Application Note 005
Version 004
07 Jan 2015

Network Control of an Allen Bradley PowerFlex 400 VFD

The concept of interacting with a VFD by using an Industrial Networking Protocol – such as Modbus or EtherNet/IP – is vastly superior to legacy methods that use discrete I/O wired to the terminal block. Why? Because there is so much more information available to the Control System when communicating directly with the VFD's microprocessor.

Network-available feedback tags include Speed (Hz), Power (HP, KW), Energy (MWH), Current (A), Voltage (V), Temperature (^{o}), and Fault Information. Furthermore, the network wiring is arguably simpler than discrete signal wiring – since it only relies upon a single twisted pair or Ethernet cable. On the other hand, extra know-how is required to collect and process the extra information. Therefore, in order to clarify and simplify the theory and practice of controlling and monitoring a VFD across a network, Navionics Research has developed a library of Application Notes, each designed to address networking techniques specific to a particular manufacturer. Notes are currently available for Allen Bradley (Modbus), ABB (Modbus), Eaton (Modbus), and Toshiba (Toshiba Proprietary Protocol). Others may be forthcoming.

Allen Bradley PowerFlex 400

This document was created to address the specifics of the Allen Bradley PowerFlex 400 VFD using the Modbus/RTU protocol over RS-485, which is included standard on all models within the PowerFlex family. For brevity, we will refer to this drive as the "PF400".

First, the following documents should be available for reference:

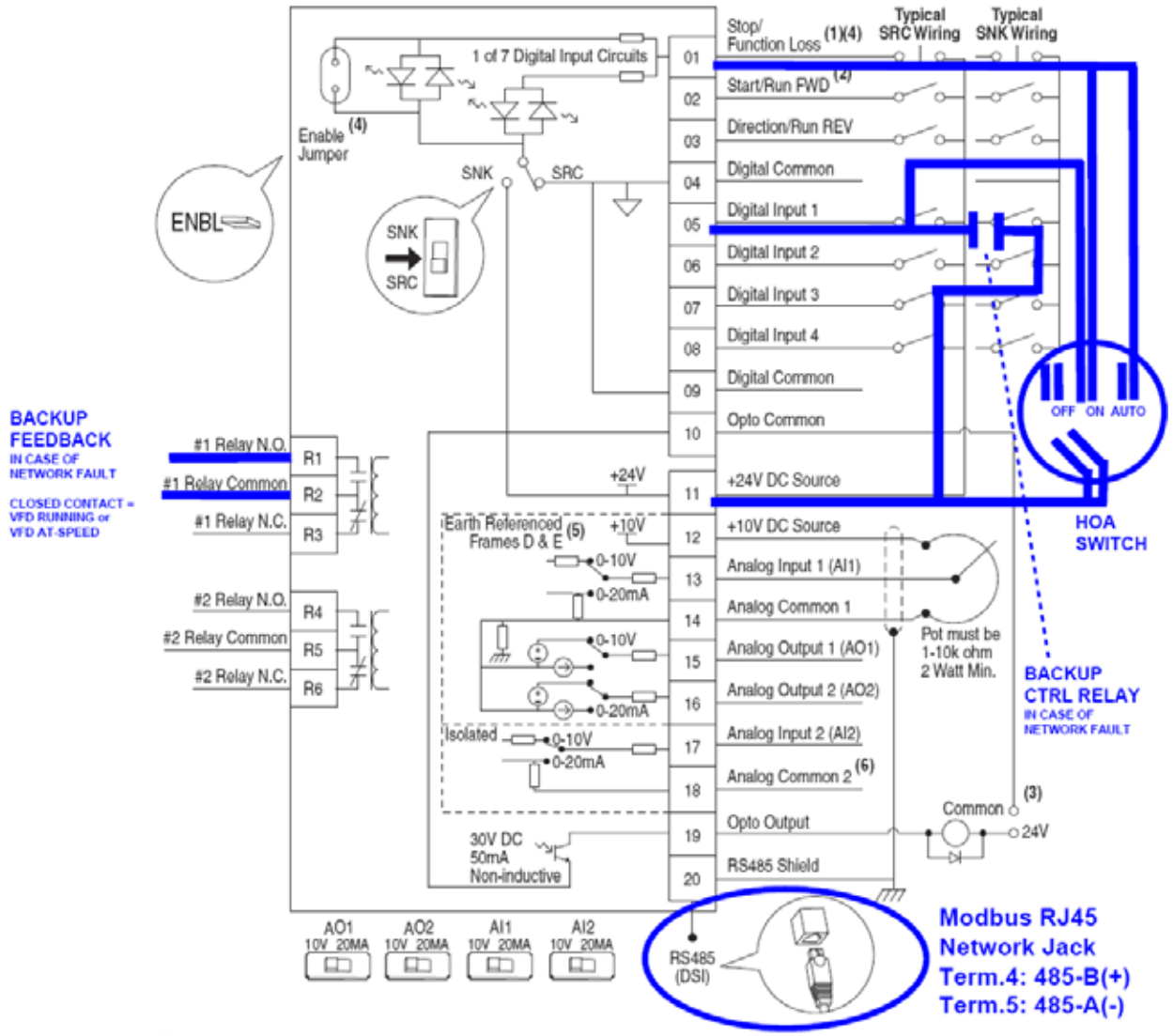
PowerFlex 400 Tech Data
PowerFlex 400 AC Drive User Manual FRN 1.xx-7.xx
PowerFlex 400 AC Drive Quick Start – FRN 1-4.xx

Signal Wiring

The VFD should be wired for Modbus/RTU Control/Monitoring. Note that the PF400's RS-485 terminals are labeled in accordance with the most predominant North American Standard: 'A' is '-', and 'B' is '+'.

In addition to the Modbus/RS-485 terminals, wiring is provided for backup discrete controls in case of communication bus failure: A single dry contact input is to provide a run signal to VFD Digital Input #1, and a 24V output signal via VFD Internal Relay #1 is to denote that the drive is at-speed.

Figure 1.10 Control Wiring Block Diagram



Keypad: Basic Configuration

The VFD should be configured using the Wizard Setup Screens with the Motor Nameplate Values.

P031	Motor NP Volts	Motor Nameplate Rated Volts	_____
P032	Motor NP Hertz	Motor Nameplate Rated Frequency	_____
P033	Motor OL Current	Maximum Allowable Motor Current	_____
P034	Minimum Frequency	Motor/Pump Min Frequency, Hz	_____
P035	Maximum Frequency	Motor/Pump Max Frequency, Hz	_____

Keypad: Communication & Terminal Block Configuration

Once the VFD is set up with the desired comm port parameters and device address, much of the configuration may be performed by the connected Master PLC. The following comm port parameters should be initially configured:

C102	RTU 8-N-1	000	Comm Port Protocol
C103	9600	003	Comm Port Baud Rate
C104	101	101	Modbus address – Set per user needs: 101 , 102 , 103 , _____
C105	FAULT	000	Action on Loss-of-Comm
C106	60.0 SEC	60.0	Loss-of-Comm Timeout (sec)
C107	RAM-ONLY	001	Modbus Parameters Changes Permanent or Ram-Only?
P037	RAMP/CF	000	Stop Mode (Ramp/Clear Fault) – Set per user needs.
P039	60.00	60.00	Accel Time
P040	60.00	60.00	Decel Time
T051	PURGE	001	Dig In 1 Select
T052	PURGE	001	Dig In 1 Select
T055	AT-FREQ	001	Relay 1 Out Select, Set per user needs.
…or…			
T055	RUNNING	002	Relay 1 Out Select, Set per user needs.
A141	60.0	600	Purge Speed – Set per user needs
A165	YES	001	Allow Start At Power-Up
A168	2.0 KHz	020	Pulse Width Modulation Frequency

Modbus Controlled VFD Parameters:

The remaining parameters are controlled by the Master PLC. And since C107 above is set to RAM-ONLY, all parameter changes made by the Master PLC are discarded upon reboot of the PF400. This fact is utilized to allow for two distinct operational control modes.

These parameters should be written to the VFD at PLC boot-up… and at regular intervals, in order to account for a VFD shutdown/restart:

P036	COMM PORT	005	Start Source
P038	COMM PORT	005	Speed Reference
P039	10.00	10.00	Accel Time (shortened, PLC handles accel)
P040	10.00	10.00	Decel Time (shortened, PLC handles decel)

Modbus Registers for PF400 Monitoring:

Master PLC <u>READS</u> These Words:

0001 OUTPUT_FREQUENCY (HZx100)
0002 COMMANDED_FREQUENCY (HZx100)
0003 OUTPUT_CURRENT (AMPSx10)
0004 OUTPUT_VOLTAGE (VOLTS)
0005 DC_BUS_VOLTAGE (VOLTS)
0006 DRIVE_BASIC_STATUS_BITS
0007 MOST_RECENT_FAULT_CODE
0008-9 PROCESS_DISPLAY (32 BIT)
0010 OUTPUT_POWER(KWx10)
0011 ELAPSED_MWH (MWHx10)
0012 ELAPSED_RUNTIME (HRS/10)
0013 TORQUE_CURRENT (AMPSx10)
0014 DRIVE_TEMP (DEG C)
0015 ELAPSED_KWH (KWHx10)

8448 DRIVE_DETAILED_STATUS_BITS

0 1 = Ready, 0 = Not Ready
1 1 = Active (Running), 0 = Not Active
2 1 = Cmd Forward, 0 = Cmd Reverse
3 1 = Rotating Forward, 0 = Rotating Reverse
4 1 = Accelerating, 0 = Not Accelerating
5 1 = Decelerating, 0 = Not Decelerating
6 1 = Alarm, 0 = No Alarm
7 1 = Faulted, 0 = Not Faulted
8 1 = At Reference, 0 = Not At Reference
9 1 = Reference Controlled by Comm
10 1 = Operation Cmd Controlled by Comm
11 1 = Parameters have been locked
12 Digital Input 1 Status
13 Digital Input 2 Status
14 Digital Input 3 Status
15 Digital Input 4 Status

Modbus Registers for PF400 Control:

Master PLC <u>WRITES</u> These Words:

8192 CONTROL_WORD

0 1 = Stop, 0 = Not Stop
1 1 = Start, 0 = Not Start
2 1 = Jog, 0 = No Jog
3 1 = Clear Faults, 0 = Not Clear Faults
5,4
- 00 = No Command
- 01 = Forward Command
- 10 = Reverse Command
- 11 = No Command

6 1 = Local Control(1), 0 = Comm Control
7 1 = MOP Increment, 0 = Not Increment
9,8
- 00 = No Command
- 01 = Accel Rate 1 Enable
- 10 = Accel Rate 2 Enable
- 11 = Hold Accel Rate Selected

11,10
- 00 = No Command
- 01 = Decel Rate 1 Enable
- 10 = Decel Rate 2 Enable
- 11 = Hold Decel Rate Selected

14,13,12
- 000 = No Command
- 001 = Freq. Source = P038 [Speed Reference]
- 010 = Freq. Source = A142 [Internal Freq]
- 011 = Freq. Source = Comms (Addr 8193)
- 100 = A143 [Preset Freq 0]
- 101 = A144 [Preset Freq 1]
- 110 = A145 [Preset Freq 2]
- 111 = A146 [Preset Freq 3]

15 1 = MOP Decrement, 0 = Not Decrement

8193 SPEED_WORD
(Hz x 100)

The CONTROL_WORD should be written as:

12,289	(1+4096+8192)	0b0011000000000001	STOP DRIVE
12,306	(2+16+4096+8192)	0b0011000000010010	RUN DRIVE
16	(16)	0b0000000000001000	RESET FAULTS

Backup/Alternative VFD Control Via Terminal Block

How should the system be configured to handle a Modbus communication failure? First and foremost, the VFD should be configured to shut down if it stops receiving commands from the Master PLC. A 60 second timeout should be sufficient for this purpose. When the VFD stops due to comm loss, it will show a Fault Code 81.

After a Modbus communication fault is detected, NRI's standard backup control method consists of parallel, discrete (ON/OFF) control circuitry. The activation of this circuitry requires the operator to perform the following steps:

1. REBOOT THE VFD (CLEARS ALL RAM-ONLY SETTINGS)
2. CLEAR THE VFD FAULT AT THE KEYPAD
3. MAKE SURE THE VFD IS IN "AUTO" MODE (ALLOWS REMOTE CONTROL).
4. ACTIVATE MASTER PLC SETPOINT: DISCRETE_VFD_CONTROL = YES/TRUE

The parallel, discrete control circuitry consists of two pairs of low-voltage wires: One for control of the drive, and one for feedback/monitoring. Through pair 1, a single dry contact will provide the run signal to the drive to run at the user-defined "PURGE" speed. Through pair 2, a single contact output will provide RUN feedback to the Master PLC: When the PF400 is "At Desired Frequency", a 24VDC signal will be transmitted. Until the Modbus communication link is re-established/repaired, this method allows for the VFD to run in ON/OFF mode at a preset speed with controlled ramp-up and ramp-down times. Note that the VFD's will run only at a pre-determined speed – No speed throttling will occur in this mode.

Detailed VFD Monitoring

Now that network communication to the PF400 has been achieved, the PLC programmer now has READ access to valuable VFD internal information.

Available DISCRETE tags for reading include (not a complete list):

VFD_READY
VFD_ACTIVE (RUNNING)
VFD_COMMAND_FORWARD/REVERSE
VFD_ROTATING_FORWARD/REVERSE
VFD_ACCELERATING
VFD_DECELERATING
VFD_ALARM
VFD_FAULTED
VFD_AT_REFERENCE_SPEED

Available ANALOG tags for reading include (not a complete list):

VFD_OUTPUT_SPEED
VFD_OUTPUT_AMPS
VFD_OUTPUT_VOLTS
VFD_DC_BUS_VOLTS
VFD_OUTPUT_POWER_KW
VFD_ENERGY_KWH
VFD_TEMPERATURE
VFD_ACTIVE_FAULT_CODE

Feedback Control Strategies

In a Water Utility, the VFD will typically be installed to control the speed of a pump motor. Available telemetry data may include pump discharge pressure, pump suction pressure, pump rate-of-flow, in addition to the data available from the drive itself. This extra data, when combined with the VFD control algorithm, may be used to implement closed-loop feedback control strategies. For example, an upper limit may be placed on the pump discharge pressure – or a lower limit on the pump suction pressure – or both. Other possibilities are to implement an upper limit on the rate-of-flow, or an upper limit on the power consumption. In any of these cases, the speed of the VFD will be throttled up or down in order to maintain the pressures and/or flow and/or power consumption within the desired envelope.

Cavitation Traps

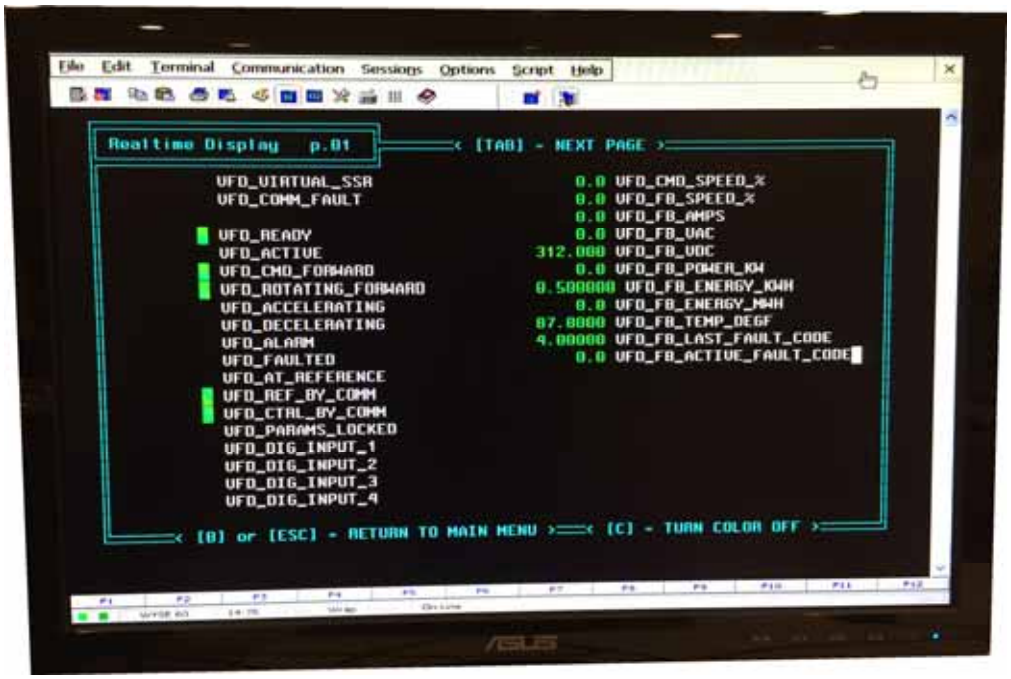
Ideally, pump "no flow" conditions are detected by monitoring a flow meter. In situations where a flow meter is not available, and because the PF400 provides realtime power consumption of the pump motor to the Master PLC, it is possible that the PLC can detect and/or alarm cavitation conditions – situations where the pump is not moving water as evidenced by the power consumption of the motor falling below the normal range.

Feedback Control

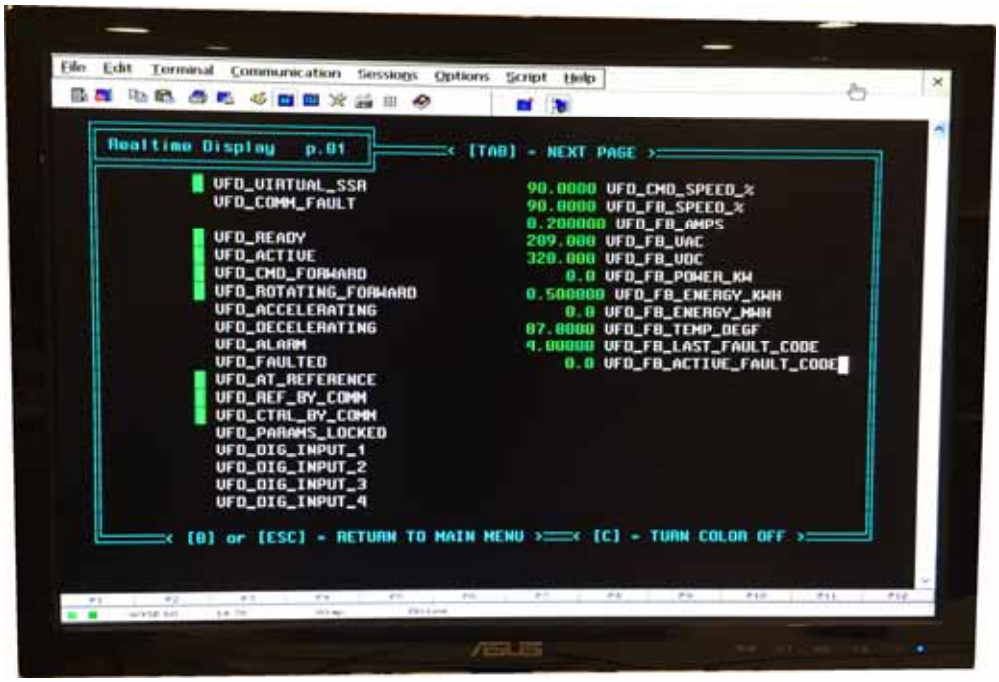
In a Water Utility, the VFD will typically be installed to control the speed of a pump motor. Available telemetry data may include pump discharge pressure, pump suction pressure, and pump rate-of-flow. This extra data, when combined with the VFD, may be used to implement closed-loop feedback control

VFD Reset Via Modbus:

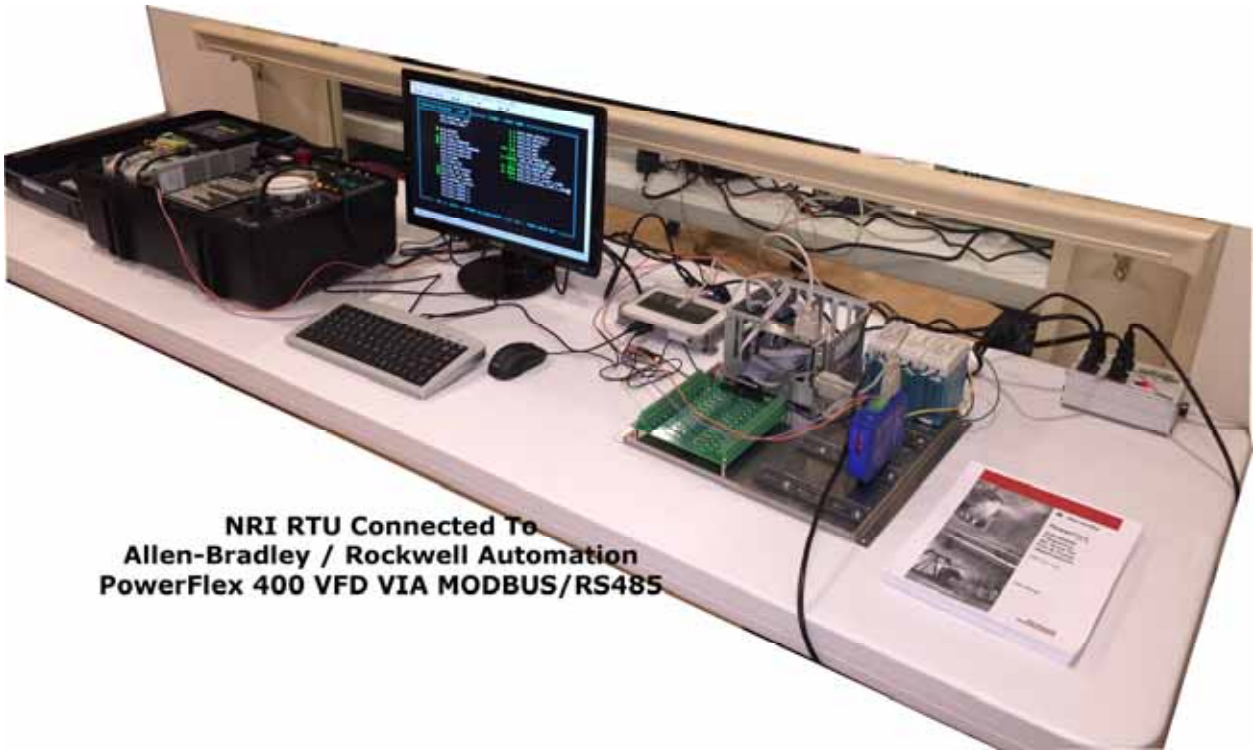
Because the PF400 provides actual VFD fault information to the Master PLC, this information can be alarmed and the operator notified of the problem. The information is transmitted as a decimal fault code, and the Operator may refer to this document (or the Allen Bradley PF400 User Manual) to decode the fault. After decoding the fault, the Operator may reset the fault remotely using a provided "one-shot" pushbutton setting within the Telemetry System.



PF400 VFD Idling: Realtime Display of an NRI RTU Flat-Panel Display



PF400 VFD Running at 90% (54 Hz): Realtime Display of an NRI RTU Flat-Panel Display



PowerFlex 400 Demonstrator
(Courtesy of French Gerleman, St. Louis MO)

PowerFlex 400 Demonstrator With Front Cover Removed
Note the RJ45-Breakout Cable Attached to the PF400 Modbus/RS-485 Port.
(Courtesy of French Gerleman, St. Louis MO)

PowerFlex 400 VFDs Installed In A Duplex 25HP Pump Station: Williamsville, IL.
These VFDs were installed as a replacement/upgrade to existing Soft Starters. Load Reactors were installed within the Circuit Breaker/Soft Starter Panels (Left).

PowerFlex 400 Fault Codes

No.	Fault. Description
2	Auxiliary Input(1). Check remote wiring.
3	Power Loss. Monitor the incoming AC line for low voltage or line power interruption.
4	UnderVoltage(1). Monitor the incoming AC line for low voltage or line power interruption.
5	OverVoltage(1). Monitor the AC line for high line voltage or transient conditions. Bus overvoltage can also be caused by motor regeneration. Extend the decel time or install a dynamic brake chopper.
6	Motor Stalled(1). Increase [Accel Time x] or reduce load so drive output current does not exceed the current set by parameter A089 [Current Limit].
7	Motor Overload(1). An excessive motor load exists. Reduce load so drive output current does not exceed the current set by parameter P033 [Motor OL Current].
8	Heatsink OvrTmp(1). Check for blocked or dirty heat sink fins. Verify that ambient temperature has not exceeded 40°C (104°F) for IP 30/NEMA 1/UL Type 1 installations or 50°C (122°F) for Open type installations. Check fan.
12	HW OverCurrent. Check programming. Check for excess load, improper DC boost setting, DC brake volts set too high or other causes of excess current.
13	Ground Fault. Check the motor and external wiring to the drive output terminals for a grounded condition.
15	Load Loss. Check for load loss (i.e., a broken belt).
29	Analog Input Loss(1). An analog input is configured to fault on signal loss. A signal loss has occurred.
33	Auto Rstrt Tries. Correct the cause of the fault and manually clear.
38	Phase U to Gnd. Check the wiring between the drive and motor. Check motor for grounded phase. Replace F39 Phase V to Gnd drive if fault cannot be cleared.
40	Phase W to Gnd.
41	Phase UV Short. Check the motor and drive output terminal wiring for a shorted condition.
42	Phase UW Short. Replace drive if fault cannot be cleared.
43	Phase VW Short.
48	Params Defaulted. The drive was commanded to write default values to EEPROM. Clear the fault or cycle power to the drive. Program the drive parameters as needed.

No.	Fault. Description
63	SW OverCurrent[1]. Check load requirements and A098 [SW Current Trip] setting.
64	Drive Overload. Reduce load or extend Accel Time.
70	Power Unit. Cycle power. Replace drive if fault cannot be cleared.
71	Net Loss. The communication network has faulted.
81	Comm Loss. If adapter was not intentionally disconnected, check wiring to the port. Replace wiring, port expander, adapters or complete drive as required. Check connection. An adapter was intentionally disconnected. Turn off using C105 [Comm Loss Action].
94	Function Loss. Close input to terminal 01 and re-start the drive.
100	Parameter Checksum. Restore factory defaults.
122	I/O Board Fail. Cycle power. Replace drive if fault cannot be cleared.

[1] Auto-Reset/Run type fault. Configure with parameters A092 and A093.

```
$NCH - ALLEN BRADLEY POWERFLEX 400 TEST, IO.02, ADDR=1, SERNO=1
   2     # Number of Discrete Setpoints
   3     # Number of Analog   Setpoints
   1     # Number of Integer  Setpoints
   0     # Number of Discrete Input Modules
   0     # Number of Analog   Input Modules
   0     # Number of Integer  Input Modules
  18     # Number of Discrete Flag States
  11     # Number of Analog   Flag States
   0     # Number of Integer  Flag States
   0     # Number of Relay    Output Modules
   0     # Number of Analog   Output Modules
# Remote Setup Information ... (No Blank Lines Allowed...)
   0     # Number of Dependent Sites (Dependent Sites Follow)
# Variable Name Definitions ... (Blank Lines Allowed...)

#
# DISPLAY OPTIONS:
# ================
# D1  // ON=GREEN          , OFF=BLANK
# D2  // ON=RED/BLINKING   , OFF=BLANK
# D3  // ON=GREEN          , OFF=RED/BLINKING
# D4  // ON=GREEN/BLINKING , OFF=BLANK
#
# $BLANK - SKIP LINE
# $PAGE  - SKIP TO NEXT PAGE
#
# 'S' PREFIX - SERIAL DISPLAY
#

ALIAS     RESET_ON_REBOOT                    LDS    0
ALIAS     VFD_RESET_1SHOT                    LDS    1
ALIAS     VFD_SPEED_%                        LAS    0
ALIAS     ACCEL_TIME_S                       LAS    1
ALIAS     DECEL_TIME_S                       LAS    2
ALIAS     VFD{ON-OFF}                        LIS    0

SDISPL_D1 VFD_VIRTUAL_SSR                    LDF    0
SDISPL_D2 VFD_COMM_FAULT                     LDF    1
$BLANK
SDISPL_D1 VFD_READY                          LDF    2
SDISPL_D1 VFD_ACTIVE                         LDF    3
SDISPL_D1 VFD_CMD_FORWARD                    LDF    4
SDISPL_D1 VFD_ROTATING_FORWARD               LDF    5
SDISPL_D1 VFD_ACCELERATING                   LDF    6
SDISPL_D1 VFD_DECELERATING                   LDF    7
SDISPL_D1 VFD_ALARM                          LDF    8
SDISPL_D1 VFD_FAULTED                        LDF    9
SDISPL_D1 VFD_AT_REFERENCE                   LDF   10
SDISPL_D1 VFD_REF_BY_COMM                    LDF   11
SDISPL_D1 VFD_CTRL_BY_COMM                   LDF   12
SDISPL_D1 VFD_PARAMS_LOCKED                  LDF   13
SDISPL_D1 VFD_DIG_INPUT_1                    LDF   14
SDISPL_D1 VFD_DIG_INPUT_2                    LDF   15
SDISPL_D1 VFD_DIG_INPUT_3                    LDF   16
SDISPL_D1 VFD_DIG_INPUT_4                    LDF   17
$BLANK

SDISPL_A  VFD_CMD_SPEED_%                    LAF    0
SDISPL_A  VFD_FB_SPEED_%                     LAF    1
SDISPL_A  VFD_FB_AMPS                        LAF    2
```

```
SDISPL_A  VFD_FB_VAC                          LAF    3
SDISPL_A  VFD_FB_VDC                          LAF    4
SDISPL_A  VFD_FB_POWER_KW                     LAF    5
SDISPL_A  VFD_FB_ENERGY_KWH                   LAF    6
SDISPL_A  VFD_FB_ENERGY_MWH                   LAF    7
SDISPL_A  VFD_FB_TEMP_DEGF                    LAF    8
SDISPL_A  VFD_FB_LAST_FAULT_CODE              LAF    9
SDISPL_A  VFD_FB_ACTIVE_FAULT_CODE            LAF   10

# DISCRETE MODBUS WRITE REGISTER(S)...
ALIAS     VFD_CTRL_WORD_MBO                   M_SOU  100  8192
ALIAS     VFD_SPEED_WORD_MBO                  M_SOU  100  8193
ALIAS     VFD_START_SRC_MBO                   M_SOU  100    36
ALIAS     VFD_REF_SRC_MBO                     M_SOU  100    38
ALIAS     VFD_ACCEL_TIME_MBO                  M_SOU  100    39
ALIAS     VFD_DECEL_TIME_MBO                  M_SOU  100    40

# DISCRETE MODBUS READ REGISTER(S)...
ALIAS     VFD_STATUS_WORD_MBI                 M_SIU  100  8448

# TIMERS...

ALIAS     VFD_REFRESH_TIMER                   TMR    0

# USER VARIABLES...

ALIAS     LASTCALL_TIME                       USR    0
ALIAS     DELTA_TIME                          USR    1

# POWERFLEX 400 VFD CONSTANTS...
ALIAS     NET_STOP_USR                        USR    2
ALIAS     NET_START_USR                       USR    3
ALIAS     NET_RESET_USR                       USR    4
ALIAS     NET_FWD_USR                         USR    5
ALIAS     NET_SOURCE_USR                      USR    6
ALIAS     UPTIME_MIN_USR                      USR    7
ALIAS     STATUS_WORD_USR                     USR    8
ALIAS     VFD_CTRL_WORD_USR                   USR    9


$NCL


# NCL Program
#
# Station : Allen Bradley / French Gerleman
#           PowerFlex 400 VFD Demo Station
# Author  : Jim Mimlitz, Navionics Research Inc.
# Date    : 01 Dec 2012
#

# TRANSFER MODULE INPUTS TO FLAG INPUTS ...

      LBL      MAIN


# IF FIRSTRUN, INITIALIZE VARIABLES AND TIMERS ...

      FIRSTRUN?
      IF_FALSE
      GOTO     10

      SYSTIME
      STORE    LASTCALL_TIME
```

```
      POP

# DEFINE POWERFLEX VFD BIT CONSTANTS...

      LOAD     1
      PSTORE   NET_STOP_USR

      LOAD     2
      PSTORE   NET_START_USR

      LOAD     8
      PSTORE   NET_RESET_USR

      LOAD     16
      PSTORE   NET_FWD_USR

      LOAD     4096
      LOAD     8192
      +
      PSTORE   NET_SOURCE_USR

      LOAD     1
      PSTORE   VFD_REFRESH_TIMER
      LOAD     120
      PSDELAY  VFD_REFRESH_TIMER

10    POP


# RESET VFD RIGHT AFTER BOOT UP...

      FIRSTRUN?
      LOAD     RESET_ON_REBOOT
      &
      IF_FALSE
      GOTO     11

      LOAD     0
      LOAD     NET_RESET_USR
      +
      STORE    VFD_CTRL_WORD_MBO
      LOAD     NET_RESET_USR
      -
      PSTORE   VFD_CTRL_WORD_MBO

11    POP


# IF NEW-SETPOINTS OR FIRSTRUN, SANITY CHECK THE SETPOINTS ...

      NEW_SETPOINTS?
      FIRSTRUN?
      |
      IF_FALSE
      GOTO     12
      GOSUB    SANITY_CHECKS
12    POP


# REFRESH VFD CONTROL PARAMETERS INTO VFD RAM
# EVERY 120 SEC, AND AFTER SETPOINT CHANGES.
# (VFD RAM ONLY -- NOT VFD FLASH/EEPROM)...

      LOAD     1
```

```
      PSTORE   VFD_REFRESH_TIMER
      LOAD     VFD_REFRESH_TIMER
      NEW_SETPOINTS?
      |
      IF_FALSE
      GOTO     13

      LOAD     5
      STORE    VFD_START_SRC_MBO
      PSTORE   VFD_REF_SRC_MBO

      LOAD     ACCEL_TIME_S
      LOAD     100
      *
      PSTORE   VFD_ACCEL_TIME_MBO

      LOAD     DECEL_TIME_S
      LOAD     100
      *
      PSTORE   VFD_DECEL_TIME_MBO

      LOAD     0
      PSTORE   VFD_REFRESH_TIMER

13    POP


# TIME CALCULATOR ...

      SYSTIME
      LOAD     LASTCALL_TIME
      -
      PSTORE   DELTA_TIME
      SYSTIME
      PSTORE   LASTCALL_TIME


# SYSTEM UPTIME CALCULATOR ...

      UPTIME
      LOAD     60.0
      /
      PSTORE   UPTIME_MIN_USR


# ASSEMBLE AND WRITE THE VFD CONTROL WORD...

      LOAD     VFD{ON-OFF}
      LOAD     1
      Y=X?
      PSTORE   VFD_VIRTUAL_SSR

      LOAD     NET_STOP_USR
      LOAD     VFD_VIRTUAL_SSR
      !
      *
      LOAD     NET_START_USR
      LOAD     VFD_VIRTUAL_SSR
      *
      +
      LOAD     NET_FWD_USR
      +
      LOAD     NET_SOURCE_USR
      +
```

```
      STORE    VFD_CTRL_WORD_USR
      PSTORE   VFD_CTRL_WORD_MBO

      LOAD     VFD_SPEED_%
      LOAD     VFD_VIRTUAL_SSR
      *
      STORE    VFD_CMD_SPEED_%
      LOAD     60.0
      *
      PSTORE   VFD_SPEED_WORD_MBO


# READ THE VFD DETAILED STATUS WORD, AND DECODE THE BITS...

      LOAD     VFD_STATUS_WORD_MBI
      PSTORE   STATUS_WORD_USR

      LOAD     STATUS_WORD_USR
      BITMASK  0
      PSTORE   VFD_READY

      LOAD     STATUS_WORD_USR
      BITMASK  1
      PSTORE   VFD_ACTIVE

      LOAD     STATUS_WORD_USR
      BITMASK  2
      PSTORE   VFD_CMD_FORWARD

      LOAD     STATUS_WORD_USR
      BITMASK  3
      PSTORE   VFD_ROTATING_FORWARD

      LOAD     STATUS_WORD_USR
      BITMASK  4
      PSTORE   VFD_ACCELERATING

      LOAD     STATUS_WORD_USR
      BITMASK  5
      PSTORE   VFD_DECELERATING

      LOAD     STATUS_WORD_USR
      BITMASK  6
      PSTORE   VFD_ALARM

      LOAD     STATUS_WORD_USR
      BITMASK  7
      PSTORE   VFD_FAULTED

      LOAD     STATUS_WORD_USR
      BITMASK  8
      PSTORE   VFD_AT_REFERENCE

      LOAD     STATUS_WORD_USR
      BITMASK  9
      PSTORE   VFD_REF_BY_COMM

      LOAD     STATUS_WORD_USR
      BITMASK  10
      PSTORE   VFD_CTRL_BY_COMM

      LOAD     STATUS_WORD_USR
      BITMASK  11
      PSTORE   VFD_PARAMS_LOCKED
```

```
      LOAD     STATUS_WORD_USR
      BITMASK  12
      PSTORE   VFD_DIG_INPUT_1

      LOAD     STATUS_WORD_USR
      BITMASK  13
      PSTORE   VFD_DIG_INPUT_2

      LOAD     STATUS_WORD_USR
      BITMASK  14
      PSTORE   VFD_DIG_INPUT_3

      LOAD     STATUS_WORD_USR
      BITMASK  15
      PSTORE   VFD_DIG_INPUT_4


#
# MODBUS BLOCK TRANSFER
# READ A BLOCK FROM THE VFD...
# LOADM <DEVICE ID> <INDEX-40001> <N_REGISTERS_TO_READ>
# VFD DEVICE ID = 100
# READ 16 REGISTERS, STARTING AT ZERO
#
      LOADM       100  0  16

      CAST_UINT   1
      LOAD        60
      /
      PSTORE      VFD_FB_SPEED_%

      CAST_UINT   3
      LOAD        0.1
      *
      PSTORE      VFD_FB_AMPS

      CAST_UINT   4
      PSTORE      VFD_FB_VAC

      CAST_UINT   5
      PSTORE      VFD_FB_VDC

      CAST_UINT   7
      STORE       VFD_FB_LAST_FAULT_CODE
      LOAD        VFD_FAULTED
      *
      PSTORE      VFD_FB_ACTIVE_FAULT_CODE

      CAST_UINT   10
      LOAD        0.1
      *
      PSTORE      VFD_FB_POWER_KW

      CAST_UINT   11
      LOAD        0.1
      *
      PSTORE      VFD_FB_ENERGY_MWH

      CAST_UINT   15
      LOAD        0.1
      *
      PSTORE      VFD_FB_ENERGY_KWH
```

```
      CAST_UINT   14
      LOAD        1.8
      *
      LOAD        32.0
      +
      PSTORE      VFD_FB_TEMP_DEGF

      MA_VLD
      !
      PSTORE      VFD_COMM_FAULT


# RESET THE VFD USING A SOFTWARE ONE-SHOT, IF REQUESTED...

      NEW_SETPOINTS?
      LOAD     VFD_RESET_1SHOT
      &
      IF_FALSE
      GOTO     998

      LOAD     0
      LOAD     NET_RESET_USR
      +
      STORE    VFD_CTRL_WORD_MBO
      LOAD     NET_RESET_USR
      -
      PSTORE   VFD_CTRL_WORD_MBO

998   POP
      LOAD     0
      STORE    VFD_RESET_1SHOT
      POP

      END


# ========================================
#
# ADDITIONAL SUBROUTINES...
#
# ========================================

      LBL      SANITY_CHECKS

      LOAD     2.0
      LOAD     1.0
      LOAD     VFD{ON-OFF}
      MAX
      MIN
      PSTORE   VFD{ON-OFF}

      RTN
```