Trane TR150
Variable Frequency Drive Guide Specification
Section 15172

I. GENERAL

A. This specification covers all variable frequency drives (VFDs) designated on the drawing schedules. All standard and optional features detailed herein shall be included within the VFD panel.

   The VFD shall be factory installed by the HVAC original equipment manufacturer. The VFD shall have been evaluated by UL and found acceptable for mounting in a plenum or other air handling compartment. Manufacturer shall supply a copy of the UL plenum evaluation upon request.

B. The VFD shall be tested to UL 508C and bear the appropriate UL label. VFDs designated for use in Canada shall have C-UL certifications.

C. The VFD shall be CE marked and conform to the European Union Electro Magnetic Compatibility directive.

D. The VFD shall be UL listed for a short circuit current rating of 100 kA and labeled with this rating either in the instruction manual or with a drive marking, in accordance with UL.

E. The VFD manufacturer shall supply the VFD and all necessary controls as herein specified. The manufacturer shall have been engaged in the production of this type of equipment for a minimum of twenty years.

F. VFD shall be manufactured in ISO 9001, 2000 certified facilities.

II. PRODUCTS

A. The VFD shall convert incoming fixed frequency three-phase AC power into an adjustable frequency and voltage for controlling the speed of three-phase AC motors. The motor current shall closely approximate a sine wave. Motor voltage shall be varied with frequency to maintain desired motor magnetization current suitable for the driven load and to eliminate the need for motor de-rating. Additionally, the VFD shall have the capability to control non-salient permanent magnet (PMAC) motors up to 22kW (30 HP).

   When properly sized, the VFD shall allow the motor to produce full rated power at rated motor voltage, current, and speed without using the motor's service factor. VFDs utilizing sine weighted/coded modulation (with or without 3rd harmonic injection) must provide data verifying that the motors will not draw more than full load current during full load and full speed operation.

B. The VFD shall include an input full-wave bridge rectifier and maintain a fundamental (displacement) power factor near unity regardless of speed or load.

C. The VFD shall be capable of full output current at frequencies in the range of 0 to 120 Hz without de-rating.

D. The VFD shall have a dual 5% impedance DC link reactor on the positive and negative rails of the DC bus to minimize power line harmonics and protect the VFD from power line transients. The DC link reactors shall be non-saturating. DC link reactors using swinging chokes that do not provide full harmonic filtering throughout the entire load range are not acceptable.

E. The VFD shall be able to provide full rated output current continuously and up to 110% of rated output current for 60 seconds.

F. The VFD shall provide full motor torque at any selected frequency from 20 Hz to base speed while providing a variable torque V/Hz output at reduced speed. This is to allow driving direct drive fans without high speed de-rating or low speed excessive magnetization, as would occur if a constant torque V/Hz curve was used at reduced speeds. Breakaway current of 130% shall be available for 0.5 seconds.

G. A programmable automatic energy optimization selection feature shall be provided standard in the VFD. This feature shall automatically and continuously

monitor the motor's speed and load to adjust the applied voltage to maximize energy savings.

H. The VFD must be able to operate a direct drive fan through its full operating range.

I. VFD shall be capable of controlling multiple induction motors simultaneously. Multiple motor operation will require additional protective devices per motor.

J. Input and output power circuit switching shall be accomplished without interlocks or damage to the VFD. Switching rate may be up to 1 time per minute on the input and unlimited on the output.

K. An automatic motor adaptation algorithm shall be provided in the VFD to measure motor stator resistance and reactance to optimize performance and efficiency. It shall not be necessary to run the motor or de-couple the motor from the load to perform the test.

L. VFD shall minimize the audible motor noise through the use of an adjustable carrier frequency. The carrier frequency shall be automatically adjusted to optimize motor and VFD operation while reducing motor noise. VFDs with fixed carrier frequency are not acceptable.

M. All VFDs rated at 480V and below shall contain integral EMI filters to attenuate radio frequency interference conducted to the AC power line.

N. Galvanic and/or optical isolation shall be provided between the VFD's power circuitry and control circuitry to ensure operator safety and to protect connected electronic control equipment from damage caused by voltage spikes, current surges, and ground loop currents.

III. **PROTECTIVE FEATURES**

A. A minimum of Class 20 I2t electronic motor overload protection for single motor applications shall be provided. Overload protection shall automatically compensate for changes in motor speed.

B. The VFD shall provide protection against input transients, loss of AC line phase, output short circuit, output ground fault, over voltage, under voltage, VFD over temperature and motor over temperature. The VFD shall display all faults in plain language. Codes are not acceptable.

C. The VFD shall be protected from input phase loss. The VFD should be able to protect itself from damage and indicate the phase loss condition. During an input phase loss condition, the VFD shall be able to be programmed to either trip off while displaying an alarm, issue a warning while running at reduced output capacity, or issue a warning while running at full commanded speed. This function is independent of which input power phase is lost.

D. The VFD shall be protected from under voltage. The VFD shall provide full rated output power with an input voltage as low as 90% of the nominal. The VFD will continue to operate with reduced output power, without faulting, with an input voltage as low as 85% of the nominal voltage as required by EN/IEC 61800-3.

E. The VFD shall be protected from over voltage. The VFD shall continue to operate without faulting with a momentary input voltage higher than 110% of the nominal voltage.

F. VFD design shall comply with IEC Part 34-17 to prevent breakdown of the motor winding insulation.

G. The VFD shall incorporate a programmable motor preheat feature which provides the motor stator with a controlled level of current to keep the motor warm and prevent condensation build up in idle motors operating in damp environments. .

H. VFD shall include a "signal loss detection" algorithm with adjustable time delay to sense the loss of an analog input signal. It shall also include a programmable time delay to eliminate nuisance signal loss indications. The functions after detection shall be programmable.

I. VFD shall function normally when the keypad is removed while the VFD is running. No warnings or alarms shall be issued as a result of removing the keypad.

J. VFD shall be capable of catching a rotating motor operating forward or reverse up to full speed without VFD fault or component damage.

K. Selectable over-voltage control shall be provided to protect the VFD from power regenerated by the motor while maintaining control of the driven load.

L. VFD shall include current sensors on all three output phases to accurately measure motor current, protect the VFD from output short circuits, output ground faults, and act as a motor overload. If an output phase loss is detected, the VFD will trip off and identify which of the output phases is low or lost.

M. If the temperature of the VFD's heat sink rises to approximately 80°C, the VFD shall automatically reduce its carrier frequency to reduce the heat sink temperature. It shall also be possible to program the VFD so that it reduces its output current limit value if the VFD's temperature becomes too high. The VFD shall automatically increase the carrier frequency and current limit to normal values as the heat sink temperature decreases.

N. The VFD shall store in memory the last 10 alarms. A description of the alarm and the relative sequences of the alarms shall be recorded.

IV. INTERFACE FEATURES

A. Hand, Off and Auto keys shall be provided to start and stop the VFD and determine the source of the speed reference. It shall be possible to either disable these keys or password protect them from undesired operation.

B. The VFD shall be programmable to provide a digital output signal to indicate whether the VFD is in Hand or Auto mode. This is to alert the Building Automation System whether the VFD is being controlled locally or by the Building Automation System.

C. The VFD shall be provided with a keypad with alphanumeric, backlit display. The display shall be capable of remote mounting up to 10 ft. from the VFD. Main Menu password protection shall be provided to guard against unauthorized parameter changes.

D. All VFDs shall have the same customer interface. The keypad and display shall be identical and interchangeable for all sizes of VFDs.

E. To set up multiple VFDs, it shall be possible to upload all setup parameters to the VFD's keypad, place that keypad on all other VFDs in turn and download the setup parameters to each VFD. To facilitate setting up VFDs of various sizes, it shall be possible to download from the keypad only size independent parameters. Keypad shall provide visual indication of copy status.

F. Display shall be programmable to communicate in multiple languages including English, Spanish and French.

G. A red FAULT light, a yellow WARNING light and a green POWER-ON light shall be provided. These indications shall be visible both on the keypad and on the VFD when the keypad is removed.

H. A quick setup menu with factory preset typical HVAC parameters shall be provided on the VFD.

I. A two-feedback PI controller to control the speed of the VFD shall be standard.

   a) This controller shall accept up to two feedback signals. It shall be programmable to follow the sum of the feedback signals, a preset reference (common set point or up to 8 individual setpoints), or the sum of both.   It shall also be possible to calculate the controlling feedback signal as the average, maximum, minimum or the difference between two feedback signals. The VFD shall be able to apply scaling to the feedback signal.

   b) For fan flow tracking applications, the VFD shall be able to calculate the square root of any or all individual feedback signals so that a pressure sensor can be used to measure air flow.

   c) The VFD's PI controller shall be able to actively adjust its set point based on flow. This allows the VFD to compensate for a pressure feedback sensor which is located near the output of the pump rather than out in the controlled system.

J. Customized meter displays shall be available. They shall include at a minimum, speed/flow, pressure, and power units relative to motor speed.

K. Programmable Sleep Mode shall be able to stop the VFD. When its output frequency drops below set "sleep" level for a specified time, the VFD may be programmed to stop. When the VFD's speed is being controlled by its PI controller, it shall be possible to program a "wake-up" feedback value that will cause the VFD to start. To avoid excessive starting and stopping of the driven equipment, it shall be possible to program a minimum run time before sleep mode can be initiated and a minimum sleep time for the VFD.

L. A run permissive circuit shall be provided to accept a "system ready" signal to ensure that the VFD does not start until dampers or other auxiliary equipment are in the proper state for VFD operation. The run permissive circuit shall also be capable of initiating an output "run request" signal to indicate to the external equipment that the VFD has received a request to run.

M. VFD shall be programmable to sense the loss of load. The VFD shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. To ensure against nuisance indications, this feature must be based on estimated motor torque, not current, and must include a proof timer to keep brief periods of no load from falsely triggering this indication.

N. Standard Control and Monitoring Inputs and Outputs
   i. Four dedicated, programmable digital inputs shall be provided for interfacing with the systems control and safety interlock circuitry.
   ii. Two terminals shall be programmable to act as either as digital or analog outputs.
   iii. Two programmable relay outputs, Form C 250 VAC, 3 A, shall be provided for remote indication of VFD status.
      a) Each relay shall have an adjustable on delay / off delay time.
   iv. Two programmable analog inputs shall be provided that can be either direct- or reverse-acting.
      b) Each shall be independently selectable to be used with either an analog voltage or current signal.
      c) The maximum and minimum range of each shall be able to be independently scalable from 0 to 10 V dc and 0 to 20 mA.
      d) A programmable low-pass filter for either or both of the analog inputs must be included to compensate for noise.
   v. Two programmable analog current outputs (0/4 to 20 mA) shall be provided for indication of VFD status. This output shall be programmable to show the reference or feedback signal supplied to the VFD and for VFD output frequency, current and power. It shall be possible to scale the minimum and maximum values of the outputs.
   vi. It shall be possible through serial bus communications to read the status of all analog and digital inputs of the VFD.
   vii. It shall be possible to command all digital and analog output through the serial communication bus.

O. Standard programmable firefighter's override mode allows a digital input to control the VFD and override all other local or remote commands. It shall be possible to program the VFD so that it will ignore most normal VFD safety circuits including motor overload. The VFD shall display FIREMODE whenever in firefighter's override mode. Fire mode shall allow selection of forward or reverse operation and the selection of a speed source or preset speed, as required to accommodate local fire codes, standards and conditions.

P. The VFD shall be able to store load profile data such as counters for operating hours, running hours, and kilowatt-hours, to assist in analyzing the system demand and energy consumption over time.

Q. The VFD shall include a sequential logic controller to provide advanced control interface capabilities. This shall include:
   i. Comparators of VFD analog values to programmed trigger values

    ii.   Logic operators to combine up to three logic expressions using Boolean algebra

  iii.   Delay timers

   iv.   A 20-step programmable structure

v. SERIAL COMMUNICATIONS

A. The VFD shall include a standard EIA-485 communications port and capabilities to be connected to the following serial communication protocols at no additional cost and without a need to install any additional hardware or software in the VFD:

    i.   BACnet MS/TP

   ii.   Johnson Controls Metasys N2

  iii.   Modbus RTU

   iv.   Siemens FLN P1

    v.   FC protocol

VI. ADJUSTMENTS

A. The VFD shall have a manually adjustable carrier frequency that can be adjusted in 1 kHz increments up to 6 kHz, 2 kHz increments up to 12 kHz, and 4 kHz up to 16 kHz to allow the user to select the desired operating characteristics. The VFD shall also be programmable to automatically reduce its carrier frequency to avoid tripping due to thermal loading.

B. Two independent setups shall be provided.

C. Eight preset references per setup shall be provided for a total of 16.

D. Each setup shall have two programmable ramp up and ramp down times. Acceleration and deceleration ramp times shall be adjustable over the range from 1 to 3,600 seconds. The shape of these ramps shall be automatically contoured to ensure no-trip acceleration and deceleration.

E. Each setup shall be programmable for a unique current limit value. If the output current from the VFD reaches this value, any further attempt to increase the current produced by the VFD will cause the VFD to reduce its output frequency to reduce the load on the VFD. If the VFD trips on one of the following conditions, the VFD shall be programmable for automatic or manual reset: external interlock, under-voltage, over-voltage, current limit, over temperature, and VFD overload.

F. The number of restart attempts shall be selectable from 0 through 20 or infinity and the time between attempts shall be adjustable from 0 through 600 seconds.

G. An automatic "start delay" may be selected from 0 to 10 seconds. During this delay time, the VFD shall be programmable to either apply no voltage to the motor or apply a DC braking current if desired.

H. Three programmable critical frequency lockout ranges to prevent the VFD from operating the load at a speed that causes vibration in the driven equipment shall be provided. Semi-automatic setting of lockout ranges shall simplify the set-up.

I. When incorporated in the air handler's design with an optional electro-mechanical bypass, provide a manual 2-contactor bypass consisting of a door interlocked main disconnect pad lockable in the off position, a built-in motor starter and a three position DRIVE/OFF/BYPASS switch controlling two contactors. In the DRIVE position, the motor is operated at an adjustable speed from the VFD. The VFD can be remotely controlled in this position with a pilot relay and analog signal or can be controlled manually using the hand function on the VFD LCD. In the OFF position, the motor and VFD are disconnected. In the BYPASS position, the motor is operated at full speed form the AC power line. In case of an external safety fault, a customer supplied normally closed dry contact shall be able to stop the motor whether in DRIVE or BYPASS mode.

VII. SERVICE CONDITIONS

    A. Ambient temperature, continuous, full speed, full load operation:
-   i.   VFD shall be available in enclosure types: UL Type 1 (NEMA 1) and IP20.
-   ii. VFD shall be able to operate at full output current in the temperature range of 0 to 40°C (32 to 104°F).
- iii. VFD must be capable of operation at 50°C (122°F). The nameplate shall indicate any reduced VFD output current.
- iv. VFD shall be capable of operation to a minimum of -10°C (14°F) with reduced performance.

    B. VFD shall be capable of operation in an environment with a relative humidity of 0% to 95%, non-condensing.

    C. VFD shall be capable of operation up to an elevation to 1000m (3,280 feet) without de-rating.

    D. VFD shall be capable of full output current with an AC line voltage variation of -10 to +10% from nominal input voltage.

    E. All VFDs shall be plenum rated.

    F. VFD shall require no side clearance for cooling. All power and control wiring shall be done from the bottom.

VIII. QUALITY ASSURANCE

    A. To ensure quality, the VFD shall be tested by the manufacturer. The VFD shall drive a motor connected to a dynamometer at full load and speed and shall be cycled during the automated test procedure.

IX. SUBMITTALS

    A. This specification lists the minimum VFD performance requirements for this project. Each supplier shall list any exceptions to the specification. If no departures from the specification are identified, the supplier shall be bound by the specification.

    B. Total harmonic distortion level estimation. If requested, the manufacturer shall perform an analysis to initially demonstrate the supplied equipment will meet the IEEE 519-1992 recommendations after installation. In such instances, the owner or engineer shall provide the manufacturer with detailed electrical power single line diagram showing all impedances in the power path to the VFDs. Analysis shall provide the estimated total harmonic distortion levels. Point of common coupling shall be the secondary of the utility transformer. Any additional harmonic filtering equipment required to meet the IEEE 519-1992 recommendations shall not be the responsibility of the HVAC manufacturer.

X. EXECUTION

    A. Start-up Service - The manufacturer shall provide start-up commissioning of the VFD and its optional circuits by a factory certified service technician who is experienced in start-up and repair services. Sales personnel and other agents who are not factory certified shall not be acceptable as commissioning agents. Start-up services shall include checking for verification of proper operation and installation for the VFD, its options and its interface wiring to the building automation system.

    B. Warranty - The VFD shall be warranted by the manufacturer for a period of 36 months from initial start-up or 42 months from date of shipment, whichever is less. The warranty shall include replacement equipment or parts as well as a labor allowance for expenses incurred by the manufacturer to provide factory authorized on-site service.