

RELION® PROTECTION AND CONTROL

# REF615R

## DNP3 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 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

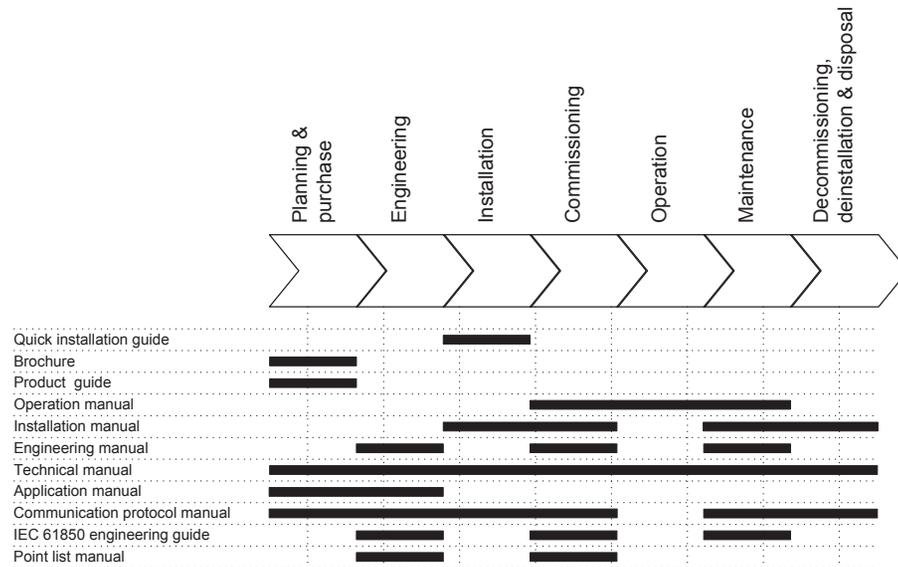


Figure 1: The intended use of documents during the product life cycle

### 1.3.2 Document revision history

Document revision/date	Product version	History
A/2013-11-22	4.0	First release
B/2016-10-24	4.1	Content updated to correspond to the product version
C/2019-07-02	4.1	Content updated



Download the latest documents from the ABB Web site  
<http://www.abb.com/substationautomation>.

### 1.3.3 Related documentation

Name of the document	Document ID
DNP3 Point List Manual	1MRS240051-IB

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

The purpose of this document is to describe specific configuration and interoperability information for an implementation of the Distributed Network Protocol, Version 3.0. This document, in conjunction with the DNP3 Basic 4 Document Set, and the DNP Subset Definitions Document, provides complete information on how to communicate via the DNP3 protocol.

## 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.
- Push button navigation in the LHMI menu structure is presented by using the push button icons.

- 
- To navigate between the options, use  and .
  - 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 nonvolatile 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 "Enabled" and "Disabled".
  - Input/output messages and monitored data names are shown in Courier font.  
When the function picks up, the `PICKUP` output is set to `TRUE`.
  - Dimensions are provided both in inches and mm. If it is not specifically mentioned, the dimension is in mm.

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## Section 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 DNP Users Group at [www.dnp.org](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.

#### 2.1.1 Physical layer

There are two specified physical layer modes; serial and Ethernet.



Additional information on the DNP3 physical layer is available at the DNP Users Group at [www.dnp.org](http://www.dnp.org).

#### 2.1.2 Data link layer

The DNP3 data link layer is designed to operate with connection-oriented and connectionless asynchronous or synchronous bit serial physical layers. Fully balanced transmission procedures were adopted to support spontaneous transmissions from outstations.

Data link functions:

- Performing message data link retransmissions.
- Synchronizing and handling the FCB in the control octet.
- Setting and clearing the DFC bit based on buffer availability.
- Packing user data into the defined frame format, include CRC checksums and transmitting the data to the physical layer.
- Unpacking the data link frame received from the physical layer into user data, check and remove CRC checksums.

- 
- Controlling all aspects of the physical layer.
  - In unsolicited reporting mode, performing collision avoidance/detection procedures to ensure reliable transfer of data across the physical link.
  - Responding to all valid frames received from the physical layer.

Data link responsibilities:

- Exchange of SDUs between peer DNP3 data links
- Error notification to data link user
- Sequencing of SDUs
- SDU delivery quality.

Link-layer confirm usage is deprecated.



See the DNP3 technical bulletin TB1998-0402, section 3 for details at [www.dnp.org](http://www.dnp.org).

### 2.1.3

## Transport pseudo-layer

To support advanced RTU functions and messages exceeding the maximum data link frame length, a transport pseudo-layer which implements message assembly and disassembly services was adopted. This pseudo-layer is actually a super-data link transport protocol, which is normally included in some OSI protocol data links.

Transport functions:

- Fragmenting user data into one or more data link frames and transmitting the data to the data link layer
- Assembling the data link frames received from the data link layer into user data
- Controlling all aspects of the data link excluding data link configuration

Transport responsibilities:

- Exchange of SDUs between peer DNP3 transport pseudo layers
- Error notification to transport users
- Sequencing of SDUs

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## 2.1.4 Application layer parameters

When *App layer confirm* is disabled, the protection relay requests application confirmation for event messages only. When it is enabled, the protection relay also requests application confirmations for all the sent application.

*App confirm TO* is the application layer confirmation timeout in milliseconds. Application layer confirmations received from the master after *App confirm TO* has expired are not acknowledged by the protection relay. It applies to both solicited and unsolicited events.

*App layer fragment* is the application layer fragment size in bytes.

*CROB select timeout* is the DNP3 selecting before operating timer.

## 2.1.5 Communication modes

The protection relay supports three DNP3 communication modes.

- Polled static mode, meaning that the master polls for class 0 or static data only
- Polled report by exception mode, where the Master polls for change events (class 1,2,3) and occasionally makes integrity polls (class 1, 2, 3, 0)
- Unsolicited report by exception mode, where the slave reports change events spontaneously without being polled by the master. Master occasionally makes integrity polls (class 1, 2, 3, 0).



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## Section 3 Vendor-specific implementation

### 3.1 DNP3 link modes

Serial and TCP/IP modes are available. They are mutually exclusive.

#### 3.1.1 DNP3 data objects

The DNP3 protocol in 615 series protection relays is built on top of the internal IEC 61850 data model. Thus, the DNP3 application data objects and Class events are derived from IEC 61850 data objects and data set reporting. The 615 series protection relays have a predefined IEC 61850 data set configuration. In other words, it is predefined which internal data object changes the 615 series protection relays detect.

The available DNP3 data objects in the 615 series protection relays are selected from the objects predefined in the IEC 61850 data sets.



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

#### 3.1.2 DNP3 serial link mode

DNP3 serial can be assigned to a serial communication port in the protection relay. Serial communication ports are named COM1...COMn, depending on how many serial ports the 615 series protection relay hosts.



If this protocol does not operate as expected, check that other serial protocols are not using the COM port also.



DNP3 protocol ignores any parity setting in the COM settings group; DNP3 is defined as an 8 bit/no parity protocol with a 16-bit CRC every 16 bytes. This provides better error detection than parity.

### 3.1.3 DNP3 TCP/IP mode

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

The protection relay listens for a connection from a DNP3 master on port 20000. A single DNP3 session can be run concurrently with IEC 61850, Modbus Serial and/or Modbus TCP. Documentation concerning DNP3 TCP/IP communication is available from [www.dnp.org](http://www.dnp.org).

## 3.2 DNP3 point settings

### 3.2.1 Binary input points

The binary input event buffer size is set to allow 200 events. Events that occur after buffer overflow are discarded.

**Table 1:** *Binary input points*

Description	Value
Static (steady-state) object number	1
Static variation reported when variation 0 requested (default setting)	1 (binary input without status)
Change event object number	2
Change event variation reported when variation 0 requested (default setting)	2 (binary input change with time)

**Table 2:** *Default Class assignment for Binary Input points*

Point index	Name/description	Default change event assigned class (1, 2, 3 or none)
	See the DNP3 point list manual.	

### 3.2.2 Binary output status points and control relay output blocks

The binary output status points (object 10) and the CROBs (object 12) are provided in the configuration specific point list.



Operation of the DNP3 control commands is blocked unless the relay is set to remote control mode. Count, off-time and on-time in the command fields are not supported in this implementation.

**Table 3:** *Binary output status points*

Description	Value
Object number	10
Default variation reported when variation 0 requested (default setting)	2 (BOS)

**Table 4:** *Control relay output blocks*

Description	Value
Object number	12

### 3.2.2.1

#### CROB index (point) types

There are two types of CROB points implemented in REF615R.

##### Single activation points

The single activation points activate a dedicated function when a supported command is received. In REF615R Ver.4.1, the DNP3 control points are all single activation points by default configuration. SPCRGGIO (ULO) and SPCGGIO control points can be configured individually to either single activation point (set to pulsed mode) or complementary latch point (set to toggle mode) through the HMIs or PCM600 by the user. For the single activation points, the supported control code includes:

- 0x01 Momentary Relay (Pulse On/NUL)
- 0x41 Close (Pulse On/Close)
- 0x81 TRIP (Pulse On/Trip)
- 0x03 Latch On (Latch On/NUL)

The 0x04 Latch Off command will be accepted but ignored (ABI).

##### Complementary latch points

The latch control points have two complementary statuses, 1 and 0. The point holds its status until the complementary command is received, for example, the latch point holds 0 (initial value) until a Latch On command is received. Then it holds 1 until a Latch Off command is received or the relay is rebooted. The SPCRGGIO and SPCGGIO control points can be configured to toggle mode to implement the latch functionality. The configuration of those control points can be changed individually through the HMIs or PCM600 by the user.

REF615R - Parameter Setting					
Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
SPCGGIO1: 1					
General					
Loc Rem restriction		False			
Output 1					
Operation mode					
Pulse length			ms	10	3600000
Description					64 characters

Figure 2: Configuring SPCGGIO1 output 1 to be latch point with PCM600

For the complementary latch points, the supported control code includes:

- 0x01 Momentary Relay (Pulse On/NUL)
- 0x41 Close (Pulse On/Close)
- 0x81 TRIP (Pulse On/Trip)
- 0x03 Latch On (Latch On/NUL)
- 0x04 Latch Off (Latch Off/NUL)

### 3.2.2.2

### Control modes

To be backward compatible to DPU2000R, REF615R Ver.4.1 DNP3 control mode can be configured to be default mode (paired mode disabled) or paired mode.

The paired mode can be configured through the HMI or PCM600 in DNP3 submenu.

Parameter Name	IED Value	PC Value	Unit	Min	Max
Data link inter char delay	4	4	char	0	20
App layer confirm	Disable	Disable			
App confirm TO	5000	5000	ms	100	65535
App layer fragm	2048	2048	bytes	256	2048
UR mode	Disable	Disable			
UR retries	3	3		0	65535
UR TO	5000	5000	ms	0	65535
UR offline interval	15	15	min	0	65535
UR Class 1 Min events	2	2		0	999
UR Class 1 TO	50	50	ms	0	65535
UR Class 2 Min events	2	2		0	999
UR Class 2 TO	50	50	ms	0	65535
UR Class 3 Min events	2	2		0	999
UR Class 3 TO	50	50	ms	0	65535
Legacy master UR	Disable	Disable			
Legacy master SBO	Disable	Disable			
Default Var Obj 01	1	1	1	2	1
Default Var Obj 02	2	2	1	2	1
Default Var Obj 30	2	2	1	4	1
Default Var Obj 32	4	4	1	4	1
Paired Mode	Disable	Disable			

Figure 3: Configuring paired mode via the Web HMI

**Paired Mode disabled (default configuration)**

- For the single activation points, by receiving any of the supported control codes, including (the Momentary Relay (Pulse On), Trip, Close and Latch On), the relay activates the corresponding functionality. The Latch Off command will be accepted, but ignored (ABI).
- For the complementary latch points, Momentary Relay (Pulse On), Trip, Close, and Latch On commands latch the point to value 1, while the Latch Off command latches the point to value 0.

**Table 5:** *DNP3 control function behavior with default configuration (Paired Mode disabled)*

CROB point type	Index and description	Control codes				
		Momentary relay	CLOSE	TRIP	Latch ON	Latch OFF
Single Activation Point	24, TRIP	Activate 24 (TRIP)	Activate 24 (TRIP)	Activate 24 (TRIP)	Activate 24 (TRIP)	ABI
	25,CLOSE	Activate 25 (CLOSE)	Activate 25 (CLOSE)	Activate 25 (CLOSE)	Activate 25 (CLOSE)	ABI
Complementary Latch Point	14, ULO1	Latch on 14 (ULO1)	Latch off 14 (ULO1)			
	15, ULO2	Latch on 15 (ULO2)	Latch off 15 (ULO2)			

**Paired Mode enabled**

If REF615R is not used to replace a DPU2000R unit, this section can be ignored and the paired mode should be kept disabled as default setting.

In the new release, DNP3 configuration added a new choice for the backward compatibility of DPU2000R paired mode<sup>[1]</sup>. The paired mode works as “network parameter 2<sup>[2]</sup>” in DPU2000R. It enables controlling two adjacent paired points through a single point. The two paired points are defined as the even index point and the following odd index point, and the controlling point is the even index point.

For the single activation control points, the Momentary Relay (Pulse On), Trip and Latch On commands sent to the even index point will activate that point, while the Close command sent to the even index point will activate the next odd point (the even index +1 point). The Latch Off command sent to the even index point will be accepted but ignored

[1] DNP3 Device Profile Document for ABB DPU2000R (DOCUMENT VERSION 1.10 MARCH 2005)

[2] Network Mode Parameter 2 enables or disables Control Relay Output Block Paired Point operation. When enabled, this setting facilitates compatibility with earlier implementations of Paired Control Point operation in the device. The TRIP point should be mapped to an even index and its CLOSE pair to the next, odd index. The Trip command acts on the destination point. Close command acts on the destination index + 1 if sent to an even index or the destination index if sent to an odd index. Note that the same rules apply even if TRIP and CLOSE point indexes are swapped, (CLOSE resides at an even index). In such a case, sending the Close command to the even index, would act on the following point, resulting in a possibly unintentional operation. Paired Point operation applies to Direct Operate Trip/ Close and SBO Trip/ Close commands, and affects all control points. Make sure SBO is sent within the same exchange if a CLOSE is meant to operate the next point. The default value of Mode Parameter 2 is disabled. Avoid sending Close to the last even index when Mode Parameter 2 is enabled.

(ABI). The control commands sent to the odd index points will work as the paired mode is disabled.

For the complementary latch control points, the Momentary Relay (Pulse On), Trip and Latch On commands sent to the even index point will latch on that point, while the Close command sent to the even index point will latch on the next odd point (the even index + 1 point). The Latch Off command sent to the even index point will latch off the even index point. The control commands sent to the odd index points will work as the paired mode is disabled.

The paired mode affects not only the legacy DPU2000R control points, but all enabled control points. Avoid sending the Close command to the last even index point if the enabled control point list ends with an even index point.

The paired mode is point index related, but not the function related. For example, by default, assigning Master Trip to even index point (24) and Close to odd index point (25) allows using a single point 24 to complete the TRIP and CLOSE functions. Sending Trip command to index 24 will trip the relay, while sending Close command to index 24 will close the relay. However, if user swaps the DNP3 indexes assignment, mapping index 24 to CLOSE and 25 to TRIP, the Trip command sent to 24 will close the breaker, while the Close command sent to 24 will trip the breaker.

**Table 6:** *DNP3 control function behavior with Paired Mode enabled*

Control point types	Index and description	Control codes				
		Momentary relay	CLOSE	TRIP	Latch ON	Latch OFF
Single Activation Point	Even number (24, TRIP)	Activate 24 (TRIP)	Activate 25 (CLOSE)	Activate 24 (TRIP)	Activate 24 (TRIP)	ABI
	Odd number (25, CLOSE)	Activate 25 (CLOSE)	Activate 25 (CLOSE)	Activate 25 (CLOSE)	Activate 25 (CLOSE)	ABI
Complementary Latch Point	Even number (14, ULO1)	Latch on 14 (ULO1)	Latch on 15 (ULO2)	Latch on 14 (ULO1)	Latch on 14 (ULO1)	Latch off 14 (ULO1)
	Odd number (15, ULO2)	Latch on 15 (ULO2)	Latch off 15 (ULO2)			

### 3.2.2.3 Binary output status points

While binary output status (BOS) points are included to be compatible to the DNP3 standard, they are not often polled by DNP3 masters. Because CROB points are controlled internally through pulse activation mechanisms, the values of the BOS, which only indicate the command status values, are normally zeros. As an alternative, the actual status values of CROB points have been looped around and mapped as BIs, or in the case of the breaker status, as AI.

For example, a DNP3 control command may be blocked through hardware or software mechanisms; in this case, the actual status value would indicate the control failed because of the blocking. Looping CROB actual status values as BIs has several advantages.

- The actual status of the control is included in class 0 polls.
- The status changes of the controlled point can generate events, which provide more efficient and time-accurate method of reporting control values.
- The time stamp of the events combined can be used to calculate the delays between the command and the status change of the controlled point.

Certain BOS points, for example, the ones related to the reset- or acknowledge points, are not looped back as binary inputs.

### 3.2.3 Analog inputs

The following table lists analog inputs (object 30). It is important to note that 16 bit and 32 bit variations of analog inputs are transmitted through DNP3 as signed numbers.



The original DNP3 analog value is the same value as the IEC 61850 value generated for the same point. Measurands in IEC 61850 are expressed as floating point values while DNP3 analog values are integers. Therefore, it may be necessary to scale the original DNP3 values in order to include possible decimals in the DNP3 integer value.

The deadband is not configured in DNP3. It is configured at the device level. The analog change events are therefore generated by the device functions, not DNP3. The analog change event time stamp will inherently be accurate and consistent with the reporting of events through other channels, for example, LHMI, WHMI and other communication protocols.

There are four scaling options associated with analog input reporting.

- None: the reported value is the process value.
- Multiplication: the process value is multiplied by a constant. An offset is added producing the reported value.
- Division: the process value is divided by a constant. An offset is added producing the reported value.
- Ratio:
  - Configuration-time ratio scaling: Find R for new set of {in\_min, in\_max, out\_min, out\_max}
 
$$R = (out\_max - out\_min) / (in\_max - in\_min)$$
  - Runtime ratio scaling: Reported value = (inval - in\_min) \* R + out\_min

The analog input event buffer size is set to 150. Events that occur after buffer overflow are discarded.

**Table 7:** *Analog inputs*

Description	Values
Static (steady-state) object number	30
Static variation reported when variation 0 requested (default setting)	2 (16-bit analog input)
Change event object number	32
Change event variation reported when variation 0 requested (default setting)	4 (16-bit analog input change with time)

**Table 8:** *Default Class assignment for analog input data*

Point index	Name/description	Default deadband	Default change event assigned class (1, 2, 3 or none)
	See the point list manual.	Configurable protection relay setting	2

### 3.2.3.1

#### Analog data scaling

There are four scaling modes available for processing DNP3 analog input data.

- None
- Multiplicative
- Divisor
- Ratio

The None mode does not include any scaling operations, and therefore the polled DNP3 value is the integer part of the IEC 61850 source value. The integer analog inputs, such as, the counter value and the multiple-state status), are normally not scaled.

In the Multiplicative mode, the polled DNP3 value is a scaled source value plus an optional offset.

$$DNP3\_Value = (Source\_Value \times Multiplication\_Coefficient) + Offset$$

(Equation 1)

The two coefficients, Multiplication\_Coefficient and Offset, can be configured in the Communication Management tool in PCM600 as “destMaxVal” and “destMinVal” respectively.

$$DNP3\_Value = (Source\_Value \times destMaxVal) + destMinVal$$

(Equation 2)

Only integer values are supported in DNP3 analog inputs. To keep the two decimals of a floating point analog input (for example current, voltage and power), the Multiplicative mode is selected, and the default multiplication factor “destMaxVal” set to 100 and offset “destMinVal” is set to 0.

[Equation 3](#) shows the calculation of the polled DNP3 value for the Divisor mode.

$$DNP3\_Value = \left[ \frac{Source\_Value}{Division\_Coefficient} \right] + Offset$$

(Equation 3)

The two coefficients, Division\_Coefficient and Offset, can be configured in the Communication Management tool as “destMaxVal” and “destMinVal” respectively.

$$DNP3\_Value = \left[ \frac{Source\_Value}{destMaxVal} \right] + destMinVal$$

(Equation 4)

For the Ratio mode, the polled DNP3 value is linearly projected from one range (from Min\_source to Max\_source) to another (from Min\_destination to Max\_destination). The four coefficients can be configured in the Communication Management tool as “sourceMinVal”, ”sourceMaxVal”, ”destMinVal” and ”destMaxVal” respectively.

$$DNP3\_Value = \left\{ (Source\_Value - sourceMinVal) \times \left[ \frac{destMaxVal - destMinVal}{sourceMaxVal - sourceMinVal} \right] \right\} + destMinVal$$

(Equation 5)

### 3.2.3.2

#### Fault record time stamp

When a new fault occurs, the fault number (LD0.FLTMSTA1.OpCnt.stVal) increases, and it is stored in the DNP3 AI event buffer. Other points associated with the fault record (LD0.FLTMSTA1) which change are also entered in the DNP3 AI event buffer. They are also time stamped, but the official time of the fault is the event time stamp on the LD0.FLTMSTA1.OpCnt.stVal point.

Fault information, including time stamps, is retrieved from the protection relay by a DNP3 master using a Class1\_Class2\_Class3 scan or an integrity (Class1\_Class2\_Class3\_Class0) scan. The AI event default variation should be set to include time stamps. It is possible that not all points of the fault generate events. This happens when the point of the new fault has the same value as the previous fault.

---

## 3.3 DNP3 points

### 3.3.1 Point configuration

The DNP3 point map is configurable in PCM600. All points in the protection relay may be remapped. In PCM600, the unmapped points in the variables list on the left may be inserted to the active point list on the right.

Point gaps may be inserted if wanted. Point gaps cannot be read by the client.



In paired mode, the TRIP point should be mapped to an even index and its CLOSE pair to the next, odd index. This ensures that the Trip and Close commands work properly.

### 3.3.2 Class assignment

The DNP3 class is defined in the DNP3 standard (IEEE Std 1815-2012), section 4.1.5.3 Classes.

*“DNP3 uses the concept of classes to organize static data and events into several categories:*

- *Class 0: Static data (may be a subset of the outstation’s total static data)*
- *Classes 1, 2, 3: Events*

*The points of most data types may be assigned to one of the four classes (see 5.1.4 for details of which data types may be assigned to which classes). If a point is assigned to Class 0, the point’s present value shall be reported by the outstation in its response to a Class 0 poll, but the outstation shall not store or report any events for that point. If a point is assigned to one of the event classes (Class 1, 2, or 3), the outstation shall store and report events for that point, and the point’s present value shall also be reported by the outstation in its response to a Class 0 poll. If a point is not assigned to any class, the outstation shall not include the point’s present value in its response to a Class 0 poll, nor shall it store or report events for that point.”*

In REF615R, all BI and AI points are assigned to class 0 by default. Only the BI or AI point, whose IEC 61850 data attribute is included in a data set, is able to generate events and can be assigned to a nonzero class. The class assignment can be changed with Communication Management tool in PCM600.

**Table 9:** *DNP3 point map configuration*

Configuration	Description
None	Integrity class 0 scan returns gap. Value is available only via static scan. Point does not generate events.
Class 0	Point is returned in the class 0 scan. Point does not generate events.
Class 0 and any class 1,2,3 combination	Point is returned in the class 0 scan. Point generates events for the selected class or classes.

BOS points exist only if the corresponding CROB point has been inserted in the active point list.

Class assignment cannot be performed on CROBs. They can only be performed on the corresponding BOS points in a limited fashion; they may only be assigned Class 0 or None and only affect the class 0 scan. This means they cannot be configured to generate events. The BOS points, however, have been made available as BI points, which can be configured to generate events.



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## Section 4 DNP3 parameters

### 4.1 Parameter descriptions

#### Link parameters

*DNP physical layer* configures DNP3 for the TCP/IP or serial channel.

*Unit address* is the slave 16 bit link address. This value should be set between 1 and 65519, since DNP3 reserves the top 16 addresses. All DNP3 devices sharing the same network should have unique addresses.

*Master address* is the 16 bit link address at which the initial unsolicited message is sent. The value should be unique, between 1 and 65519.

*Serial port* configures DNP3 for the selected serial channel only if DNP3 physical layer is set for Serial. The serial port speed is set under **Communication/COM1** and **Communication/COM2**.

*Time format* can be set to Local or UTC.

*CROB select timeout* is the DNP3 select before operate timer.

*Data link confirm* enables or disables the data link confirmation. Options are: never, only for multi-frame, messages or always. Option never is recommended in DNP3 Technical Bulletin 1998 0402.

*Data link confirm TO* is the data link confirmation timeout in milliseconds.

*Data link retries* is the data link retry count from 0 to 65535.

*Data Link Rx to Tx delay* is the turnaround delay in milliseconds of the slave replies. The timer starts at the trailing edge of the master's request.

*Data Link inter char delay* is the allowed inter character delay for incoming messages. The timer starts with the reception of each character. When the timer expires because no additional characters have been received, the protection relay regards the incoming message complete. The unit of measure is a character time at the selected baud rate.

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## Application layer parameters

*App layer confirm* When disabled, the protection relay requests application confirmation to event messages only. When enabled, the protection relay also requests application confirmations to all application messages sent.

*App confirm TO* is the application layer confirmation timeout in milliseconds. Application layer confirmations received from the master after App confirm TO has expired are not acknowledged by the protection relay. It applies to both solicited and unsolicited events.

*App layer fragment* is the application layer fragment size in bytes.

## Unsolicited mode parameters

*UR mode* Unsolicited responses mode may be set to enable or disable. If enabled, the initial unsolicited message is sent when the master opens a connection to the protection relay, the first time after a protection relay reboot. All other unsolicited response parameters are irrelevant if UR mode is disabled.



Enabling *UR mode* on a serial multidrop line is not recommended. Collisions will result from multiple protection relays reporting concurrent events. Although the DNP3 application layer will recover, collision recovery can create significant traffic.

*UR retries* is the number of times the slave will resend the unsolicited response if it is not confirmed by the master station.

*UR TO* is the unsolicited response timeout period in milliseconds. This timeout period starts after *App confirm TO* expires. A new unsolicited response is transmitted when UR TO expires. Application layer confirmations received from the master during the UR TO period are not acknowledged by the protection relay.

*UR offline interval* is the unsolicited message offline interval in minutes. Offline interval starts after the last UR retry. Offline interval never starts when UR retries = 65535 (0xFFFF).

*UR Class 1,2,3 Min events* are the class 1, 2 or 3 number of events that must accumulate before they are sent as unsolicited messages, unless the UR Class 1,2,3 TO expires causing the transmission of the events.

*UR Class 1,2,3 TO* is the time in ms, that class 1, 2 or 3 events are delayed before being sent out, unless a count of UR Class 1,2,3 Min events have accumulated causing the transmission of the events.

*Legacy master UR* provides compatibility to some older DNP3 masters. When set to disabled, the slave follows the DNP3 standard, sending its first unsolicited message after a connection has been established following protection relay reboot. The master is

expected to send the Enable/Disable Unsolicited messages command to the protection relay. When *Legacy master UR* is enabled, the protection relay does not send the initial unsolicited message. Unsolicited responses are sent without the need of the Enable Unsolicited command. The master still needs to open a connection for the slave to start sending unsolicited messages. Unsolicited mode needs to be enabled for this parameter to be operational.



*Legacy master UR* allows non-standards compliant behavior.

*Legacy master SBO* provides compatibility to some older DNP3 masters for the Select Before Operate command. When disabled, DNP3 expects the application layer sequence of the operate command to be the select command sequence + 1 modulo 16. When enabled the protection relay ignores sequence number of the operate command. This situation might occur when the master sends additional requests between the select and operate commands.



*Legacy master SBO* allows non-standards compliant behavior.

*Paired Mode* enables or disables Control Relay Output Block Paired Point operation. When enabled, this setting facilitates compatibility with earlier implementations of Paired Control Point operation in the DPU2000R unit\*.

### Additional parameters

*Need time interval* is the interval in minutes for setting the need time bit in the IIN. The IIN need time bit requests the DNP3 master to send a time synchronization to the protection relay. When set to 0 the need time IIN bit is never set, and DNP3 time synchronization is never requested. The time synchronization source needs to be set to DNP3 to allow DNP3 time synchronization. DNP3 delay measurement can have an adverse effect on time synchronization accuracy, and should be avoided for TCP/IP.

*Default Variation Obj N* is the variation that the slave replies with when the master asks for DNP3 Object type N variation 0. It is also the variation in which class events are reported.

**Table 10:** *Default variation options for supported DNP3 object types*

DNP3 Obj N	Default variation option	Variation description
1	1	Binary input
	2	Binary input with status
2	1	Binary input event
	2	Binary input event with time

Table continues on next page

DNP3 Obj N	Default variation option	Variation description
30	1	32 bit analog input
	2	16 bit analog input
	3	32 bit analog input without flag
	4	16 bit analog input without flag
32	1	32 bit analog input event
	2	16 bit analog input event
	3	32 bit analog input event with time
	4	16 bit analog input event with time

Deadbanding of the analog static values cannot be set in DNP3. Event generation is dependent on the functions employed in the protection relay, and the execution loops these functions belong to. See the protection relay's technical manual for setting deadbands.

As a result of the event generation mechanism in the protection relay, the events reported by DNP3 are very accurate and are the same events that can be retrieved over the WHMI or other protocols such as IEC 61850-8-1.



Power must be cycled to the unit after making changes to the DNP3 parameters. The LHMI or WHMI does not notify the user that this action must be taken. Either WHMI or LHMI is allowed to place the unit in the write (edit) mode, but not simultaneously.

## 4.2

### Parameter list

The DNP3 parameters can be accessed with PCM600 or via the LHMI path **Configuration/Communication/DNP3.0**.



Power must be cycled to the unit after making changes to the DNP3 parameters. The LHMI or WHMI do not notify that this action must be taken.

**Table 11:** *DNP3 settings*

Parameter	Values (Range)	Unit	Step	Default	Description
DNP physical layer	1=Serial 2=TCP/IP			2=TCP/IP	DNP physical layer
Unit address	1...65519		1	1	DNP unit address
Master address	1...65519		1	3	DNP master and UR address
Serial port	0=Not in use 1=COM 1 2=COM 2			0=Not in use	COM port for serial interface, when physical layer is serial.
Need time interval	0...65535	min	1	30	Period to set IIN need time bit
Time format	0=UTC 1=Local			1=Local	UTC or local. Coordinate with master.
CROB select timeout	1...65535	sec	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
Data link inter char delay	0...20	char	1	4	Inter character delay for incoming messages
App layer confirm	1=Disable 2=Enable			1=Disable	Application layer confirm mode
App 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	Unsolicited response timeout
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.

Table continues on next page

## Section 4 DNP3 parameters

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Parameter	Values (Range)	Unit	Step	Default	Description
Legacy master SBO	1=Disable 2=Enable			1=Disable	Legacy DNP Master SBO sequence number relax enable
Default Var Obj 01	1...2		1	1	1=BI; 2=BI with status.
Default Var Obj 02	1...2		1	2	1=BI event; 2=BI event with time.
Default Var Obj 30	1...4		1	2	1=32 bit AI; 2=16 bit AI; 3=32 bit AI without flag; 4=16 bit AI without flag.
Default Var Obj 32	1...4		1	4	1=32 bit AI event; 2=16 bit AI event; 3=32 bit AI event with time; 4=16 bit AI event with time.
Paired Mode	1=Disable 2=Enable			1=Disable	Backward compatibility to DPU2000R paired mode operation.

## Section 5 Tolerances

### 5.1 DNP3 timing considerations

**Table 12:** *The protection relay's worst-case error over the full operating temperature range*

Description	Value
Time base drift over a 10-minute interval	1.2 ms
Maximum delay measurement error	±15 ms
Maximum internal time reference error when set from the protocol	±100 ms
Maximum response time	50 ms turnaround time (TCP/IP)
Event time accuracy	4 ms for BI and 500 ms for AI
Event processing delay	20 ms for BI; 1500 ms for AI <sup>1)</sup>

- 1) This represents the time it takes for a physical input from the time it changes to the time it is reported by DNP3. The internal latency between the protection logic and the communication processor is 4 ms for BI, and 500 ms for AI.

Data link layer filtering is not performed based on the source address.

The protection relay supports collision avoidance. Collision detection is available as implemented by the DNP3 link layer and TCP/IP. When DNP3 uses the serial channel, there is no collision avoidance. Collision detection in this instance is handled by the DNP3 link layer.



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## Section 6      Glossary

<b>615 series</b>	Series of numerical protection and control relays for protection and supervision applications of utility substations, and industrial switchgear and equipment
<b>ABI</b>	Accepted but ignored
<b>AI</b>	Analog input
<b>ANSI</b>	American National Standards Institute
<b>BI</b>	Binary input
<b>BOS</b>	Binary output status
<b>CRC</b>	Cyclical redundancy check
<b>CROB</b>	Control relay output block
<b>Data set</b>	The content basis for reporting and logging containing references to the data and data attribute values
<b>DFC</b>	Data flow control
<b>DNP3</b>	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
<b>EMC</b>	Electromagnetic compatibility
<b>EPA</b>	Enhanced performance architecture
<b>Ethernet</b>	A standard for connecting a family of frame-based computer networking technologies into a LAN
<b>FCB</b>	1. Flow control bit 2. Frame count bit
<b>HMI</b>	Human-machine interface
<b>IEC</b>	International Electrotechnical Commission
<b>IEC 60870-5</b>	IEC standard for telecontrol equipment and systems. Part 5 defines transmission protocols.
<b>IEC 61850</b>	International standard for substation communication and modeling
<b>IEC 61850-8-1</b>	A communication protocol based on the IEC 61850 standard series

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<b>IED</b>	Intelligent electronic device
<b>IIN</b>	Internal indication (DNP3)
<b>ISO</b>	International Standard Organization
<b>LHMI</b>	Local human-machine interface
<b>Modbus</b>	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
<b>OSI</b>	Open systems interconnection
<b>PCM600</b>	Protection and Control IED Manager
<b>RTU</b>	Remote terminal unit
<b>SDU</b>	Service data unit
<b>TCP/IP</b>	Transmission Control Protocol/Internet Protocol
<b>UL</b>	Underwriters Laboratories
<b>UR</b>	Unsolicited response
<b>WHMI</b>	Web human-machine interface





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