Phasor Measurement Unit

PMU PRO

DNP3 Communications Protocol

Reference Guide

BG0651 Rev. A2

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For further information regarding a particular installation, operation or maintenance of equipment, contact the manufacturer or your local representative or distributor.

REVISION HISTORY

A1	Mar 2024	Initial release
A2	Dec 2024	Updated PMU time quality field.

Table of Contents

1 General

This document specifies a subset of the DNP3 communications protocol used to transfer data between a master computer station and the PMU. The document provides the complete information necessary to develop third-party communications software capable of communication with the PMU.

Additional information regarding communication operation, configuring communication parameters and communication connections can be found in the PMU Installation and Operation Manual.

2 DNP 3.0 Protocol Implementation

DNP3 (Distributed Network Protocol) is an open standard designed by the Harris Control Division. DNP3 defines a command-response method of transmitting digital information between a master station and a slave device. Detailed information regarding DNP3 can be found in the DNP3 Specification document set, which can be obtained from the DNP Users Group.

2.1 Deviations from Standard

The PMU implements Level 2 of the DNP3 communication protocol. The device does not support unsolicited requests or hardware collision avoidance.

The data link layer differs from the DNP3 specification because of the master-slave relationship between devices. When the device receives a request, no further requests can be sent until after the device makes the appropriate response.

2.2 Serial DNP3 Connections

The PMU has one 485 and one IR port, which can operate in DNP3 mode.

The port baud rate and data format are configurable via the device Serial Ports setup (see the PMU Installation and Operation Manual for details).

2.3 TCP/IP DNP3 Connections

The PMU has two Ethernet ports with the ability to support up to 8 simultaneous TCP connections each. Both ports provide DNP3 TCP servers. The TCP port number is configurable via the DNP Options setup (see Section 6.1). The default DNP3 TCP port is 20000.

The PMU uses keepalive probes to detect dead connections and prevent resource leaks. If the connection is idle longer than configured, the device sends a keepalive request to check if the connection is alive. If no response is received after 5 successive keepalive retransmissions, the connection is considered dead and will be closed. The idle time before sending a probe to test for an inactive session is configurable through the device Network Setup (see the PMU Installation and Operation Manual) and can be set from 1 to 60 seconds. The default value is 20 seconds.

The client connection idle timeout can be used to terminate a connection if it has been inactive for too long. It can be configured from 30 to 300 seconds, or set to 0 to inactivate it. The default value is 120 seconds. If the idle timeout is enabled, then the master station should periodically send probe requests to the device to maintain some kind of activity on the connection socket if it wants to keep the connection open.

2.4 DNP3 Requests

Refer to Appendix A for specific requests and responses. Appendix B contains the standard DNP Device Profile Document.

The PMU allows retrieving regular analog and binary data from the device by executing directed (non-broadcast) Read requests.

Binary-Output-Status objects and Analog-Output-Status objects are sent with flags that always indicate ONLINE.

A Binary-Output-Status object that indicates the current state of a control digital point (relay) uses remote forced data as well as local forced data bits. The value of a state bit indicates the current state of the digital output point.

The PMU executes the parameter clear function using the Direct-Operate, SBO/Operate or Direct-Operate-No-Acknowledge command to specified points of the Control-Relay-Output-Block object.

Issuing the Direct-Operate, SBO/Operate or Direct-Operate-No-Acknowledge command to appropriative points of the Analog-Output-Block object can change the setup parameters. The device also supports the DNP functions Write, Cold-Restart and Delay Measurement.

The device attempts to respond with the same object variation and qualifier as those in the request. Exceptions to this rule include changing variation 0 to a specific variation and changing qualifier code 6 to 1. Requests with object variation 0 (no preferred format specified) are responded by objects formatted per variation 1.

If the device receives an invalid request, it sets the internal indication to the error code. The following internal indication bits are supported:

Octet Position	Bit Position	Description
0	0	Set when a request received with a broadcast destination address. Cleared after next response.
0	7	Device restart - set when the device powers up or after executing Cold Restart, cleared by writing zero to object 80.
0	4	Time-synchronization required from the master. Cleared when master sets the time.
0	5	Set when the device is in the Local state. Cleared when the device is in the Remote state.
1	5	Set when the current configuration in the device is corrupted. May also be set as a result of the legal changes in the setup configuration whenever another setup is affected by the changes made. Cleared by resetting the device diagnostics.

2.4.1 Class 0 Response

The PMU DNP implementation supports a wide variety of messages. The most common method of getting static object information from the device via DNP is to issue a read Class 0 request.

The PMU allows you to configure the Class 0 response by assigning ranges of points to be polled via Class 0 requests (see Section 6.2).

2.4.2 Event Objects

The PMU allows you to assign any static object point to a predefined object change event point for Class 1, Class 2 or Class 3 event polling. A total of 64 change event points are available. You can assign any of the Analog Input, Binary Input or Binary Counter static points to the corresponding change event point through the DNP Event setup (see Section 6.3). You can also link any point to Class 1, Class 2 or Class 3 object polling.

By default, a change event point index is the same as for the corresponding static object point. The PMU gives you an option to re-map a static point index for the corresponding event point starting with index 0, separately for each object type - Analog Input, Binary Input or Binary Counter change events. For example, if the re-mapping option is active and you first assign static point AI:23 (1-sec frequency) to an event Class 1 point, the corresponding Analog Input change event point will be identified as point 0 in the Class 1 poll response.

Each point assigned to an event class can be separately enabled or disabled for scanning.

The conditions for Analog Input change events can be specified by either an operating threshold, or a deadband, using one of the following three relations:

Delta – a new event is generated when the absolute value of the difference between the last reported value of the point and its current value exceeds the specified deadband value;

More than (Over) - a new event is generated when the point value rises over the specified threshold, and then when the point value returns below the threshold taking into consideration a predefined hysteresis;

Less than (Under) - a new event is generated when the point value drops below the specified threshold, and then when the point value returns above the threshold taking into consideration a predefined hysteresis.

For Binary Counter and Binary Input change events, a Delta relation is only applicable.

The number of event points for each object type (Analog Input, Binary Input or Binary Counter) is limited through the DNP Options setup (see Section 6.1). Every time you change the number of points for any of the objects, the device clears all event buffers and links the default set of static points to each event object type.

The scan time rates for polling events of different types are as follows:

- 1/2 cycle for Binary Input points
- 200 ms for Binary Counter and Analog Input points

The memory consumption for keeping events depends on the event objects variation, or DNP object size. For each event object type and event class, the device uses a separate buffer. The maximum buffer size (MBS) per DNP event object/event class is 512 bytes. The maximum number of events per class that the device can hold can be calculated as follows:

Maximum number of events = MBS/(DNP Event Object Size + 1)

For example, the device can hold up to 512/12=40 measures of the 32-bit Analog change event with Time objects, or up to 512/8=64 measures of the 8-bit Binary change event with Time objects.

To disable change event objects, explicitly set all registers that specify the number of the Analog Input, Binary Input and Binary Counter objects to generate events to 0. In this case, the device will support only static objects.

2.4.3 Device Address

Each device on a serial DNP link must have a unique address. The PMU allows a device address in the range of 0 to 65532 to be selected. The DNP master can use addresses 65533 to 65535 for broadcast requests. A broadcast request never generates a DNP response.

When communicating via the Internet, the address field is not checked and is returned in the response message header.

2.4.4 Serial Transaction Timing

The PMU response time to master requests via serial ports is indicated in Table 2-1. It includes the receive termination delay - 4 character times plus a default 4-ms character timeout (user-programmable from 1 to 1000 ms), and a default 5-ms response delay (user-programmable from 0 to 1000 ms).

Table 2-1 Response Time

Baud Rate, bps	Response Time, ms (including a 5-ms response delay)		
	Min	Max	Typical
9600	13	15	13
19200	11	12	11
57600	9	10	9
115200	9	10	9

The Direct-Operate, SBO/Operate or Direct-Operate-No-Acknowledge requests for reset/clear registers and setpoint changing are immediately confirmed.

2.4.5 Scaling 16-bit Analog Inputs

Any of the variations 1 through 4 can be used with the Analog Input objects. Variations specified in Sections 3.1 and 3.5 show those that can be used to read a full-range value without a possible over-range error when no scaling is used to accommodate the value to the requested object size.

When over-range occurs, a positive value is reported as 32767 and a negative value as -32768, with the over-range bit in the flag octet being set to 1 if a variation 2 is requested. To avoid over-range errors when a variation 2 or 4 is required, a liner scaling may be used to scale 32-bit analog readings to 16-bit Analog Input objects (see Section 6.1, DNP Options setup). Scaling is enabled in the device by default.

When scaling is enabled, either analog input requested with variation 2 or 4 will be scaled to the range of -32768 to 32767 for bi-directional parameters (such as power and power factor), and to the range of 0 to 32767 for single-ended positive parameters (voltage, current, frequency, etc.). To get a true reading, the reverse conversion should be done using the following formula:

$$Y = ((X - DNP\_LO) \times (HI - LO)) / (DNP\_HI - DNP\_LO) + LO$$

where:

Y	-	True reading in engineering units
X	-	Raw input data in the range of DNP_LO – DNP_HI
LO, HI	-	Data low and high scales in engineering units (for device data scales, see Section 4)
DNP_LO	-	DNP low conversion scale: DNP_LO = -32768 for a point with a negative LO scale DNP_LO = 0 for a point with a zero or positive LO scale
DNP_HI	-	DNP high conversion scale: DNP_HI = 32767

EXAMPLE

If you have read a value of 2000 for point AI:3 that shows the I1 current (see Section 3.1), the CT ratio is 200A : 5A = 40 and the secondary current scale is 10A (the high current scale is 40 × 10 = 400A), then the current reading in engineering units is as follows:

$$(2000 - 0) \times (400 - 0)/(32767 - 0) + 0 = 24.41A$$

2.4.6 Scaling 16-bit Binary Counters

Binary counters are stored in the device in 32-bit integer format. Using 16-bit Binary Counter objects can cause over-range errors if the counter value exceeds 32767.

Scaling binary counters (see DNP Options setup in Section 6.1) allows changing a binary counter unit from 1 to 1000 in powers of 10 to accommodate a 32-bit counter value to 16-bit object format. If the scaling unit is greater than 1, the counter value is reported being divided by the scaling unit. To get the actual value, multiply the counter reading by the selected scaling unit.

2.5 Password Protection

The PMU has a password protection option allowing you to protect your setups, cumulative registers and logs from being changed or cleared through communications. You can disable or enable password protection through communications or via the front display. For details, refer to your device Installation and Operation Manual.

The user password must be written to the device authorization register (point AO:192) before another write request is issued. If the correct password is not supplied while password protection is enabled, the device will respond to all write requests with the exception response "Control operation not supported for this point".

After making changes, it is recommended to write a zero in the device authorization register to activate password protection.

3 DNP Point Map

3.1 Analog Inputs - Basic Set

Object : Var.	Object : Point	Description[2]	Options/Range[1]	Units[1]	Type	R/W	Notes
30:3	AI:0	V1 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:1	V2 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:2	V3 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:3	I1 current	0-Imax	U2	UINT32	R	
30:3	AI:4	I2 current	0-Imax	U2	UINT32	R	
30:3	AI:5	I3 current	0-Imax	U2	UINT32	R	
30:3	AI:6	kW L1	-Pmax-Pmax	U3	INT32	R	
30:3	AI:7	kW L2	-Pmax-Pmax	U3	INT32	R	
30:3	AI:8	kW L3	-Pmax-Pmax	U3	INT32	R	
30:3	AI:9	kvar L1	-Pmax-Pmax	U3	INT32	R	
30:3	AI:10	kvar L2	-Pmax-Pmax	U3	INT32	R	
30:3	AI:11	kvar L3	-Pmax-Pmax	U3	INT32	R	
30:3	AI:12	kVA L1	0-Pmax	U3	UINT32	R	
30:3	AI:13	kVA L2	0-Pmax	U3	UINT32	R	
30:3	AI:14	kVA L3	0-Pmax	U3	UINT32	R	
30:4	AI:15	Power factor L1	-1000-1000	×0.001	INT16	R	
30:4	AI:16	Power factor L2	-1000-1000	×0.001	INT16	R	
30:4	AI:17	Power factor L3	-1000-1000	×0.001	INT16	R	
30:4	AI:18	Total PF	-1000-1000	×0.001	INT16	R	
30:3	AI:19	Total kW	-Pmax-Pmax	U3	INT32	R	
30:3	AI:20	Total kvar	-Pmax-Pmax	U3	INT32	R	
30:3	AI:21	Total kVA	0-Pmax	U3	UINT32	R	
30:3	AI:22	In (neutral) current	0-Imax	U2	UINT32	R	
30:4	AI:23	Frequency	0-10000	×0.01Hz	UINT16	R	

NOTES:

1 For volts, amps and power scales and units, refer to Section 4 "Data Scales and Units". For analog input scaling formulas and examples, see Section 2.2.5, "Scaling Analog Input Objects".

2 All AC measurements are one-second average fundamental frequency values updated at the UTC second rollover.

3.2 Binary Inputs - Basic Set

Object : Var.	Object : Point	Description	Range	Units	Type	R/W	Notes
		Relays					
01:1	BI:0	Relay #1 status	0-1			R	
01:1	BI:1	Relay #2 status	0-1			R	
…	…	…	0-1			R	
01:1	BI:12	Relay #13 status	0-1			R	

Object : Var.	Object : Point	Description	Range	Units	Type	R/W	Notes
		Digital Inputs					
01:1	BI:64	Digital input #1	0-1			R	
01:1	BI:65	Digital input #2	0-1			R	
…	…	…					
01:1	BI:88	Digital input #25	0-1			R	

3.3 Binary Counters - Basic Set

Object : Var.	Object : Point	Description	Range	Units	Type	R/W	Notes
20:5	BC:0	Counter 1	0-999,999,999		UINT32	R	
20:5	BC:1	Counter 2	0-999,999,999		UINT32	R	
…	…	…			UINT32	R	
20:5	BC:31	Counter 32	0-999,999,999		UINT32	R	

3.4 Analog Inputs, Binary Inputs and Counters – Extended Set

Object : Var.	Object : Point	**Description**[2]	**Options/Range**[1]	**Units**[1]	Type	R/W	Notes
30:4	AI:32768	**None**	0		UINT16	R	
		Digital Inputs				R	
01:1	BI:34304	DI1	0-1			R	
01:1	BI:34305	DI2	0-1			R	
		…				R	
01:1	BI:34328	DI25	0-1			R	
		Relay Outputs				R	
01:1	BI:34816	Relay #1	0-1			R	
01:1	BI:34817	Relay #2	0-1			R	
		…				R	
01:1	BI:34828	Relay #13	0-1			R	
		Counters					
20:5	BC:35328	Counter #1	0-999,999,999		UINT32	R	
20:5	BC:35329	Counter #2	0-999,999,999		UINT32	R	
		…				R	
20:5	BC:35359	Counter #32	0-999,999,999		UINT32	R	
		RT Phase Values					
30:3	AI:35840	V1 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:35841	V2 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:35842	V3 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:35843	I1 current	0-Imax	U2	UINT32	R	
30:3	AI:35844	I2 current	0-Imax	U2	UINT32	R	
30:3	AI:35845	I3 current	0-Imax	U2	UINT32	R	
30:3	AI:35846	kW L1	-Pmax-Pmax	U3	INT32	R	
30:3	AI:35847	kW L2	-Pmax-Pmax	U3	INT32	R	
30:3	AI:35848	kW L3	-Pmax-Pmax	U3	INT32	R	

Object : Var.	Object : Point	Description[2]	Options/Range[1]	Units[1]	Type	R/W	Notes
30:3	AI:35849	kvar L1	-Pmax-Pmax	U3	INT32	R	
30:3	AI:35850	kvar L2	-Pmax-Pmax	U3	INT32	R	
30:3	AI:35851	kvar L3	-Pmax-Pmax	U3	INT32	R	
30:3	AI:35852	kVA L1	0-Pmax	U3	UINT32	R	
30:3	AI:35853	kVA L2	0-Pmax	U3	UINT32	R	
30:3	AI:35854	kVA L3	0-Pmax	U3	UINT32	R	
30:4	AI:35855	Power factor L1	-1000-1000	×0.001	INT16	R	
30:4	AI:35856	Power factor L2	-1000-1000	×0.001	INT16	R	
30:4	AI:35857	Power factor L3	-1000-1000	×0.001	INT16	R	
30:4	AI:35858-35869	Not used	0		UINT16	R	
30:3	AI:35870	V12 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:35871	V23 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:35872	V31 voltage	0-Vmax	U1	UINT32	R	
		RT Total Values					
30:3	AI:36608	Total kW	-Pmax-Pmax	U3	INT32	R	
30:3	AI:36609	Total kvar	-Pmax-Pmax	U3	INT32	R	
30:3	AI:36610	Total kVA	0-Pmax	U3	UINT32	R	
30:4	AI:36611	Total PF	-1000-1000	×0.001	INT16	R	
		RT Auxiliary Values					
30:3	AI:36864	Not used	0		UINT32	R	
30:3	AI:36865	In (neutral) current	0-Imax	U2	UINT32	R	
30:4	AI:36866	Frequency	0-10000	×0.01Hz	UINT16	R	
30:4	AI:36867	Voltage unbalance	0-3000	×0.1%	UINT16	R	
30:4	AI:36868	Current unbalance	0-3000	×0.1%	UINT16	R	
30:3	AI:36869-36871	Not used	0		UINT32	R	
30:3	AI:36872	Frequency (3 decimals)	0-100000	×0.001Hz	UINT32	R	
		Average Phase Values					
30:3	AI:37120	V1	0-Vmax	U1	UINT32	R	
30:3	AI:37121	V2	0-Vmax	U1	UINT32	R	
30:3	AI:37122	V3	0-Vmax	U1	UINT32	R	
30:3	AI:37123	I1 current	0-Imax	U2	UINT32	R	
30:3	AI:37124	I2 current	0-Imax	U2	UINT32	R	
30:3	AI:37125	I3 current	0-Imax	U2	UINT32	R	
30:3	AI:37126	kW L1	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37127	kW L2	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37128	kW L3	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37129	kvar L1	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37130	kvar L2	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37131	kvar L3	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37132	kVA L1	0-Pmax	U3	UINT32	R	
30:3	AI:37133	kVA L2	0-Pmax	U3	UINT32	R	
30:3	AI:37134	kVA L3	0-Pmax	U3	UINT32	R	
30:4	AI:37135	Power factor L1	-1000-1000	×0.001	INT16	R	

Object : Var.	Object : Point	Description[2]	Options/Range[1]	Units[1]	Type	R/W	Notes
30:4	AI:37136	Power factor L2	-1000-1000	×0.001	INT16	R	
30:4	AI:37137	Power factor L3	-1000-1000	×0.001	INT16	R	
30:4	AI:37138-37149	Not used	0		UINT16	R	
30:3	AI:37150	V12 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:37151	V23 voltage	0-Vmax	U1	UINT32	R	
30:3	AI:37152	V31 voltage	0-Vmax	U1	UINT32	R	
		Average Total Values					
30:3	AI:37888	Total kW	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37889	Total kvar	-Pmax-Pmax	U3	INT32	R	
30:3	AI:37890	Total kVA	0-Pmax	U3	UINT32	R	
30:4	AI:37891	Total PF	-1000-1000	×0.001	INT16	R	
		Average Auxiliary Values					
30:3	AI:38144	Not used	0	U2	UINT32	R	
30:3	AI:38145	In (neutral) current	0-Imax	U2	UINT32	R	
30:4	AI:38146	Frequency	0-10000	×0.01Hz	UINT16	R	
30:4	AI:38147	Voltage unbalance	0-3000	×0.1%	UINT16	R	
30:4	AI:38148	Current unbalance	0-3000	×0.1%	UINT16	R	
30:3	AI:38149-38152	Not used	0		UINT32	R	
30:3	AI:38153	Internal temperature	-2000 to 2000	×0.1ºC	INT32	R	
30:3	AI:38154	Frequency (3 decimals)	0-100000	×0.001Hz	UINT32	R	
30:3	AI:38155	Lithium battery voltage	0-100000	×0.001V	UINT32	R	
		RT Analog Inputs					
30:3	AI:47872	Analog input AI1	AI1min-AI1max		UINT32	R	
		Synchrophasor					
30:3	AI:25408	Frame number	0-239		UINT32	R	
30:3	AI:25409	Frame timestamp, UTC seconds since 1/1/1970		sec	UINT32	R	
30:3	AI:25410	Frame timestamp, fraction of second		µsec	UINT32	R	
30:3	AI:25411	Time quality, bitmap	F39		UINT32	R	
30:3	AI:25412	Data source/stream ID number	1-65534		UINT32	R	
30:3	AI:25413	Frame status, bitmap	F40		UINT32	R	
30:3	AI:25414	Frequency deviation from nominal or actual frequency, Hz	-32767 to 32767, or 0 to 100000	×0.001 Hz	UINT32	R	
30:3	AI:25415	Rate of change of frequency (ROCOF), Hz/s	-32767 to 32767	×0.01 Hz/s	UINT32	R	
30:3	AI:25416	V1 phasor magnitude	0-Vmax	U1	UINT32	R	
30:3	AI:25417	V1 phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:3	AI:25418	V2 phasor magnitude	0-Vmax	U1	UINT32	R	
30:3	AI:25419	V2 phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:3	AI:25420	V3 phasor magnitude	0-Vmax	U1	UINT32	R	
30:3	AI:25421	V3 phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:3	AI:25422	I1 phasor magnitude	0-Imax	U2	UINT32	R	
30:3	AI:25423	I1 phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:3	AI:25424	I2 phasor magnitude	0-Imax	U2	UINT32	R	
30:3	AI:25425	I2 phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	

Object : Var.	Object : Point	Description[2]	Options/Range[1]	Units[1]	Type	R/W	Notes
30:3	AI:25426	I3 phasor magnitude	0-Imax	U2	UINT32	R	
30:3	AI:25427	I3 phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:5	AI:25428	V1 phasor, Re	0-Vmax	V	FLOAT32	R	
30:5	AI:25429	V1 phasor, Im	0-Vmax	V	FLOAT32	R	
30:5	AI:25430	V2 phasor, Re	0-Vmax	V	FLOAT32	R	
30:5	AI:25431	V2 phasor, Im	0-Vmax	V	FLOAT32	R	
30:5	AI:25432	V3 phasor, Re	0-Vmax	V	FLOAT32	R	
30:5	AI:25433	V3 phasor, Im	0-Vmax	V	FLOAT32	R	
30:5	AI:25434	I1 phasor, Re	0-Imax	A	FLOAT32	R	
30:5	AI:25435	I1 phasor, Im	0-Imax	A	FLOAT32	R	
30:5	AI:25436	I2 phasor, Re	0-Imax	A	FLOAT32	R	
30:3	AI:25437	I2 phasor, Im	0-Imax	A	FLOAT32	R	
30:5	AI:25438	I3 phasor, Re	0-Imax	A	FLOAT32	R	
30:5	AI:25439	I3 phasor, Im	0-Imax	A	FLOAT32	R	
30:3	AI:25440	V1seq positive sequence voltage phasor magnitude	0-Vmax	U1	UINT32	R	
30:3	AI:25441	V1seq positive sequence voltage phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:3	AI:25442	I1seq positive sequence current phasor magnitude	0-Imax	U2	UINT32	R	
30:3	AI:25443	I1seq positive sequence current phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:5	AI:25444	V1seq positive sequence voltage phasor, Re	0-Vmax	V	FLOAT32	R	
30:5	AI:25445	V1seq positive sequence voltage phasor, Im	0-Vmax	V	FLOAT32	R	
30:5	AI:25446	I1seq positive sequence current phasor, Re	0-Imax	A	FLOAT32	R	
30:5	AI:25447	I1seq positive sequence current phasor, Im	0-Imax	A	FLOAT32	R	
30:3	AI:25448	V2seq negative sequence voltage phasor magnitude	0-Vmax	U1	UINT32	R	
30:3	AI:25449	V2seq negative sequence voltage phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:3	AI:25450	I2seq negative sequence current phasor magnitude	0-Imax	U2	UINT32	R	
30:3	AI:25451	I2seq negative sequence current phasor angle	-179999 to 180000	×0.001 deg	UINT32	R	
30:5	AI:25452	V2seq negative sequence voltage phasor, Re	0-Vmax	V	FLOAT32	R	
30:5	AI:25453	V2seq negative sequence voltage phasor, Im	0-Vmax	V	FLOAT32	R	
30:5	AI:25454	I2seq negative sequence current phasor, Re	0-Imax	A	FLOAT32	R	
30:5	AI:25455	I2seq negative sequence current phasor, Im	0-Imax	A	FLOAT32	R	

NOTES:

1 For volts, amps, power and frequency scales and units: refer to Section 4 ”Data Scales and Units”. For analog input scaling formulas and examples, see Section 2.2.5 “Scaling Analog Input Objects”.

2 All AC measurements are fundamental frequency values. Real-time (RT) measurements are synchronized with the PMU frame rate. All average measurements are one-second average values updated at the UTC second rollover.

3.5 Factory Device Settings and Identification

Object:Var.	Object:Point	Description	Options/Range	Units	Type	R/W	Notes
Device Identification							
30:3	AI:256	Device serial number	0-999999		UINT32	R	
30:3	AI:257	Device model ID	230000		UINT32	R	
30:3	AI:258-261	Device model name	"PMU"		UINT32	R	Null-terminated string. Each four characters are packed into a 32-bit word.
30:3	AI:262	Device options			UINT32	R	
30:3	AI:263-265	Not used			UINT32	R	
30:4	AI:266	Device firmware version number	4801-4899		UINT16	R	Two higher decimal digits = major version number, two lower decimal digits = minor version number
30:4	AI:267	Device firmware build number	1-99		UINT16	R	
30:4	AI:268-269	Not used			UINT16	R	
30:4	AI:270	Bootloader version number			UINT16	R	Two higher decimal digits = major version number, two lower decimal digits = minor version number
30:4	AI:271	Bootloader build number	1-99		UINT16	R	
30:3	AI:272-274	Not used			UINT32	R	
Factory Device Settings							
30:4	AI:275	V1-V3 input range	120, 480	V	UINT16	R	
30:4	AI:276	V1-V3 input overload	120	%	UINT16	R	
30:4	AI:279	I1-I3 input range	1, 5	A	UINT16	R	
30:4	AI:280	I1-I3 input overload	200	%	UINT16	R	
Port Identification							
30:4	AI:320	Active port number	0 = serial port COM1 5 = USB/Modbus port 6… = Ethernet/TCP port		UINT16	R	

3.6 Device Control

Object : Var.	Object : Point	Description	Options/Range	Units	Type	R/W	Notes
Device Authorization Register							
40:1(read) 41:1(write)	AO:192	When write: 8-digit password. When read: 0 = access permitted, -1 = authorization required.	0/-1 (read) 0-99999999(write)			R/W	
Remote Relay Control							
10:2(read) 12:1(write)	BO:0 CROB:0	Relay #1 Force operate/Force release/Normal	0/1 = state OFF/ON			R/W	[4]
10:2(read) 12:1(write)	BO:1 CROB:1	Relay #2 Force operate/Force release/Normal	0/1 = state OFF/ON			R/W	[4]
		…					

Object : Var.	Object : Point	Description	Options/Range	Units	Type	R/W	Notes
10:2(read) 12:1(write)	BO:12 CROB:12	Relay #13 Force operate/Force release/Normal	0/1 = state OFF/ON			R/W	[4]
Device Reset/Clear							
10:2(read) 12:1(write)	BO:76 CROB:76	Clear pulse counters (all counters)	0/1 = state OFF/ON			R/W	Returns zero PULSE ON [1]
10:2(read) 12:1(write)	BO:77-84 CROB:77-84	Clear pulse counter#1-#8	0/1 = state OFF/ON			R/W	Returns zero PULSE ON [1]
10:2(read) 12:1(write)	BO:94-101 CROB:94-101	Clear pulse counter#9-#16	0/1 = state OFF/ON			R/W	Returns zero PULSE ON [1]
Device Diagnostics							
10:2(read) 12:1(write)	BO:128 CROB:128	Critical error	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:129 CROB:129	Permanent fault (critical error)	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:130 CROB:130	RAM/Data error	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:131 CROB:131	CPU watchdog reset	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:132 CROB:132	DSP/Sampling fault	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:133 CROB:133	CPU exception	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:134 CROB:134	Reserved	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:135 CROB:135	Software watchdog reset	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:136 CROB:136	Power down	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:137 CROB:137	Device reset [3]	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:138 CROB:138	Configuration reset [3]	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:139 CROB:139	RTC fault (critical error)	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:140 CROB:140	Configuration fault (critical error)	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:141 CROB:141	Reserved	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:142 CROB:142	Expanded memory fault	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:143 CROB:143	CPU EEPROM fault	0/1 = state OFF/ON			R/W	[2]
10:2(read) 12:1(write)	BO:144 CROB:144	AC board EEPROM fault	0/1 = state OFF/ON			R/W	[2]

Object : Var.	Object : Point	Description	Options/Range	Units	Type	R/W	Notes
10:2(read) 12:1(write)	BO:145 CROB:145	I/O board EEPROM fault	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:146 CROB:146	Reserved	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:147 CROB:147	Reserved	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:148 CROB:148	C Library error	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:149 CROB:149	RTOS Kernel error	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:150 CROB:150	Task error	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:151 CROB:151	Reserved	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:152 CROB:152	IRIG-B/PTP signal lost	0/1 = state OFF/ON			R/W	2
10:2(read) 12:1(write)	BO:153 CROB:153	IRIG-B/PTP time unlocked	0/1 = state OFF/ON			R/W	2

NOTES:

1 The following restriction should be noted when using object 12 to control the listed points.

- The Count byte is ignored.
- The Control Code byte is checked:
  - Pulse On (1) is valid for all points; other codes are invalid and will be rejected.
- The On Time and Off Time fields are ignored.
- The status byte in the response will reflect the success or failure of the control operation:
  - Request Accepted (0) will be returned if the command was accepted;
  - Request not Accepted due to Formatting Errors (3) is returned if the Control Code byte was incorrectly formatted or if an invalid code was present in the command;
  - Control Operation not Supported for this Point (4) is returned if the Control Point was out of control.

2 The device diagnostics points indicate possible problems with the device hardware or setup configuration. The hardware problems are indicated by the appropriate points, which are set whenever the device fails self-test diagnostics, or in the event of loss of power. The dedicated binary point indicates the setup configuration problems, which is set when either configuration register is corrupted. In this event, the device will use the default configuration. The configuration corrupt bit may also be set as a result of the legal changes in the setup configuration since the device might implicitly change or clear other setups if they are affected by the changes made.

Issuing the Direct-Operate, SBO/Operate or Direct-Operate-No-Acknowledge command using the Control-Relay-Output-Block object (with the code operation Latch-Off) to points 128-153 resets device diagnostics points.

The following restrictions should be noted when using Object 12 to control these points:

- The Count byte is ignored.
- The Control Code byte is checked:

- Latch Off is valid for all points; other codes are invalid and will be rejected.

- The On Time and Off Time fields are ignored.
- The status byte in the response will reflect the success or failure of the control operation:
  - Request Accepted (0) is returned if the command was accepted;
  - Request not Accepted due to Formatting Errors (3) is returned if the Control Code byte was incorrectly formatted or if an invalid Code was present in the command.

[3] These self-check alarms are doubled with the corresponding internal indication bits.

[4] To manually operate relays, use the Direct-Operate, SBO/Operate or Direct-Operate-No-Acknowledge command to points 0-31 of the Control-Relay-Output-Block object with the Control Code value Latch On. To manually release relays, use the Direct-Operate (or SBO/Operate or Direct-Operate-No-Acknowledge) command to point 0-31 of the Control-Relay-Output-Block object with the Control Code value Latch Off. To revert relays to normal operation, use the Direct-Operate, SBO/Operate or Direct-Operate-No-Acknowledge command to the corresponding points of the Control-Relay-Output-Block object with the Control Code value Null Operation and the Clear sub-field set to 1.

To operate a relay in pulse mode with the Pulse On or Pulse Off control code, put the relay in pulse mode and select a required pulse polarity via the Relay Outputs setup (use the supplemental PAS software to change the relay properties). The actual pulse width will be taken from the On Time/Off Time fields of the Control-Relay-Output-Block object.

The following restrictions should be noted when using object 12 to control these points:

- The Count byte is ignored.
- The Control Code byte is checked:
  - Pulse On, Pulse Off, Latch On (Pulse On/Close) and Latch Off (Pulse On/Trip) are valid for all points; other codes are invalid and will be rejected;
  - Clear sub-field is valid; other sub-fields are ignored.
- The On Time specifies in ms the amount of time the digital point is to be turned on. The minimal value of the On Time is 500 ms and the actual value may differ from the specified value by up to 10 ms.
- The Off Time specifies in ms the amount of time the digital point is to be turned off. The minimal value of the Off Time is 500 ms and the actual value may differ from the specified value by up to 10 ms.
- The Status byte in the response reflects the success or failure of the control operation:
  - Request Accepted (0) will be return if the command was accepted;
  - Request not Accepted due to Formatting Errors (3) will be returned if the Control Code byte was incorrectly formatted or an invalid Code was present in the command;
  - Control Operation not Supported for this Point (4) will be returned if the Control Point was out of control.

3.7 Device Setup

Object:Var.	Object:Point	Description	Options/Range	Units	Type	R/W	Notes
Basic Setup							
40:1 (read)	AO:0	Reserved	65535		UINT16	R	
40:1 (read) 41:1 (write)	AO:1	PT ratio (primary to secondary ratio)	10-65000	×0.1	UINT16	R/W	
40:2 (read) 41:2 (write)	AO:2	PT secondary (line-to-line voltage)	500-7000	×0.1V	UINT16	R/W	
40:2 (read)	AO:3-4	Reserved	65535		UINT16	R	
40:2 (read) 41:2 (write)	AO:5	CT primary current	1-30000	A	UINT16	R/W	
40:2 (read)	AO:6-16	Reserved	65535		UINT16	R	
40:2 (read) 41:2 (write)	AO:17	Nominal line frequency	50, 60	Hz	UINT16	R/W	
40:2 (read) 41:2 (write)	AO:18	Phase order	0=ABC, 1=CBA		UINT16	R/W	
40:2 (read)	AO:19-22	Reserved	65535		UINT16	R	
40:2 (read) 41:2 (write)	AO:23	Data rate, frames/s	1,2,3,4,5,6,10,12,15,20,25,30,50, 60,100,120,200,240		UINT16	R/W	
40:2 (read)	AO:24-59	Reserved	65535		UINT16	R	
40:2 (read) 41:2 (write)	AO:60	L1 current direction	0=regular, 1=reverse		UINT16	R/W	
40:2 (read) 41:2 (write)	AO:61	L2 current direction	0=regular, 1=reverse		UINT16	R/W	
40:2 (read) 41:2 (write)	AO:62	L3 current direction	0=regular, 1=reverse		UINT16	R/W	
Communication Port Setup							
40:2 (read) 41:2 (write)	AO:112	Communication protocol	0 = Modbus RTU, 1 = Modbus ASCII, 2 = DNP3.0		UINT16	R/W	
40:2 (read) 41:2 (write)	AO:113	Interface	2 = RS-485		UINT16	R/W	
40:2 (read) 41:2 (write)	AO:114	Device address	Modbus: 1-247 DNP3.0: 0–65532		UINT16	R/W	
40:2 (read) 41:2 (write)	AO:115	Baud rate	4 = 2400 bps, 5 = 4800 bps, 6 = 9600 bps, 7 = 19200 bps, 8 = 38400 bps, 9 = 57600 bps, 10 = 115200 bps		UINT16	R/W	
40:2 (read) 41:2 (write)	AO:116	Data format	0 = 7 bits/even parity, 1 = 8 bits/no parity, 2 = 8 bits/even parity		UINT16	R/W	
40:2 (read)	AO:117	Reserved	65535		UINT16	R	
40:2 (read)	AO:118	Reserved	65535		UINT16	R	
40:2 (read)	AO:119	Minimum delay before sending data	0-1000 (default = 5)	ms	UINT16	R/W	

Object:Var.	Object:Point	Description	Options/Range	Units	Type	R/W	Notes
41:2 (write)							
40:2 (read) 41:2 (write)	AO:120	Inter-character timeout	1-1000 (default = 4)	ms	UINT16	R/W	Added to standard 4-character time
40:2 (read)	AO:121-127	Reserved	65535		UINT16	R	

3.8 DNP Protocol Setup

Object:Var.	Object:Point	Description	Options/Range	Units	Type	R/W	Notes
DNP Options Setup							
40:2 (read) 41:2 (write)	AO:64	Default Binary Input Static object variation	F3 (default=0)		UINT16	R/W	1
40:2 (read) 41:2 (write)	AO:65	Default Binary Input Change object variation	F3 (default=1)		UINT16	R/W	1
40:2 (read) 41:2 (write)	AO:66	Default Binary Counter static object variation	F3 (default=1)		UINT16	R/W	1
40:2 (read)	AO:67	Reserved	65535		UINT16	R	
40:2 (read)	AO:68	Reserved	65535		UINT16	R	
40:2 (read) 41:2 (write)	AO:69	Default Binary Counter Change Event object variation	F3 (default=1)		UINT16	R/W	1
40:2 (read) 41:2 (write)	AO:70	Default Analog Input object variation	F3 (default=1)		UINT16	R/W	1
40:2 (read)	AO:71	Reserved	65535		UINT16	R	
40:2 (read)	AO:72	Reserved	65535		UINT16	R	
40:2 (read) 41:2 (write)	AO:73	Default Analog Input Change Event object variation	F3 (default=1)		UINT16	R/W	1
40:2 (read) 41:2 (write)	AO:74	Re-mapping static point indices for event objects	0=disabled (default), 1=enabled		UINT16	R/W	
40:1 (read) 41:2 (write)	AO:75	16-bit BC scaling	0=×1 (default), 1=×10, 2=×100, 3=×1000		UINT16	R/W	6
40:1 (read) 41:2 (write)	AO:76	16-bit AI scaling	0=disabled, 1=enabled (default)		UINT16	R/W	3
40:2 (read) 41:2 (write)	AO:77	Number of Analog Input change event points	0 to 64 (default=0)		UINT16	R/W	2
40:2 (read) 41:2 (write)	AO:78	Number of Binary Input change event points	0 to 64 (default=0)		UINT16	R/W	2
40:2 (read) 41:2 (write)	AO:79	Number of Binary Counter change event points	0 to 64 (default=0)		UINT16	R/W	2
40:2 (read) 41:2 (write)	AO:80	Select/Operate Timeout	2 to 30 (default=10 sec)	sec	UINT16	R/W	4
40:2 (read) 41:2 (write)	AO:81	Multi Fragment Interval	50 to 500 (default=50 ms)	ms	UINT16	R/W	
40:2 (read) 41:2 (write)	AO:82	DNP3.0 TCP port number	5001 to 49151 (default=20000)		UINT16	R/W	
40:1 (read)	AO:83-AO:84	Reserved	65535		UINT16	R	
40:1 (read) 41:1 (write)	AO:85	Time Sync Period	1 to 86400 (default=86400 sec) 0 = disable time requests	sec	UINT32	R/W	5
40:2 (read) 41:2 (write)	AO:86	Voltage scale, secondary volts	60 to 600	V	UINT16	R/W	
40:2 (read)	AO:87	Current scale, secondary amps	10 to 200	×0.1A	UINT16	R/W	

Object:Var.	Object:Point	Description	Options/Range	Units	Type	R/W	Notes
41:2 (write)							
DNP Events Setup							
40:2(read) 41:2(write)	+0	DNP point index	DNP point index for the selected object		UINT16	R/W	
40:1(read) 41:1(write)	+1	Threshold/Deadband			INT32	R/W	A hysteresis for the point return threshold is 0.05Hz for frequency and 2% of the operating threshold for other points
40:2(read) 41:2(write)	+2	Event scan control field (bitmap)	Bits 0-1 - DNP Object: 0=none, 1=AI, 2=BI, 3=BC Bit 2 – Object change event scan: 0= disabled, 1=enabled Bits 5-6 - DNP event poll class: 0=Class 1, 1=Class 2, 2=Class 3 Bit 7 – unused Bits 8-9 – Threshold/Deadband relation: 0=Delta, 1=more than (over threshold), 2=less than (under threshold)		UINT16	R/W	
	AO:896-AO:898	**DNP Event #1**					
	AO:899-AO:901	**DNP Event #2**					
		…					
	AO:1085-AO:1087	**DNP Event #64**					
DNP Class 0 Point Assignments							
40:1(read) 41:1(write)	+0	DNP object and variation	F4		UINT32	R/W	
40:1(read) 41:1(write)	+1	Start point index in a range			UINT32	R/W	
40:2(read) 41:2(write)	+2	Number of points in a range	0-128		UINT16	R/W	
	AO:1152-AO:1154	**DNP Class 0 Points Range 1**					
	AO:1155-AO:1157	**DNP Class 0 Points Range 2**					
		…					
	AO:1245-AO:1247	**DNP Class 0 Points Range 32**					

NOTES:

1 The default object variation indicates the variation that is used for requests with qualifier code 06 (variation 0) when no specific variation is requested by a master station.

2 The sum of all points allocated for change event objects should not exceed 64. If no points are allocated for events, the report-by-exception mode is not supported.

3 Scaling 16-bit AI objects (see Section 2.2.5) allows 32-bit analog input readings to fit into a 16-bit object format. Scaling is enabled by default. It is not applied to 32-bit AI objects (object 30, variations 1, 3 and 5).

4 The Select-Before-Operate command causes the device to start a timer. The following Operate command must be sent before the value specified by the Select/Operate Timeout expires.

5 The device requests time synchronization by bit 4 in the first octet of the internal indication word being set when the time specified by the Time Sync Period elapses. The master should synchronize the time in the device by writing the Time and Date object. The device does not request time synchronization if the Time Sync Period is set to 0.

[6] Scaling 16-bit Binary Counters (see Section 2.2.6) allows changing a counter unit in powers of 10 to accommodate a 32-bit counter value to 16-bit BC object format.

4 Data Scales and Units

Code	Condition	Value/Range	Notes
Data Scales			
Vmax		Voltage Scale × PT Ratio, V	2
Imax		Current Scale × CT Ratio, A,	1, 3
Pmax	PT Ratio = 1	Vmax × Imax × 2, W	4
	PT Ratio > 1	(Vmax × Imax × 2)/1000, kW	4
AImin AImax	+/-1mA	AImin = -AI full scale (at -2 mA) AImax = AI full scale (at +2 mA)	5
	0-20mA	AImin = AI zero scale AImax = AI full scale	5
	4-20mA	AImin = AI zero scale AImax = AI full scale	5
	0-1mA	AImin = AI zero scale AImax = AI full scale (at 2 mA)	5
Data Units			
U1	PT Ratio = 1	0.1V	
	PT Ratio > 1	1V	
U2		0.01A	
U3	PT Ratio = 1	1W/Var/VA	
	PT Ratio > 1	1kW/kvar/kVA	

1 CT Ratio = CT primary current/CT secondary current

2 The Voltage Scale is configurable via the DNP Protocol Setup (see Section 3.8) or via the Basic Setup in PAS. The default value is 144V.

3 The Current Scale is configurable via the DNP Protocol Setup (see Section 3.8) or via the Basic Setup in PAS. The default value is 2×CT secondary current.

4 Pmax is rounded to whole kilowatts. When PT=1.0, Pmax is limited to 9,999,000 watts and is truncated to this value if greater.

5 AI zero and full scales are engineering scales configurable via the Analog Input Setup in PAS (see the PMU Installation and Operation Manual).

5 Data Formats

Format Code	Value	Description	Notes
DNP Object Variations			
F3		**Static Binary Input Objects**	
	0	Single-Bit Binary Input	
	1	Binary Input With Status	
		Binary Input Change Event Objects	
	0	Binary Input Change	
	1	Binary Input Change With Time	
		Static Binary Counters	
	0	32-bit Binary Counter With Flag	
	1	32-bit Binary Counter	
	2	16-bit Binary Counter With Flag	
	3	16-bit Binary Counter	
		Binary Counter Change Events	
	0	32-bit Counter Change Event	
	1	32-bit Counter Change Event With Time	
	2	16-bit Counter Change Event	
	3	16-bit Counter Change Event With Time	
		Static Analog Input Objects	
	0	32-bit Analog Input With Flag	
	1	32-bit Analog Input	
	2	16-bit Analog Input With Flag	
	3	16-bit Analog Input	
	4	32-bit Float Analog Input With Flag	
		Analog Input Change Events	
	0	32-bit Analog Change Event	
	1	32-bit Analog Change Event With Time	
	2	16-bit Analog Change Event	
	3	16-bit Analog Change Event With Time	
DNP Class 0 Objects			
F4	0x1E01	Analog Input 30:01	
	0x1E02	Analog Input 30:02	
	0x1E03	Analog Input 30:03	
	0x1E04	Analog Input 30:04	
	0x1E05	Analog Input 30:05	
	0x2801	Analog Output 40:01	
	0x2802	Analog Output 40:02	
	0x0101	Binary Input 01:01	
	0x0102	Binary Input 01:02	
	0x1401	Binary Counter 20:01	
	0x0A01	Binary Output 10:01	
	0x0A01	Binary Output Status 10:02	
	0x1402	Binary Counter 20:02	
	0x1405	Binary Counter 20:05	
	0x1406	Binary Counter 20:06	
Timestamp			
F5		Local time in a UNIX-style format. Represents the number of seconds since midnight (00:00:00), January 1, 1970. The time is valid after January 1, 2000.	
PMU Time Quality (bitmap)			
F39	Bits 0:3	0xF = clock failure, time not reliable 0xB = time within 10 s 0xA = time within 1 s 0x9 = time within 100 ms 0x8 = time within 10 ms 0x7 = time within 1 ms 0x6 = time within 100 µs 0x5 = time within 10 µs 0x4 = time within 1 µs 0x3 = time within 100 ns 0x2 = time within 10 ns 0x1 = time within 1 ns 0x0 = locked to UTC traceable source	
	Bit 4	Leap second pending	

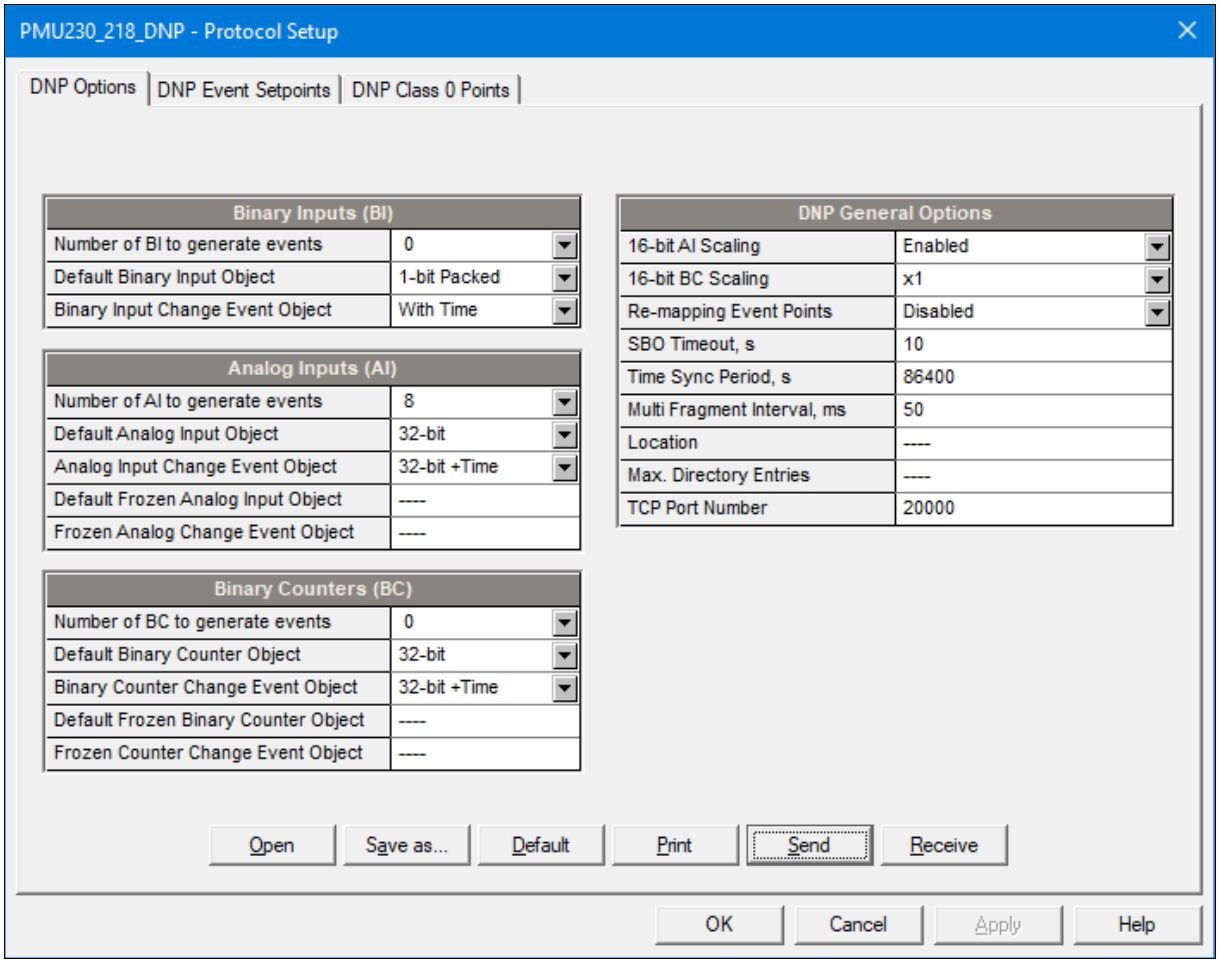
Format Code	Value	Description	Notes
	Bit 5	Leap second occurred	
	Bit 6	Leap second direction, 0 = add, 1=delete	
PMU Frame Status (bitmap)			
F40	Bits 0:3	Trigger reason	
	Bits 4:5	Unlocked time: 0 = sync locked or unlocked time < 10 s (best quality) 1 = unlocked time < 100 s 2 = unlocked time <= 1000 s 3 = unlocked time > 1000 s	
	Bits 6:8	PMU time quality: 1 = maximum time error < 100 ns 2 = maximum time error < 1 µs 3 = maximum time error < 10 µs 4 = maximum time error < 100 µs 5 = maximum time error < 1 ms 6 = maximum time error < 10 ms 7 = maximum time error > 10 ms or time error unknown	
	Bit 9	1 = data modified by post processing, 0 = otherwise	
	Bit 10	Configuration change, set to 1 for 1 min to advise configuration will change, and cleared to 0 when change effected	
	Bit 11	1 = PMU trigger detected, 0 = no trigger	
	Bit 12	Data sorting, 0 = by timestamp, 1 = by arrival	
	Bit 13	0 = PMU in sync with a UTC traceable time source	
	Bits 14:15	Data error: 0 = good measurement data 1 = PMU error (no information about data) 2 = PMU in test mode or absent data tags inserted (do not use values) 3 = PMU error (do not use values)	

6 Configuring DNP3

The PAS software supplied with the PMU provides a configuration tool for customizing your device for use with DNP3 client applications. See the PMU Installation and Operation Manual for more information on installation and operating PAS on your computer.

6.1 DNP Options

From the Meter Setup menu select Protocol Setup and click on the DNP Options tab.



Available DNP options are described in the following table. See the document "DNP3 Specification, Volume 6, DNP3 Object Library" available from the DNP Users Group for information on DNP3 object types.

Parameter	Options	Default	Description
Binary Inputs (BI)			
Number of BI to Generate events	0-64 [3]	0	Indicates the actual number of selected BI event points for monitoring
Binary Input Object	1-bit packed With Flags	1-bit packed	The default BI object variation for requests with qualifier code 06 when no specific variation is requested
Binary Input Change Event Object	Without Time With Time	With Time	The default BI event object variation for requests with qualifier code 06 when no specific variation is requested
Analog Inputs (AI)			
Number of AI to Generate events	0-64 [3]	0	Indicates the actual number of selected AI event points for monitoring

Parameter	Options	Default	Description
Analog Input Object	32-bit +Flag 32-bit 16-bit +Flag 16-bit 32-bit float +Flag	32-bit	The default AI object variation for requests with qualifier code 06 when no specific variation is requested
Analog Input Change Event Object	32-bit 32-bit +Time 16-bit 16-bit +Time	16-bit +Time	The default AI event object variation for requests with qualifier code 06 when no specific variation is requested
Binary Counters (BC)			
Number of BC to Generate events	0-64 [3]	0	Indicates the actual number of selected BC event points for monitoring
Binary Counter Object	32-bit +Flag 32-bit 16-bit +Flag 16-bit	32-bit	The default BC object variation for requests with qualifier code 06 when no specific variation is requested
Binary Counter Change Event Object	32-bit 32-bit +Time 16-bit 16-bit +Time	32-bit +Time	The default BC event object variation for requests with qualifier code 06 when no specific variation is requested
DNP General Options			
16-bit AI Scaling	Disabled Enabled	Enabled	Allows scaling 16-bit analog input objects (see description below)
16-bit BC Scaling	x1, x10, x100, x1000	x1	Allows scaling 16-bit binary counter objects (see description below)
Re-mapping Event Points	Disabled Enabled	Disabled	Allows re-mapping event points starting with point 0.
SBO Timeout [1]	2-30 sec	10	Defines the Select-Before-Operate (SBO) timeout when using the Control-Relay-Output-Block object
Time Sync Period [2]	0-86400 sec	86400	Defines the time interval between periodic time synchronization requests
Multi Fragment Interval	50-500 ms	50	Defines the time interval between fragments of the response message when it is fragmented
TCP Port Number	5001-20000	20000	Defines the DNP TCP port number

[1] The Select-Before-Operate command causes the device to start a timer. The following Operate command must be sent before the specified timeout value expires.

[2] The device requests time synchronization by bit 4 in the first octet of the internal indication word being set to 1 when the time interval specified by the Time Sync Period elapses. The master should synchronize the time in the device by sending the Time and Date object to clear this bit. The device does not send time synchronization requests if the Time Sync Period is set to 0.

[3] These items show the actual numbers of the event points configured via the DNP Event Setpoints setup.

Scaling 16-bit AI objects

Scaling 16-bit AI objects allows accommodating native 32-bit analog input readings to 16-bit object format; otherwise it may cause an over-range error if the full-range value exceeds a 16-bit point limit.

Scaling is enabled by default. It is not applied to points that are read using 32-bit AI objects.

Refer to Sections 3 and 4 for information on the data point scales and on a reverse conversion that should be applied to the received scaled values.

Scaling 16-bit Binary Counters

Scaling 16-bit Binary Counters allows changing a counter unit in powers of 10 to accommodate a 32-bit counter value to 16-bit BC object format.

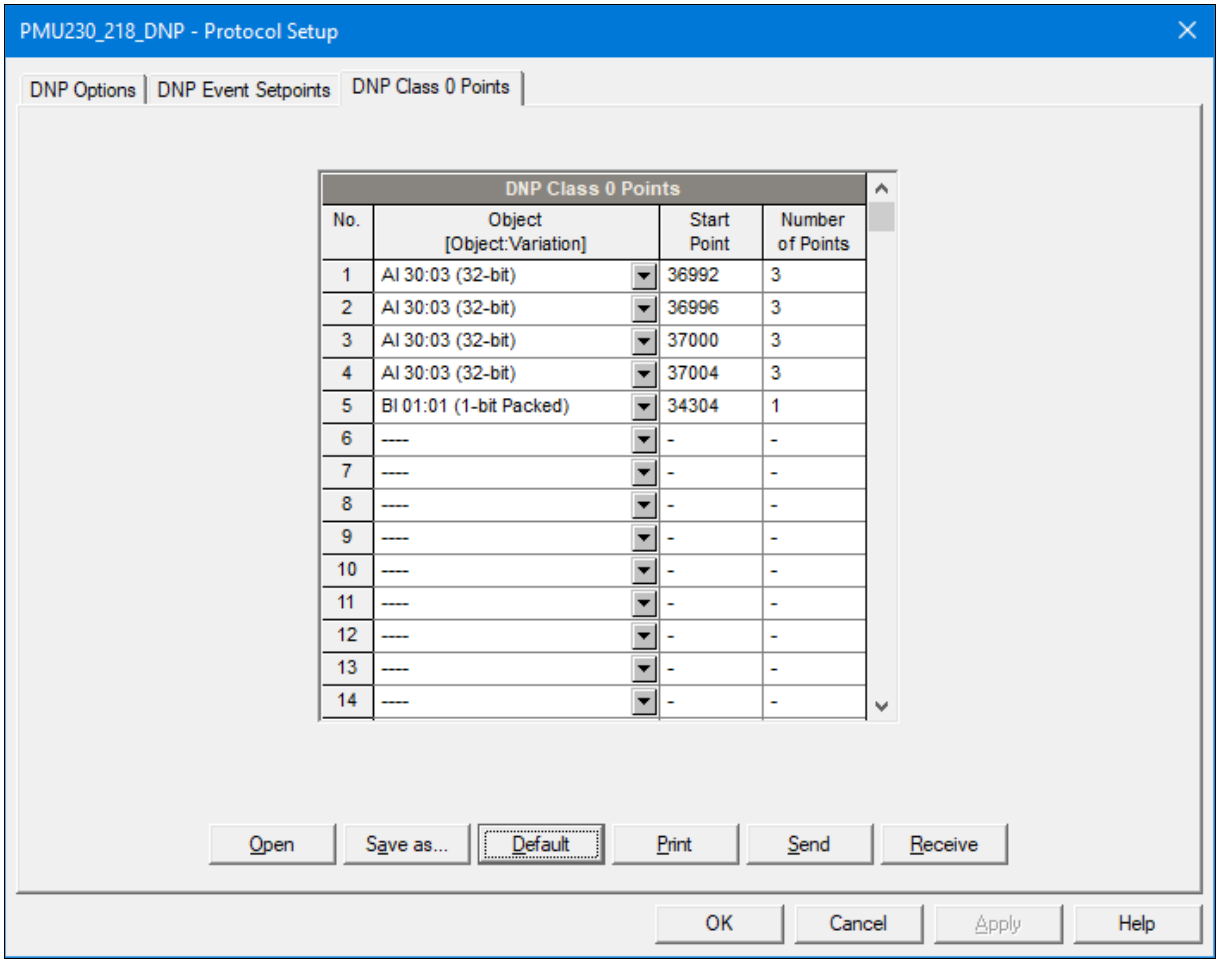
If the scaling unit is greater than 1, the counter value is reported being divided by the selected scaling unit from 10 to 1000. To get the actual value, multiply the counter reading by the scaling unit.

6.2 Configuring DNP Class 0 Response

The most common method of getting static object information from the device via DNP is to issue a read Class 0 request. The device allows you to configure the Class 0 response by assigning ranges of points to be polled via Class 0 requests.

To view the factory-set DNP Class 0 assignments or build your own Class 0 response message:

1. From the Meter Setup menu select Protocol Setup and click on the DNP Class 0 Points tab. The factory-set Class 0 point ranges are shown in the picture below.



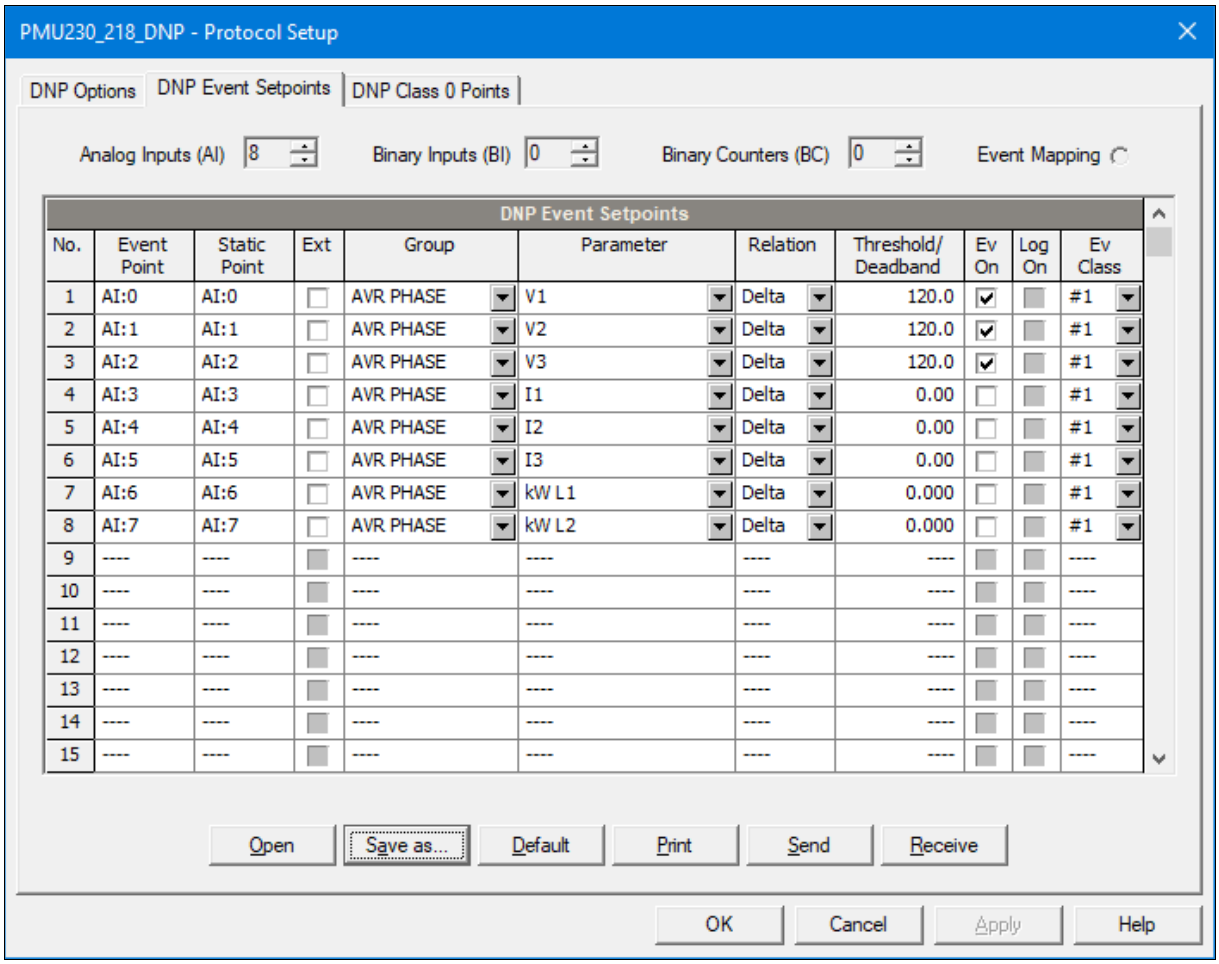
2. Select the object and variation type for a point range.
3. Specify the start point index and the number of points in the range. Refer to Section 3 for available data points.
4. Repeat these steps for all point ranges you want to be included into the Class 0 response.
5. Click Send to download your setup to the device.

6.3 Configuring DNP Event Classes

The device generates object change events for any static analog input, binary input, and binary counter point when a corresponding point either exceeds a predefined threshold, or the point status changes. A total of 64 change event points are available for monitoring.

To view or change DNP event setpoints:

1. From the Meter Setup menu select Protocol Setup and click on the DNP Event Setpoints tab.



2. In the scroll boxes at the top, select the number of static analog input, binary input, and binary counter points you want to monitor.
3. Select a parameter group and then a desired parameter to be monitored for change events for each event setpoint.
4. Check the "Ext" box if you wish to use the extended point list.
5. For analog input and binary counter points, select a relation and an operating threshold or a deadband to be used for detecting events. All thresholds are specified in primary units. The following relations are available:
   - Delta – a new event is generated when the absolute value of the difference between the last reported point value and its current value exceeds the specified deadband value;
   - More than (over) - a new event is generated when the point value rises over the specified threshold, and then when it returns below the threshold minus a predefined return hysteresis – applicable for AI objects;

- Less than (under) - a new event is generated when the point value drops below the specified threshold, and then when it returns above the threshold plus a predefined return hysteresis – applicable for AI objects.

Hysteresis for the return threshold is 0.05 Hz for frequency and 2% of the operating threshold for all other points.

6. Check the "Ev On" box for the points you wish to be included into event poll reports.
7. In the "Ev Class" box, select the event poll class for the change event points.
8. Repeat these steps for all points you want to be monitored for events.
9. Click Send to download your setup to the device.

Object change events are normally polled via DNP Class 1, Class 2 or Class 3 requests. You can link any change event point to any event class upon the event priority.

A change event point index is normally the same as for the corresponding static object point. To use independent numeration for event points, enable re-mapping event point indices via DNP Options setup (see above) so they start with index 0.

NOTE

The device clears all event buffers and links the default set of static points to each event object type every time you change the number of points for one of the objects.

APPENDIX A DNP3 Application Messages

The device is a DNP IED responding to external DNP Master requests. Table A-1 describes the PMU application level responses to external requests, including object variations, functions, codes and qualifiers supported by the device. The object and formats are detailed in the DNP3 Specification, Volume 6, Part 2, DNP3 Object Library.

Table A-1 Application Responses

Object			Request		Response	
Object	**Variation**	**Description**	**Function Code**	**Qualifier Code**	**Function Code**	**Qualifier Code**
01	0	Binary Input (responds with 01:1)	1	B	129	01
01	1	Binary Input - Packed format	1	A	129	C
01	2	Binary Input With flags	1	A	129	C
02	0	Binary Input Event (responds with 02:1)	1	06	129	17,28
02	1	Binary Input Event Without time	1	07,08	129	17,28
02	2	Binary Input Event With time	1	07,08	129	17,28
10	0	Binary Output (responds with 10:1)	1	B	129	01
10	1	Binary Output - Packed format	1	A	129	C
10	2	Binary Output With flag	1	A	129	C
12	1	Control Relay Output Block	3,4,5	A	129	C
12	1	Control Relay Output Block	6	A	None	N/A
20	0	Binary Counter (responds with 20:1)	1, 7,9, 8,10	B B B	129 129 129	01 N/R N/A
20	1	32-bit Binary Counter With flag	1	A	129	C
20	2	16-bit Binary Counter With flag	1	A	129	C
20	5	32-bit Binary Counter Without flag	1	A	129	C
20	6	16-bit Binary Counter Without flag	1	A	129	C
22	0	Counter Change Event (responds with 22:1)	1	06	129	17
22	1	32-bit Counter Event Without time	1	07,08	129	17
22	2	16-bit Counter Event Without time	1	07,08	129	17
22	5	32-bit Counter Event With time	1	07,08	129	17
22	6	16-bit Counter Event With time	1	07,08	129	17
30	0	Analog Input (responds with 30:1)	1	B	129	01
30	1	32-bit Analog Input With flag	1	A	129	C
30	2	16-bit Analog Input With flag	1	A	129	C
30	3	32-bit Analog Input Without flag	1	A	129	C
30	4	16-bit Analog Input Without flag	1	A	129	C
30	5	32-bit Floating-point Analog Input With flag	1	A	129	C
32	0	Analog Input Event (responds with 32:1)	1	06	129	17
32	1	32-bit Analog Input Event Without time	1	07,08	129	17
32	2	16-bit Analog Input Event Without time	1	07,08	129	17
32	3	32-bit Analog Input Event With time	1	07,08	129	17
32	4	16-bit Analog Input Event With time	1	07,08	129	17
40	0	Analog Output Status (responds with 40:1)	1	B	129	01
40	1	32-bit Analog Output Status	1	A	129	C
40	2	16-bit Analog Output Status	1	A	129	C
41	1	32-bit Analog Output Block	3,4,5	A	129	C
41	2	16-bit Analog Output Block	3,4,5	A	129	C
41	1	32-bit Analog Output Block	6	A	None	N/A
41	2	16-bit Analog Output Block	6	A	None	N/A
50	1	Time and Date [1]	1,2	A	129	C
60	1	Class 0	1	B	129	01
60	2	Class 1	1	06,07,08	129	17
60	3	Class 2	1	06,07,08	129	17
60	4	Class 3	1	06,07,08	129	17
80	1	Internal indication [2]	2	D	129	
N/A	N/A	Cold Restart [3] (respond Obj. 52:2)	13	N/A	129	07
N/A	N/A	Delay Measurement (respond Obj. 52:2)	23	N/A	129	07

[1] For this object, the quantity specified in the request must be exactly 1 or an index of 0, as there is only one instance of this object defined in the device.

[2] For this object, the qualifier code must specify an index 7 only.

[3] Respond with time object 50 variation 2 indicating time until device availability.

Qualifier Hex Codes for each category:
A - 00,01,03,04,07,17,27,08,18,28
B - 06 only
C - Qualifier echo
D - 00,01,03,04,17,27,18,28

N/A - Not Available

N/R - Null Response

Appendix B DNP3 Device Profile

DNP3

DEVICE PROFILE DOCUMENT

This document must be accompanied by a table having the following headings:

Object Group Request Function Codes Response Function Codes

Object Variation Request Qualifiers Response Qualifiers

Object Name (optional)

Vendor Name: SATEC Ltd.

Device Name: PMU Substation Automation Unit

Highest DNP Level Supported:	Device Function:
For Requests L2	☐ Master■ Slave
For Responses L2	

Device supports READ of each object using either all points (Qualifier = 6) or specific points using qualifier defined in DNP3 Specification: 00, 01, 03, 04, 07, 17, 27, 08, 18, 28. Control Relay Block requires specific parameters described in this manual. Treats range field of qualifier 07 and 08 to mean point range [0..N-1].

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted 292	Transmitted 2048
Received 292	Received 249

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
■ None	■ None
☐ Fixed at_____	☐ Configurable, range _____ to _____
☐ Configurable, range ___ to_____	(Fixed is not permitted)

Requires Data Link Layer Confirmation:

■ Never

☐ Always

☐ Sometimes If 'Sometimes', when?

_____

☐ Configurable If 'Configurable', how? _____

Requires Application Layer Confirmation:

☐ Never

☐ Always (not recommended)

■ When reporting Event Data (Slave devices only)

☐ When sending multi-fragment responses (Slave devices only)

☐ Sometimes If 'Sometimes', when?

_____

☐ Configurable If 'Configurable', how? _____

Device Profile Document (continued)

Timeouts while waiting for:

Data Link Confirm ■ None ☐ Fixed at _____ ☐ Variable ☐ Configurable

Complete Appl. Fragment ■ None ☐ Fixed at _____ ☐ Variable ☐ Configurable

Application Confirm ☐ None ■ Fixed at 5 sec ☐ Variable ☐ Configurable

Complete Appl. Response ■ None ☐ Fixed at _____ ☐ Variable ☐ Configurable

Others

Timeouts between fragments of the multi-fragment responses. Configurable: 50-500 ms (50 ms by default).

Attach explanation if 'Variable' or 'Configurable' was checked for any timeout

Sends/Executes Control Operations:

WRITE Binary Outputs	■ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT/OPERATE	☐ Never	■ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE	☐ Never	■ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK	☐ Never	■ Always	☐ Sometimes	☐ Configurable
Count > 1	■ Never	☐ Always	☐ Sometimes	☐ Configurable
Pulse On	☐ Never	☐ Always	■ Sometimes [1]	☐ Configurable
Pulse Off	■ Never	☐ Always	☐ Sometimes [4]	☐ Configurable
Latch On	☐ Never	☐ Always	■ Sometimes [2]	☐ Configurable
Latch Off	☐ Never	☐ Always	■ Sometimes [3]	☐ Configurable
Queue	■ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☐ Never	☐ Always	■ Sometimes	☐ Configurable

- **Select timeout period is configurable : 2s to 30s**

[1] used to activate the Reset function associated with points 64 to 101

[1] [2] [3] [4] used to control Relays associated with points 0 to 31

Reports Binary Input Change Events when no specific variation requested:

■ Never

☐ Only time-tagged

☐ Only non-time-tagged

☐ Configurable to send both, one or the other (attach explanation)

Reports time-tagged Binary Input Change Events when no specific variation requested:

■ Never

☐ Binary Input Change With Time

☐ Binary Input Change With Relative Time

☐ Configurable (attach explanation)

Device Profile Document (continued)

Sends Unsolicited Responses: ■ Never ☐ Configurable (attach explanation) ☐ Only certain objects ☐ Sometimes (attach explanation) ☐ ENABLE/DISABLE UNSOLICITED Function codes supported	Sends Static Data in Unsolicited Responses: ■ Never ☐ When Device Restarts ☐ When Status Flags Change No other options are permitted.
Default Counter Object/Variation: ☐ No Counters Reported ☐ Configurable (attach explanation) ■ Default Object 20 Default Variation 5 ☐ Point-by-point list attached	Counters Roll Over at: ☐ No Counters Reported ☐ Configurable (attach explanation) ☐ 16 Bits ☐ 32 Bits ■ Other Value Counters -999999999 to 99999999 (point 2) 0 to 9999999 (points 0,1,3) ☐ Point-by-point list attached
Sends Multi-Fragment Responses: ■ Yes ☐ No	