Application Note 007
Version 001
23 Dec 2015

Network Control of a Toshiba VFD

The concept of interacting with a VFD by using an Industrial Networking Protocol 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), 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 (Proprietary Toshiba Inverter Protocol). Others may be forthcoming.

Toshiba VFD

This document was created to address the specifics of the Toshiba VFD family and the proprietary Toshiba Inverter Protocol (TIP). TIP, which is transmitted over an integral RS-485 port in the VFD, is included standard on most Toshiba models. It is important to emphasize that TIP is proprietary, and it does not resemble any other standard protocol, such as Modbus, DF1, or EtherNet/IP. However, the Navionics Research RTU offers support for TIP – and it is perhaps the only RTU/PLC known to natively do so. It has been NRI's experience that not all Toshiba VFD's offer identical TIP support. However, NRI has determined a subset of TIP commands that work across most of the Toshiba VFD model lines.

First, the following documents should be available for reference:

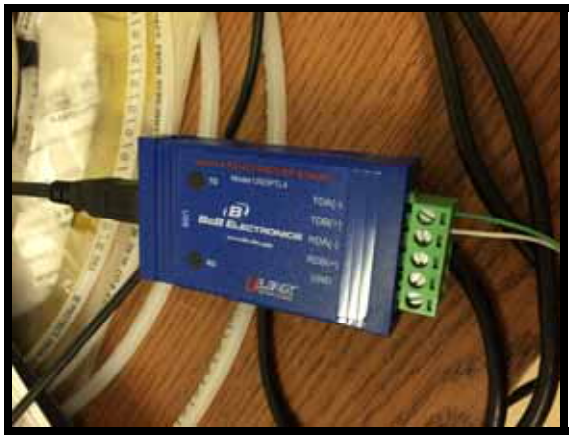
Toshiba Q9 Manual with NRI Notes
Toshiba P9 Manual
Toshiba H9 Manual
Toshiba TIP Protocol Manual

Signal Wiring

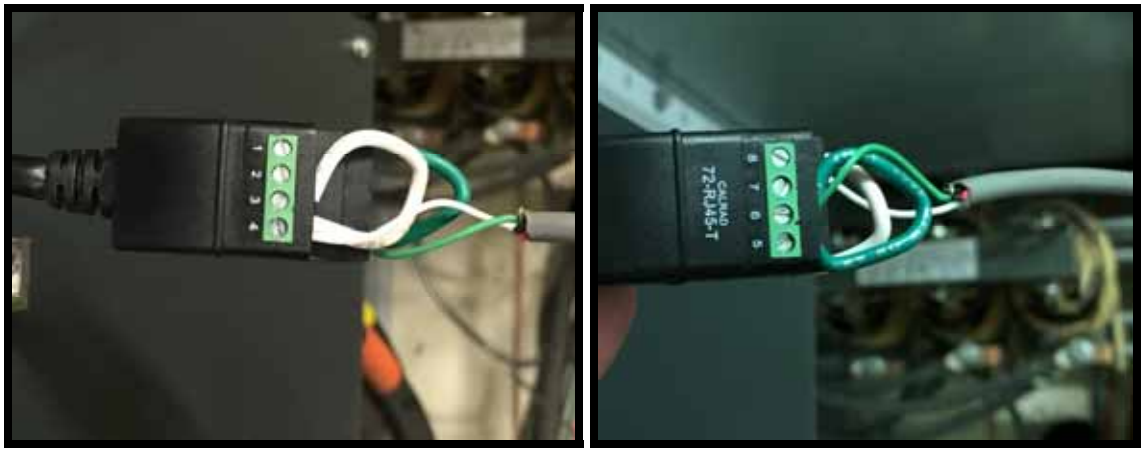
The VFD should be wired for TIP/RS-485 Control/Monitoring. Note that the Toshiba RS-485 terminals are not labeled consistently and in accordance with the most predominant North American Standard. The standard is: 'A' is '-', and 'B' is '+'. However, the Toshiba VFD wiring is occasionally wired where: 'A' is '+', and 'B' is '-'.

RJ45.TERM.3,4 is RS485B(+).
RJ45.TERM.5,6 is RS485A(–).

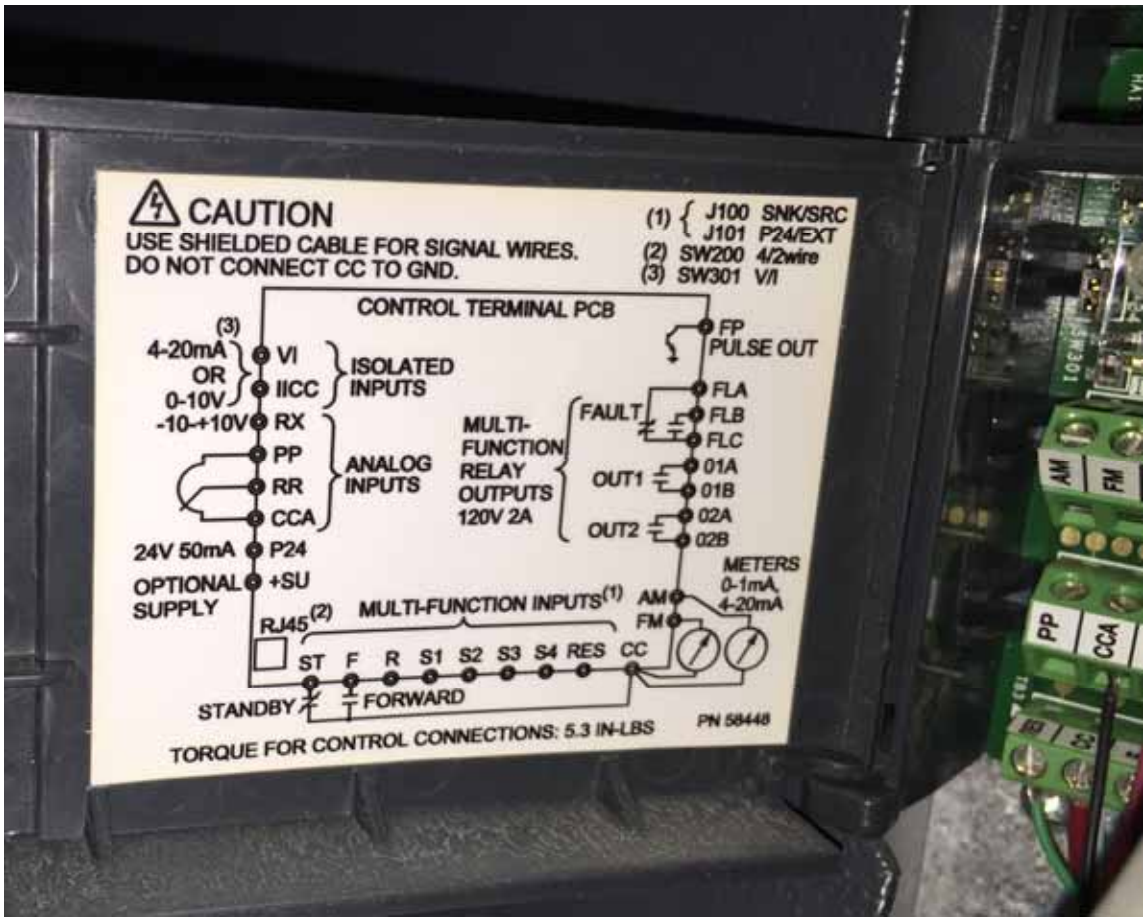
In addition to the TIP/RS-485 terminals, wiring is provided for backup discrete controls in case of communication bus failure: A single dry contact input is to provide a run signal to VFD Digital Input #1, and a 24V output signal via VFD Internal Relay #1 is to denote that the drive is at-speed.



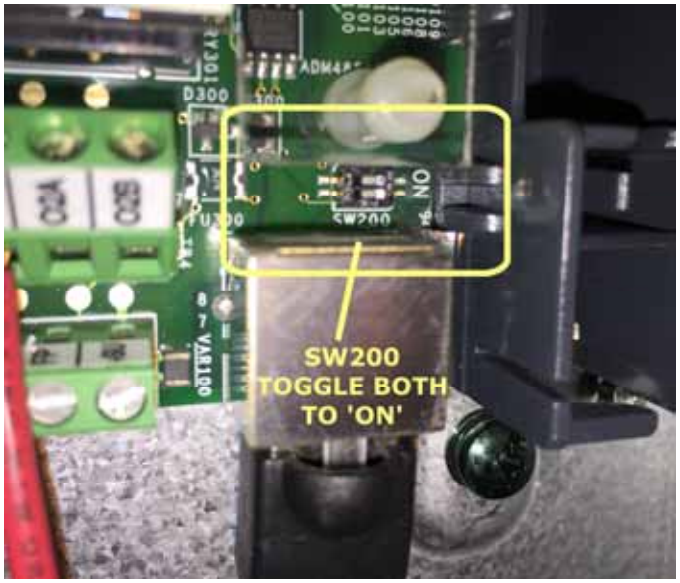
VFD/RS-485 Wiring with a USB-RS485 Converter.

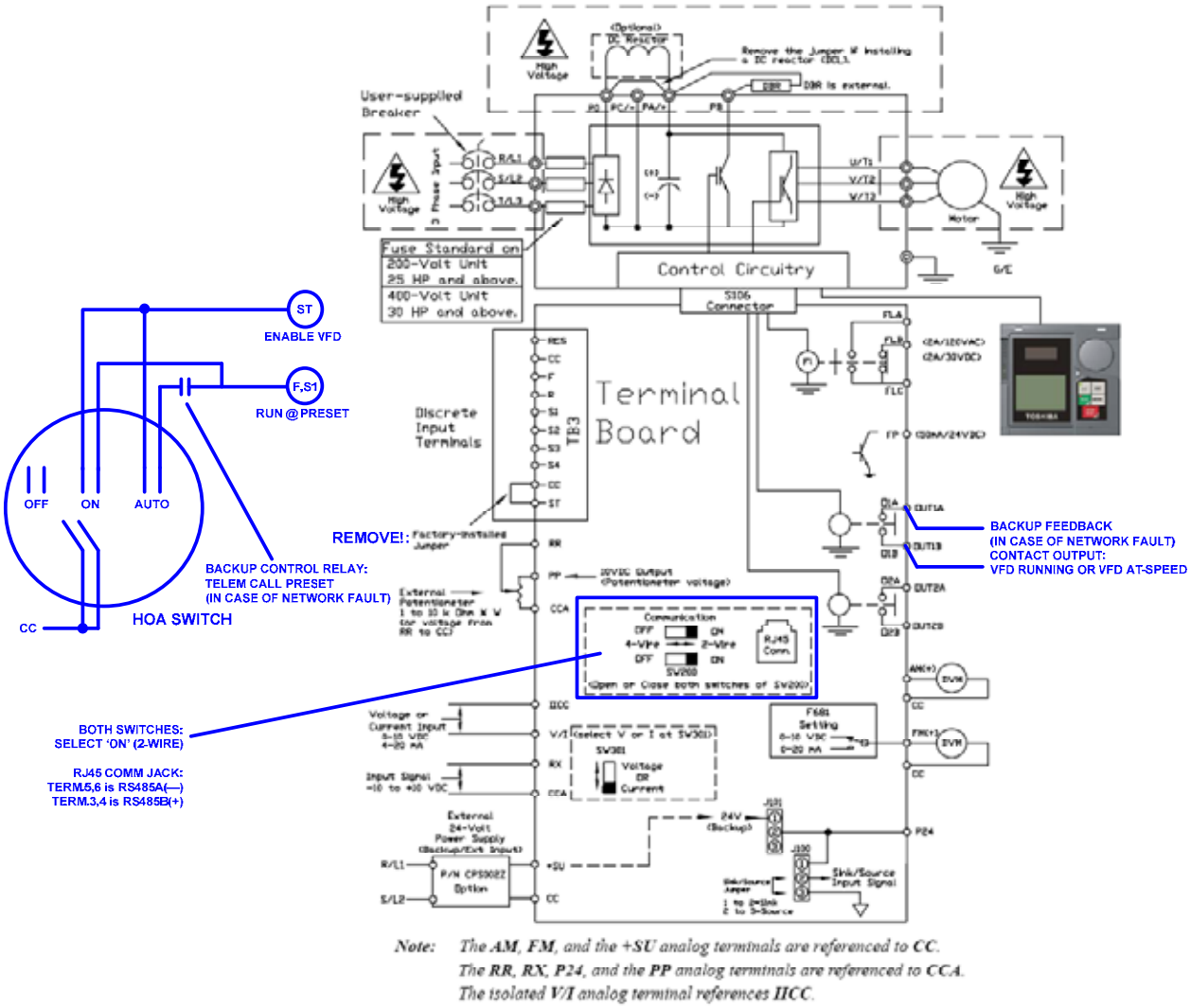


Correct VFD/RS-485 Wiring at the VFD RJ45 Interface Port.



Typical Toshiba VFD Wiring Diagram on VFD Access Panel Door.



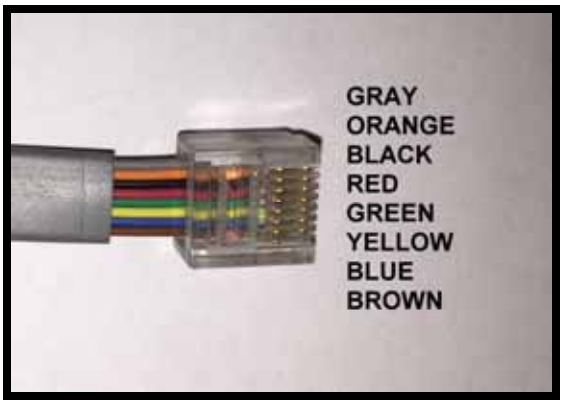


*Note: The **AM**, **FM**, and the **+SU** analog terminals are referenced to **CC**. The **RR**, **RX**, **P24**, and the **PP** analog terminals are referenced to **CCA**. The isolated **V/I** analog terminal references **IICC**.*

Example Wiring Diagram for Toshiba P9 VFD.
Wiring For Other Drives Should Be Similar.

Software-Based or Keypad Basic Configuration

The VFD should be configured using the Toshiba ASD Pro Software, or using the keypad Wizard Setup Screens with the Motor Nameplate Values. If using the ASD Pro Software, the Toshiba programming cable should be used (P/N ASD-CAB-USB).



Toshiba ASD-CAB-USB Programming Cable.

If using the keypad, begin by repeatedly Press [MODE] key until the LCD display shows "PROG SEARCH". (On some VFD's, you must then press [ESC].) Then turn the SELECTOR KNOB to get to "PROGRAM DIRECT ACCESS". Then Press the SELECTOR KNOB. Now, you have access to all user-modifiable parameters. Please note that, after programming is complete, the VFD should be power-cycled to ensure that all new settings are activated.

Note!: It is good practice to document all non-factory settings that are programmed into an installed VFD so that a replacement can be installed in the future using identical settings.

F014	Base Frequency 1 (Nameplate Rated Frequency)	(Nameplate Frequency)
F409	Base Voltage 1 (Nameplate Rated Volts)	(Nameplate Volts)
F600	Electronic Thermal Protect (Often 100%) = Nameplate Rated Amps / VFD Rated Amps x 100%	_____
F405	Motor Rated Capacity KW (Note: 0.746KW per HP)	(Nameplate KW)
F406	Motor Rated Current/Amps	(Nameplate Amps)
F407	Motor Rated RPM	(Nameplate RPM)
F003	Command Mode	0 = TERM BLK
F004	Frequency Mode 1	1 = V/I
F009	Acceleration Time	15 SEC (OR OTHER)
F010	Deceleration Time	15 SEC (OR OTHER)
F011	Maximum Output Frequency	90.00 HZ (OR OTHER)
F012	Upper Limit Frequency	90.00 HZ (OR OTHER)
F013	Lower Limit Frequency	0.00 HZ (OR OTHER)
F015	V/F Pattern	1 = VARIABLE TORQUE
F018	Preset Speed 1	(Pump Failover Speed Hz)
F111	F Terminal	2=FWD, NO
F113	ST Terminal	6=STANDBY, NO
F115	S1 Terminal	10=RUN PRESET BIT 0, NO
F116	S2 Terminal	12=RUN PRESET BIT 1, NO
F117	S3 Terminal	14=RUN PRESET BIT 2, NO
F118	S4 Terminal	16=RUN PRESET BIT 3, NO
F130	OUT1 Terminal	156=DAMPER CMD, NO

F201	V/I Reference 1	0.00 %
F202	V/I Frequency 1	0.00 HZ
F203	V/I Reference 2	100.00 %
F204	V/I Frequency 2	60.00 HZ
F300	PWM Carrier Frequency Lower Freq. = Easier On Motor, Harder on Ears	1.0 or 2.0 KHZ
F311	Disable Forward/Reverse Run	1=DISABLE REVERSE RUN
F608	Input Phase Loss For Add-A-Phase Apps, Change to 0=DISABLE TRIP	1=ENABLE TRIP
F701	Units for Voltage/Current	0 = %
F800	2-Wire Baud	0 = 9600
F801	Parity	0 = NONE
F802	ASD Number (1…247, Except 47)	_____

Important Note!

Modbus RTU can deterministically co-exist on the same RS-485 network without conflict, as long as there are no Modbus/RTU devices with Address 47 – as each TIP transmission is begun with starting delimiter 0x2F (Decimal 47).

F803	Time Out Time (RS-485, 2W,4W)	60s
F804	Time Out Action (RS-485 2W,4W)	8 = TRIP/TRIP
F805	Send Wait Time (2W)	0.000s
F810	Communication Reference Selection	1 = RS-485/2-WIRE
F820	4-Wire Baud	0 = 9600
F825	Send Wait Time (4W)	0.000s

TIP Registers for VFD Monitoring:

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

0xFD00 VFD SPEED
0xFC90 ACTIVE TRIP CODE
0xFE10 LAST TRIP CODE
0xFA00 COMMAND STATUS WORD (SEE DETAILED BREAKOUT)
0xFE03 OUTPUT CURRENT (x 0.01%)
0xFE04 INPUT VOLTAGE (x 0.01%)
0xFE05 OUTPUT VOLTAGE (x 0.01%)
0xFE29 INPUT POWER (KW x 0.01)
0xFE30 OUTPUT POWER (KW x 0.01)
0xFE76 INPUT ENERGY (KWH x 0.01)
0xFE77 OUTPUT ENERGY (KWH x 0.01)

COMMAND STATUS WORD	
Bit	**Description**
0	PRESET SPEED BIT 0
1	PRESET SPEED BIT 1
2	PRESET SPEED BIT 2
3	PRESET SPEED BIT 3
4	MOTOR 2 SELECT
5	PI OFF
6	ACCEL PATTERN 2
7	FORCED DC BRAKING
8	JOG RUN
9	REVERSE RUN
10	RUNNING
11	COAST/STOP
12	EMERGENCY STOP
13	RESET
14	FREQUENCY PRIORITY SELECT
15	COMMAND PRIORITY SELECT

TIP Registers for VFD Control:

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

0xFA00 VFD COMMAND WORD
0xFA01 VFD SPEED REQUEST (HZ x 100)

To Run VFD, Write 0xC400 to VFD COMMAND WORD

To Reset VFD, Write 0xE000 to VFD COMMAND WORD
(Make sure that there is an active fault before performing RESET.)

Backup/Alternative VFD Control Via Terminal Block

How should the system be configured to handle a TIP communication failure? First and foremost, the VFD should be configured to shut down if it stops receiving commands from the Master PLC. A 60-75 second timeout should be sufficient for this purpose. When the VFD stops due to comm loss, it will show a Fault Code 24 (Comm Timeout).

After a TIP 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 "PRESET 1" speed. Through pair 2, a single contact output will provide RUN feedback to the Master PLC: When the VFD is "At Desired Frequency", a 24VDC signal will be transmitted. Until the TIP 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.

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

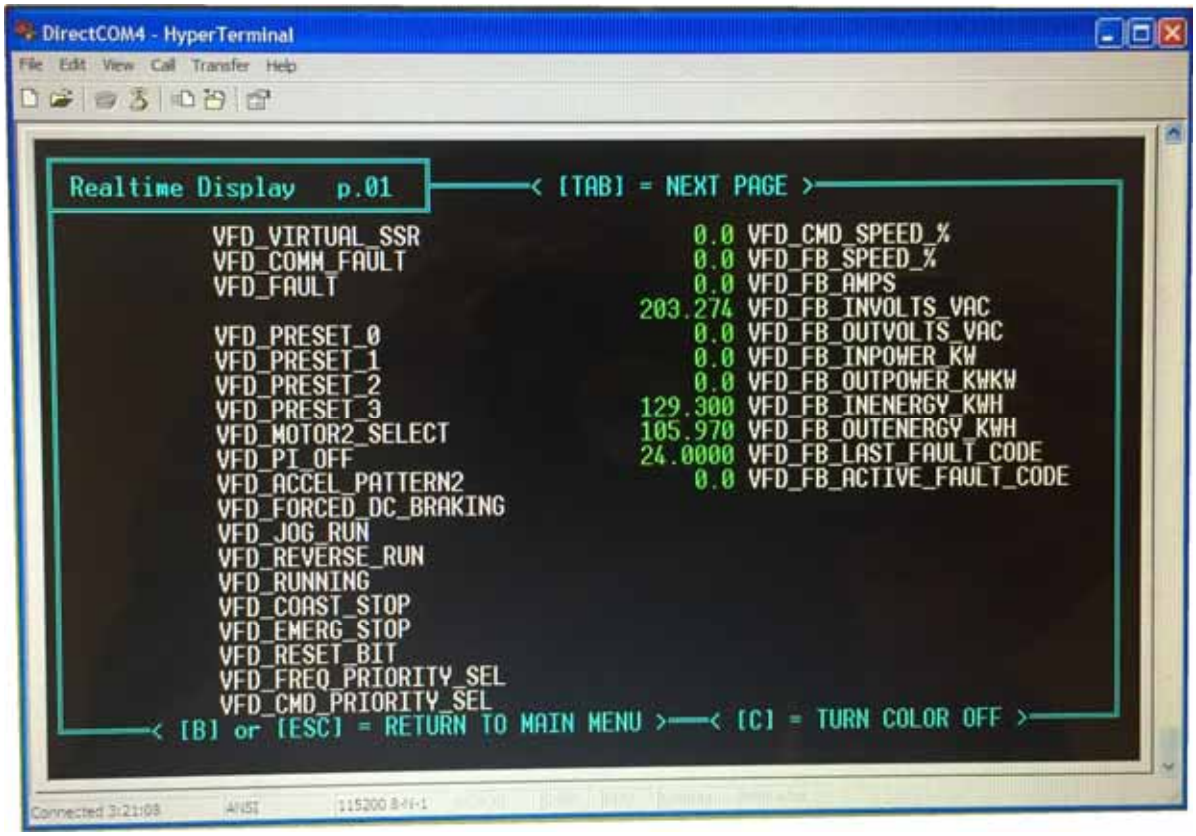
Ideally, pump "no flow" conditions are detected by monitoring a flow meter. In situations where a flow meter is not available, and because the Toshiba VFD provides realtime power consumption of the pump motor to the Master PLC, it is possible that the PLC can detect and/or alarm cavitation conditions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

Feedback Control

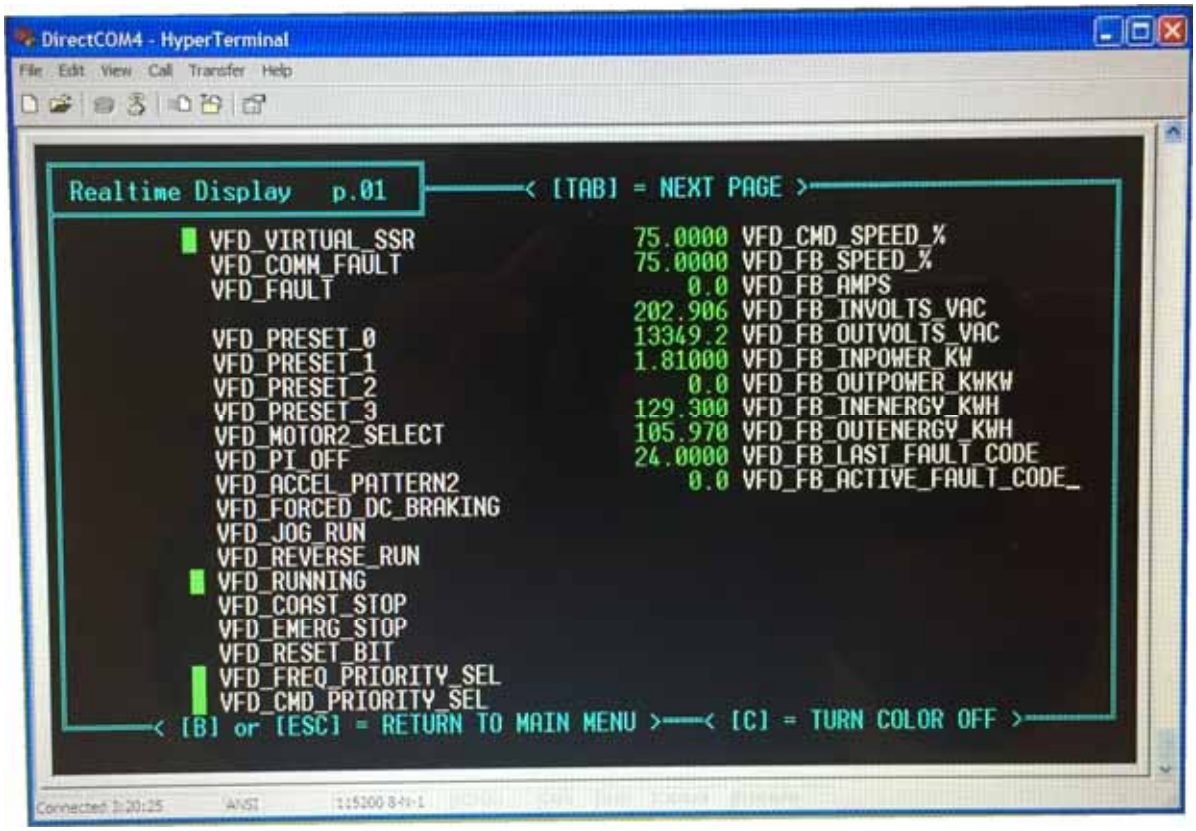
In a Water Utility, the VFD will typically be installed to control the speed of a pump motor. Available telemetry data may include pump discharge pressure, pump suction pressure, and pump rate-of-flow. This extra data, when combined with the VFD, may be used to implement closed-loop feedback control

VFD Reset Via TIP:

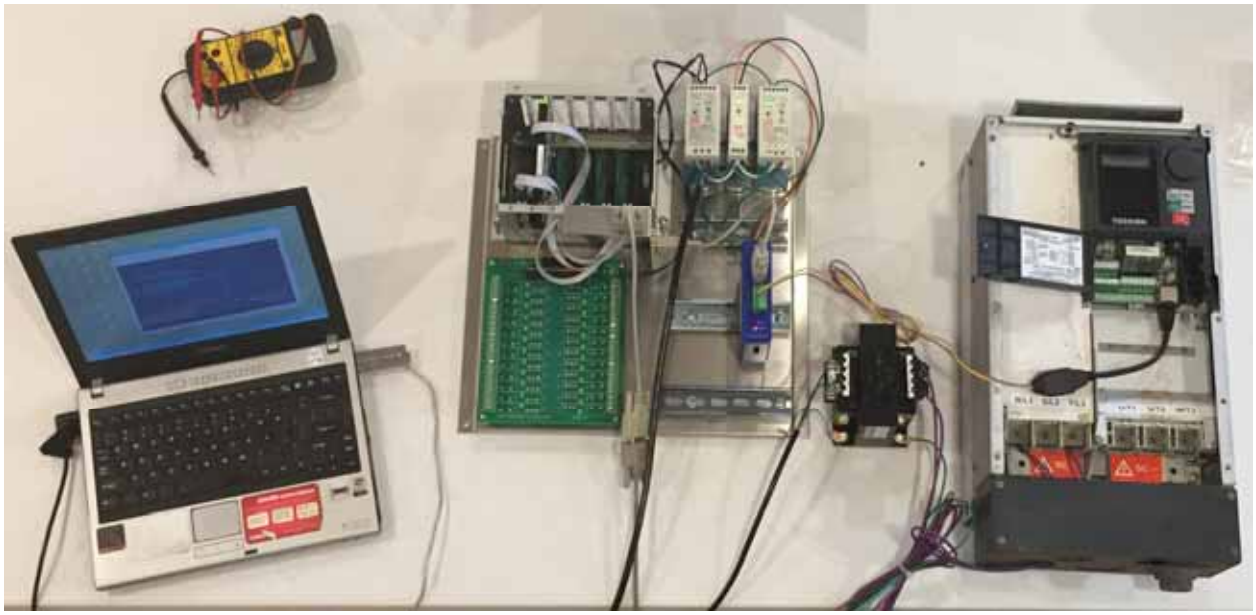
Because the Toshiba VFD provides actual fault information to the Master PLC, this information can be alarmed and the operator notified of the problem. The information is transmitted as a decimal fault code, and the Operator may refer to this document (or the Toshiba VFD User Manual) to decode the fault.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



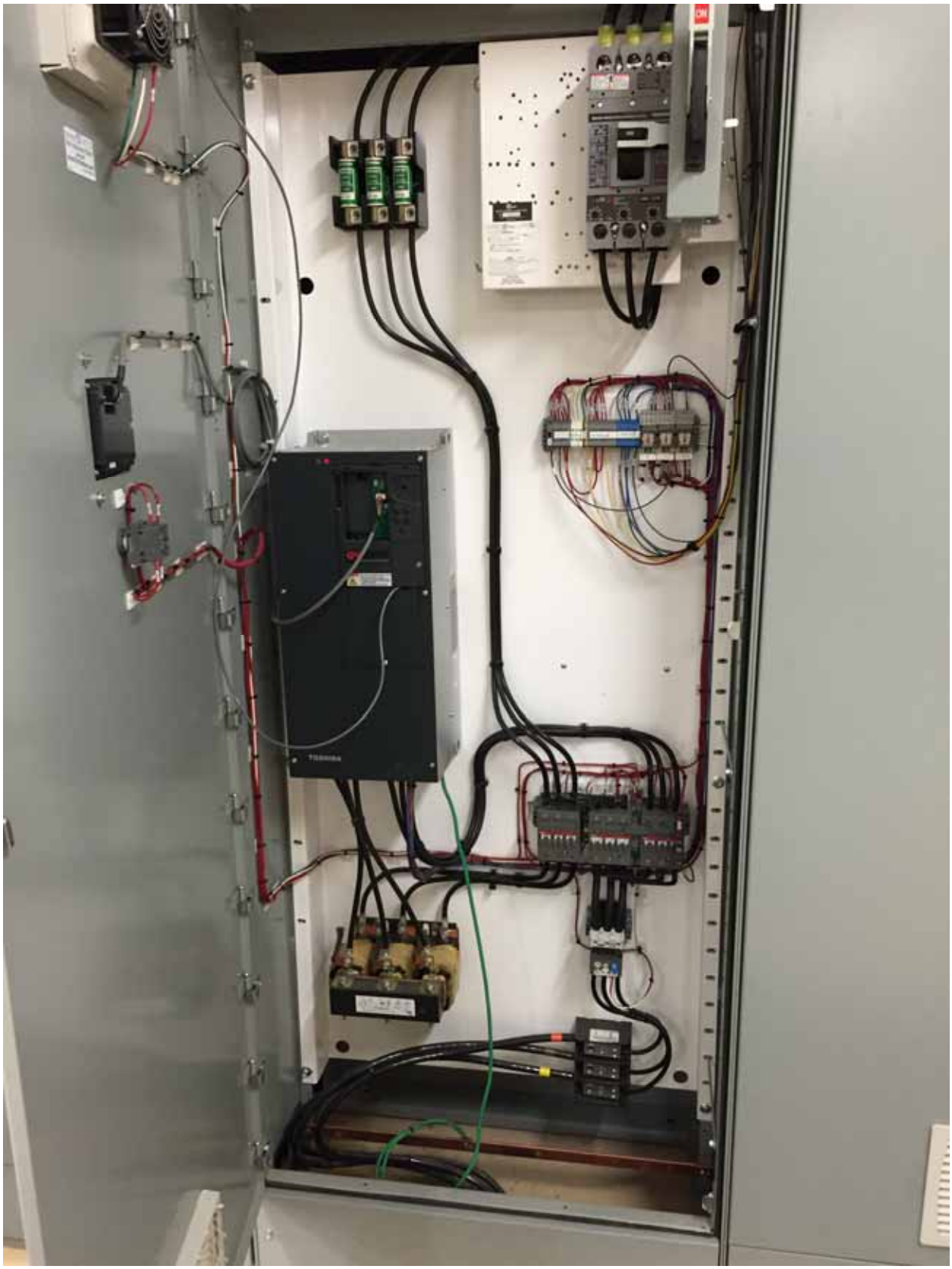
Toshiba VFD Idling: Realtime Display of an NRI RTU Flat-Panel Display.



Toshiba VFD Running at 75% (45 Hz): Realtime Display of an NRI RTU Flat-Panel Display. Note that the Output Voltage Reading is Not Correct, Due To No Connected Load Present.



Lab Demonstration Station: Notebook Terminal, NRI RTU-6030, Transformer, Toshiba VFD.



Toshiba Q9 VFD Installed In A Triplex 25HP Pump Station: Lake Piasa, IL.
Jersey County Rural Water Company.
Panel Also Equipped with Fuses, Disconnect, ACL Bypass, Reactor, Ventilation Fan.

Toshiba VFD Fault Codes

LED Display Message	Fault Code	Explanation
nErr	0	No error has been recorded since the last drive reset or trip clear
OC 1	1	Overcurrent during acceleration
OC2	2	Overcurrent during deceleration
OC3	3	Overcurrent during constant-speed run
OCL	4	Load-end overcurrent detected at start-up (output terminals, motor wiring etc.)
OCA 1	5	U-phase IGBT short circuit
OCA2	6	V-phase IGBT short circuit
OCA3	7	W-phase IGBT short circuit
EPH 1	8	Lost input phase (option)
EPHO	9	Lost output phase (option)
OP 1	10	Overvoltage during acceleration
OP2	11	Overvoltage during deceleration
OP3	12	Overvoltage during constant-speed run
OL In	13	Drive overload
OLMt	14	Motor overload
OLr	15	Dynamic braking resistor overload
OH	16	Drive overheat
E	17	Emergency off
EEP 1	18	EEPROM failure during write
EEP2	19	EEPROM failure during initial read
—	20	Unused
Err2	21	RAM error
Err3	22	ROM error
Err4	23	CPU error
Err5	24	RS232C timer time-out
Err6	25	Gate array error
Err7	26	Output current detection circuit error
Err8	27	Communication interface card error (check that parameter Ino in Or.tr is not 0)
Err9	28	Option ROM error / option ROM not detected
UC	29	Low current
UP 1	30	Main circuit undervoltage
—	31	Unused
Ot	32	Overtorque
EF 1	33	Earth fault (software)
EF2	34	Earth fault (hardware)
EFU	35	Open fuse
OCr	36	Dynamic braking resistor overcurrent
OC 1P	37	Overcurrent in DC section during acceleration
OC2P	38	Overcurrent in DC section during deceleration
OC3P	39	Overcurrent in DC section during constant-speed run
Etn	40	Auto-tuning error
EtYP	41	Drive typeform error
—	42 ~ 80	Unused
dAMP	81	Closed damper detected
LOSS	82	Loss of IV input detected

```
$NCH - TOSHIBA VFD TEST, 0=NO-IO-CARD, 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
  19     # 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     RATED_VOLTAGE                      LAS    1
ALIAS     RATED_CURRENT                      LAS    2
ALIAS     VFD{OFF-ON}                        LIS    0

SDISPL_D1 VFD_VIRTUAL_SSR                    LDF    0
SDISPL_D2 VFD_COMM_FAULT                     LDF    1
SDISPL_D2 VFD_FAULT                          LDF   18
$BLANK

SDISPL_D4 VFD_PRESET_0                       LDF    2
SDISPL_D4 VFD_PRESET_1                       LDF    3
SDISPL_D4 VFD_PRESET_2                       LDF    4
SDISPL_D4 VFD_PRESET_3                       LDF    5
SDISPL_D4 VFD_MOTOR2_SELECT                  LDF    6
SDISPL_D4 VFD_PI_OFF                         LDF    7
SDISPL_D4 VFD_ACCEL_PATTERN2                 LDF    8
SDISPL_D4 VFD_FORCED_DC_BRAKING              LDF    9
SDISPL_D4 VFD_JOG_RUN                        LDF   10
SDISPL_D4 VFD_REVERSE_RUN                    LDF   11
SDISPL_D4 VFD_RUNNING                        LDF   12
SDISPL_D4 VFD_COAST_STOP                     LDF   13
SDISPL_D4 VFD_EMERG_STOP                     LDF   14
SDISPL_D4 VFD_RESET_BIT                      LDF   15
SDISPL_D4 VFD_FREQ_PRIORITY_SEL              LDF   16
SDISPL_D4 VFD_CMD_PRIORITY_SEL               LDF   17

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_INVOLTS_VAC                   LAF    3
SDISPL_A  VFD_FB_OUTVOLTS_VAC                  LAF    4
SDISPL_A  VFD_FB_INPOWER_KW                    LAF    5
SDISPL_A  VFD_FB_OUTPOWER_KW                   LAF    6
SDISPL_A  VFD_FB_INENERGY_KWH                  LAF    7
SDISPL_A  VFD_FB_OUTENERGY_KWH                 LAF    8
SDISPL_A  VFD_FB_LAST_FAULT_CODE               LAF    9
SDISPL_A  VFD_FB_ACTIVE_FAULT_CODE             LAF   10


# TOSHIBA INVERTER PROTOCOL (9600BPS, 8/N/2, NO PARITY)
# NOTE! - CERTAIN PARAMETERS AT 0xFEnn ADDRESSES MAY NEED TO
#         BE READ AT 0xFDnn ADDRESSES FOR CERTAIN DRIVE MODELS

# TOSHIBA INPUTS…

ALIAS     VFD_SPEED_FB_IMOD                    V_SIU  1  0xFD00
ALIAS     VFD_TRIPCODE_IMOD                    V_SIU  1  0xFC90
ALIAS     VFD_TRIP_HIST_IMOD                   V_SIU  1  0xFE10
ALIAS     VFD_CMD_IMOD                         V_SIU  1  0xFA00

# CURRENT x 0.01%
ALIAS     VFD_OUTCURRENT_IMOD                  V_SIU  1  0xFE03

# VOLTAGE x 0.01%
ALIAS     VFD_INVOLTS_IMOD                     V_SIU  1  0xFE04
ALIAS     VFD_OUTVOLTS_IMOD                    V_SIU  1  0xFE05

# KW x 0.01
ALIAS     VFD_INPWR_IMOD                       V_SIU  1  0xFE29
ALIAS     VFD_OUTPWR_IMOD                      V_SIU  1  0xFE30

# KWH x 0.01
ALIAS     VFD_INENERGY_IMOD                    V_SIU  1  0xFE76
ALIAS     VFD_OUTENERGY_IMOD                   V_SIU  1  0xFE77

# TOSHIBA OUTPUTS…

ALIAS     VFD_CMD_OMOD                         V_SOU  1  0xFA00
ALIAS     VFD_SPEED_OMOD                       V_SOU  1  0xFA01


# TIMERS...


# USER VARIABLES...

ALIAS     LASTCALL_TIME                        USR    0
ALIAS     DELTA_TIME                           USR    1

# TOHSIBA VFD CONSTANTS...

ALIAS     UPTIME_MIN_USR                       USR    2
ALIAS     NET_STOP_USR                         USR    3
ALIAS     NET_START_USR                        USR    4
ALIAS     NET_RESET_USR                        USR    5
ALIAS     NET_FWD_USR                          USR    6
ALIAS     NET_SOURCE_USR                       USR    7
ALIAS     STATUS_WORD_USR                      USR    8
ALIAS     VFD_CTRL_WORD_USR                    USR    9


$NCL
```

```
# NCL Program
#
# Station : Toshiba VFD Demo Station
#           Toshiba Inverter Protocol - RS485
#
# Author  : Jim Mimlitz, Navionics Research Inc.
# Date    : 24 Dec 2015
#

# TRANSFER MODULE INPUTS TO FLAG INPUTS ...

      LBL      MAIN


# IF FIRSTRUN, INITIALIZE VARIABLES AND TIMERS ...

      FIRSTRUN?
      IF_FALSE
      GOTO     10

      SYSTIME
      STORE    LASTCALL_TIME
      POP

# RESET TOSHIBA VFD's...
# (INHIBIT RESET IF FAULT_CODE=ZERO)…

      LOAD     RESET_ON_REBOOT
      LOAD     VFD_TRIPCODE_IMOD
      &
      IF_FALSE
      GOTO     9
      LOAD     0xE000
      PSTORE   VFD_CMD_OMOD
9     POP

10    POP


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

      NEW_SETPOINTS?
      FIRSTRUN?
      |
      IF_FALSE
      GOTO     12
      GOSUB    SANITY_CHECKS
12    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


# TIP - FIRST, READ THE FAULT CODES...

      LOAD     VFD_TRIPCODE_IMOD
      STORE    VFD_FB_ACTIVE_FAULT_CODE
      LOAD     0.0
      Y>X?
      PSTORE   VFD_FAULT

      LOAD     VFD_TRIP_HIST_IMOD
      PSTORE   VFD_FB_LAST_FAULT_CODE


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

      LOAD     VFD_CMD_IMOD
      PSTORE   STATUS_WORD_USR

      MA_CACHED
      PSTORE   VFD_COMM_FAULT

      LOAD     STATUS_WORD_USR
      BITMASK  0
      PSTORE   VFD_PRESET_0

      LOAD     STATUS_WORD_USR
      BITMASK  1
      PSTORE   VFD_PRESET_1

      LOAD     STATUS_WORD_USR
      BITMASK  2
      PSTORE   VFD_PRESET_2

      LOAD     STATUS_WORD_USR
      BITMASK  3
      PSTORE   VFD_PRESET_3

      LOAD     STATUS_WORD_USR
      BITMASK  4
      PSTORE   VFD_MOTOR2_SELECT

      LOAD     STATUS_WORD_USR
      BITMASK  5
      PSTORE   VFD_PI_OFF

      LOAD     STATUS_WORD_USR
      BITMASK  6
      PSTORE   VFD_ACCEL_PATTERN2

      LOAD     STATUS_WORD_USR
      BITMASK  7
      PSTORE   VFD_FORCED_DC_BRAKING

      LOAD     STATUS_WORD_USR
      BITMASK  8
      PSTORE   VFD_JOG_RUN

      LOAD     STATUS_WORD_USR
      BITMASK  9
```

```
      PSTORE   VFD_REVERSE_RUN

      LOAD     STATUS_WORD_USR
      BITMASK  10
      LOAD     VFD_FAULT
      !
      &
      PSTORE   VFD_RUNNING

      LOAD     STATUS_WORD_USR
      BITMASK  11
      PSTORE   VFD_COAST_STOP

      LOAD     STATUS_WORD_USR
      BITMASK  12
      PSTORE   VFD_EMERG_STOP

      LOAD     STATUS_WORD_USR
      BITMASK  13
      PSTORE   VFD_RESET_BIT

      LOAD     STATUS_WORD_USR
      BITMASK  14
      PSTORE   VFD_FREQ_PRIORITY_SEL

      LOAD     STATUS_WORD_USR
      BITMASK  15
      PSTORE   VFD_CMD_PRIORITY_SEL


# TIP Output Speed...

      LOAD     VFD_SPEED_FB_IMOD
      LOAD     60.0
      /
      PSTORE   VFD_FB_SPEED_%


# TIP Input (Line) Voltage…

      LOAD     VFD_INVOLTS_IMOD
      LOAD     0.0001
      *
      LOAD     RATED_VOLTAGE
      *
      PSTORE   VFD_FB_INVOLTS_VAC


# TIP Output (Motor) Voltage…

      LOAD     VFD_OUTVOLTS_IMOD
      LOAD     0.01
      *
      LOAD     RATED_VOLTAGE
      *
      PSTORE   VFD_FB_OUTVOLTS_VAC


# TIP Input (Utility) Power…

      LOAD     VFD_INPWR_IMOD
      LOAD     0.01
      *
      PSTORE   VFD_FB_INPOWER_KW
```

```
# TIP Output (Motor) Power…

      LOAD     VFD_OUTPWR_IMOD
      LOAD     0.01
      *
      PSTORE   VFD_FB_OUTPOWER_KW


# TIP Input (Utility) Energy…

      LOAD     VFD_INENERGY_IMOD
      LOAD     0.01
      *
      PSTORE   VFD_FB_INENERGY_KWH


# TIP Output (Motor) Energy…

      LOAD     VFD_OUTENERGY_IMOD
      LOAD     0.01
      *
      PSTORE   VFD_FB_OUTENERGY_KWH


# Toshiba Protocol Control (Write) to VFD...

      LOAD     VFD{OFF-ON}
      LOAD     2
      Y=X?
      PSTORE   VFD_VIRTUAL_SSR

      LOAD     0xC400
      LOAD     VFD_VIRTUAL_SSR
      *
      PSTORE   VFD_CMD_OMOD

      LOAD     VFD_SPEED_%
      LOAD     VFD_VIRTUAL_SSR
      *
      STORE    VFD_CMD_SPEED_%
      LOAD     60
      *
      PSTORE   VFD_SPEED_OMOD


# IF REQUESTED,
# RESET THE VFD USING A SOFTWARE ONE-SHOT...
# (INHIBIT RESET IF FAULT_CODE=ZERO)…

      NEW_SETPOINTS?
      LOAD     VFD_RESET_1SHOT
      LOAD     VFD_TRIPCODE_IMOD
      &
      &
      IF_FALSE
      GOTO     998

      LOAD     0xE000
      PSTORE   VFD_CMD_OMOD

998   POP
```

```
      LOAD     0
      STORE    VFD_RESET_1SHOT
      POP

      END


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

      LBL      SANITY_CHECKS

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

      LOAD     VFD_SPEED_%
      LOAD     0.0
      MAX
      LOAD     200.0
      MIN
      PSTORE   VFD_SPEED_%

      LOAD     RATED_VOLTAGE
      LOAD     480.0
      MIN
      LOAD     115.0
      MAX
      PSTORE   RATED_VOLTAGE

      RTN
```