TM GE Automation Systems

How Isolation Transformers In MV Drives Protect Motor Insulation

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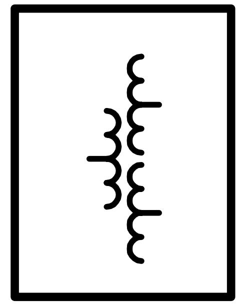

Motors connected to medium voltage drives see voltages different from the voltages imposed by fixed frequency utility power. Isolation transformers are included as standard in GE-Toshiba Dura-Bilt5i® MV drives. Some competitors' offerings propose substituting reactors for drive input isolation transformers to reduce first cost.
Find out why this approach stresses motor insulation enough to require using a special higher cost motor and why it cannot be used with existing standard motors.

Motors on Utility Power When a motor is fed directly from 3-phase utility power, the voltage applied to the motor windings and the current flowing through them are both sinusoidal in nature and in-phase with one another at the motor inputs. Assuming all three power phases coming into the motor windings are equal in the neutral (center) point of a wye-wound motor will very near the zero volt potential of the earth ground connection to the motor chassis. Figure 1 below illustrates this idea. The good result is that the winding insulation within the crowded winding slot area of the motor is subjected only to normal phase-to-ground and phase-to-phase voltage stresses.

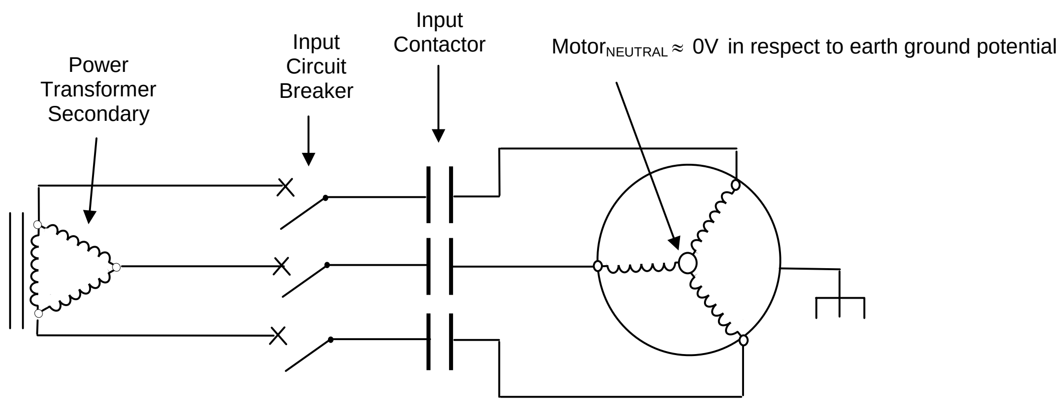

Figure 1. Utility Fed AC Motor Simplified Diagram

What If the Neutral Was Not at Zero?

If for some reason the neutral point in the motor were to somehow be shifted to some voltage level other than zero, then the winding insulation would be subjected to an increase in overall voltage stress. This new neutral-to-ground voltage level is additive to the normal phase-to-ground and phase-to-phase voltage stress levels. This additional stress is of special concern in the winding slot area of the motor due to the tight phase-to-chassis spacing**.**
Drive *Neutral shift* means that motor's neutral point potential to varies with respect to system neutral. In turn, system neutral potential is ideally very close to zero volts with respect to true earth ground potential.

Common Mode Voltage

The primary cause of a voltage shift at a motor's neutral point is *common mode voltage* created by AC motor drives. *Common mode voltage* is generally defined as any voltage that is common to both conductors of a pair. This common mode voltage shows up at the motor neutral point. The drive power circuit arrangement, also called its topology, affects level of voltage stress experienced by the motor due to this "neutral point shift". Two families of drive topologies and their difference follow.

Current Source and Voltage Source AC Motor Drives

Of the various types of AC drive methodologies currently employed, the first models that came to market were *current source* drives. The vast majority of modern MV drives being placed into service today are *voltage source* drives. The terms *current source* and *voltage source* derive from the form of the source for the energy being switched. Current source drives switch current stored in inductors to the output motor phases, while voltage source drives switch voltage stored in a capacitor to the motor phases. Figures 2a and 2b illustrate these two drive types.

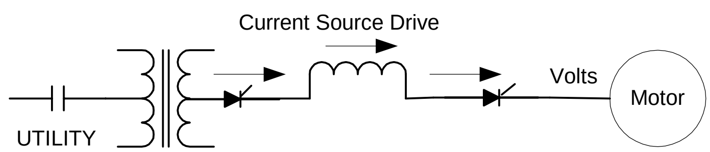

Figure 2a General Current Source Drive Arrangement

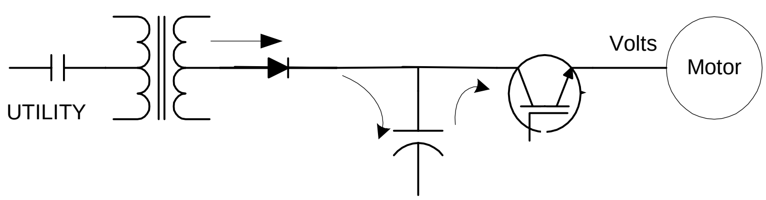

Figure 2b General Voltage Source Drive Arrangement

As a general rule, *current source* AC induction motor] drives [such as Allen Bradley Powerflex™ 7000] generate a greater level of *neutral shift* than the more modern voltage source drives, such as the GE Toshiba Dura-Bilt5i® MV. Figure 3 shows a simplified schematic of a typical *current source* AC drive with reactors feeding the drive from a grounded wye Utility transformer source. Until recently, most current source drives used isolation transformers between the utility source and the drive. As we shall see, the configuration of Figure 3 subjects the motor to much more ground insulation stress than the transformer isolated arrangement to be described later.

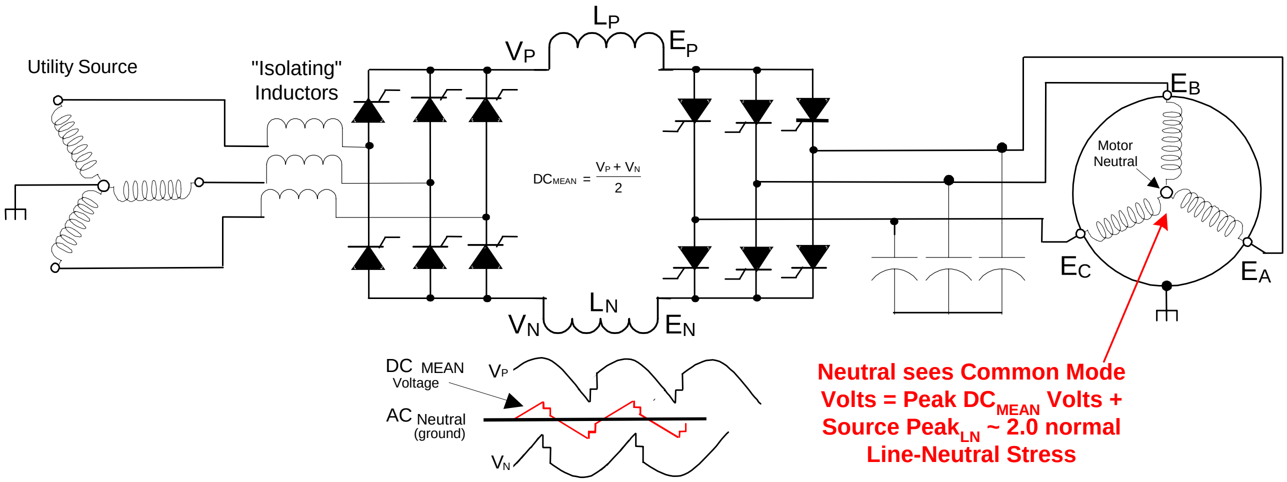

Figure 3 Typical Current Source AC Motor Drive
with Grounded WYE Power Source

The drive illustrated in **Figure 3** above consists of two, 6-thyristor converters, with their DC terminals coupled together through a pair of DC link inductors. The input converter changes the incoming AC into positive and negative DC bus voltages through phase-angle control of the firing of the thyristors. The waveform diagram, (below the schematic) shows the V_P and V_N outputs of the input converter during one cycle of utility power, with the firing angle of the thyristors delayed by 20°, as this is typical of full-speed, full-load operation.

Why Does the Neutral Shift?

The center trace of the waveform in Figure 3 shows the component of AC Neutral voltage impressed by the drive in addition to normal line voltage. This component of voltage causes the neutral point potential of the motor varies a lot with respect to frame and earth ground potential. There are two basic sources for this neutral shift voltage component:

1) In a current-source VFD only two of the motor's three inputs will be carrying current at any one time. Because of this, the wye center point between these two conducting windings acts as the center point of a voltage divider between the conducting phases. This wye center point will always be at the same voltage potential as the mean [average] voltage between the positive and negative DC bus potentials.

2) The mean value of the two DC bus voltages must be equal for both utility input and motor output converters. As all points in a series circuit have equal amounts of current flowing through them. Since the DC link inductors are of equal value, the voltage drop across both inductors will be equal as well.

The Impact of Neutral Shift on System and Motors

The operation of each of the two converters causes the mean value of its DC system to vary in respect to the neutral of the AC system connected to that converter. If the AC neutral feeding the input converter is grounded, (as shown Figure 3) then the AC neutral of the motor connected to the output converter will be shifted by the sum of these differences of the DC system from ground.

The DC mean voltage generally varies at three times the motor [inverter output] frequency, with the DC mean peak voltage value reaching 38% to 50% of the phase-to-neutral voltage. The output frequency of the inverter converter is generally different from the utility input frequency, so their respective peaks will periodically coincide. Since the variation of either DC bus, connected by an inverter switch to its phase winding, can reach 50% of the input phase-to-neutral voltage, the sum of the variations can reach 100% of input Line-Neutral voltage. When added to the normal 100% L-N voltage, the DC bus variation effectively doubles the nominal phase-to-neutral voltage stress on the winding insulation in the motor winding slots.

The Bottom Line The additional voltage stress created by *neutral point shift* may not cause an immediate motor insulation failure, but the effective life of a standard motor can be significantly shortened. Its winding insulation could be degraded by corona discharge induced by the higher voltage stress.
The extra voltage present prevents standard, existing motors from be safely applied to current source drives with only input reactors isolation. In their published Powerflex^{TM} 7000 Brochure literature, Allen Bradley states that the elimination of the Drive Isolation Transformer on 6-Pulse and PWM rectifier designs is “for new motor applications”, meaning applications where the user can specify double insulation levels.
For the benefit of a possibly lower priced MV drive, the user would have to spend more to buy a motor having 10 kV to 12 kV class insulation to withstand the additional voltage stress placed on the slot liner. This special motor would not always be easily replaced in the event of a failure. Such a motor is more costly, larger, and possibly less efficient. Not good.

Solving the Neutral Shift Problem with an Isolation Transformer

The same *current source* AC drives can avoided the *neutral shift* problem of common mode voltage stress by using isolation transformers on the input of the drive. **Figure 4** shows such a configuration. GE’s successful GTO Induction Motor Drives all used this configuration.

The neutral of the isolation transformer secondary in Figure 4 is ungrounded, so any *common mode* voltage generated by the drive is now "shared" between the isolation transformer secondary neutral and the motor neutral. This sharing is in inverse proportion to the winding capacitances of the transformer and the motor. Motors usually have a winding to ground capacitance of 150 times that of a typical transformer. As shown in Figure 4, the relatively high coupling capacitance of the motor causes almost all the common mode voltage to appear on the transformer winding instead of the motor winding. This is a good thing, because a transformer's secondary insulation is rated much higher than motor winding insulation and is well able to handle this additional stress. Additionally, unlike motors, transformer windings are not laid into slots close to grounded steel magnetic material. This means that any voltage appearing on transformer windings does not subject ground insulation to the same degree voltage stress as motor windings.

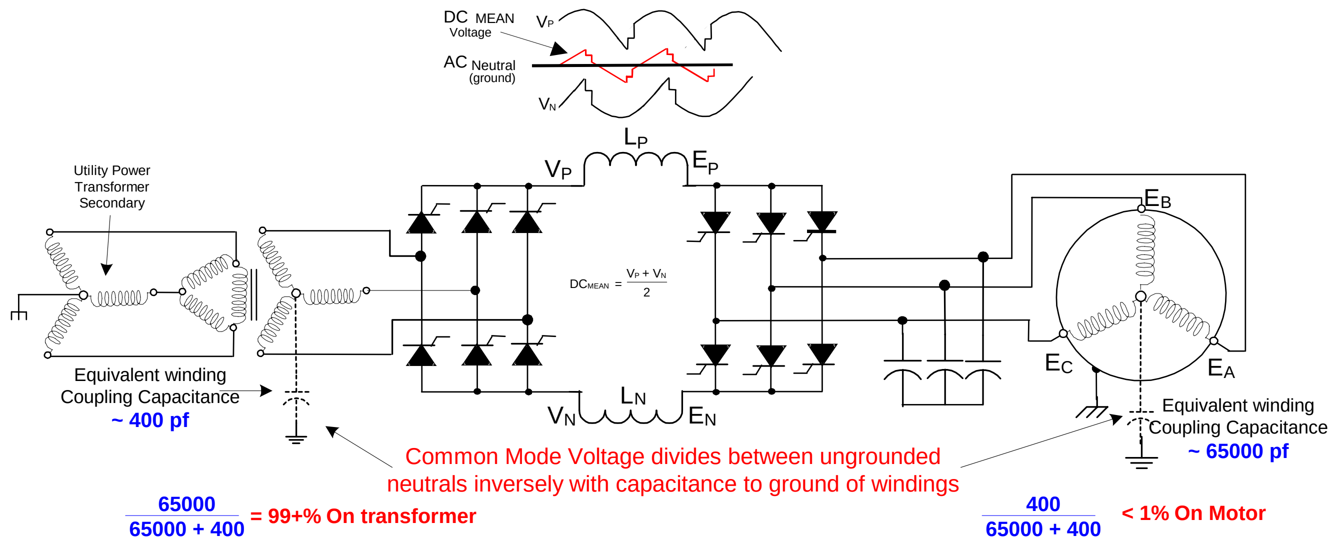

Figure 4 Typical Current Source AC Motor Drive
With Input Isolation Transformer

In summary, the use of an isolation transformer does not actually *eliminate* neutral point shift, but instead transfers the effect from the motor, (where it could eventually cause motor insulation failure) and applies it to the transformer, which can handle the additional stress without creating problems.

Conclusion

Including an isolation transformer in AC MV drives is an effective way to eliminate excess voltage stress in connected motors. Modern drives such as the Dura-Bilt5i® MV include isolation transformers as standard. Substituting reactors for transformers does not provide true protection, requires the special motors, and simply shifts costs and problems to the motor. Don't be caught!

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