Monthly Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #25

(Proper Grounding and VFD Cables)

Background

As previously mentioned in Application Guideline #12, PWM drives utilizing Bipolar Junction Transistors (BJTs) or IGBTs can cause Electric Discharge Machining (EDM) currents. PWM inverters excite capacitive couplings between the stator windings, the rotor and the stator frame. This common mode current does not circulate but rather travels to ground (see Figure 1). The path to ground can be through both motor bearings and/or load or auxiliary equipment bearings (see Fig 2 below).

Fig.1 Capacitively coupled current flow

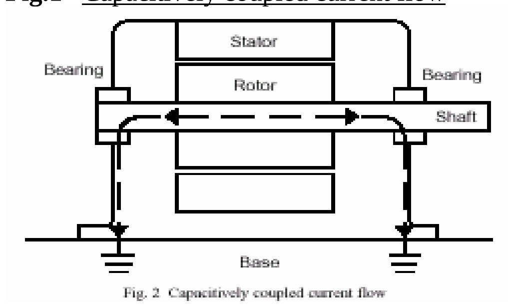
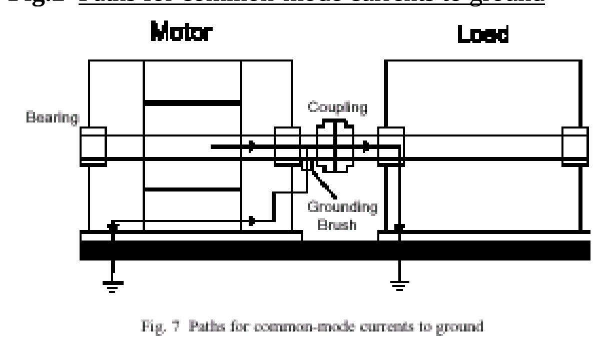


Fig.2 Paths for common-mode currents to ground



The existence of EDM currents with PWM voltage source inverter drives depends on the presence of all of the following conditions:

1. Excitation, which is provided by the source voltage to ground
2. A capacitive coupling mechanism, between stator and rotor
3. Sufficient rotor voltage build-up which is dependent on the existence of bearing capacitance

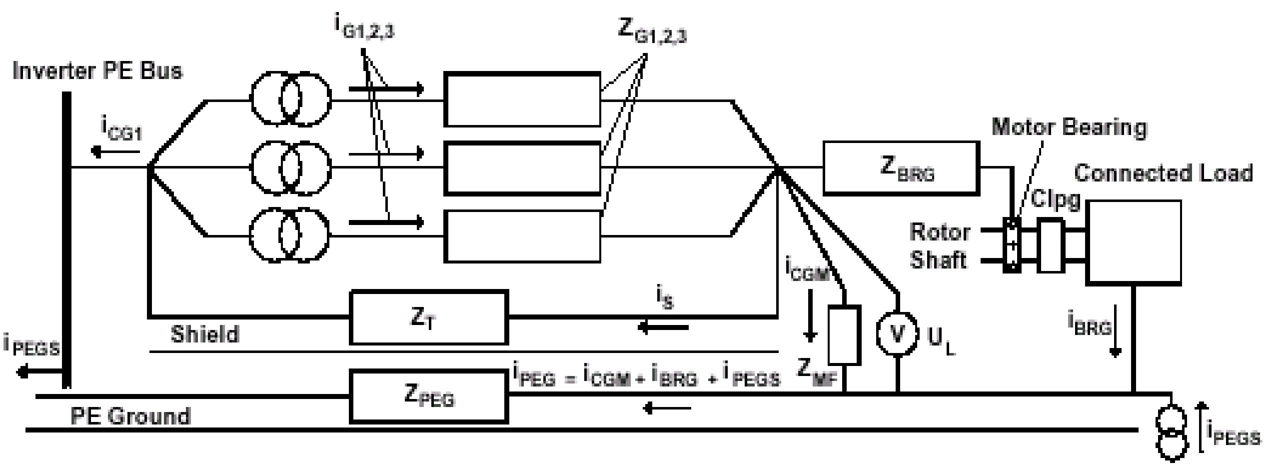
Proper Grounding

Common mode current flows from the three phases to ground through distributed capacitance. There is capacitance between the stator windings and the rotor and between the stator windings and the motor frame. The rotor can become "charged" due to this capacitance and as discussed above can discharge through the motor bearings to ground or through the connected load to ground. The capacitance between the stator windings and the frame can cause the frame to become "charged" if it is not properly grounded. Without getting into a detailed explanation, the common mode voltage and current are at high frequencies. Standard round, code sized, ground conductors can have relatively high impedance to high frequencies, especially if the cable length is greater than a few feet. It is advisable to provide a ground strap between the motor base and the load's base, especially if the load's base is well grounded to the building structure or in the case of a pump, connected to ground through the water piping system. This method of grounding affords much lower impedance to high frequencies. Alternatively, the motor base can be welded to the mechanical load's base. This is important for both personnel safety and to prevent current flow through the bearings from the motor frame, through the bearings then to ground through the load bearing(s).

VFD Cables

Another method of minimizing motor frame voltages and to help minimize common mode current is to use a proper cable. According to a paper titled "Evaluation of Motor Power Cables for PWM AC Drives,"[1] the recommended cable has a solid, corrugated sheath (or armor) with three symmetrical conductors and three symmetrical ground wires. To take advantages of the benefits of this cable, proper cable terminators are required. A cable, which almost works as well, has the same construction but only a single ground conductor. This type of cable is available from several companies. Some companies are manufacturing cables specifically for ASD applications. For example, Rockbestos manufactures a cable called Gardex. Alcatel manufactures Alcatel VFD Cable. These cables look similar to Teck cable but Teck cable has a wound, interlocking armor instead of the continuous corrugated armor of the recommended cables.

Fig. 3: Equivalent Schematic of a typical cable



$Z_{G1,2,3}$	is the common mode impedance in each of phases 1, 2 & 3
Z_{BRG}	is the equivalent bearing impedance
Z_S	is the shield or sheath impedance
Z_{MF}	is the common mode impedance to ground through the motor frame
Z_T	is the cable-shield or sheath-transfer impedance
Z_{PEG}	is impedance of the Protective Earth Ground
$i_{G1,2,3}$	is the common mode current in each of phases 1, 2 & 3
i_S	is the shield or sheath current
i_{PEG}	is the Protective Earth Ground current
i_{CGM}	is the common mode current through the motor frame to ground
i_{BRG}	is the bearing current to ground
i_{PEGS}	is the Protective Earth Ground System current flowing from other parts of the system
U_L	is the Transfer Impedance voltage drop

The figure above is the equivalent schematic of a typical cable. Due to the existence of stray capacitance, cables cause common-mode currents to flow. If the motor frame is not grounded (Z_{MF} is open-circuited) or if Z_{MF} has a high impedance to high frequencies, the return path for common-mode current is the cable shield (or armor). Shield currents produce a resultant cable-transfer impedance (Z_T) voltage drop, shown as U_L. The higher the value of the cable-shield or sheath-transfer impedance (Z_T) and of common-mode impedance to ground through the motor frame (Z_{MF}), the more likely discharge will occur through the alternative current return path, which is through the PE Ground via the motor and/or load bearings. Testing has shown that cables which have a continuous shield or continuous armor provide the lowest common-mode current plus relatively low frame voltage. The recommended cable for PWM ASD application has six symmetrical conductors (3∅ and 3 ground conductors), with a continuous corrugated-aluminum armor-type sheath. To ensure that the cable characteristics are fully exploited, proper connectors need to be utilized to maintain low ohmic contact resistance to the armor which essentially becomes a shield.