HAMPTON ROADS SANITATION DISTRICT
Electrical Department
2391 G Avenue
Newport News, VA 23602
Phone: 757-833-1702
Fax: 757-875-0273

Drive Specifications:
Date: 09-10-15

Variable Frequency Drive w/ Waste Water Package

1.) Horsepower: ________
2.) Full Load Amps: ________
3.) _______ VAC, Three Phase, 60 Hertz, with internal DC Link Choke and Line Reactor.
4.) NEMA 12 free standing enclosure, 90" x 36" x 20" with viewing window and positive pressure blower & filter. Viewing window shall be made by Tegam (www.tegam.com- Item# AWXXXX). Also note, width may vary depending on air exchanges needed for correct cooling factor and/ or dimension of the VFD.
Tegam windows are not required if the VFD's are installed in a controlled environment.
5.) Door mounted digital keypad operator
6.) Fully NEMA rated door interlocking circuit breaker approved for thermal & magnetic trips. ***IEC or DUAL RATED NOT ACCEPTED.***
7.) Fully NEMA rated three contactor by-pass configuration fully rated for continuous drive operation. Also, shall operate automatically when in the by-pass position. ***IEC or DUAL RATED NOT ACCEPTED.***
8.) NEMA rated – "Drive/ Off/ By-Pass" and "Test/Off/Run" selector switches.

9.) NEMA Rated- "Manual/Auto" selector switch programmed for a voltage (manual) and current (auto) input. Additional contact on "Auto" side of switch to provide closure in auto mode and wired to terminal on drive.

10.) Door mounted ~~Yokogawa elapsed time meter Model # 240311AAAB7 120~~ VAC non- resettable. Crompton elapsed time meter is UL listed

11.) 4-20 MADC speed reference for input and output signals.

12.) NEMA rated speed potentiometer mounted on door for manual speed control.

13.) Isolation form "C" relay TPDT for each "Run", "Fault" and "Man/ Auto" status.

14.) Enclosure shall be manufactured by Hoffman.

15.) Control transformer should be ***1,000 VA or larger*** based on control needs in cabinet.

16.) Auxiliary contact for cabinet cooling fans to be form "C" relay TPDT and controlled from Run Status contacts of VFD.

17.) Cooling air fans shall be sized to provide correct air exchanges in cabinet to maintain temperature in cabinet below VFD rating.

18.) Extended 5 year warranty must be included.

19.) The assembly shall be listed per UL508 and 508A or equivalent NRTL standard. The entire assembly shall be affixed with UL508A label prior to shipment.

20.) Application specific - evaluate need for soft start for bypass for 100 HP motors or greater.

21.) Door mounted cradle for controller that could be removed and connected via (3m or 9ft) cable so that drive can be operated outside of the arc flash boundary.

Note for Vendor:

1.) Must visit the site to verify that equipment ordered is correct for operation.

2.) Drawings for approval are required to be submitted to HRSD Electrical Department.

3.) Items 6 & 7 shall be approved NEMA rated Cutler-Hammer, Allen-Bradley or Square D. Or other manufacture NEMA rated with written approval by the HRSD site.

4.) All switches and lights shall be heavy duty NEMA Rated Cutler-Hammer or Allen-Bradley 30mm.

5.) All switches, lights and keypad shall be mounted inside of viewing window on door. If applicable

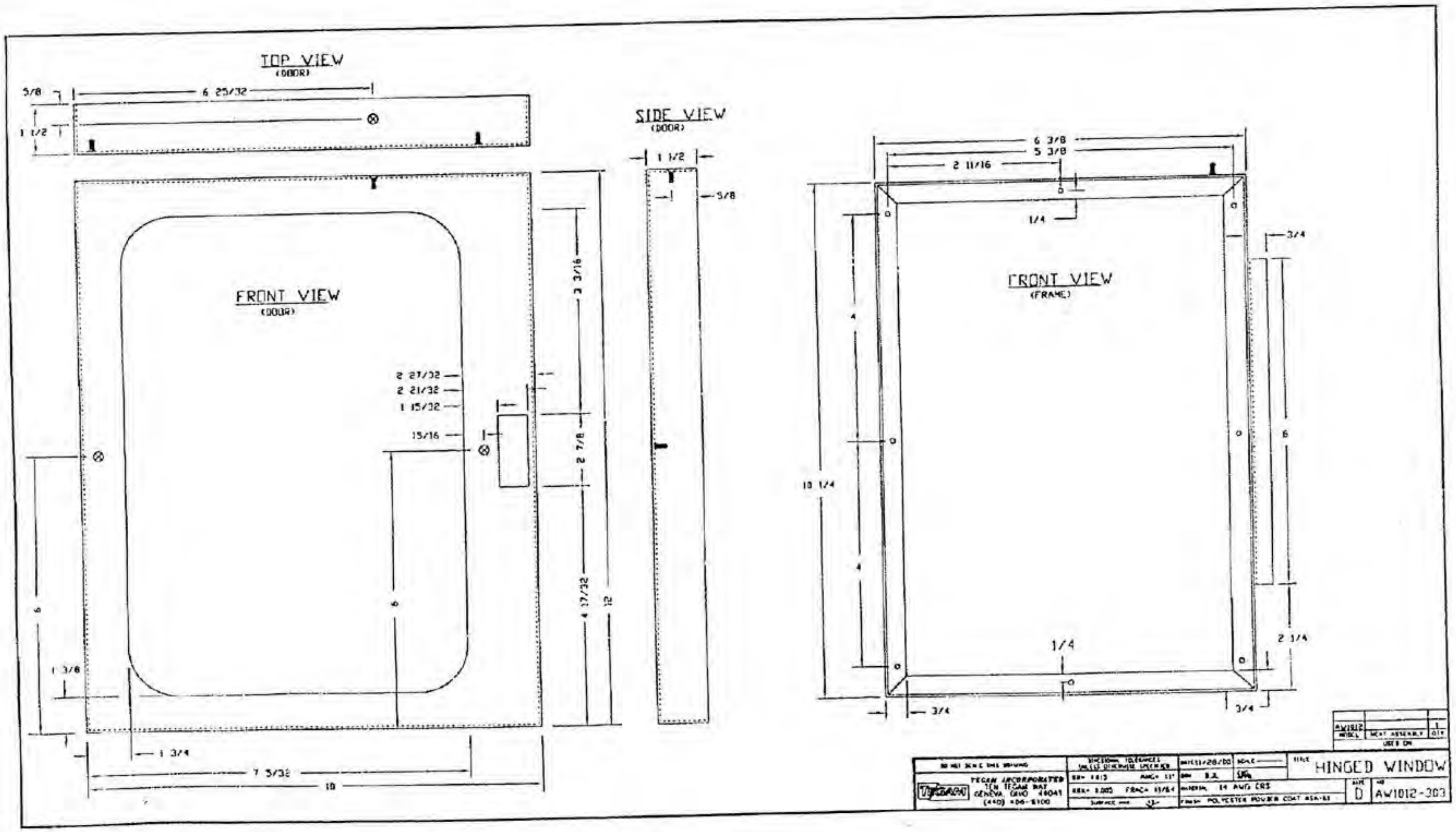
6.) All spare relay contacts should be wired to terminal blocks.

7.) Fault relay should be controlled from Normally Closed (N.C.) contacts of VFD MB & MC Terminals and to be wired after Overload (O/L) contacts on drawing.

8.) All VFD's will be shipped attached Horizontally on pallets and with sufficient protection for the switches, lights and On/Off breaker.

9.) ***<u>THERE SHALL BE NO IEC OR DUAL RATED NEMA DEVICES ACCEPTED.</u>***
Examples: Lights, position switches, circuit breakers, contactors and speed potentiometer.

Mount Thermostat above or close to the VFD. Not at the bottom of the cabinet



TOP VIEW
(DOOR)
5/8
6 25/32
1 1/2
SIDE VIEW
(DOOR)
1 1/2
5/8
FRONT VIEW
(DOOR)
2 27/32
2 21/32
1 15/32
15/16
3 3/16
2 7/8
4 17/32
12
9
9
1 3/8
1 3/4
7 5/32
10
FRONT VIEW
(FRAME)
6 3/8
5 3/8
2 11/16
1/4
3/4
4
4
10 1/4
6
2 1/4
1/4
3/4
3/4
AW1012
MODEL
NEXT ASSEMBLY
1
QTY
USED ON
DO NOT SCALE THIS DRAWING
TEGAM INCORPORATED
TEN TEGAM WAY
GENEVA, OHIO 44041
(440) 466-6100
DIMENSIONAL TOLERANCES
UNLESS OTHERWISE SPECIFIED
DATE 11/28/00
SCALE
DWN B.J.
MATERIAL 14 AWG CRS
FINISH POLYESTER POWDER COAT
TITLE HINGED WINDOW
SIZE D
NO AW1012-303

Technical Memorandum

VFD Harmonic Mitigation

To:
Laura Kirkwood, PE, HRSD

Issued By:
Mike Gaffney, PE, RK&K
Ryan Delo, PE, RK&K
Tim Bollinger, PE, RK&K
Jason Hoyt, RK&K

Date:
June 12, 2018

Program Name:
Hampton Roads Sanitation District
Chesapeake Elizabeth Interceptor System Diversion Improvements

Subject:
Technical Memorandum to Provide Harmonic Mitigation Recommendation for Variable Frequency Drives at Pressure Reducing Stations

Introduction

It is our experience variable frequency drives (VFDs) operating motors 100HP or larger benefit from harmonic filters to reduce the effects of harmonic distortion. Harmonic distortion can increase generator sizing, reduce equipment life expectancy, and reduce the efficiency of the power system ultimately resulting in higher operation and maintenance costs. HRSD's standard Yaskawa A1000 VFD with a line reactor reduces the harmonic distortion, but it is estimated the total distortion will be greater than the limits recommended by IEEE-519. See **Figure 1** below for the IEEE-519 recommended limits, and **Figure 2** for the harmonic estimation of HRSD's standard configuration.

Harmonic Mitigation Options

There are two options for mitigating the harmonics generated by the VFDs. The first option for harmonic mitigation is to add a passive harmonic filter. A passive harmonic filter may be added to HRSD's standard configuration. Adding a passive harmonic filter will reduce the effects of harmonic distortion within the limits recommended by IEEE-519, see **Figure 3** for the harmonic estimation. This option will increase the foot print of the drive enclosure, additional labor will be required for wiring, and additional ventilation will be required for heat dissipation.

The second option for harmonic mitigation is to utilize the Yaskawa U1000 Matrix VFD. The Yaskawa U1000 Matrix VFD will replace the Yaskawa A1000 VFD and line reactor. Use of the Yaskawa U1000 Matrix VFD will reduce the effects of harmonic distortion within the limits recommended by IEEE-519, see **Figure 4** for the harmonic estimation. This option will not impact the foot print of the drive enclosure, labor for wiring will be reduced because the line reactor is no longer required, and additional ventilation will not be required for heat dissipation.

Either option will increase the cost an estimated $25,000 per drive, based on powering a 215 hp motor.

Recommendation

Of the options available for harmonic mitigation we recommend the Yaskawa U1000 Matrix VFD be used as the standard variable frequency drive for all motors 100HP and larger. Use of the Yaskawa U1000 Matrix VFD will reduce the effects of harmonic distortion to within the limits recommended by IEEE-519, eliminate the need for a line reactor and passive harmonic filter, and reduce the foot print of the drive enclosure compared to a variable frequency drive panel with a line reactor and passive harmonic filter. The Yaskawa A1000 VFD uses the typical AC to DC conversion, then DC to variable AC pulse width modulated (PWM) waveform for speed control. The Yaskawa U1000 Matrix VFD reduces harmonics by AC to AC operation with the use of 9 bi-directional insulated-gate bipolar transistors (IGBTs) for speed control. In addition to the low harmonics of the Yaskawa U1000 Matrix VFD the use of bi-directional IGBTs allows the variable frequency drive to handle continuous power regeneration.

Aside from the advantages listed above for the Yaskawa U1000 Matrix VFD, the variable frequency drive has the same user interface and terminal layout as the Yaskawa A1000 VFD, eliminating the need for any additional operator training for the set-up and programming of the VFD.

Allen Bradley manufactures the PowerFlex 755TL VFD capable of reducing harmonics. While an extensive evaluation of this drive was not completed (as it is not the model indicated in HRSD's Preferences) as part of this technical memorandum, this alternative may be worthy of evaluation to determine suitability for installation in the pressure reducing stations.

Figure 1. IEEE-519 (2014) Limits

IEEE-519 (2014)

Current Distortion Limits

Harmonic Current Distortion Limits for general distribution systems (120V through 69kV)

Isc/IL	TDD
<20	5.0 %
20 - 50	8.0 %
50 - 100	12.0 %
100 - 1000	15.0 %
> 1000	20.0 %

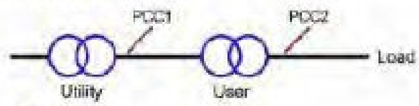
TDD = Total Demand Distortion, in percent of IL
Isc = Maximum short circuit current at PCC (Point of Common Coupling)
IL = Maximum demand load current at PCC (Point of Common Coupling)

Voltage Distortion Limits

Bus voltage V at PCC	THD
V <= 1.0 kV	8.0 %
1 kV < V <= 69 kV	5.0 %
69 kV < V <= 161 kV	2.5 %
161 kV < V	1.5 %

Figure 2. Harmonic Estimation with a Yaskawa A1000 VFD and Line Reactor

Project: Providence Road PRS



Linear: 15 HP

Non-Linear: 860 HP

Utility: Dominion Energy

Source Data I

Source	Frequency (Hz)	Rating (kVA)	Impedance Z (%)	Sec. Voltage (V)	Isc (A)
Utility XFMR	60	50,000	8.00	13,800	26,148
User XFMR	60	1,500	5.75	480	31,378

Source Data II

Source	Rated Amps, rms (A)	Amps Fundamental (A)	Amps Harmonics (A)	Total Amps (A)
Utility XFMR	2,092	30.9	8.6	32.1
User XFMR	1,804	889.7	247.4	923.5

Harmonic Summary

Location	Current TDD (%)	Voltage TDD (%)	Isc/Load	Transformer Load (%)
PCC2	27.8	4.7	35.3	56.7

IEEE-519 (2014) limits at PCC2 for specified system based on Isc/IL: Voltage THD: 8.0 %, Current TDD: 20.0 %

Project Compliance

Location	IEEE-519 (2014)	IEC
PCC2	No	No

Figure 3. Harmonic Estimation with a Yaskawa A1000 VFD and Passive Filter

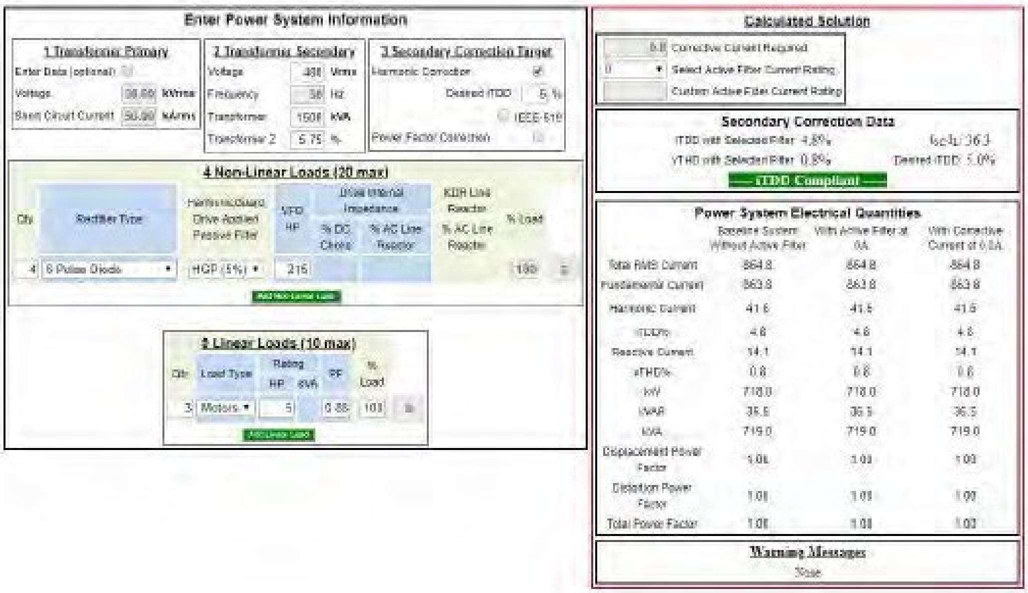
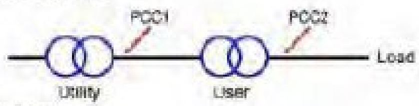


Figure 4. Harmonic Estimation with a Yaskawa U1000 Matrix VFD

Project: Providence Road PRS



Linear: 15 HP

Non-Linear: 960 HP

Utility: Dominion Energy

Source Data I

Source	Frequency (Hz)	Rating (kVA)	Impedence Z (%)	Sec. Voltage (V)	Isc (A)
Utility XFMR	60	50,000	8.00	13,800	26,148
User XFMR	60	1,500	5.75	480	31,378

Source Data II

Source	Rated Amps, rms (A)	Amps Fundamental (A)	Amps Harmonics (A)	Total Amps (A)
Utility XFMR	2,092	30.9	0.9	31.0
User XFMR	1,804	889.7	25.0	890.1

Harmonic Summary

Location	Current TDD (%)	Voltage TDD (%)	Isc/Load	Transformer Load (%)
PCC2	2.9	1.2	35.3	49.9

IEEE-519 (2014) limits at PCC2 for specified system based on Isc/IL: Voltage THD: 8.0 %, Current TDD: 8.0 %

Project Compliance

Location	IEEE-519 (2014)	IEC
PCC2	Yes	Yes

Click here to return to VFH (AUX) (PSs)

Click here to return to VFD (AUX) (TPs)

Safety Switches with Variable Frequency Drives

Introduction

The National Electrical Code® (NEC®) requires that a disconnecting means shall be located in sight from the motor location and the driven machinery location (Article 430.102(B)). The NEC® defines "in sight" as visible and not more than 50 feet (15.24 m) distant (Article 100 – definitions).

In many cases, motor starters will be located in another space then the motor and to meet code requirements, a safety switch is used to add a way to disconnect and lockout a motor. When an across the line starter is used, this won't cause an issue, but it can cause issues with a Variable Frequency Drive. When a motor is running with a VFD and is turned off at the safety switch, the VFD does not have a way of sensing that the motor load has dropped off completely in V/Hz control. The drive is designed to supply as much voltage as the motor is demanding and it would not be uncommon for the motor to not require any power once the load is moving due to inertia. Because of this, the VFD will continue to function and run as it normally would even though the load has been disconnected. When the safety switch is closed again, the VFD will function like an across the line starter and an enormous amount of inrush current will be generated and pulled through the drive.

Across the line starters are designed to handle these large current spikes for a short amount of time, but a VFD is meant to be used to ramp up and down the speed of a motor. Until recently, this inrush current could cause the IGBTs to fail and require complete replacement which can be very costly due to down time and the process being very labor intensive. A way to prevent these issues is to provide feedback from the safety switch back into the VFD that the switch has been opened and the VFD should stop running.

As a standard, safety switches are simple devices that cut off power to the motor, however, they have additional options including an auxiliary contact that will change states when the switch is changed. There are multiple ways to tie this back into the VFD to prevent it from running, but the two most common ways are to use it as a lockout contact that is wired into the RUN input of the drive or a Normally Closed contact is wired into the EXTERNAL FAULT input on the drive. Each method will be discussed in more detail below.

Interlocking with RUN signal

Eaton provides terminal blocks to interlock an external signal to the RUN input as a standard on all Enclosed VFD Assemblies. From the factory, these terminal blocks come jumpered as in most cases this interlock signal is not required. This makes interlocking your safety switch as easy as running two wires from the safety switch into the VFD enclosure that are rated for 120Vac.

In the case that an open component VFD is being used or the drive was installed into an enclosure by a local panel builder, it will take some rewiring to interlock the VFD with the Safety Switch. Figure 1 below shows a simplified wiring scheme. By wiring a Normally Open Contact from the Safety Switch in series with the VFD's RUN Input, the drive will only be allowed to RUN when the switch is closed.

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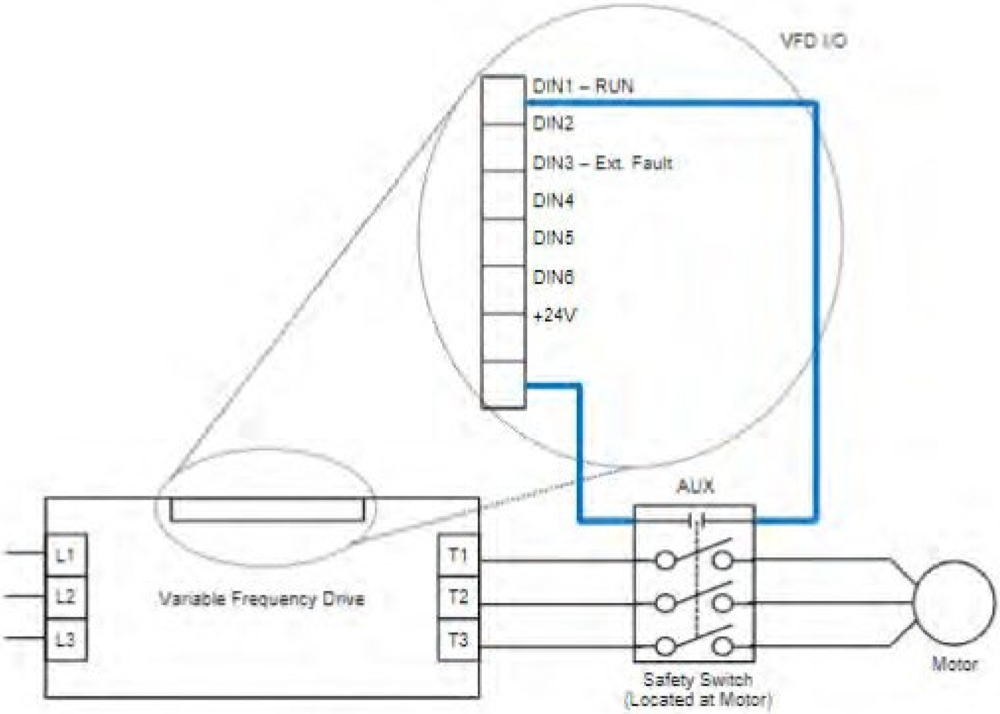

Figure 1 – Interlocking with the VFD RUN input

One of the main advantages of going this route is that the VFD will start to run again as soon as the Safety Switch is put back into the closed position. In the case where you don't have a local control station near the motor, this will save some time from having to go back to the main VFD to reset it to allow the unit to start back up. Some people would prefer that the motor needs to be manually restarted again in which case interlocking the Safety Switch with the VFD EXTERNAL FAULT input is a better solution.

Interlocking with EXTERNAL FAULT signal

Wiring into the EXTERNAL FAULT input on the drive is a less common way of interlocking the Safety Switch with the VFD, but it will provide similar results. Figure 2 below shows a simplified wiring scheme on how to do this. By wiring a Normally Closed Contact from the Safety Switch in series with the VFD's EXTERNAL FAULT Input, the drive will register a Fault anytime the Switch is opened, causing the VFD to shut down.

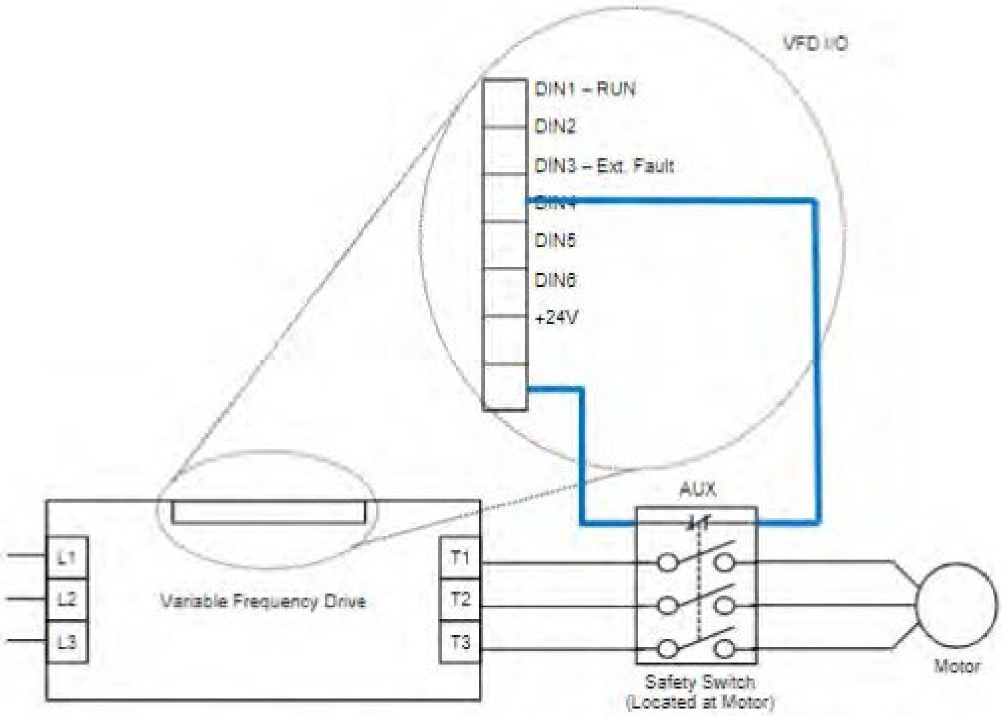

Figure 2 – Interlocking with the VFD EXTERNAL FAULT Input

External Faults are typically looking for low signals to prevent issues with wires coming lose and faults not registering. In this case, as soon as the motor's power is cut at the safety switch, the drive will register an External Fault which cannot be cleared until the Safety Switch is closed again. The Drive can then be reset locally at the keypad or through a remote reset button with is wired into a RESET input on the VFD. The reset can also be done over the communication bus as well.

Additional Help

In the US or Canada: please contact the Technical Resource Center at 1-877-ETN-CARE or 1-877-326-2273 option 2, option 6.

All other supporting documentation is located on the Eaton web site at www.eaton.com/Drives

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