Protecting Against VFD Front End Damage

General Application

- Line side of VFD
- Protection for diodes
- Current limiting of charging currents
- Protection of motor drive electronics

This application note offers advice about protecting input rectifiers (diodes) and pre-charge circuitry from failure due to transient over voltage and in-rush current.

During normal operation, variable frequency drives (VFDs) may be exposed to transient overvoltage due to capacitor switching, utility equipment switching or lightning. Diodes in the input rectifier stage may be damaged by excessive transient voltage. Pre-charge circuit components may be damaged if an automatic restart is attempted prior to complete discharging of the DC bus capacitor.

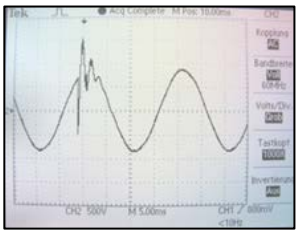
This paper explains simple ways to protect the VFD input rectifier diodes from voltage transients and to protect the pre-charge circuit components from damaging inrush currents.

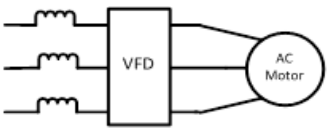
Approvals / Standards

- UL Listed (E173113)
- IEC/EN60076-6 VDE0532-76-6

RoHS 2011/65/EU

Transient Voltage Waveform





VFD with input line reactor

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Input rectifier failures can be experienced when variable frequency drives (VFDs) are subjected to severe voltage transients. Diode failures may occur due to excessive peak voltage associated with a transient. Diode failure may also be caused by excessive charging current that can occur during restarting of a VFD if the dc bus capacitors have not fully discharged.

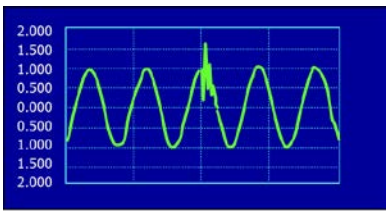

Fig. 1 Voltage transient at VFD

Fig. 1 shows a voltage transient as measured at the input terminals of a VFD. In this case, it is produced by switching of a utility power factor capacitor. The amplitude of the peak voltage at this location is dependent upon the instantaneous voltage available at the moment switching occurs. This is a function of the system voltage and the instantaneous value of voltage on the waveform. If the capacitor is switched near the peak of the voltage sine wave (Fig. 2), then the transient can be as large and may double the peak voltage. If the capacitor switching occurs at a point in the voltage sine wave that is near to the zero axes, the transient can be lower in amplitude. Capacitor switching near the peak of the sine wave and near the zero cross are illustrated below in Fig 2.

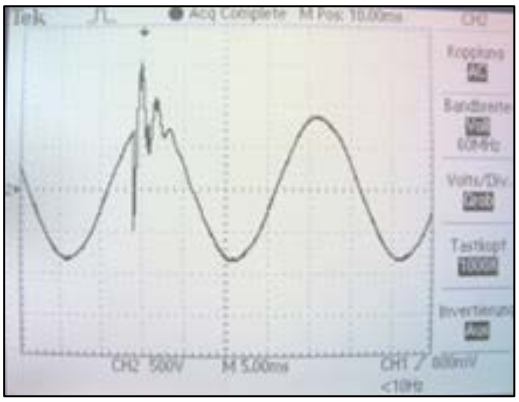

Fig. 2 Capacitor switched near voltage peak

Most capacitor switching is not synchronized with the AC line voltage and therefore occurs randomly. Peak transient voltage due to capacitor switching will therefore be anywhere up to about 2.0 p.u. and will often cause VFDs to trip off due to activation of their over-voltage protection feature.

Another source of transient voltage is lightning. This is more severe than capacitor switching and may cause immediate and catastrophic damage to drives. For best protection, lightning arrestors and transient voltage surge suppressors (TVSS) should be used. The amplitude of the peak voltage at the drive terminals due to lightning will depend on the location of the strike and the impedance between the strike and the drive.

When a VFD trips off-line due to either over-voltage or under-voltage, the drive shuts down and the DC bus capacitors need one minute or longer to fully discharge. Restarting the VFD before the DC bus capacitors have fully discharged may cause excessive charging current to flow through the pre-charge circuit components and into the DC bus capacitor. This may damage the DC bus capacitor or pre-charge components.

The magnitude of inrush current into the DC bus capacitor and pre-charge circuit is a function of the available short circuit current, the amount of DC bus capacitance, and the amount of input circuit impedance. The line reactor increases the impedance at the input of the drive and thereby reduces inrush current. For this function, it is very important to use a line reactor with high linearity so the maximum inductance is available to be used against the high peak current.

Protection of the diodes and against inrush current can typically be accomplished by the addition of a line reactor in series with the input terminals of the drive. As the name implies, the line reactor is connected at the line (input) side of the drive.

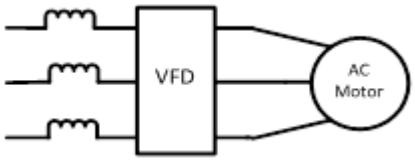

Fig. 3 VFD + Motor with AC Line Reactor

The purpose of the line reactor is to absorb a significant amount of the voltage transient so that the residual peak voltage is within the withstand voltage level of the diodes. By absorbing transient energy on the AC input lines. In order to be effective, the line reactor should be minimum of 3% impedance, but 5% impedance is recommended for best protection. For protection against lightning, the facility needs to be protected through the use of lightning arrestors and TVSS, which is beyond the scope of this technical note.

Additionally, the reactor functions as a current limiting device by inserting impedance into the input circuit of the drive. The reactor limits the amount of inrush current that can flow into the drive. Higher impedance means current will be limited to a lower value; therefore, the line reactor should be rated 5% impedance for best protection.

Although some VFDs may include internal DC reactors (chokes), these will not offer protection for the input diodes, nor limit the inrush current into the DC bus capacitors and pre-charge circuit. If the drive has an internal DC choke, it is still possible and advisable to add an input line reactor (5% impedance).

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