



**User Manual for the  
*HE200ACM530***

## **Dual AC Power Monitor**

**MAN0787-03**



## PREFACE

This manual explains how to use the Dual AC Power Monitor.

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**Note: The programming examples shown in this manual are for illustrative purposes only. Proper machine operation is the sole responsibility of the system integrator.**

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## CHAPTER 1: INTRODUCTION

### 1.1 Overview

The HE200ACM530 (ACM) is a stand alone module that monitors voltage and current on two separate circuits of 3-phase AC lines and provides indications of voltage, current, real power, reactive power, apparent power, power factor, power usage, frequency and phase difference between circuits. The ACM provides this information over the CsCAN network as global data, which can be monitored by devices such as a Horner APG Operator Control Station (OCS). In addition, the ACM is user configurable to allow either 'Delta' or 'Wye' connections and different Potential Transformer (PT) and Current Transformer (CT) ratios. Loading of these configuration parameters is accomplished over the CsCAN network by a selected master (OCS), which allows these modules to be simply 'plugged in' or replaced with little or no user intervention.

The ACM also provides eight sourcing inputs and eight 1/2 amp protected sinking outputs, which are read and controlled respectively by a network master. Network heartbeat functionality is supported in both directions to provide fail-safe operation of this discrete I/O.

This model of the ACM also provides ANSI protective relay and synchronization functions. The protective relay functions may be used to indicate over or under limit indications on the monitored values. Threshold and delay on/off values for each function are fully configurable and are provided by the network master. The synchronization function may be used to indicate phase synchronization of the two circuits. Protection relay and synchronization indicators are always available through CsCan global data from the ACM; however, the ACM allows the digital outputs to be individually configured to be directly driven from the protection relay and synchronization functions to drive line contactors.

The ACM uses a Digital Signal Processor for data capture, true power and true RMS processing, and I/O. An internal watchdog circuit is used to improve reliability. Firmware and calibration constants are stored in FLASH memory.

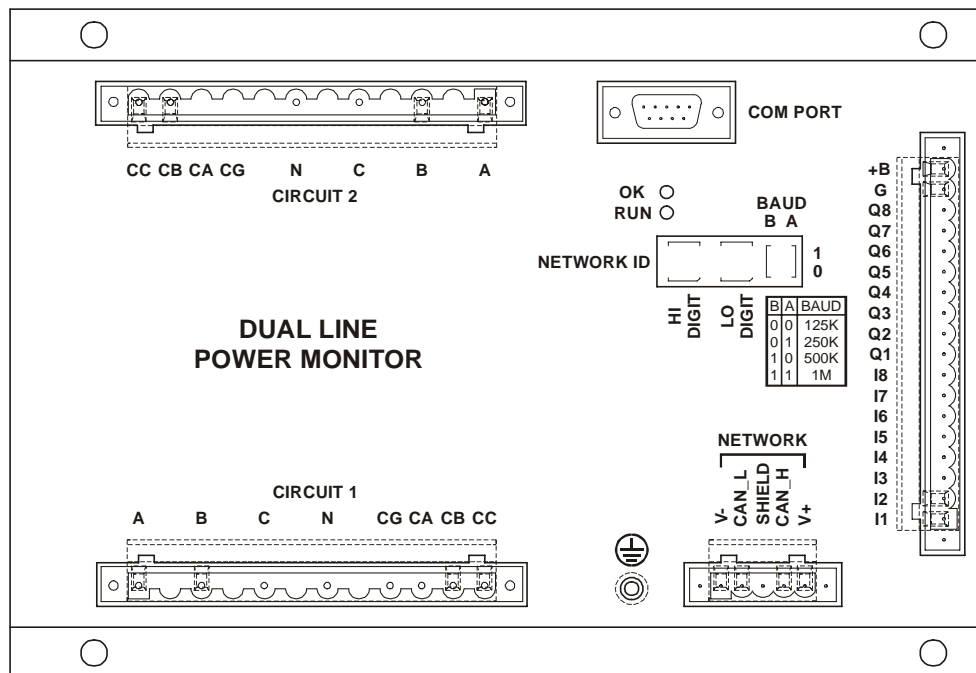


Figure 1.1 – ACM530 Dual AC Power Monitor

004ACM008

## 1.2 Specifications

<b>Table 1.1 – ACM530 Specifications</b>			
<b>VOLTAGE INPUTS</b>			
<b>Input Range</b>	90-600Vac	<b>Input Frequency</b>	40 to 70Hz
<b>Conversion Time</b>	0.18 Sec <sup>1</sup>	<b>Voltage Measurement</b>	True RMS
<b>Accuracy</b>	1%	<b>Voltage Resolution</b>	0.1Vac
<b>Differential Phase Accuracy</b>	0.5°	<b>Frequency</b>	Referenced to Line A
<b>Differential Phase</b>	Circuit 1A to Circuit 2A	<b>Frequency Resolution</b>	0.01Hz
<b>Differential Phase Resolution</b>	0.1°	<b>Frequency Accuracy</b>	0.1%
<b>Input Impedance</b>	> 2 Megohm to neutral;		
<b>CURRENT INPUTS</b>			
<b>AC Current</b>	Three-phase 5A, External Current Transformers (CTs) required	<b>Common Mode</b>	CTs returned to neutral
<b>Overrange</b>	50%	<b>Input Frequency</b>	40 to 70Hz
<b>Accuracy</b>	1%	<b>Current Measurement</b>	True RMS
<b>Conversion Time</b>	0.18 Sec <sup>1</sup>	<b>Resolution</b>	0.001A
<b>DIGITAL INPUTS</b>			
<b>Inputs per Module</b>	8	<b>ON Voltage Level</b>	40% of V Supply
<b>Commons per Module</b>	1	<b>OFF Voltage Level</b>	60% of V Supply
<b>Input Voltage Range</b>	6-36 VDC	<b>Input Characteristics</b>	Sourcing
<b>Peak Voltage</b>	36VDC Max.	<b>Input Impedance</b>	10K Ohms – Pull up to V Supply
<b>DIGITAL OUTPUTS</b>			
<b>Outputs per Module</b>	8	<b>ON Voltage Level</b>	1.5VDC Max.
<b>Commons per Module</b>	1	<b>Maximum Load Current per channel</b>	0.5A Max.
<b>Operating Voltage</b>	6 - 36VDC	<b>Output Protection</b>	Short Circuit
<b>Output Type</b>	Sinking / 10K Pull-Up	<b>Maximum Leakage Current</b>	100µA
<b>Peak Voltage</b>	36VDC Max.	<b>Maximum Inrush Current</b>	600mA.
<b>Output Characteristics</b>	Current Sinking	<b>Minimum Load</b>	None
<b>GENERAL SPECIFICATIONS</b>			
<b>Required Power (Steady State)</b>	12-24VDC nominal; 6-36VDC Maximum; Approximately 7 Watts	<b>Recommended Number of ACMs per Network</b>	8 or less
<b>Current (Inrush)</b>	< 3 Amp for 10mSec	<b>Network Bandwidth</b>	80 messages per second (8%)
<b>Connectors</b>	Front access	<b>Relative Humidity</b>	5 to 95% Non-condensing
<b>Terminal Type</b>	Screw Clamp, Removable	<b>Operating Temperature</b>	0° to 60° Celsius
<b>Protocol Supported</b>	CsCAN	<b>Weight</b>	9 oz. (256 g)
<sup>1</sup> Differential phase conversion time = 90mSec.			



### 1.3 Technical Assistance

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NOTES

## CHAPTER 2: INSTALLATION

### 2.1 Safety

#### 2.1.1 Warnings



**WARNING!:** To avoid the risk of electric shock or burns, always connect the safety (or earth) ground before making any other connections.

**WARNING!:** To reduce the risk of fire, electrical shock, or physical injury it is strongly recommended to fuse the voltage measurement inputs. Be sure to locate fuses as close to the source as possible.

**WARNING!:** Replace fuse with the same type and rating to provide protection against risk of fire and shock hazards. Use only a fast blow-type fuse, which is rated 600 Volts. The recommended fuse type is Littelfuse (KLKD.300 rated 600 V AC/DC, 0.3A fast blow).

**WARNING!:** In the event of repeated failure, do not replace the fuse again as a repeated failure indicates a defective condition that will not clear by replacing the fuse.

**ATTENTION:** Only qualified electrical personnel familiar with the construction and operation of this equipment and the hazards involved should install, adjust, operate, or service this equipment. Read and understand this manual and other applicable manuals in their entirety before proceeding. Failure to observe this precaution could result in severe bodily injury or loss of life.

**ATTENTION:** The ACM is directly connected to incoming AC power. Disconnect, lock out, and tag all incoming power to the ACM before performing the following procedure. Failure to observe this precaution could result in severe bodily injury or loss of life.

**ATTENTION:** For ease of installation and replacement, plug-in connectors are provided for the AC inputs. These connectors **MUST NOT BE UNPLUGGED** if any current is flowing through the CT primaries. Failure to observe this precaution will result in damage to the connector and an electrical shock hazard. Screw locks are provided on all I/O connectors to prevent accidental circuit interruption. Installation personnel must verify that the connectors are properly secured.

**ATTENTION:** All applicable codes and standards should be followed in the installation of this product.

### 2.1.2 Safety Precautions

Adhere to the following safety precautions whenever any type of connection is made to the module.

Connect the green safety (earth) ground first before making any other connections.

When connecting to electric circuits or pulse-initiating equipment, open their related breakers. Do not make connections to live power lines.

Make connections to the module first; then connect to the circuit to be monitored.

Route power wires in a safe manner in accordance with good practice and local codes.

Wear proper personal protective equipment including safety glasses and insulated gloves when making connections to power circuits.

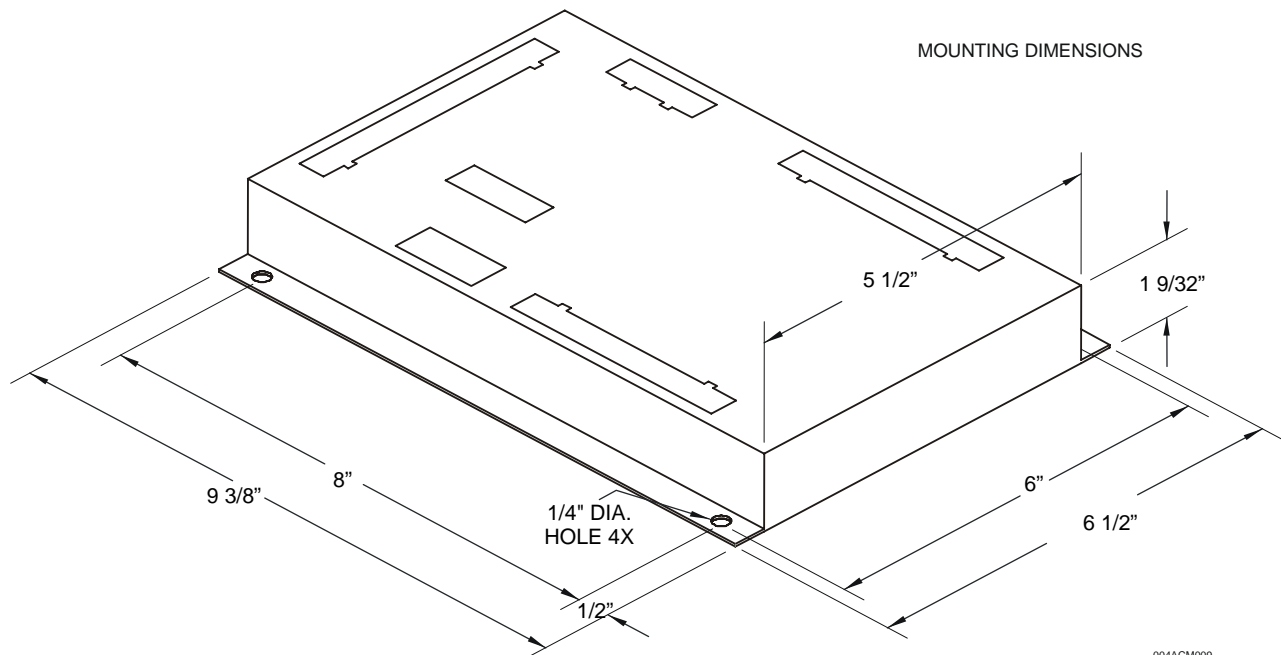
Ensure hands, shoes, and floors are dry before making any connection to a power line.

Make sure the unit is turned OFF before making connection to terminals. Make sure all circuits are de-energized before making connections.

Before each use, inspect all cables for breaks or cracks in the insulation. Replace immediately if defective.

## 2.2 Mounting

Physical dimensions for the ACM are shown in Figure 2.1



**Figure 2.1 – ACM Dimensions**

### 2.3 Isolation

The AC monitoring circuits are isolated from the input power and from each other to at least 1500VAC. The CAN interface (network) is also isolated and powered from its connector (meets DeviceNet specifications). The RS-232 port is not isolated and is powered from the main input supply.

### 2.4 Power Connection

The ACM is powered from a DC source between 6 and 36 volts and draws approximately 7 watts. Refer to Figure 2.2 below for wiring.

### 2.5 Discrete I/O Connection

The eight DC sourcing inputs are provided with internal 10K ohm pull-ups to V+ power and are intended for switch contact to VC. The input threshold is approximately ½ VC. The eight ½ Amp DC sinking outputs, sink current to power common (VC) and are protected against over-current and over-voltage spikes.

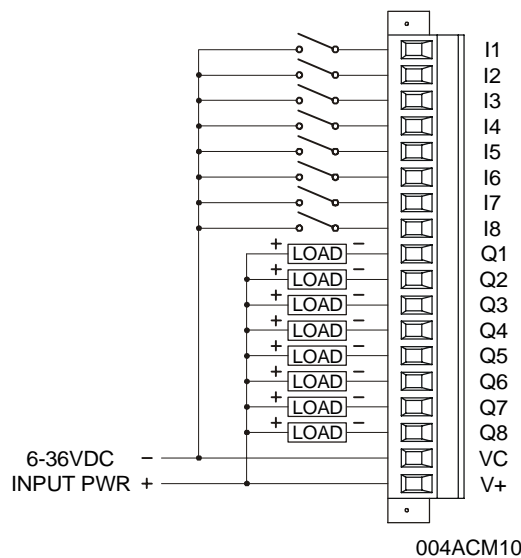


Figure 2.2 - Power and Discrete I/O wiring diagram

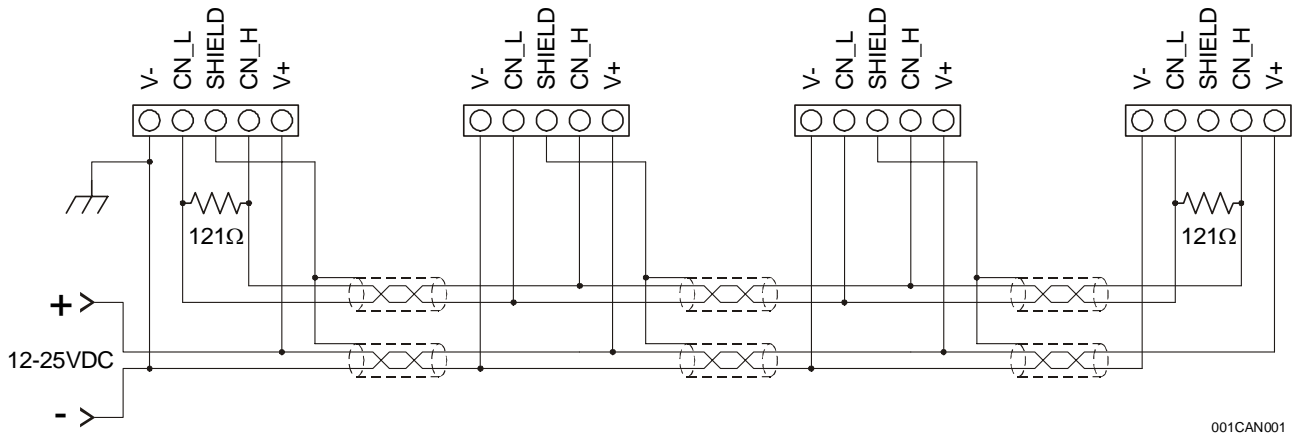
### 2.6 CsCAN (network) Connection

Can Wiring rules (Refer to Figure 2.3.)

1. Wire the CAN network in a daisy-chained fashion such that there are exactly two physical end-points on the network.
2. The two nodes at the physical end-points need to have 121 ohm 1% terminating resistors connected across the CAN\_L and CAN\_H terminals
3. Use data conductors (CAN\_L and CAN\_H) that are 24 AWG shielded twisted pair for 'thin cable' and 18 AWG shielded twisted pair for 'thick cable'. They must also have 120-ohm characteristic impedance. In typical industrial environments, use a Belden wire #3084A ("thin"). Use #3082A ("Thick") for network cable lengths greater than 100 meters in environments where noise is a concern.
4. Use power conductors (V- and V+) that are 22 AWG twisted-pair for 'thin cable' and 15 AWG twisted-pair for 'thick cable'.
5. Connect the V- power conductor to a good earth ground **at one place only** on the network, preferably at a physical endpoint.
6. For a section of cable between two nodes, the cable shield is connected to the cable shield input at **one end of the cable only**.

7. A CAN network (without repeaters) is limited to 64 nodes (with 63 cable segments) with a maximum combined cable length of 1500 ft. at 125Kbaud.
8. Up to four CAN network segments, which adhere to the above rules, may be connected together using three CAN repeaters. In this manner, a CAN network may be extended to 253 nodes with a total cable distance of 6000 ft. at 125Kbaud.

For more information on wiring the CsCAN network, refer to an OCS users manual.



**Figure 2.3 – CsCAN wiring diagram**

## 2.7 Serial Port Connection

Currently, the serial port is not available for field applications.

## 2.8 AC Voltage and Current input Connection

The AC inputs are divided into two circuits (Refer to Figure 1.1 for circuit connector location). Each circuit has three voltage signals (A, B, C), which accept input voltages from 0 – 600VAC with respect to neutral (N). These inputs can be directly connected or passed through external potential transformers (PTs). If voltages greater than 600VAC are to be measured, external PTs are required.

Each circuit also has three current signals (CG, CA, CB, CC), which are designed for standard 5 amp secondary current transformers (CTs) with their commons tied to the neutral (CG) pin. Correct polarity as indicated in the wiring diagram is essential for valid power measurements.

For three phase Wye hookups, the Wye neutral is connected to the ACM neutral pin (refer to Figure 2.4 and 2.6). For Delta hookups, line B is connected to the ACM neutral pin. (Refer to Figure 2.6).

**Note:** The mode (Wye or Delta) and PT and CT ratios must be provided to the ACM as configuration data and must match the physical configuration for proper operation. Ratios are used to scale voltage and current input measurements to match those on the primary side of the PTs and CTs for internal power calculations. ACM accuracy specification assumes no error is contributed from the external PTs and CTs.

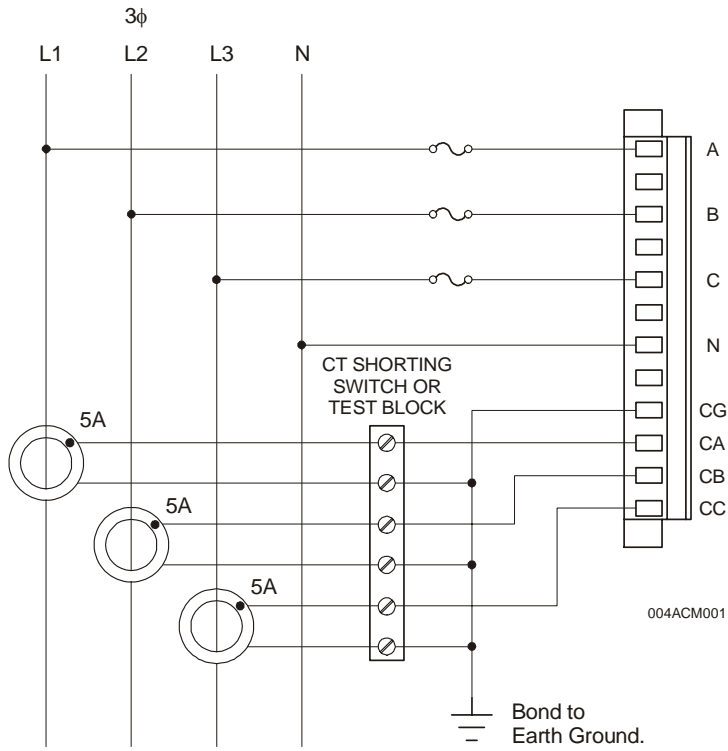


Figure 2.4 – 4-Wire WYE with 3 Elements Direct Voltage Connection

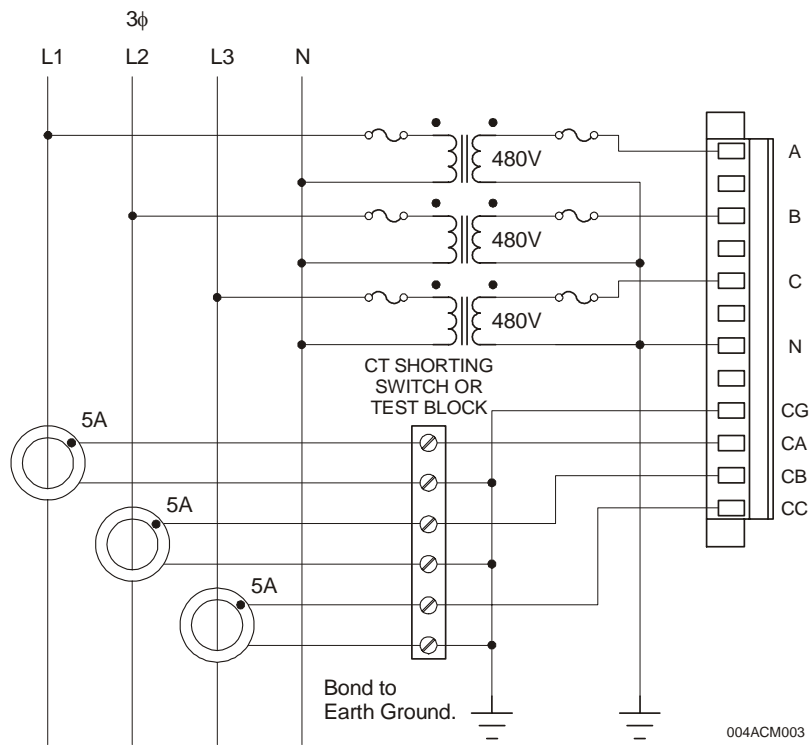
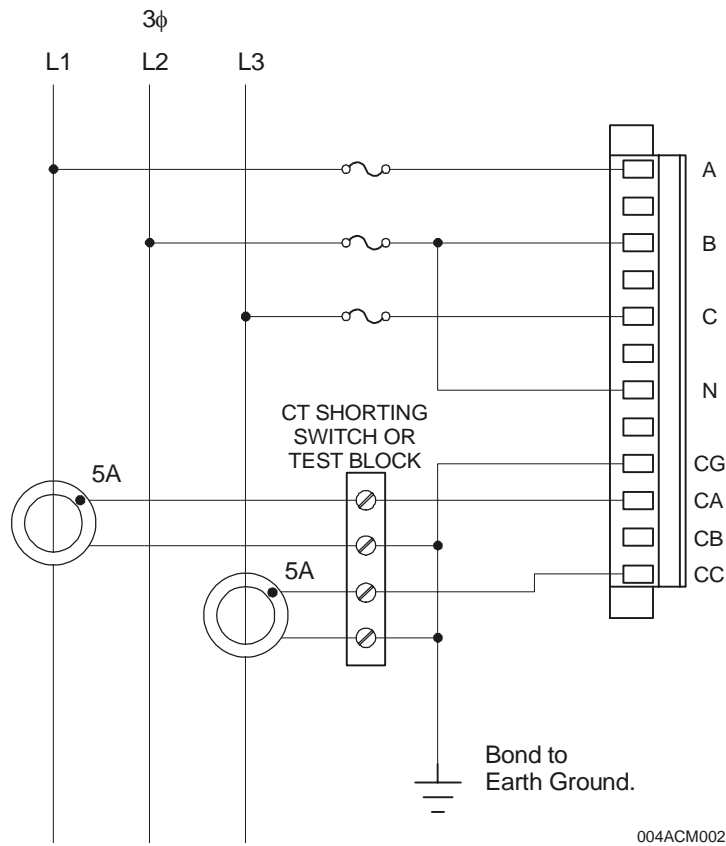
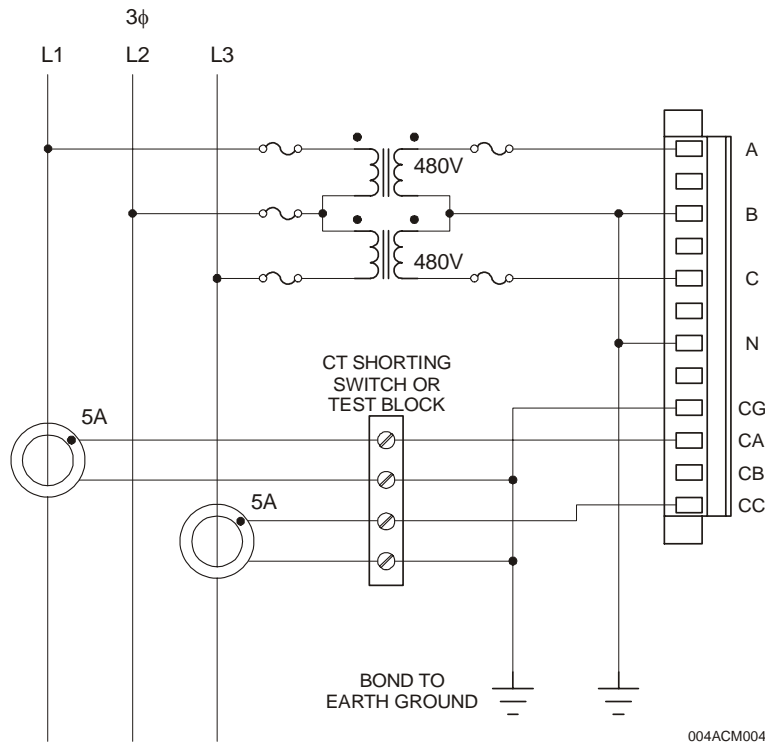


Figure 2.5 – 4-Wire WYE with 3 Elements and 3 PTs Connection



004ACM002

Figure 2.6 – 3-Wire Delta with 2 ½ Element Direct Voltage and 2 CTs Connection



004ACM004

Figure 2.7 – 3-Wire Delta with 2 Element 2 PTs and 2 CTs



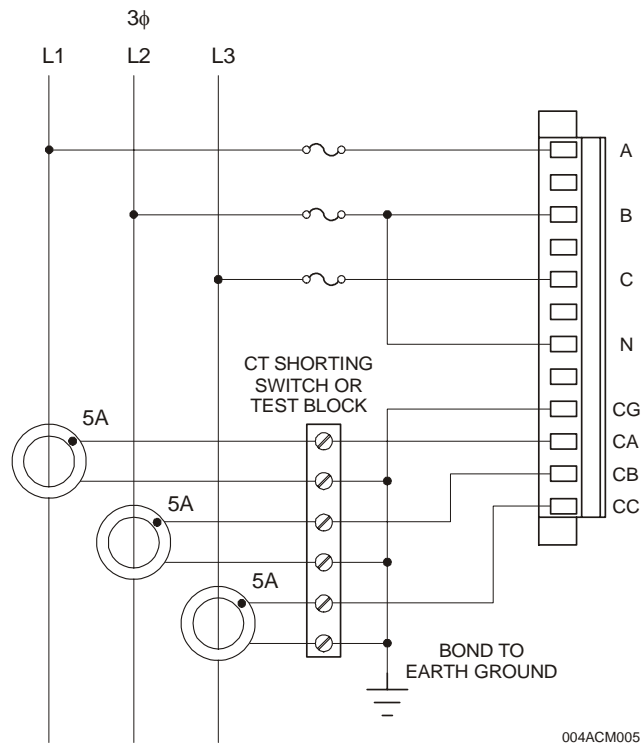


Figure 2.8 – 3-Wire Delta with 3 Elements with 3 CTs Direct Voltage Connection

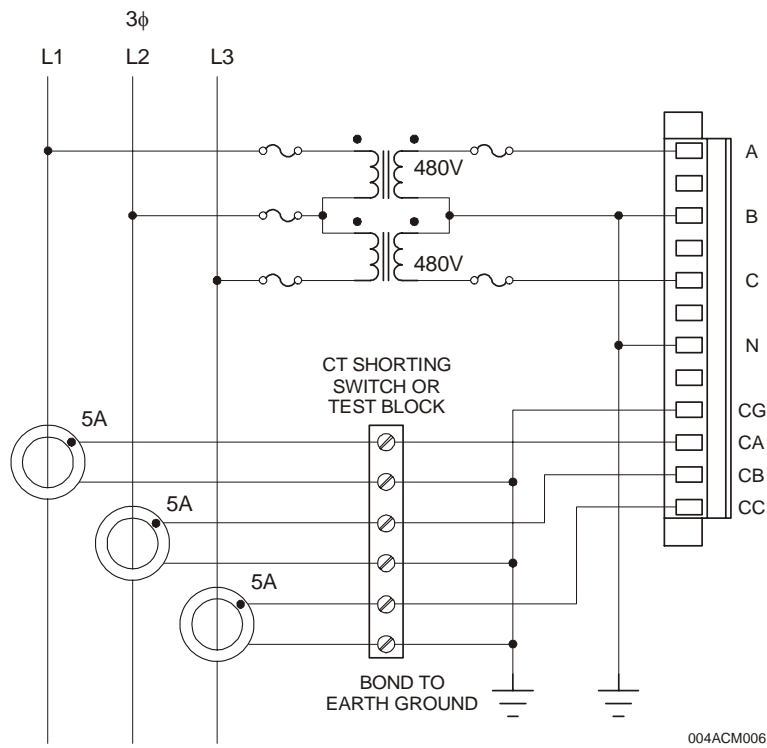


Figure 2.9 – 3-Wire Delta with 2 1/2 Elements with 2 PTs and 3 CTs Connection

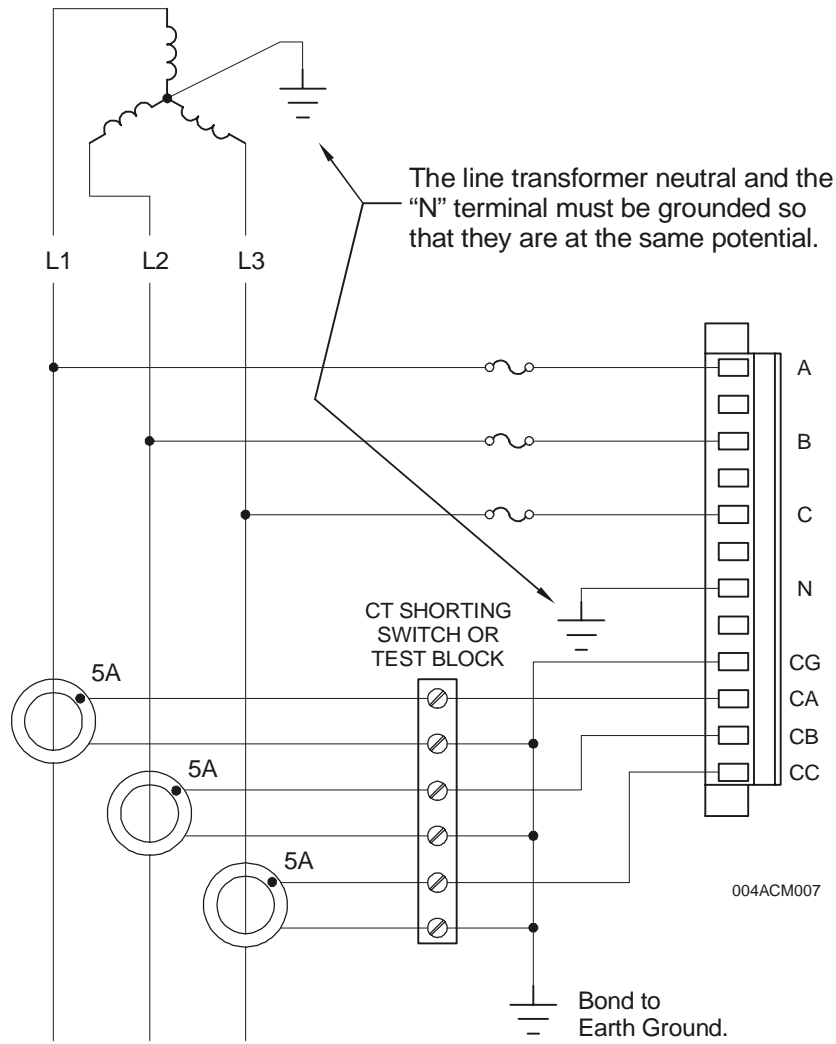


Figure 2.10 – 3-Wire WYE with 3 Elements Direct Voltage with Grounded Neutral Connection

## CHAPTER 3: CONFIGURATION

### 3.1 Network Baud Rate

Select the appropriate CsCAN baud rate [125, 250, 500 or 1000Kbaud] using with the front panel DIP switches. (See Figure 3.1. for location of switches.)

B	A	Baud
0	0	125K
0	1	250K
1	0	500K
1	1	1M

Note: The user should verify that this Network Baud Rate matches that of the other devices on the CsCAN network. Failure to observe this precaution could disable network communications.

### 3.2 Network Address

#### 3.2.1 Network Address Switches

The ACM Network ID is configured with the two multi-position rotary switches on the face surface of the ACM. (See Figure 3.1.) These are 16 position switches that require the ID to be entered as a hexadecimal number. While the maximum address on a CsCAN network is 253 (FDh), the maximum address accepted from the switch is 100 (64h). Attempting to enter an address greater than 100 causes the unit to go offline and indicate “No network or Duplicate Network ID” error. The limit of 100 is based on internal memory limitations.

These Network ID switches are read at power-up and continuously thereafter allowing the user to change the Network ID on the fly. When a Network ID switch change is detected, a 5 sec delay occurs before the ACM attempts to re-connect to the network. This allows the user a little time to dial in both switches before the ACM attempts to reconnect to the network. See LED Indications in Chapter 4 to determine the state of the network connection.

ACM Network ID of 255 (FFh) is reserved for factory use and stalls the unit (both LEDS flash in unison) if the ACM is powered up with that ID. To correct: power-down the ACM, change ID switches to valid address and re-apply power.

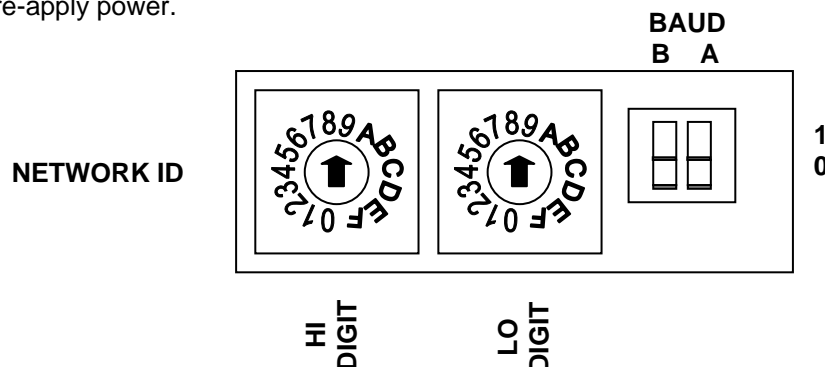


Figure 3.1 – Close-up of Network ID Switches and Baud Switches

To set a unique Network ID on the ACM530, insert a screwdriver into the two Network ID switches (HI Digit and LO Digit).

## 3.2.2 Network ID Table

Table 3.2 shows the decimal equivalent of hexadecimal numbers. HI Digit and LO Digit settings are also shown. Refer to the table when setting Network IDs for ACM100 modules used in CsCAN networks.

Table 3.2 – Hexadecimal to Decimal Conversion (HI Digit and LO Digit Settings)															
Hex	Dec	HI	LO	Hex	Dec	HI	LO	Hex	Dec	HI	LO	Hex	Dec	HI	LO
00	0	0	0	29	41	2	9	53	83	5	3				
01	1	0	1	2A	42	2	A	54	84	5	4				
02	2	0	2	2B	43	2	B	55	85	5	5				
03	3	0	3	2C	44	2	C	56	86	5	6				
04	4	0	4	2D	45	2	D	57	87	5	7				
05	5	0	5	2E	46	2	E	58	88	5	8				
06	6	0	6	2F	47	2	F	59	89	5	9				
07	7	0	7	30	48	3	0	5A	90	5	A				
08	8	0	8	31	49	3	1	5B	91	5	B				
09	9	0	9	32	50	3	2	5C	92	5	C				
0A	10	0	A	33	51	3	3	5D	93	5	D				
0B	11	0	B	34	52	3	4	5E	94	5	E				
0C	12	0	C	35	53	3	5	5F	95	5	F				
0D	13	0	D	36	54	3	6	60	96	6	0				
0E	14	0	E	37	55	3	7	61	97	6	1				
0F	15	0	F	38	56	3	8	62	98	6	2				
10	16	1	0	39	57	3	9	63	99	6	3				
11	17	1	1	3A	58	3	A	64	100	6	4				
12	18	1	2	3B	59	3	B								
13	19	1	3	3C	60	3	C								
14	20	1	4	3D	61	3	D								
15	21	1	5	3E	62	3	E								
16	22	1	6	3F	63	3	F								
17	23	1	7	40	64	4	0								
18	24	1	8	41	65	4	1								
19	25	1	9	42	66	4	2								
1A	26	1	A	43	67	4	3								
1B	27	1	B	44	68	4	4								
1C	28	1	C	45	69	4	5								
1D	29	1	D	46	70	4	6					FF*	255*	15	F
1E	30	1	E	47	71	4	7								
1F	31	1	F	48	72	4	8								
20	32	2	0	49	73	4	9								
21	33	2	1	4A	74	4	A								
22	34	2	2	4B	75	4	B								
23	35	2	3	4C	76	4	C								
24	36	2	4	4D	77	4	D								
25	37	2	5	4F	79	4	F								
26	38	2	6	50	80	5	0								
27	39	2	7	51	81	5	1								
28	40	2	8	52	82	5	2								

**Note:** ID Addresses 100 – 254 are not used.

\* ID Address 255 is invalid. Reserved for Factory Use Only.

### **3.3 Operational mode and PT/CT Ratios**

The mode and ratio configuration data for the ACM are provided by an associated OCS over the CSCAN network once the ACM powers up. This allows replacement of an ACM in the field without operator intervention in providing the configuration data. However, this also requires additional initial programming of the associated OCS to initialize and send that configuration data when the OCS powers-up. See Network operation in Chapter 4.

### **3.4 Calibration**

The ACM is calibrated at the factory and calibration data is not user accessible.

NOTES

## CHAPTER 4: OPERATION

### 4.1 Power-up

At power-up, the ACM performs the necessary hardware checks, verifies the integrity of the factory calibration data and prepares to receive operational parameters from the network.

### 4.2 States of Operation

This ACM provides two states of operation (Basic Monitor, Monitor w/Protection). The Basic Monitor mode is simple to configure but only provides simple monitoring. The Monitor w/Protection is somewhat more complex to configure but provides ANSI type protection and synchronization functions.

### 4.3 Network Configuration

A network master such as an OCS is required to provide the configuration data for the ACM over the network when the ACM powers-up. The ACM may be configured by the OCS to operate in one of two states of operation (Basic Monitor or Monitor w/Protection). The amount of configuration data provided by the OCS determines which state of operation is selected. Note that the selected state of operation applies to both ACM circuits.

The configuration for the Basic Monitoring state requires 16 words of directed data per circuit. In network terms, this equates to the OCS sending Analog Directed Data to AQQ1-AQG15 for both network addresses consumed by the ACM.

The configuration for the Monitor w/Protection state requires 64 words of directed data per circuit. However, since each CSCAN network ID is limited to 32 words of Analog Directed Data (AQQ1-AQG32) and because the lower 16 words are dedicated, the additional configuration data is divided into 3 - 32 word pages of analog directed data and sent one page at a time. Additional ladder logic is required in the OCS to sequence the additional 48 words of data through the upper 16 words of analog directed data for each network ID.

After power-up initialization, the ACM verifies the integrity of the network. If a valid network connection exists, the ACM broadcasts global data with relative data only in the model and version fields (AQQ31-32, first network ID only) and the expected configuration page field (QG17-24, second network ID only). The expected configuration page contains a value of 1 indicating that the ACM is waiting for a configuration.

If the OCS, at power-up, detects that the expected configuration page field is zero then it can be assumed that the ACM already is configured.

The ACM continue to stalls while waiting to receive the first two CSCAN analog directed data packets (one for each network id) of 16 words from the OCS. One of the parameters in this analog directed data (AQQ14 - first network ID only) indicates the number of extended configuration data pages that the ACM should expect to receive. If only Basic Monitoring is desired, AQQ14 is set to zero and AQQ1-AQG16 provides all the required configuration data. However, if Monitor w/Protection mode is require, AQQ14 is set 1 indicating that this is the first of three pages of extended configuration data and each page contains a full 32 words (AQQ1-AQG32) of configuration data.

While the ACM is waiting for a valid configuration, it generates a Network Heartbeat a rate of approximately 1 second. Once a configuration is received, the Network Heartbeat is programmed to occur at the provided rate.

When sequencing through the extended configuration data, the ACM must acknowledge each page of configuration data before OCS sends the next page. This acknowledgment is provided by the global digital data QG17-QG32 of the second ACM network ID (**Expected Configuration Page**). These eight

bits return the next extended configuration page number expected. Once an entire page of extended configuration data is received by the ACM, the value indicated by these eight bits is incremented to indicate that the OCS can send the next page of data. Once page 3 of the extended configuration data is received, these eight bits are set to zero indicating the configuration process is complete. Should the sequence fail in any manner, these eight bit will revert to 1 indicating that the sequence needs to be repeated starting at page 1.

Note that with the exception of AQG14, the first 16 words of configuration data must be duplicated for each page of data. Failure to duplicate this data for each page may result in unpredictable operation.

Once the analog configuration data has been received, the ACM continues to stall until it receives the QG output data, which sets the Digital Outputs on the ACM.

While the ACM is stalled, no AC input sampling occurs, no indicators are calculated (including KWHs) and the discrete outputs are held at zero.

**Note: Required configuration data includes *all* analog values and *all* digital values for *both* circuits of the ACM. This is required even if only one circuit or only analog or digital values are used in the application. Failure to provide valid configuration data for all parameters can cause the ACM not to work in any capacity.**

#### 4.3.1 Mode (circuit type/connection)

This field specifies if the AC inputs are to be treated as 4-wire WYE or 3-wire Delta and must match what is physically wired.

- 0 - Wye 4-wire (3 PTs, 3 CTs)
- 1 - Delta 3-wire (2 PTs, 2 CTs)
- 2 - Delta 3-wire (2 Pts, 3 CTs)

#### 4.3.2 Ratios

These fields specify the multiplier for each Voltage and Current input. This is a floating-point number used to scale the PT/CT secondary value to represent the true (primary) value.

For voltage direct connection, supply a ratio of 1.00

input		ratio	=	displayed output
480 V	*	1.00	=	480 Volt

For CT with 500 Amp primary and 5 Amp secondary (500:5) use a ratio of 100.00

5 Amp	*	100.00	=	500 Amp
-------	---	--------	---	---------



4.4 Network Input Data

4.4.1 Basic Monitoring Configuration and Control

The ACM receives command and configuration data from its associated OCS's directed data. More specifically, Circuit 1's control/configuration data is retrieved from the directed data associated with the OCS's first Network ID. Circuit 2's control/configuration data is retrieved from the directed data associated with the OCS's second Network ID. With a few exceptions, the format of the sent data is the same for both circuits and shown below in Table 4.1. For non-circuit specific data, such as discrete output commands, Table 4.1 indicates which OCS Network ID's directed data contains that information.

Table 4.1 – Network Input data (OCS Directed QG/AQG) Format						
<b>Digital (QG)</b> – Control Registers (from OCS) [registers for circuit 2 duplicated at ID + 1]						
<b>Basic control Bits</b>		<b>QG</b>	<b>Note</b>			
Reserved		1-6				
KWh Freeze		7	Both Circuits			
Protective Relay Reset (Monitor w/Protection state only)		8	Both Circuits			
Reserved		9-16				
<b>Network ID 1 only</b>		<b>QG</b>	<b>Note</b>			
Digital Output (Qn) 1-8		17 - 24				
Digital Output Polarity (Qn) 1-8 (redirected points only)		25 - 32	1 = Inverted (Active OFF)			
<b>Analog (AQG)</b> – Configuration Registers (from OCS) [registers for circuit 2 duplicated at ID + 1]						
<b>Basic ACM configuration</b>	<b>AQG</b>	<b>Size</b>	<b>Format</b>	<b>Min.</b>	<b>Max.</b>	<b>Typical</b>
VT1 ratio	1-2	Float	###.#			
VT2 ratio	3-4	Float	###.#			
VT3 ratio	5-6	Float	###.#			
CT1 ratio	7-8	Float	###.#			
CT2 ratio	9-10	Float	###.#			
CT3 ratio	11-12	Float	###.#			
Mode	13	Word	####	0	2	
Wye						0
Delta 2CT						1
Delta 3Ct						2
Extended Configuration Page (first ID only)	14	Word	####	0	3	
Basic Monitory						0
Extended Page						1-3
Heartbeat send time (first ID only)	15	Word	####			
Heartbeat receive time (first ID only)	16	Word	####			

4.4.2 Protective Relay and Synchronization Configuration

Parameters designated as WORD size that have a decimal point in the format, are entered with an imaginary decimal point. For example, when entering the Failure Confirmation Delay for ANSI 59 function, 5.5 Seconds should be entered as 55.

Configuration is duplicated for node id + 1 for circuit #2

Table 4.2 - Page 1 Configuration Data:						
Basic ACM configuration	AQG	Size	Format	Min.	Max.	Typical
Ratios	1-12	Float				
Mode	13	Word	####			
Extended Configuration Page* *Extended configuration page specification is only required in the first node id's word 14	14	Word	####	0	3	1
Heartbeat (first id only)	15-16	Words				
Over-voltage ANSI 59	AQG	Size	Format	Min.	Max.	Typical
Over-voltage Threshold	17-18	Float	###.# V			1.1 V <sub>n</sub>
Failure Confirmation Delay	19	Word	###.# s	0.1	180.0	3.0
Normality Confirmation Delay	20	Word	###.# s	0.1	300.0	10.0
Under-voltage ANSI 27	AQG	Size	Format	Min.	Max.	Typical
Under-voltage Threshold	21-22	Float	###.# V			0.9 V <sub>n</sub>
Failure Confirmation Delay	23	Word	###.# s	0.1	180.0	3.0
Normality Confirmation Delay	24	Word	###.# s	0.1	300.0	10.0
Instantaneous over-current ANSI 50	AQG	Size	Format	Min.	Max.	Typical
Rated Current I <sub>n</sub>	25-26	Float	##### A			-
Over-current Threshold (percent of rated)	27	Word	#### %	0	1200	300
Failure Confirmation Delay	28	Word	##.## s	0.05	10.0	0.10
Timed over-current ANSI 51	AQG	Size	Format	Min.	Max.	Typical
Pickup value (percent of rated)	29	Word	#### %	111	300	111
Trip Curve Type* * Timed over-current trip curve types: 0 = ANSI_EI 1 = ANSI_VI 2 = ANSI_SI 3 = IEC_MI 4 = IEC_SI (Curve A) 5 = IEC_VI (Curve B) 6 = IEC_EI (Curve C)	30	Word	#	0	6	-
Multiplier N	31	Word	##.#	0.1	99.9	1.0
Reset Delay	32	Word	##.#	0.1	99.9	-

Table 4.3 - Page 2 Configuration Data

Duplicate of Basic Configuration	AQG	Size	Format	Min.	Max.	Typical
Ratios	1-12	Float				
Mode	13	Word				
Extended Configuration Page	14	Word	####			2
Heartbeat (first id only)	15-16	Words				
Unbalanced Voltage (or) Current ANSI 60	AQG	Size	Format	Min.	Max.	Typical
Source Select (0-voltage, 1-current)	17	Word	#	0	1	0
Max Deviation Ratio	18	Word	##.# %	0.1	20.0	2.0
Failure Confirmation Delay	19	Word	###.# S	0.1	180.0	3.0
Normality Confirmation Delay	20	Word	###.# S	0.1	300.0	10.0
Active power overflow ANSI 32O	AQG	Size	Format	Min.	Max.	Typical
Power Overload Threshold	21-22	Float	#### W			-
Failure Confirmation Delay	23	Word	##.# s	0.1	99.9	10.0
Active power underflow ANSI 32R	AQG	Size	Format	Min.	Max.	Typical
Reverse Power Threshold	24-25	Float	#### W	-	-	-
Failure Confirmation Delay	26	Word	##.# s	0.1	99.9	10.0
Under/over excitation ANSI 40Q			Format	Min.	Max.	Typical
Nominal Apparent Power	26-27	Float	#### VA	-	-	-
Maximum Inductive Reactive Power (percent of nominal VA)	28	Word	###.# %	0.0	99.9	60
Failure Confirmation Delay (Inductive Reactive)	29	Word	##.# s	0.1	60.0	10.0
Maximum Capacitive Reactive Power (percent of nominal VA)	30	Word	###.# %	0.0	99.9	50
Failure Confirmation Delay (Capacitive Reactive)	31	Word	###.# s	0.1	60.0	5.0

Table 4.4 - Page 3 Configuration Data						
Duplicate of Basic Configuration	AQG	Size	Format	Min.	Max.	Typical
Ratios	1-12	Float				
Functions / Mode	13	Word				
Configuration Page	14	Word	####			3
Heartbeat (first id only)	15-16	Words				
Over-frequency ANSI 81O	AQG	Size	Format	Min.	Max.	Typical
Over-frequency Threshold	17	Word	##.# Hz	40.0	70.0	1.01
Failure Confirmation Delay	18	Word	##.## s	0.05	10.0	0.15
Under-frequency ANSI 81U	AQG	Size	Format	Min.	Max.	Typical
Under-frequency Threshold	19	Word	##.# Hz	40.0	70.0	0.99
Failure Confirmation Delay	20	Word	##.## s	0.05	10.0	0.15
DOUT Mapping						
<b>0:</b> Function has no effect on DOUT point <b>1-8:</b> Specifies DOUT point which that is controlled by function.	AQG	Bits 13-16	Bits 9-12	Bits 5-8	Bits 1-4	
Over-voltage (59)	21				0-8	
Under-voltage (27)	21			0-8		
Over-current (50)	21		0-8			
Timed over-current (51)	21	0-8				
Unbalanced voltage (60)	22				0-8	
Active power overflow (32o)	22			0-8		
Active power underflow (32r)	22		0-8			
Reactive power overflow (40q)	22	0-8				
Over-frequency (81o)	23				0-8	
Under-frequency (81u)	23			0-8		
Phase reversal	23		0-8			
(NOT) Dead bus	23	0-8				
(NOT) Safe to close (25) [first id only]	24					0-8
Reserved	24				0-8	
Directed %QG17 control [first id only]	24		0-8			
Directed %QG18 control [first id only]	24	0-8				
Dead Bus	AQG	Size	Format	Min.	Max.	Typical
Dead-bus Confirmation Delay	25	16	###.# s	0.1	180.0	3.0
Sync control ANSI 25 (first id only)	AQG	Size	Format	Min.	Max.	Typical
Maximum Current Angle <sup>1</sup>	26	16	### °	0	20	10
Synchronism Confirmation Delay	27	16	##.# s	0.1	10.0	2.0
Maximum Slip Frequency	28	16	### Hz	0.01	1.00	0.07
Maximum Voltage Deviation	29	16	##.# %	0.01	10.0	5.0
Relay Close Delay	30	16	### s	0.01	1.00	0.08
Maximum Future Angle <sup>1</sup>	31	16	### °	0	20	6
Required Angular Shift Direction	32	16	#	0	2	0
<sup>1</sup> Zero value disables that components effect on the output calculation; however, at least one angle must be greater than zero.						

#### 4.5 Network Output Data

The ACM is similar to its associated OCS in that it also consumes two Network IDs. The global data associated with the ACM's first Network ID is used to broadcast circuit 1's data while the global data associated with the second Network ID used to broadcast the circuit 2's data.

**Note:** Because the ACM broadcasts a large amount of global data on a continuous basis (every 90 mSec.), it is recommend that the ACM not be used on a network that requires other device data to be passed in a time-critical manner.

##### 4.5.1 Basic Monitoring Values and Status

The ACM broadcasts the monitored and calculated AC values and status indications through its global data. The ACM consumes two consecutive Network IDs. Circuit 1's output data is sent in the QG/AQGs associated with the ACM's first Network ID. Likewise, circuit 2's output data is sent in the QG/AQGs associated with the ACM's second Network ID. With a few exceptions, the format of the sent data is the same for both circuits and shown below in Table 4.2. For non-circuit specific data, such as discrete input status, Table 4.2 indicates which ACM Network ID's global data contains that information.

Table 4.5 - Network Output data (ACM QG/AQG) Format		
Digital (QG) – Status registers (ACM outputs)		
Basic status Bits	QG	Note
Loss of phase A	1	
Loss of phase B	2	
Loss of phase C	3	
AB phase error (variation of greater than ±3 degrees)	4	
AC phase error (variation of greater than ±3 degrees)	5	
Reserved	6	
KWh Freeze acknowledge	7	
Protection Relay Reset Acknowledge	8	
Reserved	9 - 16	
Network ID 1 only	QG	Note
Digital Input (In) 1-8	17 - 24	
Network ID 2 only	QG	Note
Expected Configuration Page	17 - 24	

<b>Continued Table 4.5 - Network Output data (ACM QG/AQG) Format</b>						
<b>Analog (AQG) – Monitored and Calculated values (ACM outputs)</b>						
<b>Basic ACM Monitoring</b>	<b>AQG</b>	<b>Size</b>	<b>Format</b>	<b>Min.</b>	<b>Max.</b>	<b>Typical</b>
Voltage A (Volts) [Delta: Voltage A-B]	1-2	Float	###.#			
Voltage B (Volts) [Delta: Voltage B-C]	3-4	Float	###.#			
Voltage C (Volts) [Delta: Voltage C-A]	5-6	Float	###.#			
Current A (Amps)	7-8	Float	###.#			
Current B (Amps)	9-10	Float	###.#			
Current C (Amps)	11-12	Float	###.#			
Frequency (Hz)	13-14	Float	###.#			
Watts	15-16	Float	###.#			
PF	17-18	Float	#.###			
VA	19-20	Float	###.#			
VAR	21-22	Float	###.#			
KWahr (see note)	23-24	Float	###.#			
Reserved	25-30					
<b>Network ID 1 Only</b>	<b>AQG</b>	<b>Size</b>	<b>Format</b>	<b>Min.</b>	<b>Max.</b>	<b>Typical</b>
Model	31	Word				
Version	32	Word				
[high byte = major]						
[low byte = minor]						
<b>Network ID 2 Only</b>	<b>AQG</b>	<b>Size</b>	<b>Format</b>	<b>Min.</b>	<b>Max.</b>	<b>Typical</b>
Phase Difference between circuits	31-32	Float				
Requires phase A voltage on both circuits						

4.5.2 Protective Relay and Synchronization Status

The number of QG global data sent from the ACM increases when the protection relay is enabled. Outputs are duplicated for node id + 1 for circuit #2

<b>Table 4.6 – Network Output Protection Relay and Synchronization</b>		
<b>Over-voltage ANSI 59</b>	<b>QG</b>	<b>Note</b>
Phase A	33	
Phase B	34	
Phase C	35	
<b>Under-voltage ANSI 27</b>	<b>QG</b>	<b>Note</b>
Phase A	36	
Phase B	37	
Phase C	38	
<b>Instantaneous over-current ANSI 50</b>	<b>QG</b>	<b>Note</b>
Phase A	39	
Phase B	40	
Phase C	41	
<b>Timed over-current ANSI 51</b>	<b>QG</b>	<b>Note</b>
Phase A	42	
Phase B	43	
Phase C	44	
<b>Unbalanced voltage (or) current ANSI 60</b>	<b>QG</b>	<b>Note</b>
Phase A	45	
Phase B	46	
Phase C	47	
Reserved	48	
<b>Active power overflow ANSI 32O</b>	<b>QG</b>	<b>Note</b>
Sum	49	
<b>Active power underflow ANSI 32R</b>	<b>QG</b>	<b>Note</b>
Sum	50	
<b>Under/over Excitation ANSI40Q</b>	<b>QG</b>	<b>Note</b>
Inductive Reactive Overload	51	
Capacitive Reactive Overload	52	
<b>Over-frequency ANSI 81O</b>	<b>QG</b>	<b>Note</b>
Over-frequency	53	
<b>Under-frequency ANSI 81U</b>	<b>QG</b>	<b>Note</b>
Under-frequency	54	
<b>Phase Reversal</b>	<b>QG</b>	<b>Note</b>
Phase reversed	55	
<b>Dead Bus</b>	<b>QG</b>	<b>Note</b>
Out of frequency and voltage range	56	

Continued		
Table 4.6 – Network Output Protection Relay		
ANSI 25	QG	Note
Safe-to-close	57	Only available on circuit 1
Parameter error (safe-to-close disabled)	58	“
Voltage deviation exceeded	59	“
Slip frequency exceeded	60	“
Slip direction incorrect	61	“
Outside current angular window	62	“
Outside future angular window	63	“
Reserved	64	“

**Notes:**

1. Confirm On/Off timing resolution is limited to the actual circuit update time of 180mS.
2. Reset does not clear the status or optional digital output point of a function that is currently detecting an exception.
3. Multiple functions may be assigned to a single digital output point. If any function is in exception that point is set. All functions must be at normality (and reset) before the digital point is reset.
4. Once one or more functions take possession of a digital output point, the network no longer has any control over that point,
5. Digital output points set by a protection function are NOT affected by loss of network. **However, resetting the network or the controller DOES reset each protection function and its corresponding outputs when the ACM is re-configured.**



#### 4.6 Network Heartbeat (Network Connection Good)

The ACM supports the CsCAN heartbeat functionality. This feature is used to detect when either the associated OCS or the ACM fails or is disconnected from the network. The OCS may be programmed to use this feature to determine if the Discrete Input or AC monitoring information last received from the ACM is valid. Likewise, the ACM uses this feature to determine if the network data is valid for controlling the Discrete Outputs. Should the ACM lose the heartbeat from the OCS, the **discrete outputs are all set to OFF (except those configured for protection features which continue to operate with loss of network)**

To use the heartbeat functionality, a send and receive timeout must be configured at both the associated OCS and the ACM. For the OCS, heartbeat timeouts are controlled with the NetPut HB and the NetGet HB function blocks. For the ACM, timeout values are received as part of the configuration data sent from the OCS. From this data, the HB Send Timeout specifies the period at which the ACM broadcasts its heartbeat to the network. The HB Recv Timeout specifies the period at which the ACM expects a heartbeat from its associated OCS. Should this time expire without a heartbeat, the ACM enters a lost connection mode, which sets the discrete outputs to zero. Generally, the receive timeout must be greater than the send timeout to account for delays in either device or the network.

Sending a HB Recv Timeout value of zero in the configuration data disables the heartbeat-monitoring feature at the ACM. This allows the discrete outputs to remain at the last network commanded value if the associated OSC fails; however, if a network failure is detected, the discrete outputs are all set to off.

#### 4.7 Discrete I/O

Eight sourcing DC inputs are provided which individually report a 1 (ON) when switched to common and are broadcasted on the network after the ACM receives the configuration data. Refer to Network Output data for format information.

Eight sinking DC outputs are also provided which activate when driven with a logic 1 or true register value. The associated OCS drives these outputs through its associated QG data. If the heartbeat function is enabled, the OCS must send consistent heartbeats (verifying its existence) or the outputs are set to a logic 0 or false state. Refer to Network Input Data for format information.

#### 4.8 AC Monitored and Calculated Data

AC Monitored and calculated data are broadcast continuously over the network. Refer to Network Output Data for format information.

##### 4.8.1 RMS Voltage and Current

Voltage and current indications are true RMS values and are calculated by squaring each sample over one line cycle, averaging the resulting squares, and taking the square root of the result. User supplied configuration ratio (scaling) constants are then applied for the appropriate PT or CT attached to the input (direct attachment of voltage input requires a ratio of 1.00).

For delta mode, the third phase voltage and current are computed from the difference of the measurements of the other phases. Should the load on the third phase become open, the third phase values will not be correct.

##### 4.8.2 Power Calculations

True power consists of a point-by-point product of the associated voltage and current values averaged over one line cycle. Volt-amperes (VA) is the sum of the product of the RMS voltage and current values. The VA value is absolute and contains no sign. Volt-amperes-reactive (VAR) is the vector difference of

volt-amperes (VA) and true power. The VAR value is signed and may be used to determine if current is leading or lagging the voltage (negative when current is leading - capacitive load). Power factor is true power divided by volt-amperes (VA).

#### 4.8.3 Power Usage (kWh)

Power usage (kWh) is calculated as the time integral of true power and is expressed in Kilowatt-hours. To prevent overflow and loss of this accumulated value over power-cycles, the associated OCS must periodically sample and reset this accumulation. Synchronization is provided for reading and resetting the power usage (kWh) accumulation such that an immediate calculation is not lost. To start this process, the OCS asserts the broadcasted 'kWh Freeze' (QG) bit. The ACM responds by making a copy of the kWh accumulator and queues that copied (frozen) value for transmission over the network (AQG). Next, the ACM resets the kWh accumulator and begins a new calculation. Finally, the ACM asserts the broadcasted 'kWh Freeze Acknowledge' (QG) bit once the frozen value is actually sent on the network. The associated OCS is then free to use the received kWh value for internal storage or accumulation.

Once the OCS has retrieved the 'frozen' copy, it releases the 'kWh Freeze' (QG) bit to allow the ACM's kWh network variable to revert to reflecting the real-time value of the kWh accumulator.

4.8.4 *Circuit 1 and 2 Phase Difference*

The phase difference is calculated by comparing the zero crossings of the voltage (A) input of each circuit. Phase difference is calculated in degrees and is the difference of circuit 2 from circuit 1. Each of the voltage (A) inputs must fall with-in the voltage and frequency limits of this device. If either circuit is providing a status of Loss-of-Phase (A), then the phase information is not calculated and displayed as zero.

**4.9 Status**

Status information is broadcasted over the network. See Network Output Data.

4.9.1 *Loss of Phase (A, B, C ) Bits*

For each circuit, a minimal voltage and frequency must be applied to each voltage input to determine the AC values for proper indication and calculations. Should a signal on one of the voltage inputs fall out of the minimal range, its associated bit is asserted to warn the operator of the problem

4.9.2 *Circuit A/B and A/C Phase Error Bits*

For each circuit, the phase difference of each voltage input zero crossing is continuously tested for a valid difference. In wye mode, if the phase varies more than  $\pm 3$  degrees from 120 and 240 degrees respectively, the appropriate bit is asserted to warn the operator of a phase imbalance. Likewise, in delta mode, if the phase varies more than  $\pm 3$  degrees from 60 degrees (between circuit A/C), the appropriate bit is asserted. In delta mode, the A/B phase error bit is inactive.

4.9.3 *Freeze kWh Acknowledge*

This value is asserted when the frozen kWh value is broadcasted on the network. See Power usage (kWh) above.

**4.10 LED Indicators**

OK	RUN	State
-----		
Both flash in continuous sequence		ACM is in monitor mode with the network ID set to FF. See section 3.2.
Both flash in numbered sequence		ACM failed power-up self-test. Contact technical support for assistance.
Fast Flash	Off	ID change delay
Slow Flash	Off	No network or Duplicate Network ID
On	Off	Waiting for configuration data
On	Fast Flash	Lost Factory calibration data
On	Slow Flash	Lost Network heartbeat
On	On	Run mode

NOTES

## CHAPTER 5: PROTECTIVE RELAY OPERATION

### 5.1 Overview

This ACM provides several protective *relay type* functions that can be combined or used individually. The protective relay functions provided are those typically found in a generator control system and provide overload and under-load protection of voltage, current, power and frequency. Each protective function provides at least one network global digital output point that provides a tripped indication. In addition, each function can optionally provide a tripped indication on one of the ACM's physical digital output points (DOUT).

Each protective relay function typically has a threshold, a failure confirmation delay and in some cases a normality delay. If the monitored value exceeds the threshold for the failure confirmation delay, then a latched (tripped) indication is provided. If a protective relay function provides separate indicators for all three phases, only the indicator for the phase(s) exceeding the threshold at the end of the failure confirmation delay is latched.

Once latched, a protective relay function indicator can not be reset until the monitored value drops below the threshold and remains below the threshold for any normality confirmation delay. Once the normality confirmation delay has expired, the indicator can be reset from the master (OCS) by asserting the Protective Relay Reset QG (for that particular circuit). The ACM acknowledges the reset command by asserting the Protect Relay Reset Acknowledge QG. This positive acknowledge can be used to release the latched reset request provided by the OCS.

**Note:** For protective relay functions that have an indicator for all three phases, it is important to realize that only the faulted phase(s) at confirmation delay is latched. Thereafter, if additional phases fault, those phase indicators are NOT latched. This functionality provides the ability to determine which phase(s) initially set the latch. Inversely, ALL phases must NO longer be faulted for the normality delay before a reset signal is accepted to clear ANY of the indicators.

Each protective relay function indicator is available in the ACM's QG global network data. This network data is typically used by an OCS(s) for monitoring and/or logging purposes. In addition, each protective relay function can redirect a physical DOUT point to its indicator. Thus, if any of the protective relay function indicators are latched, the associated (redirected) DOUT point is also activated. Once the indicators are reset, the associated (redirected) DOUT point is also de-activated.

### 5.2 Over-Voltage (ANSI 59)

If any phase voltage exceeds the specified **Over-voltage Threshold** for the **Failure Confirmation Delay**, all the phase voltages above the over-voltage threshold (at that instant) are latched in their associated QG indicators.

All phase voltages must remain below the over-voltage threshold for the **Normality Confirmation Delay** before the Protective Relay Reset QG can release latched indicators.

### 5.3 Under-Voltage (ANSI 27)

If any phase voltage falls below the specified **Under-voltage Threshold** for the **Failure Confirmation Delay**, all the phase voltages below the under-voltage threshold (at that instant) are latched in their associated QG indicators.

This function is held inactive until at least one phase voltage level rises above the detectable voltage level (less than 90VAC pre-scaled value). This prevents false trips when the bus is not active.

All phase voltages must remain above the under-voltage threshold for the **Normality Confirmation Delay** before the Protective Relay Reset QG can release latched indicators.

#### 5.4 Instantaneous Over-Current (ANSI 50)

The instantaneous over-current threshold is based on Rated Current (amps) \* Over-current Threshold (percent of rated).

If any phase current exceeds the instantaneous over-current threshold for the Failure Confirmation Delay, all the phase currents above the under-current threshold (at that instant) are latched in their associated QG indicators.

Once all phase currents drop below the instantaneous over-current threshold (no delay), the Protective Relay Reset QG can release latched indicators.

#### 5.5 Timed Over-Current (ANSI 51)

This function provides non-linear short-term over-current protection in accordance with selectable ANSI (C37.90) and IEC (255-4) curves. This protection function maintains an accumulator, which represents the thermal capacity of the generator. When the capacity reaches 100%, the protection function is tripped. Once the current drops below the pickup current, the accumulator is reduced at a specified rate representing the reducing thermal effect based on the **Reset Delay** value. Once the accumulator reaches zero percent, the function latch can be reset.

In addition, a **Multiplier N** (0.1-100%) provides the ability to tune the trip response rate of this protection function.

The timed over-current threshold is based on **Rated Current (amps) \* Pickup current (percent of rated)**.

Trip Equation:

$$\text{Delay} = N * ( A / (M^P - 1) ) + B$$

$$\text{Where } M = I_{\text{measured}} / I_{\text{pickup}}$$

$$N = \text{Multiplier}$$

Curve Type	A	B	P
ANSI Extremely Inverse	6.407	0.025	2.0
ANSI Very Inverse	2.855	0.0712	2.0
ANSI Standard Inverse	0.0086	0.0185	0.02
IEC Moderately Inverse	0.005	0	0.04
IEC Standard Inverse (Curve A)	0.14	0	0.02
IEC Very Inverse (Curve B)	13.5	0	1.0
IEC Extremely Inverse (Curve C)	80	0	2.0

Release Equation:

$$\text{Delay} = D / M^2 - 1$$

$$\text{Where } M = I_{\text{measured}} / I_{\text{pickup}}$$

$$D = \text{time for function to reset if } I = 0 \text{ and thermal capacity was at } 100\%$$

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Curve Type	D (Recommended Value)
Extremely Inverse	29.1
Very Inverse	21.6
Moderately Inverse	4.85

### 5.6 Voltage <or> Current Imbalance (ANSI 60)

This function is selectable (based on a **Source Select**) on whether voltage or current is monitored.

If any phase reading varies from the average of all three phases by more than **Max Deviation Ratio** for the **Failure Confirmation Delay**, then the phase that varies the most (at that instant) is latched in its associated QG indicator.

All phase readings must remain below the maximum deviation ratio for the **Normality Confirmation Delay** before the Protective Relay Reset QG can release the latched indicator.

### 5.7 Active Power Overflow (ANSI 32O)

If a circuit's active power exceeds the **Power Overload Threshold** for **Failure Confirmation Delay**, the associated QG indicator is latched.

The circuit's active power must drop below the power overload threshold before the Protective Relay Reset QG can release the latched indicator.

### 5.8 Active Power Underflow (ANSI 32R)

If a circuit's active power is below the **Reverse Power Threshold** for **Failure Confirmation Delay**, the associated QG indicator is latched.

This function is held inactive until at least one phase voltage level rises above the detectable voltage level (less than 90VAC pre-scaled value). This prevents false trips when the bus is not active.

The circuit's active power must rise above the reverse power threshold before the Protective Relay Reset QG can release the latched indicator.

Note that both active power and reverse power threshold are signed values where a negative value denotes reverse power flow.

### 5.9 Under / Over Excitation (ANSI 40Q)

This function provides VAR limits in both the inductive reactive quadrant and the capacitive reactive quadrant. Generally, these limits provide over-excitation and under-excitation protection respectively. Note that at a PF of zero, the appropriate VAR limit is the product of Maximum Reactive Power percentage and nominal apparent power (VA). However, as PF approaches one, this function further reduces the VAR limits internally in an attempt to match the typical generator capability curve:

$$\text{VAR}_{\text{LIMIT}} = \text{VA}_{\text{NOMINAL}} * (K - (K * \text{PF\_factor}))$$

$$\text{Where } K = \text{Maximum Inductive or Capacitive Reactive Power ratio}$$

$$\text{PF\_factor} = 1 - ((1 - \text{PF}^2)^{1/2})^{1/2}$$

If a circuit's reactive power (VAR) is positive and above **Maximum Inductive Reactive Power Threshold** for **Failure Confirmation Delay (Inductive Reactive)**, the associated QG indicator is latched.

If a circuit's reactive power (VAR) is negative and below **Maximum Capacitive Reactive Power Threshold** for **Failure Confirmation Delay (Capacitive Reactive)**, the associated QG indicator is latched.

The circuit's reactive power (VAR) must return between the Maximum Inductive and Capacitive Reactive Power thresholds before the Protective Relay Reset QG can release the latched indicator.

#### 5.10 Over-Frequency (ANSI 81O)

If a circuit's frequency is above the **Over-frequency Threshold** for **Failure Confirmation Delay**, the associated QG indicator is latched.

The circuit's frequency must drop below the over-frequency threshold before the Protective Relay Reset QG can release the latched indicator.

#### 5.11 Under-Frequency (ANSI 81U)

If a circuit's frequency is below the **Under-frequency Threshold** for **Failure Confirmation Delay**, the associated QG indicator is latched.

This function is held inactive until at least one phase voltage level rises above the detectable voltage level (less than 90VAC pre-scaled value). This prevents false trips when the bus is not active.

The circuit's frequency must rise above the under-frequency threshold before the Protective Relay Reset QG can release the latched indicator.

#### 5.12 Phase Sequence

This function provides an indication of an improper phase sequence (i.e. A-C-B) or of an extreme phase imbalance. If either the AB\_PHASE\_LOSS or AC\_PHASE\_LOSS indicator is set, the associated QG indicator is immediately latched.

Both PHASE\_LOSS indicators must be reset before the Protective Relay Reset QG can release the latched indicator.



## CHAPTER 6: BACKUP/SYNCHRONIZATION OPERATION

### 6.1 Overview

The Synchronization function has both Dead-Bus and Safe-to-Close indicators, which are typically used in genset applications. The Dead-bus indicator is generally used for backup applications and indicates when the main bus is no longer active. The Safe-to-Close indicator is generally used for load sharing applications and indicates when the genset is in synchronization with the bus.

The Dead-bus and Safe-to-Close indicators are available as network global digital output points. In addition, each indicator can optionally take control of one of the ACM's physical digital output points (DOUT). Note that redirected output is the INVERSE of the indicator (i.e. a redirected Safe-to-close DOUT point is active when the Safe-to-close indicator is NOT active). The redirected output inversion is necessary when assigning multiple functions to a single DOUT point.

### 6.2 Dead-Bus

Dead-Bus is an indication that voltage has dropped below a detectable state (< 90VAC pre-scaled voltage) on all three phases for the designated circuit and is maintained in that state for period longer than **Dead-Bus Confirmation Delay**.

Each circuit's Dead-Bus indicator is available as a network indicator or optionally as a redirected DOUT point (inverted). This is a non-latched indication (Protective Relay Reset signal is NOT required to reset indicator).

### 6.3 Safe-to-Close

Safe-to-Close is an indication that it is safe to make breaker closure between two monitored 3-phase circuits (synchronization). The ACM's calculations are based on the reference (or grid) being connected to circuit 1 and the generator-coming-on-line connected to circuit 2.

This function uses several calculations to determination when it is Safe-to-Close. **All** calculations must be within acceptable values before the indication is made. Once made, any calculation that falls out tolerance resets the indicator. These calculations are:

- All phase voltages present**
- Voltage Deviation**
- Slip Frequency**
- Phase Shift Direction**
- Phase Angle**

The phase angle calculation is selectable between two options

- Current Angle (made after confirmation delay)**
- Future Angle (made immediately once rate calculation fall in window)**

Each calculation requires associated Safe-to-Close configuration parameter(s). **All** Safe-to-Close configuration parameters must be within their respective limits before a Safe-to-Close indication is allowed. Any parameter not within its respective limits causes the ACM to provide a parameter error indication and prevents Safe-to-Close operation. If a parameter error indication is set, the respective measurement indicator is also set as an aid in determining which parameter is incorrect.

Safe-to-Close is available as network indicator or optionally as a redirected DOUT point (inverted). This is a non-latched indication (Protective Relay Reset signal is NOT required to reset indicator).



**WARNING!: Improper synchronizing of a generator to a system can result in extreme damage, bodily injury or death. Only a qualified technician shall install and tune the ACM's Safe-to-Close parameters. It is highly recommended that the operation of a synchronization control system implementing the ACM be verified with protective relay/synchronization test equipment before implementation.**

**It is highly recommended that only the optional digital output indicator be used for actual control purposes with the network indication available for monitoring purposes. Network indications can be indeterminately delayed by network communications loading.**

The following sections describe each measurement or calculation used in determining the Safe-to-Close indication.

### 6.3.1 All Phase Voltages Present

Both circuits must NOT indicate any Loss-of-Phase condition. Loss-of-Phase indicators are available at network QG1-3 points (phases A-C respectively) at the network Id corresponding to the appropriate circuit.



**WARNING!: Synchronization is determined from each circuit's phase A voltage. It left to the installer to insure proper phase sequence for B and C phases of each circuit. Proper phase sequence protection requires utilization of the Phase Sequence protection function.**

### 6.3.2 Voltage Deviation

Voltage deviation is the deviation (in percentage) of circuit 2 average voltage readings to circuit 1 average voltage readings. The measured voltage deviation must be lower than the **Maximum Voltage Deviation** set point before Safe-to-Close can be indicated.

$$\begin{aligned} \text{Ckt1}_{\text{avg}} &= ( \text{Ckt1VA} + \text{Ckt1VB} + \text{Ckt1VC} ) / 3 \\ \text{Ckt2}_{\text{avg}} &= ( \text{Ckt2VA} + \text{Ckt2VB} + \text{Ckt2VC} ) / 3 \\ \text{Deviation} &= (( \text{Ckt1}_{\text{Avg}} - \text{Ckt2}_{\text{Avg}} ) \setminus \text{Ckt1}_{\text{Avg}}) * 100 \end{aligned}$$

A non-latched indication of voltage deviation exceeding the Maximum Voltage Deviation is available on a network QG.

### 6.3.3 Slip Frequency

Slip frequency is the difference between circuit 2 and circuit 1's frequency readings. The measured slip frequency must be lower than the **Maximum Slip Frequency** set point before Safe-to-Close can be indicated.

$$\text{Freq}_{\text{slip}} = \text{Ckt2}_{\text{freq}} - \text{Ckt1}_{\text{freq}}$$

A non-latched indication of slip frequency exceeding the Maximum Slip Frequency is available on a network QG.

#### 6.3.4 Angular Shift Direction

The angular shift direction is the direction of the phase change (with respect to ckt1) caused by a slip frequency.

$$\text{If( sign( Freq}_{\text{slip}} ) \neq \text{current shift direction \&\& Freq}_{\text{slip}} \geq .01 \text{ Hz )}$$
$$\text{Current shift direction} = \text{sign( Freq}_{\text{slip}} )$$

**Note:** To protect against false indications due to system noise or jitter, the slip frequency must change at a rate greater than or equal to 0.01 cycles/second before a direction change is indicated.

The current shift direction must match the **Required Angular Shift Direction** set point before Safe-to-Close can be indicated.

Required Angular Shift Direction options:  
0 = any angular shift;  
1 = angular shift negative direction;  
2 = angular shift positive direction.

A non-latched indication of the current angular shift direction NOT matching the Required Angular Shift Direction is available on a network QG.

#### 6.3.5 Phase Angle

Phase angle is the phase difference between the two measured circuits. When the phase angle is zero or in very close proximity, those circuits are considered to be in synchronization and a Safe-to-Close indication can be made. The ACM allows the user to select one of two modes for determining synchronization: current angle or future angle. The method selected is accomplished by setting a angle value greater than zero in the corresponding angle configuration parameter (**Maximum Current Angle** or **Maximum Future Angle**). Failure to set either of the configuration angle values higher than zero causes a parameter error. Setting both configuration angle values to a value higher than zero is allowed (while NOT typical) which would require both tests to indicate synchronization before Safe-to-Close can be indicated.

#### 6.3.6 Current Angle Method

This selection provides an indication of synchronization after the phase difference has remained less than that specified by the **Maximum Angular Window** set point for a period longer than **Synchronism Confirmation Delay** set point. The Maximum Angular Window is specified as a range that passes through zero (i.e. a maximum angular window of 10 degrees indicates synchronized if phase difference is maintained between +5 and -5 degrees).

A non-latched indication of the current angle NOT synchronized condition is available on a network QG.

### 6.3.7 Future Angle Method

This selection provides an indication when the ACM anticipates that the circuits will be in synchronization by the time the contactor (with a measurable delay) is able to make closure. That is, if the current angle plus the future angle difference (as calculated by the current slip frequency and **Relay Close Delay**) falls within the **Maximum Future Window**, then the indication is made immediately.



**WARNING!** It is the responsibility of the user to verify that the system has sufficient rotational momentum and frequency stability to maintain the current phase trend during the relay close delay period. This requirement is especially critical when the relay closure delay is long. An insufficiently stable system can cause the relay to close outside the safe synchronization window resulting in possible damage to equipment, bodily injury, and death.

$$\text{Future angle} = \text{Current angle} + (360 * (D_{RC} + D_{ACM}) * \text{Freq}_{\text{slip}})$$

Where:

$D_{RC}$  = Relay Closure Delay

$D_{ACM}$  = Internal calculation period

A non-latched indication of the future angle NOT synchronized condition is available on a network QG.

## CHAPTER 7: REDIRECTION OF PHYSICAL DIGITAL OUTPUTS

### 7.1 Overview

Eight physical DOUT points (Q1-Q8) are provided on the ACM. When the ACM is configured for Basic Monitoring, these outputs are under control of the network. However, when the ACM is configured for Monitoring w/Protection, these DOUT points can be individually redirected to be under the control of protective relay or synchronization functions. When NOT redirected, a DOUT point remains under the control of the network as in Basic Monitoring. However, when redirected, a DOUT point is entirely controlled by the associated protective relay function's indicator and is NOT affected by either network control or network status (exception with %QG17/%QG18 Digital Output Q(n) redirection).

The polarity of each redirected DOUT point is configurable. That is, the redirected DOUT can act as either a normally-open (Active On) or a normally-closed contact (Active Off). Additionally, multiple protection and/or synchronization functions can be assigned to a single DOUT point to provide a reduced or single external relay solution.

### 7.1 Configuring DOUT Point Redirection

Each protective/synchronization function is provided 4 bits (nibble) in the configuration data to specify which, if any, DOUT point to redirect to that particular function. (This configuration begins at AQQ21 in the Configuration Data Table on page 28.)

0 - Does not effect any DOUT	
1 - DO1 (Q1)	5 - DO5 (Q5)
2 - DO2 (Q2)	6 - DO6 (Q6)
3 - DO3 (Q3)	7 - DO7 (Q7)
4 - DO4 (Q4)	8 - DO8 (Q8)

Values 9-15 are reserved and are not set.

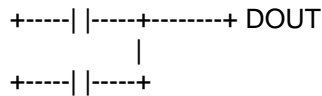
The active polarity of each redirected DOUT point is configurable in the Network Input Data QG25-32 on the first network Id only. Setting a bit in these QG points during the ACM configuration process causes the DOUT to invert its active state. Note that these QG points are ONLY read during the configuration sequence.

### 7.3 Assigning Multiple Protection / Synchronization Functions to a Single DOUT Point

Since it is possible to have more enabled protective/synchronization functions than DOUT points, it is possible to redirect multiple functions to each DOUT point. The summing of the multiple function outputs to a redirected DOUT point behaves differently depending on the DOUT point's configured polarity.

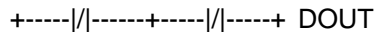
#### Digital Output Polarity Normal (Active On)

The output of each function is logically OR'd to control the DOUT point



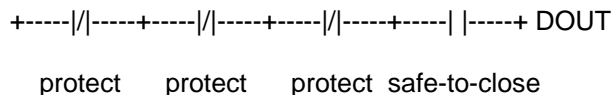
#### Digital Output Polarity Inverted (Active Off )

The output of each function is logically OR'd and then inverted to control the DOUT point. This inversion of the output causes the DOUT point to appear to be the AND'd sum of the inverted function outputs.



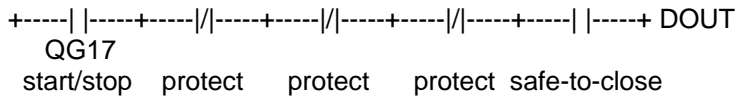
#### Digital Output Polarity Inverted w/Synchronization Function Indicators)

Note that the dead-bus and safe-to-close synchronization function indicators are inverted before driving a redirected DOUT point. This inversion is provided such that when driving a redirected DOUT point configure for inversion, the following virtual logic solution is created:



### 7.4 Single External Control Relay Solution with Network Control

To save external I/O cost, a single relay solution may be desired where both network control AND protection (and/or synchronization) function control of a single DOUT point is provided. Therefore, a method is provided to redirect a DOUT point to either network directed data points %QG17 or %QG18. This provides the following virtual logic solution (DOUT polarity = Inverted) when combined with other functions:



This feature is enabled by two DOUT redirection configuration parameters that treat directed network data points %QG17 and %QG18 as if they are protection circuit outputs. That is, directed network points %QG17 and %QG18 can be individually redirected to any output, and therefore, be used with multiple protection functions.

Regardless of the redirected DOUT 's polarity, a virtual contact created with the DOUT redirection to either directed network data point (%QG17 or %QG18) is always activated when the associated directed network point (QG) is activated. This is done to ensure that if the network fails, the virtual contact opens.

NOTES



## APPENDIX A: PROGRAMMING EXAMPLES

### A.1 Overview

When using the extended protection features of the ACM, it is imperative to get the precise timing down in ladder logic to send the three pages of extended configuration data to the ACM. In general, there is a lot of data to process to and from the ACM. Therefore, the following programming examples are provided.



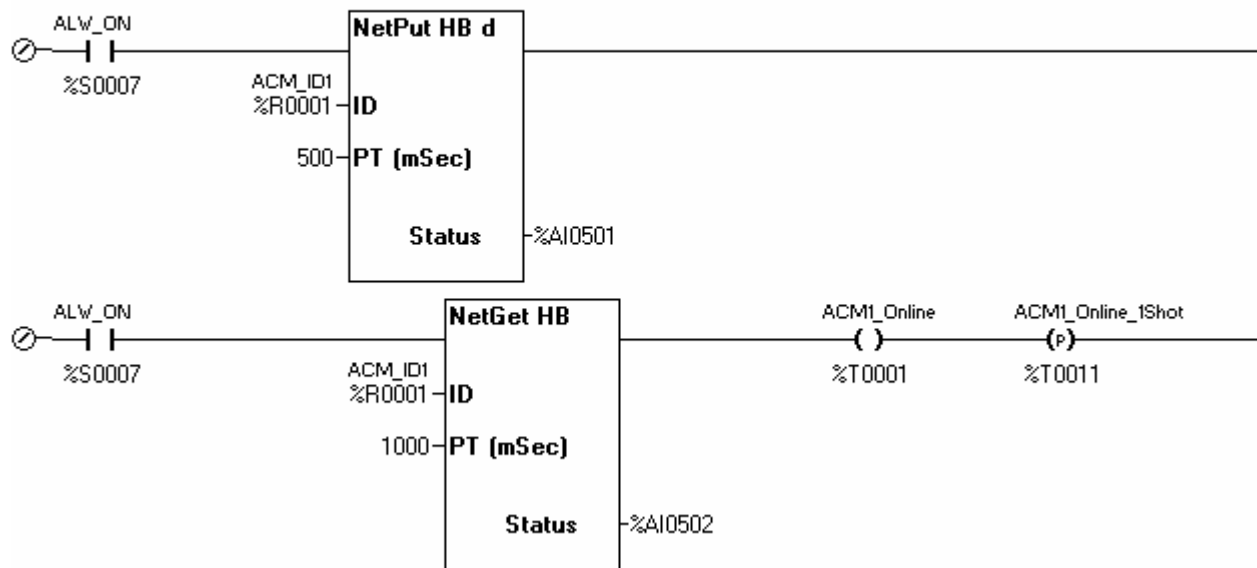
**WARNING!: The provided examples are only that; examples. It is the responsibility of the user to verify that their programming operates in a fashion so that harm is not caused to equipment or any person operating the equipment.**

### A.2 Heartbeats

The ACM provides a heartbeat for controllers to monitor. It will send this heartbeat out at an interval determined by the Heartbeat Send Time setting. The ACM will also expect a heartbeat pulse directed to it at an interval determined by the Heartbeat Receive Time setting. In general, for any device on CsCAN, a heartbeat should be sent at twice the rate that it is expected.

To make full use of the heartbeat functionality on the ACM, it is required that the controller provide a heartbeat to the ACM and monitor for one from the ACM. This is in addition to providing the ACM with heartbeat send and receive times in the configuration. The following example sends a heartbeat every 500ms and expects one every 1000ms. %T1 can be used as an indicator on a screen that the ACM is currently online. %T11 is a 1-shot that initiates the configuration sequence later on when the ACM first comes online.

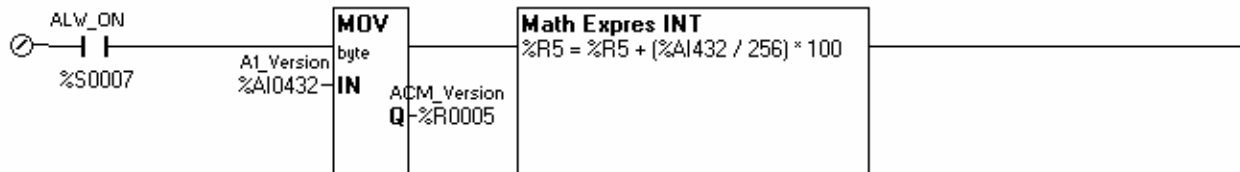
**[\* A heartbeat is put directly to the ACM. One is received to indicate that the ACM is online. The NetGet heartbeat will pass power when the ACM is online. \*]**



### A.3 ACM Version

The ACM reports its firmware version split into 2 bytes. Getting it into an integer value so that it may be displayed with a normal Integer data field with 2 decimal points can be done as follows, with %R5 containing the reformatted version:

(\* Compile version number into a display-friendly format (i.e. 1.02). The lower byte of the reported version is moved to the display register. Then, the reported version is divided by 256 (100h), taken times 100 to clear the lower 2 digits and, finally, added to the lower byte that is already in the display register. \*)



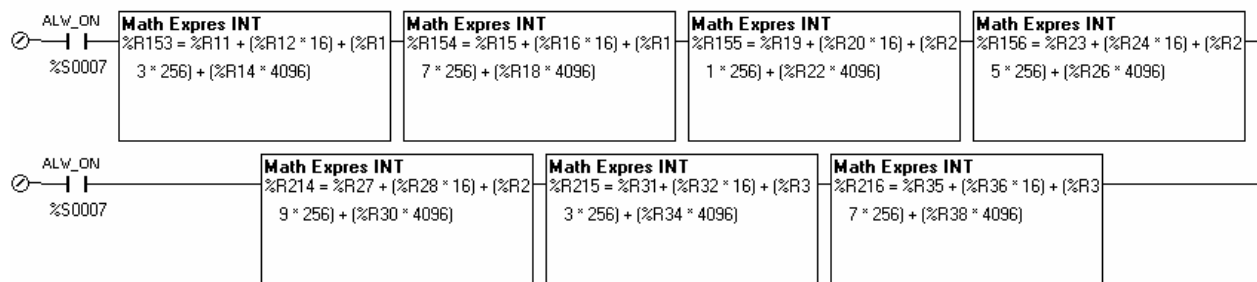
### A.4 Compiling Redirected Outputs

In Chapter 4 (page 28) of the extended configuration data includes redirected output mapping. Since there are only eight outputs available, a value of 0-8 is all that is needed for this setting. This value can fit within half of a byte (a nibble) and, therefore, a word-length register can hold four of these values. See Chapter 7, also, for more information on Redirected Digital Outputs.

Hard-coding the values is always an option using Setpoints or move functions on First Scan. However, if it is desired for these settings to be dynamically changeable, compiling all of these values can be done using the Math Expression function by multiplying the settings by 10h, 100h or 1000h (16, 256, 4096) depending on their place in the word.

Set aside 28 registers for the user to make changes to (16 for Circuit 1, 12 for Circuit 2) depending on where the output is to be redirected (%R11-%26 for Circuit 1, %R27-%R38 for Circuit 2 in this example). %R153-%R156 then contain the compiled redirects for Circuit 1 and %R214-%R216 contain the compiled redirects for Circuit 2.

(\* Selections to redirect outputs based on error conditions are compiled into their respective registers. Each selection only takes up 4 bits, so 4 selections are compiled into a 16-bit register. \*)



### A.5 Configuration Pages

Sending each of the configuration pages at the correct times is imperative and there may be times when there is no indication that the correct configuration data got to the correct place until errors are seen in readings. Just because the incorrect data is sent to the ACM does not necessarily make it invalid data as far as the ACM is concerned.

It is suggested that a “transmit buffer” be set aside that is 32 words in length for each circuit. The first 16 words of these buffers can be directly linked to the data fields on the screen that contain the standard configuration parameters for the ACM as these parameters are kept consistent through all of the

configuration pages. The second 16 words of these buffers will have different data moved into them depending on which page is being transmitted.

Three pages worth of word-length registers for extended data for each circuit (96 registers total) should be set aside. These registers can be linked directly to the data fields on the screen that contain the extended configuration parameters for the ACM. They will then be moved, at the appropriate times, to the transmit buffer.

The process of initiating the sending and “handshaking” of pages to the ACM for extended configuration consists of the following steps:

1. Move Page 1 extended configuration parameters to the last 16 words of the transmit buffers for Circuit 1 and Circuit 2.
2. Move a ‘1’ to the 14<sup>th</sup> word of the first page for Circuit 1.
3. Trigger (1-shot) the Net Puts for Circuit 1 and Circuit 2.
4. Wait for the ACM to report back that it wants page 2 in the Expected Configuration Page register (the value in the input bits 17-24 of the second ID, read as a byte value).
5. Move Page 2 extended configuration parameters to the last 16 words of the transmit buffer for Circuit 1 and Circuit 2.
6. Move a ‘2’ to the 14<sup>th</sup> word of the first page for Circuit 1.
7. Trigger (1-shot) the Net Puts for Circuit 1 and Circuit 2.
8. Wait for the ACM to report back that it wants page 3.
9. Move Page 3 extended configuration parameters to the last 16 words of the transmit buffer for Circuit 1 and Circuit 2.
10. Move a ‘3’ to the 14<sup>th</sup> word of the first page for Circuit 1.
11. Trigger (1-shot) the Net Puts for Circuit 1 and Circuit 2.
12. Wait for the ACM to report back a value of 0 in its Expected Configuration Page register, indicating that it has received the configuration.

It is also required that the ACM’s Expected Configuration Page be constantly monitored. Should it report that it needs a certain page of configuration for any reason, that page will have to be sent. This may happen if the ACM is power cycled or otherwise loses its 24VDC power.

With all of the suggested blocks of register space, there are now the following register areas:

- Circuit 1 Transmit Buffer, 32 registers (%R221 - %R252 in the example program)
- Circuit 2 Transmit Buffer, 32 registers (%R253 - %R284 in the example program)
- Circuit 1 Extended Page 1, 16 registers (%R117 - %R132 in the example)
- Circuit 1 Extended Page 2, 16 registers (%R133 - %R148 in the example)
- Circuit 1 Extended Page 3, 16 registers (%R149 - %R164 in the example)
- Circuit 2 Extended Page 1, 16 registers (%R178 - %R193 in the example)
- Circuit 2 Extended Page 2, 16 registers (%R194 - %R209 in the example)
- Circuit 2 Extended Page 3, 9 registers (%R210 - %R219 in the example)\*

\* Note that Page 3 of Circuit 2 only has nine extended configuration parameters as the last seven are only needed for Circuit 1.

In the following example,

- %T2 is linked to a pushbutton on a touch screen, but could just as easily be a %K F-key.
- %T11 is the positive transition that from the heartbeat function explained earlier.
- %I385 is the start of the Expected Configuration Page byte reported by the ACM.
- %Q305 is the start of Circuit 1 Digital Configuration.
- %Q337 is the start of Circuit 2 Digital Configuration.
- %R1 is a register containing the first ID of the ACM
- %R2 is a register containing the second ID of the ACM

Setting up the data to be transmitted is most of the work:

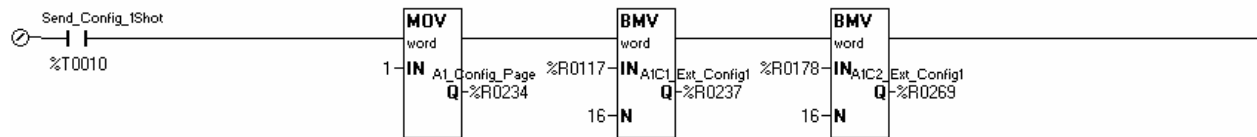
(\* On First Scan, the last 3 words of Circuit 2 Config are zeroed because they are not used. \*)



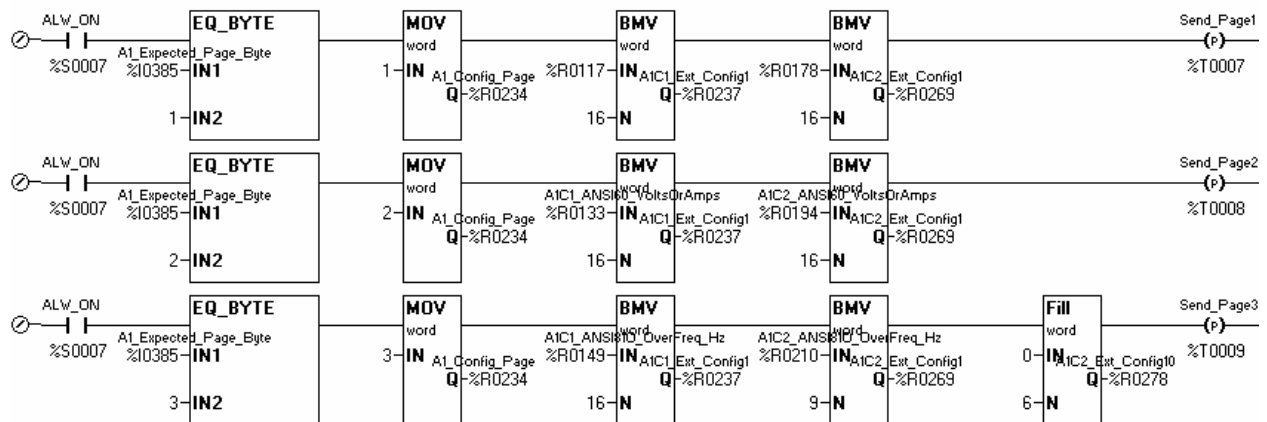
(\* A 1-shot is sent out every time the "Send Config" button is sent or when the ACM comes online. Also on First Scan. \*)



(\* When the "Send Config" button is pressed, a value of 1 is moved into the Config Page register to let the ACM know that configuration data is going to be sent. Page 1 data is also moved into the "transmit buffer". \*)

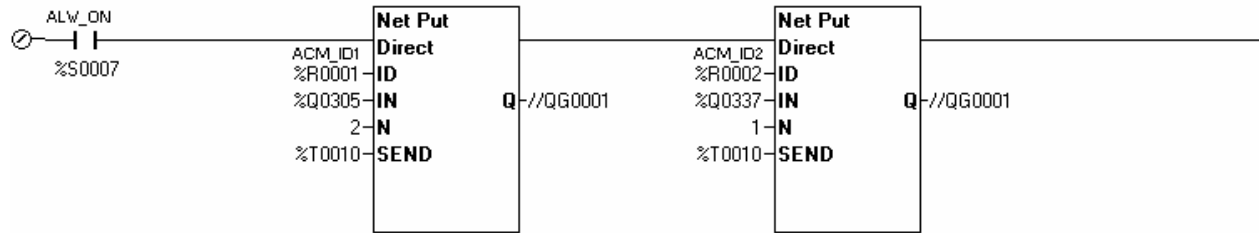


(\* Depending on what page the ACM wants, the corresponding page's data is moved into the transmit buffer. On Page 3, the last 6 registers are zeroed because they are unused registers for circuit 2. A 1-shot is fired as a trigger after each move. \*)

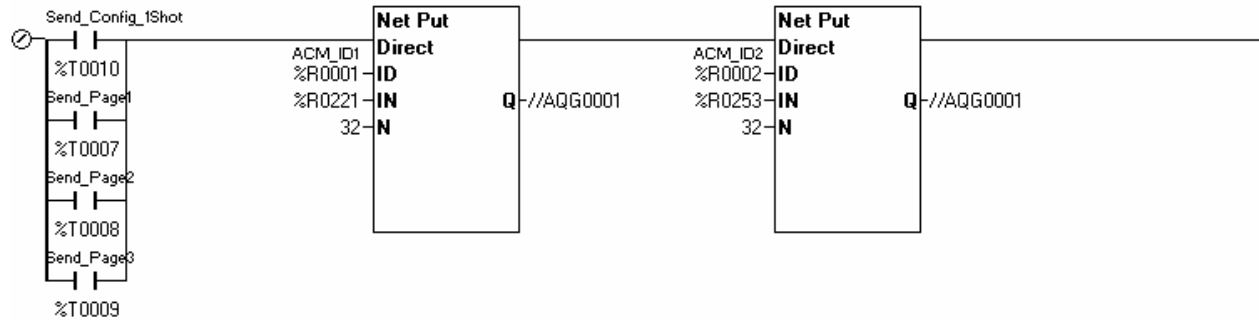


Transmitting the configuration data to the ACM is done with Net Put Direct functions.

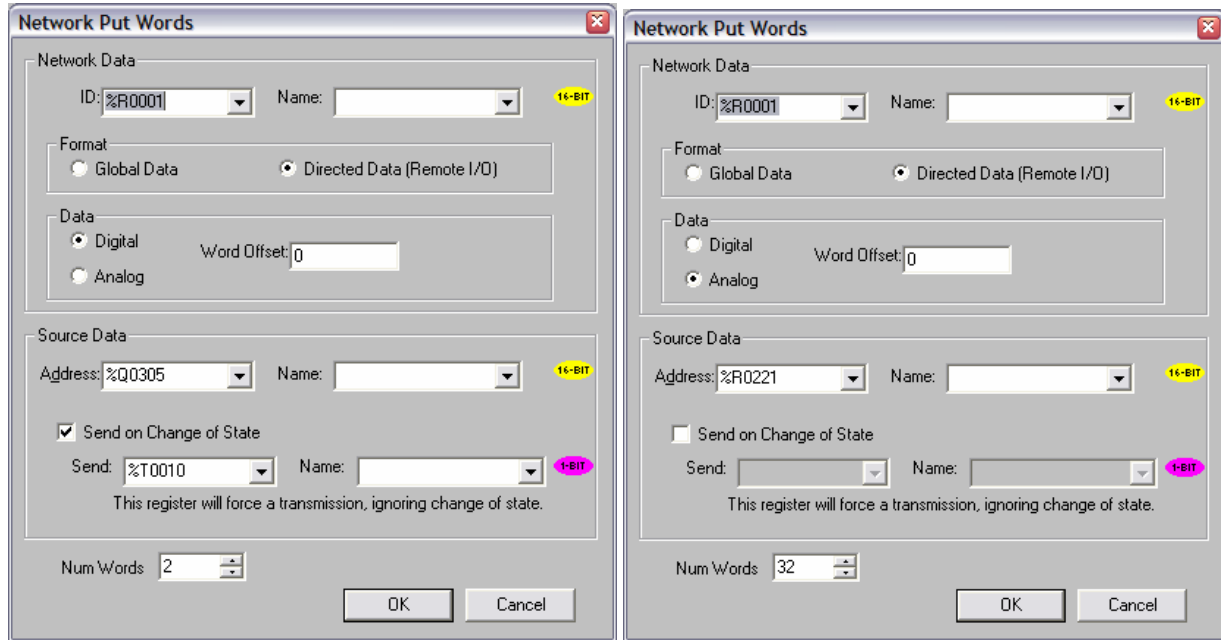
(\* The Digital Configuration and outputs are always sent on change-of-state. \*)



(\* The rest of the configuration is only sent when the "Send Config" button is pressed or when the ACM asks for a new page. \*)



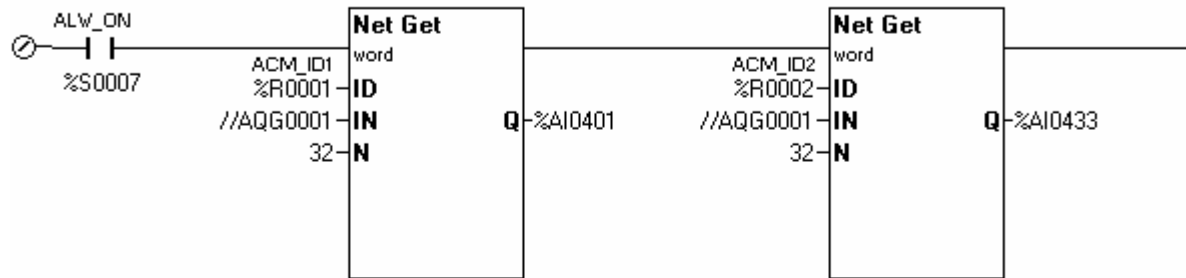
The first of each Digital Net Put Direct and Analog Net Put Direct is detailed below:



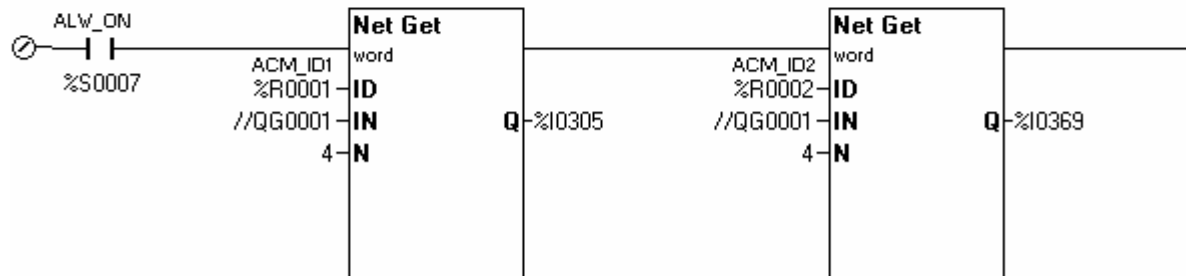
**A.6 Retrieving ACM Data**

Once the configuration is sent to the ACM, both of its LEDs (OK and RUN) should be on solidly. The ACM is now transmitting data to the network with its measurements and calculations within 32 analog words and 64 digital bits per each of the 2 nodes it occupies. Gathering this data is done with NetGet functions. Normally, the controller supplying the configuration data would read this data, but it is broadcast globally and any controller on the network may read it. Notice that the destination of the NetGet function can be analog %AI and digital %I registers as long as they are not overwriting other I/O points that are already configured.

**(\* These NetGet functions bring in all of the data that the ACM is reporting. The Analog values... \*)**



**(\* And the Digitals... \*)**



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