arranged in a standard dual in-line package
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
EMC	Electromagnetic compatibility
EPA	Enhanced performance architecture
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN.
FIFO	First in, first out
HMI	Human-machine interface
IEC	International electrotechnical commission
IEC 60870-5	IEC standard for telecontrol equipment and systems. Part 5 defines transmission protocols.
IEC 61850	International standard for substation communication and modeling.
IED	Intelligent electronic device
IP	Internet protocol
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.
ISO	International Standard Organization
MMS	1. Manufacturing message specification 2. Metering management system
OSI	Open systems interconnection
PCM600	Protection and control IED manager
RS-485	Serial link according to EIA standard RS485

Table continues on the next page

RTU	Remote terminal unit
SBO	Select-before-operate
SI	Sensor input
SPC	Single-point status of a controllable object
SPS	Single-point status
SSC600	Smart substation control and protection device
ST	Connector type for glass fiber cable
TCP	Transmission control protocol
TCP/IP	Transmission control protocol/Internet protocol
TLS	Transport layer security
UDP	User datagram protocol
UR	Unsolicited response

ABB Distribution Solutions
Digital Substation Products
P.O. Box 699
FI-65101 VAASA, Finland
Phone +358 10 22 11

abb.com/mediumvoltage
abb.com/relion
go.abb/digitalsubstations

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