



Using Yaskawa VFD's "ModbusTCP-Ethernet Option" with Allen Bradley PLC 5 Programmable Controllers

INTRODUCTION:

In today's world of systems and industrial automation there are several vendors supplying equipment to OEM's, machine designers and end users. However, not all equipment in a system or specific solution is available from one individual equipment vendor. When designing systems there are several features of products, or product lines that a particular equipment vendor may excel in. These features many system designers take into account when deciding on a specific brand of product, or feature of a product, to use in an automated system. Therefore, it is desirable to provide the ability to interface cross vendor equipment to various equipment manufacturers, in order to provide the control and system equipment that best suits the automation system design. One method used for these interconnects are open networks, and in particular the ModbusTCP version of Industrial Ethernet has been gaining strength on the industrial automation system floors.

The following document shall describe the system application details of implementing Yaskawa's 5 and 7 series Variable Frequency Drives with ModbusTCP-Ethernet option cards to an Allen Bradley series PLC 5 controller utilizing off the shelf industrial network interfaces. Specifically, the Prosoft Technology, Inc, MVI71-MNET (FW Ver 1.29) module provides an interface from the Allen Bradley controller to the Modbus TCP-Ethernet network to allow the communication, monitoring and control for the Yaskawa Series VFD's.

Since each system's requirements are typically different, the following design steps may be accomplished in different ways, yet form a base design, which may be built on for the specific system's application requirements.

INTENDED AUDIENCE:

This document assumes that the reader is familiar with Yaskawa 5 and 7 Series Inverters, Modbus TCP and Ethernet technical terminology and operation, and is also familiar with PLC programming of Allen Bradley "PLC 5" series PLC's.

REFERENCES:

Yaskawa SI-E Modbus TCP – Ethernet Interface Option : IG.AFD.25
Prosoft Technology, Inc. – MVI71-MNET Users Manual
Allen Bradley Programmable Controller Documentation for PLC 5

SYSTEM OVERVIEW:

The example system used for this description includes three Yaskawa Variable Frequency Drives (CIMR-G5M20P4, CIMR-G5M20P7, CIMR-F7U20P4) with CM090 MBTCP- Ethernet options, an Allen Bradley PLC 5 Controller, a Prosoft Technologies MVI71-MNET series ethernet module and the required interconnecting hardware, programming and commissioning tools, etc. Please see figure 1, for a conceptual system diagram.

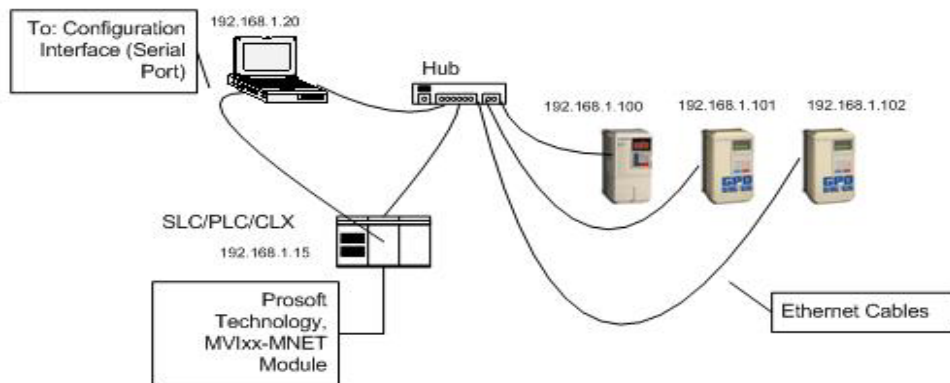


Figure 1: Example System

The Prosoft Technologies MVI71-MNET module provides the network interface, fitting directly into the AB controllers rack. This along with some configuration and ladder logic programming allows the Yaskawa VFD's to communicate with the programmable controller through the ethernet network. For more detailed information regarding the Prosoft Technologies Modules, Allen Bradley Controllers or CM090 Yaskawa MBTCP Ethernet Option Setup, please refer to the referenced information sources.

The following information describes the general, and some product specific steps required to “start-up” the example system. The main intent of the example system is to allow system designers to get familiar with the equipment in a typical system setting, such that this system may be used as a base test system, starting point or building block, and can be expanded upon for specific systems project requirements.

The application is rather straight-forward. The system application allows drive control and frequency reference control from the PLC 5 controller, to each of the 3 drives that are networked on the ethernet.

GENERAL SETUP:

The following discusses some general setup procedures that can be done to verify individual equipment and system components, before the configuration and start-up of the example system. This enables us, to make sure the system equipment is operating correctly (separately) before introducing any complexities of the system being combined and thus prepares a starting point for troubleshooting, if needed.

Setup the system hardware: Connect and verify operation of the equipment individually before attempting to operate and commission the full system. This includes verifying the PLC programming interface is functional. Check to assure that the VFD's are operating correctly from the VFD's digital operator, and that the programming laptop's serial interface is functioning correctly for accessing the Prosoft ethernet module's configuration interface. Note, the MVI71-MNET module configuration will be discussed later in this document.

Connect the Ethernet Network and verify "Network Link" operation to each node: Connect each of the devices (Drives, PLC, etc.) to the Ethernet network switch/hub, verifying that the appropriate LINK indicator (LED) is 'ON' for the connected port, and the link LED on the Yaskawa CM090 Option or other device is displayed, to indicate a successful link status between the devices. The Link LED is a main diagnostic used indicating that the physical interface of the ethernet connection is operational.

Setup the node IP addresses and network parameters:

Setup the node IP addresses and network parameters for the Yaskawa Variable Frequency Drives and the configuration computer. Please refer to the Yaskawa IG.AFD.25 installation guide for setup instructions regarding the CM090 option.

NOTE: Please verify that the network settings to be used 'are appropriate' with the Information Systems department, 'if' using a corporate ethernet network. This check should be completed before connecting to a corporate ethernet hub or switch, because of possible disruptions to the corporate network if the addresses are not correctly configured or setup.

Configure the Prosoft Technologies Module and Control Programming:

Next, install the Prosoft Ethernet Interface module in the PLC rack, program the network configuration and messaging list for the module, and program the PLC for control of the Modbus TCP messaging, to the Yaskawa drives and devices on the ethernet network. These procedures will be discussed in the following pages.

PROSOFT MODULE CONFIGURATION AND SETUP:

There are mainly four sections of configuration and setup associated with the Prosoft Technology MVI71-MNET interface and Yaskawa VFD application:

- 1.) Setup the Configuration/Programming interface for the Prosoft Module.
- 2.) Configure the Prosoft Module on the ethernet network, and PLC rack.
- 3.) Configure the Prosoft Module's network messaging list.
- 4.) Program the PLC to control the communication data transfer process and application messaging to drive the Prosoft Ethernet Interface Module.

Setup the MVI71-MNET Module's "Configuration" Interface:

Configuration Interface Description: The MVI71-MNET modules can be configured through multiple interfaces (serial port, FTP, Etc.). In this example the modules configuration port shall be used to setup the modules' operational settings. The MVI71-MNET module, utilizes a standard serial interface (i.e. the P1 connector) to a terminal application (i.e. Hyperterm or Terminal that is provided with the various versions of Windows operating systems) to configure and validate the programming of the Prosoft Module. When initializing the terminal program, please setup the communication values shown below for the COM port used (i.e. The COM port which you will be connected to the MVI71-MNET module).

The following are the detailed settings for the COM port:

Baud Rate: 57,600bps
Parity: None
Data Bits: 8
Stop Bits: 1
Flow Control: Software Handshake.

Connect the serial interface cable from the setup COM port on the configuration PC to the RJ45 connector / 'P1' port, on the Prosoft module and run the Hyperterm or Terminal application.

When connected to the MVI71-MNET module you will be able to see the modules command menu, by pressing the '?' key. Please refer to figure 2, for a diagram of the connection requirements.

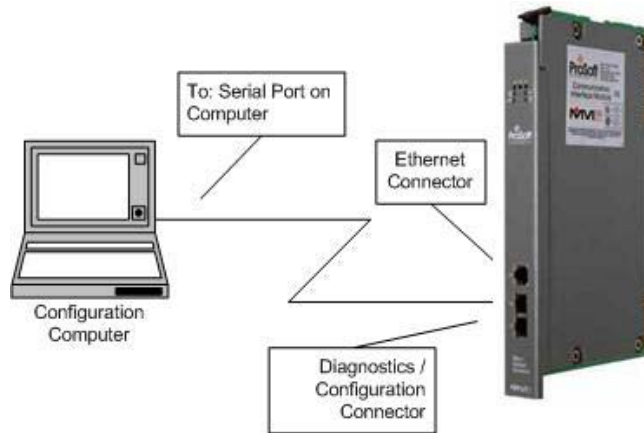


Figure 2: Configuration Port Connections.

2.) Prosoft MVI71-MNET Module Configuration:

Setup Description: The Prosoft module must first be assembled into one of the PLC rack slots before it can be configured for operation. Typically, to configure the module you should attach to the PLC with the required programming software in order to configure the module in the PLC rack as required by the PLC manufacturer.

Setup the Network Parameters: The configuration port is used to setup the Ethernet IP address for the module. This is accomplished by sending the MVI71-MNET module a text description file that defines the network operating parameters. The module reads the file ‘contents’ on initialization, and uses the contents as the address parameters configuration for the module. The following is an example of the “wattcp.cfg” file used for this purpose. Use this file to define the IP address, subnet mask and gateway address for the Prosoft MVI71-MNET module for use on the example system.

Example:

```
# ProLinx Communication Gateways, Inc.
my_ip=192.168.1.15
netmask=255.255.255.0
gateway=192.168.1.1
```

To configure the Prosoft module, save the text file as filename: “wattcp.cfg”, and use the configuration interface to upload the configuration file to the Prosoft module. To perform this action, use the Hyperterm configuration interface to the module. At the main configuration menu, press the ‘@’ key to display the “Network Menu”. Next, press the ‘R’ for Receive file: “wattcp.cfg”. After this selection is complete, follow the displayed instructions to send or upload the new “wattcp.cfg” file to the module.

Note: The next power cycle of the PLC will allow the new settings to take affect.

Note: Also, as an intermediate verification step, utilize the configuration computer's command prompt, to "ping", each of the nodes on the Ethernet network and verify their presence after the configuration is effective. This check allows verification that the Ethernet network's devices are running correctly at this point in the system start-up process. With the configuration PC connected to the ethernet network open a command prompt and type:

"C:\ ping xxx.xxx.xxx.xxx"

Where the xxx's indicate each octet of the Prosoft modules programmed IP address.

3.) Scanlist Configuration:

Setup the Prosoft modules device scanlist: In order to configure the Prosoft module for the controlled and monitored nodes on the ModbusTCP – Ethernet network, we need to define the required registers in the Yaskawa VFD's, that we would like to access. These registers must then be mapped within the accessible data scope of the PLC, to be integrated into the control system programming. For our typical VFD control, the application consists of:

- 1.) Control of the run/stop, fwd/rev, and fault/reset associated bits,
- 2.) Commanding a frequency reference,
- 3.) Monitoring of the VFD's state and output frequency.

Therefore the ModbusTCP messaging requirements and register accesses would be the following, for each Yaskawa VFD on the ethernet network:

1.) Multi Register Write "func code (16)": Command registers 01h & 02h, for a size of 2 registers.
(Note, Register 01h is the Drive command word, and 02h is the commanded frequency reference word.)
2.) Read Register "func code (3)" : Drive status register 10h, 1 register. (32h for F7).
3.) Read Register "func code (3)" : Drive Frequency register 20h, 1 register. (36h for F7).

Each of these messaging requirements needs to be sent from the Prosoft module to each drive, in order to be controlled or monitored, and therefore must be defined in the MVI71-MNET module. These messaging definitions are accomplished by formatting a text file (similar to the network configuration file) with the messaging instructions. This file can then be uploaded to the Prosoft technology module. This is accomplished again, through the configuration port of the Prosoft module. The text file to be used is named: “mnet.cfg”, and the following example shows the configuration section used for the Yaskawa VFD’s in this example system.

Example of “client 0” section:

```
[MNet Client 0 Commands]
#
# The file contains examples for a Modbus TCP/IP control using MBAP (port 502)
#
# 1      2  3      4      5      6      7      8      9      10
#      DB Poll  Reg  Swap      Serv Slave Func  Address
#Enab Addr Delay Count Code Node IP Address Port Addr Code In Dev
START
  1      1  0      1      0  192.168.1.100  502  1  3      31
  1      2  0      1      0  192.168.1.100  502  1  3      35
  1     120  0      2      0  192.168.1.100  502  1  16     0
  1      3  0      1      0  192.168.1.101  502  1  3      15
  1      4  0      1      0  192.168.1.101  502  1  3      32
  1     122  0      2      0  192.168.1.101  502  1  16     0
  1      5  0      1      0  192.168.1.102  502  1  3      15
  1      6  0      1      0  192.168.1.102  502  1  3      32
  1     124  0      2      0  192.168.1.102  502  1  16     0
END
```

This indicates the message configuration for each of the Yaskawa Drives in the example system. The messages functions and properties are defined by each of the values in each line. Specifically each drive has a set of three messages defined, two are monitoring (Drive Status and Frequency Output) and the other performs a two register write to the drives control and frequency reference register.

Note: Each of these entries have specific meanings or function that are defined in the Prosoft Technology users manual. Please refer to the manual for additional details.

Next, after defining and entering the VFD messaging requirements of the example system, save the text file as “mnet.cfg”. Use the configuration interface to upload the configuration to the module. To perform this action, establish a connection (if not already established) with the Prosoft module using Hyperterm (or the terminal application) as discussed above. At the main configuration menu, press the ‘R’ for Transfer Configuration from PC to the MVI module. After selecting the ‘R’, press ‘Y’(yes) to

confirm the action and follow the displayed instructions to send or upload the "mnet.cfg" file to the module. Note: After the file is sent the module will restart, and allow the new settings to take affect. The Prosoft ethernet module should then start scanning the enabled messages per the transferred device message configuration. You will be able to observe this by observing the green flashing 'NS/CON' LED on the VFD ethernet interface.

Note: As an intermediate verification step, utilize the configuration computer's menu item 'I', to verify the modules device configuration for each of the VFD's parameter messaging requirements. By pressing the 'I' at the main menu of the configuration interface, the module should display it's current message configuration.

4.) Ladder Logic Programming Overview:

Background Description: Before getting into the ladder programming, first it is important to understand how the MVI71-MNET module looks to the PLC and the outside network. The scanner is essentially an array of approx. 5000 word registers, each with a specific Modbus register address. The scanner maps the external Modbus device registers (located in the networked devices) to various defined spots of this 5000 word array. This is accomplished by the contents of the "mnet.cfg" file. The ladder logic looks at the information located in the scanner module and performs application logic required for the system control, which includes the transfer of data from the module to the PLC processor. Please refer to the following figure 3 for the data array illustration.

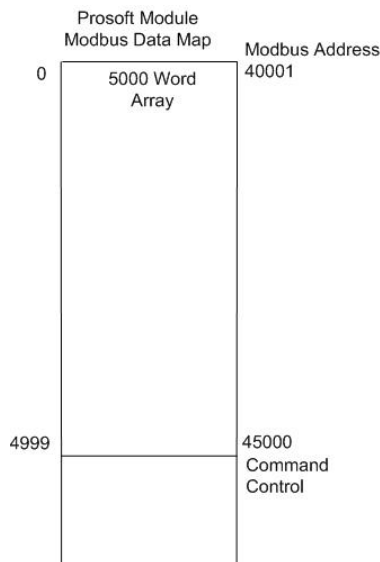


Figure 3: Prosoft Module Modbus Data Map

PLC module control and messaging: There are basically 3 methods of control and messaging that is (or can be) used to control the Yaskawa VFD's through the MVI71-MNET module:

1.) Scanned, which is configured by the messaging information sent to the Prosoft module. The messages defined are sent in a cyclic fashion to the networked devices in the system.
2.) Event messaging, which is messaging triggered by the internal PLC ladder logic.
3.) Command messaging, which is a combination of allowing the programmer/system designer to use the "mnet.cfg" file to define the messaging for the device registers to be accessed, and then selecting those messages to be sent by event driven PLC logic.

These methods along with some module control commands (which shall be explained later) are used to control the communications module interface and in turn the system application.

5.) Ladder Logic Programming:

System Review: The system example consists of three drives that we want to control. Up to this point we have defined the Prosoft modules messaging list to access the VFD's control word's and frequency reference's for each drive, along with monitoring the VFD's status word's and output frequencies for each drive as such:

Modbus Data Array:

Word 1: Drive 1 (192.168.1.100) – Drive Status
Word 2: Drive 1 (192.168.1.100) – Output Frequency
Word 3: Drive 2 (192.168.1.101) – Drive Status
Word 4: Drive 2 (192.168.1.101) – Output Frequency
Word 5: Drive 3 (192.168.1.102) – Drive Status
Word 6: Drive 3 (192.168.1.102) – Output Frequency
-
-
-
Word 100: Drive 1(192.168.1.100) – Drive Control
Word 101: Drive 1(192.168.1.100) – Frequency Reference
Word 102: Drive 2(192.168.1.101) – Drive Control
Word 103: Drive 2(192.168.1.101) – Frequency Reference
Word 104: Drive 3(192.168.1.102) – Drive Control
Word 105: Drive 3(192.168.1.102) – Frequency Reference

In order for the PLC to use and operate correctly on the drive interface data, the data must be read and written to the Prosoft module, to allow control and monitoring access for the PLC application logic to control the drives. Therefore, the following ladder logic is implemented which handles these functions along with various other logic examples such as “command messaging” to allow event control of Modbus TCP messaging . These details will also be covered in the following description of ladder logic programming required for the Prosoft modules operation.

Main Program Ladder: The ladder program consists of a main program, calling a main subroutine to read and write data to the Prosoft ethernet module and handle the commanded requests from the application. The following ladder example is based on application ladder from Prosoft Technology, Inc. and calls one subroutine to enable data transfer, “to and from” the Prosoft ethernet interface module. Please refer to the following figure 4.

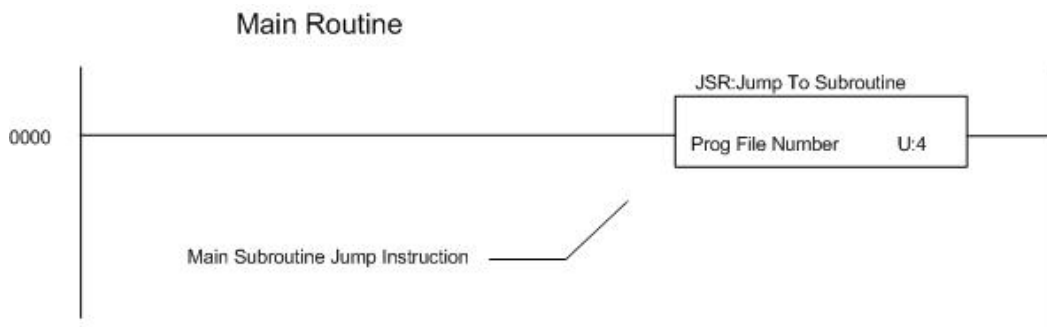


Figure 4: Main Program

Data Transfer Functions: The following ladder logic is where the main operations take place. It handles the transfer of the defined data to/from the Prosoft Ethernet module data array to the PLC through Block Transfer methods. This data transfer is used for the cyclic message transfer or when the Prosoft Module messages are defined to be sent, on a time driven basis. This mode of operation should be sufficient for most basic control operations of the Yaskawa VFD’s. (i.e. controlling RUN/STOP and drive frequency reference, monitoring the status, and output frequency of the drive). Note: The example PLC program uses the following defined files for use in the program. Please refer to figure 5 and figure 6 for this ladder logic:

PLC File Mapping for Prosoft I/O:

N12: Output Data (Data sent to the Prosoft Ethernet Module)

N11: Input Data (Data received from the Prosoft Ethernet Module)

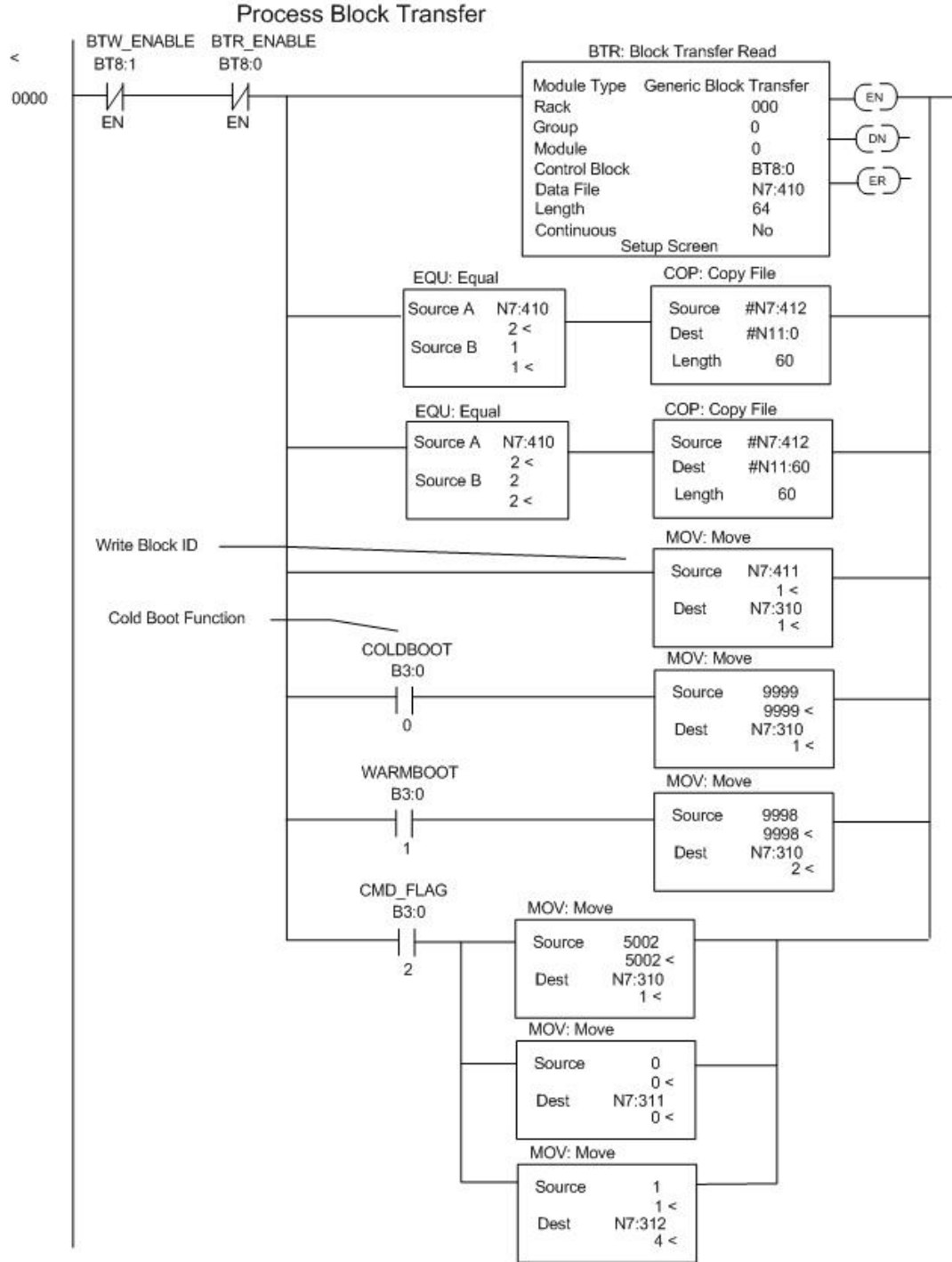


Figure 5: Read Data Transfer Logic

Process Block Transfer Cont.

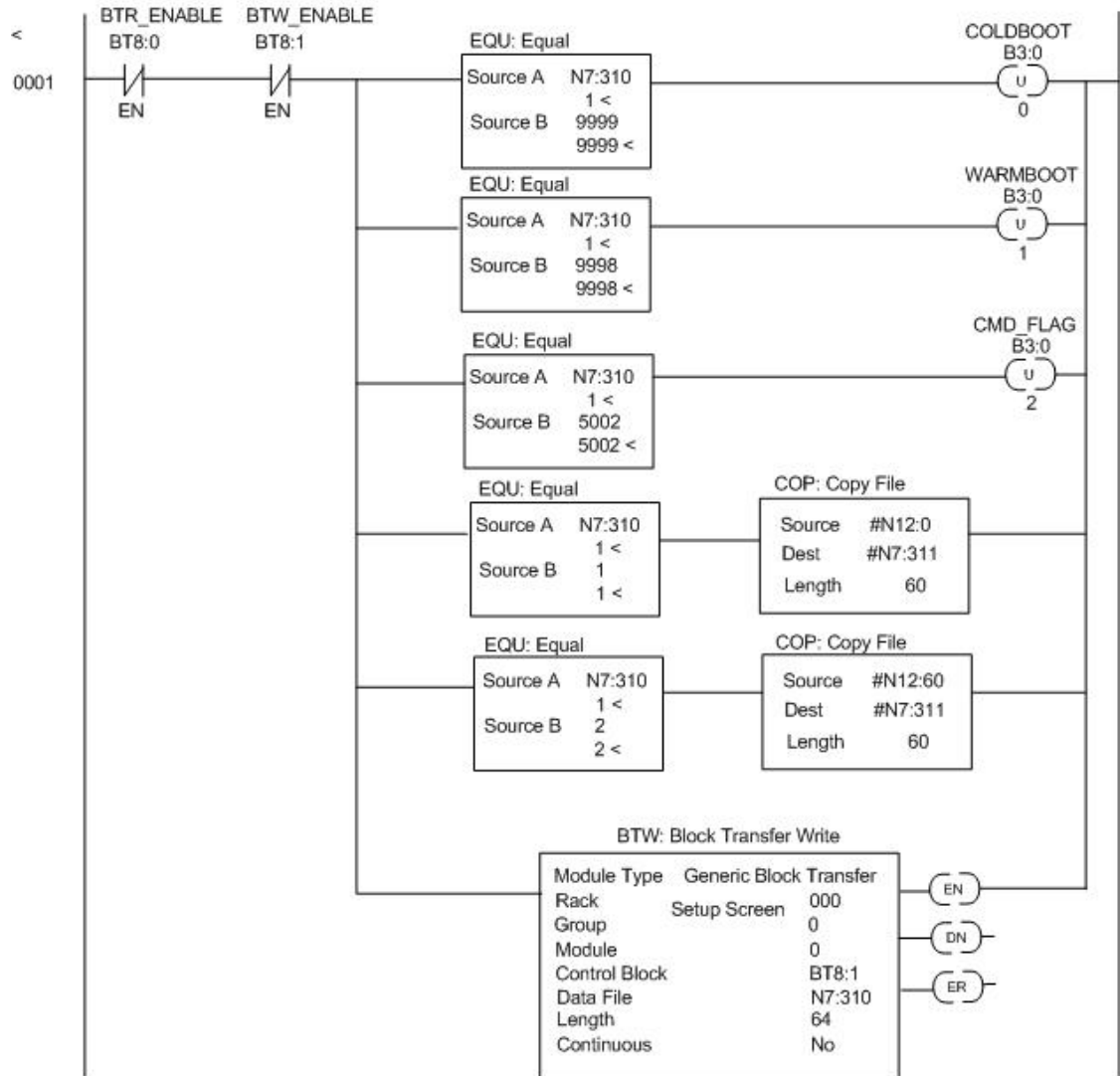


Figure 6: Write Data Transfer Logic

Description: The ladder logic can be seen as two separate sections, a Read Block Transfer (Rung 0000), and a Write Block Transfer Rung (0001). The logic in each is run, when there are no other block transfers occurring. The read section reads up to 120 words of data from the module based on the current read block specified and copies the read data to the N11 file for use in the PLC application ladder. In addition there are several activation contacts (WARMBOOT, COLDBOOT, CMD_FLAG) to perform the module control functions described below. The write block ladder acts in the same fashion, and does not evaluate the rung unless there are no block transfers currently executing. The rung evaluates the reset required for the module control functions and then updates the configured message data from file N12, to the Prosoft module to update the devices on the LAN.

Module Control Functions: The Prosoft module control functions implement the event handling of the specific application messaging and control requirements, which are driven from the application program ladder. These interfaces will be used if there are specific control requirements, such as required messaging triggers, or specific ordered messaging sequences, needed in the system application. Also, control requirements such as restart of the Prosoft module, and output initialization are discussed in the following descriptions.

Module Restart: The previous ladder examples perform a hardware or software reset, in order to re-start or re-initialize the Prosoft interface as required by the control program. These functions perform a reboot of the Prosoft module such that new configuration information becomes active. The restart functions are controlled, by activating the ladder contacts labeled, “WARMBOOT” and “COLDBOOT”.

Command Messaging: The command messaging type of event messages are driven by application program ladder in the example from the “CMD_FLAG” contact. The messages are pre-defined in the module through the device configuration file but not enabled in the message configuration. This allows the selection of up to six messages at one time, out of 100 messages to be queued and sent to the Ethernet network devices. The messages are queued in the module with the previous ladder example to trigger sending the messages, at any point required in the application programming. The ladder example shows 2 messages being queued by the ladder activation. The messages are defined at offset 0 and 1 in the command list.

Event Messaging: Event messaging provides the ability to form any Modbus TCP message, and transfer it to a device on the Modbus TCP network. The ladder logic can drive the message event queue process of the Prosoft module by the activation in the PLC ladder program using the ‘2000’ command code sent to the prosoft module.

The message data is placed in the PLC at the ladder defined source and then queued in the module by activation of the logic. Note, the response data is validated and processed based on the requirements of the system application’s definition of the following software structure.

The block data transferred should be in the following form:

Word 1: Command	- Command for Event Transfer
Word 2: IP address #1:	- 1st IP Octet
Word 3: IP address #2:	- 2 nd IP Octet
Word 4: IP address #3:	- 3 rd IP Octet
Word 5: IP address #4:	- 4 th IP Octet
Word 6: Service Port:	- Modbus TCP Port #
Word 7: Slave Address:	- Modbus Node Address
Word 8: DB address:	- Prosoft Module Database Offset
Word 9: Point Count:	- # of registers associated with the command
Word 10: Swap Code:	- Swap Code is 0, for Yaskawa VFD's.
Word 11: Modbus Func:	- The modbus function code for the command

The process result of the command is then determined by reading the status of the return block placed at offset 0 in the Prosoft module block. If the value read is '0' the command was processed. Also, block offset 2, indicates the success or failure of the message event and should also be verified before using the returned data. If a '1' is present the message was queued successfully, if a '0' is present the event process could not queue the message.

Error/Status Information: In addition, there is module "status" data included in the module transfers, which includes the following data. The data may or may not be required in the application programming, but is still supplied as part of the features for the module interface regardless of the requirement. Typically this data is used for scanner module monitoring and checks of system operation and is transferred during the Read Block Transfers to the programmed PLC area.

Program Scan Count	Offset 0
Product Code	Offset 1-2
Version	Offset 3-4
Operating System Number	Offset 5-6
Run Number	Offset 7-8
Read Block Count	Offset 9
Write Block Count	Offset 10
Parse Block Count	Offset 11
Command Event Block Count	Offset 12
Command Block Count	Offset 13
Error Block Count	Offset 14
MBApp Request Count	Offset 38
MBApp Response Count	Offset 39

Initialization of Prosoft Module Data: To assure correct and controlled start-up of systems and related equipment, control data must sometimes be initialized to a known state before the operation of the system may start. In the case of this application example, it is accomplished by initializing the data to the Prosoft module output values communicating to the network devices and running the first pass messages to update the network devices. This function is enabled by setting the: Initialize Output Data to 'Yes' in the configuration file. During start-up the PLC shall initialize Block transfers with the output codes of 1000-1083 and write the data to the appropriate Block Transfer data area to initialize the modules output data. Please refer to the Prosoft user manual for further information regarding this feature.

6.) Command Errors Status:

The command error code list below represents the error status of each of the defined commands in the message list. The error data is located in the modules database array, which is defined in the [MNet Client 0] section of the mnet.cfg file as such:

Command Error Pointer : XXXX #Database offset for client command error list

Note: XXXX indicates the correct database offset address where the error data starts. Each location starting from this offset indicates the status of the message command list entry (0-100). Please refer to the following table for the listed error codes, such that appropriate action can take place in the ladder program application code if necessary, for control responses, due to equipment failure, malfunction or error. Further information on the description of these error codes may be found in the Prosoft Modules user manual.

Command Error Code List:

<i>Standard Errors</i>	
Code '1' :	Illegal Function
Code '2' :	Illegal Address
Code '3' :	Illegal Data Value
Code '4' :	Failed Device
Code '5' :	Acknowledge
Code '6' :	Device Busy
<i>Module Communication Errors</i>	
Code '-1' :	CTS not set before Tx
Code '-2' :	Timeout while msg Tx
Code '-11' :	Response Timeout
Code '253' :	Incorrect Slave addr response
Code '254' :	Incorrect Function code in response
Code '255' :	Invalid CRC
<i>Module Communication Errors</i>	
Code '-41' :	Invalid Enable Code
Code '-42' :	Invalid Internal Address
Code '-43' :	Invalid Node Address
Code '-44' :	Count is '0'
Code '-45' :	Invalid Function Code
Code '-46' :	Invalid Swap Code
<i>Client Driver Errors</i>	
Code '-33' :	Failed server connection
Code '-36' :	Command response timeout
Code '-37' :	Session ended before response completed

7.) Email Error Configuration:

The last feature of the Prosoft Ethernet module discussed in this example system allows the configuration of the module to send an email if for some reason the drive faulted, or statistics are required to be monitored, etc. The email capability is configured in the [EMAIL] section of the “mnet.cfg” file as such:

```
[E-MAIL]
# DB Trigger Mail TO
# Reg Value Server IP Name E-Mail File Name
START
# 100 X 192.168.1.61 support@yaskawa.com stat
# 100 X 192.168.1.61 support@yaskawa.com errlist
END
```

This feature can be used to log failure data and notify the responsible associates in case of a machine shutdown or maintenance situation that should be addressed. The information configured looks at the defined database register, for the specific trigger value used. Upon a match the module sends the email file to the configured email account and server utilizing pre-configured email formats.

System Example Results:

Finally as a result, and by implementing the system as described above the three Yaskawa VFD’s can be basically accessed in the PLC by the following mapping:

“Definition of PLC 5 to VFD access points:”

N12:1 = Drive 1 Control Status
N12:2 = Drive 1 Frequency Reference
N12:3 = Drive 2 Control Status
N12:4 = Drive 2 Frequency Reference
N12:5 = Drive 3 Control Status
N12:6 = Drive 3 Frequency Reference

N11:0 = Drive 1 Run/Stop Control
N11:1 = Drive 1 Frequency Reference Command
N11:2 = Drive 2 Run/Stop Control
N11:3 = Drive 2 Frequency Reference Command
N11:4 = Drive 3 Run/Stop Control
N11:5 = Drive 3 Frequency Reference Command

Conclusion:

The previous information gave an example of developing a basic Modbus/TCP Ethernet control system utilizing the Allen Bradley PLC 5, a Prosoft MVI71-MNET Ethernet interface and three Yaskawa Variable Frequency Drives with CM090 MB/TCP Ethernet Interface options. Also, the information should have given the starting point to allow continuation in development of the programming requirements for a specific application or control system user requirements that is necessary for implementing most systems. Definitions of the methods for accessing data from the Yaskawa Variable Frequency Drives that are networked through the Allen Bradley PLC 5 controllers were discussed and examples were described. If there are questions regarding this information, please feel free to contact Yaskawa Electric America at 1-800-YASKAWA.

For information regarding Yaskawa's, Prosoft Tested and certified communication solutions, please refer to the following www link:

<http://www.verlinx.com/content/view/full/6617>

Todd Wiese
Sr. Development Engineer
Yaskawa Electric America
8/2004