The proper application of power capacitors to a bus with harmonic currents requires an analysis of the power system to avoid potential harmonic resonance of the power capacitors in combination with transformer and circuit inductance. For power distribution systems which have several motors connected to a bus, power capacitors connected to the bus rather than switched with individual motors are recommended to minimize potentially resonant combinations of capacitance and inductance, and to simplify the application of any tuning filters that may be required. This requires that such bus-connected capacitor banks be sized so that proper bus voltage limits are maintained. [MG1-30.1.3] (See MG1 Part 14.)

12. APPLICATION CONSIDERATIONS FOR GENERAL PURPOSE DESIGN A AND B INDUCTION MOTORS USED WITH ADJUSTABLE-VOLTAGE OR ADJUSTABLE-FREQUENCY CONTROLS OR BOTH

12.1 Torque

12.1.1 Motor Torque During Operation Below Base Speed

To develop constant torque below base speed by maintaining constant air-gap flux the motor input voltage should be varied to maintain approximately rated volts per hertz. At frequencies below approximately 30 hertz an increase in the volts per hertz ratio (boost voltage) may be required to maintain air-gap flux (i.e., constant torque). For applications that require less than rated torque below base speed, system economics may be improved by operation at a reduced volts per hertz ratio. [MG1-30. 2.2.2.1]

12.1.2 Torque Derating at Reduced Speeds

Induction motors to be operated in adjustable-speed drive applications should be derated as a result of the reduction in cooling of the motor resulting from the reduction in operating speed and the effect of the additional losses introduced by harmonics in the power source. The effect of derating must be evaluated on an application-by-application basis. [MG1-30.2.2.2.2 and MG1-30.2.2.2.3]

12.1.3 Motor Torque During Operation Above Base Speed

Above base speed, a motor input voltage having a fundamental component equal to rated motor voltage (which may be limited by the control and its input power) as frequency increases will result in constant horsepower operation (torque reducing with reduced volts per hertz). The maximum (breakdown) torque capability of the motor within this speed range will limit the maximum frequency (and speed) at which constant horsepower operation is possible.

General purpose motors are capable of constant horsepower above base speed up to 90 Hz. The maximum frequency of 90 hertz is established based on the approximate peak torque capability of greater than 175 percent for NEMA Design A and B motors assuming operation at a constant level of voltage equal to rated voltage from 60 to 90 hertz. For the capability of motors for which the minimum breakdown torque is less than 175 percent, consult the motor manufacturer.

For operation above 90 hertz at a required horsepower level, it may be necessary to utilize a motor with a greater horsepower rating at 60 hertz.

However, the maximum speed at which a motor can safely operate may be limited to some speed below the maximum speed related to its load carrying capability because of mechanical considerations. (See 12.4.) [MG1-30. 2.2.2.4]

12.2 Current

12.2.1 Running Current

Controls are generally rated in terms of a continuous output current capability, a short term output current , and a peak output current. To properly choose the size of control required in an application, consideration should be given to the peak and transient values in addition to the rms value of motor current, and the manner in which the system is to be operated. Because some level of current will exist at each of the harmonic frequencies characteristic of the particular type of control, the total rms sum of current required at full load may be from 5 percent to 10 percent greater than that level of current corresponding to operation on a sinusoidal power source. The magnitude of the peak values of the current waveform may vary from 1.3 to 2.5 times the rms value of the current, depending on the type of control considered and the motor characteristics. An additional margin from 10 percent to 50 percent in the current rating of the control should be considered to allow for possible overload conditions on the motor so as not to trip the control on such short time overcurrent demand. When the motor and control are used in a system where sudden changes in load torque or frequency might occur, the control should be sized based on the peak value of the transient current which results from the sudden change. Also, when changing from one operating speed to another, if the rate of change in frequency is greater than the possible rate of change in motor speed and if the slip increases beyond the value of slip at rated load, then the amount of rms current or peak current required from the control may exceed that of the steady state requirements. [MG1-30. 2.2.4.1]

12.2.2 Starting Current

In a stall condition, the amount of current drawn by an induction motor is primarily determined by the magnitude and frequency of the applied voltage and the impedance of the motor. Under variable frequency control, motors are normally started by applying voltage to the motor at a low frequency (less than 3 hertz). The current drawn by the motor under this condition is mainly a function of the equivalent stator and rotor resistances since the reactive impedance is small because of the low frequency. In order to provide sufficient starting torque, it is necessary to provide an increase in voltage (voltage boost) at low frequencies in order to overcome this resistive drop in the motor. This voltage boost is the product of the required phase current (for the level of breakaway torque needed) and the stator phase resistance and the square root of 3 (to convert phase quantity to line-to-line value). A wye connection is assumed. For rated torque at start it will be necessary to adjust the voltage boost to have at least rated current. Since stator and rotor resistances vary with temperature, the actual starting current will be a function of the machine temperature. [MG1-30. 2.2.4.2]

12.3 Efficiency

Motor efficiency will be reduced when it is operated on a control. The harmonics present will increase the electrical losses, which decrease efficiency. This increase in losses will also result in an increase in motor temperature, which further reduces efficiency. [MG1-30. 2.2.5]

12.4 Maximum Safe Operating Speeds

The maximum safe operating speed capability of a typical standard general-purpose Design A or B motor, direct-coupled, at 0–40°C ambient temperature should not exceed the values given in Table 54. For possible operation at speeds greater than those given in the table or conditions other than those stated consult the motor manufacturer. For motors not covered by the table, refer to 9.16 consult the motor manufacturer if required. [MG1-30. 2.2.3]

12.5 Sound

Sound levels should be considered when using induction motors with an adjustable frequency and voltage power supply. Sound levels produced thus will be higher than published values when operated above rated speed.

Experience has shown that typically an increase in the A-weighted noise level by up to 6 dB can occur at rated frequency when motors are used with non-PWM (pulse width modulated) controls, in comparison with operation at sinusoidal supply voltage and frequency. An increase of up to 5 dB to 15 dB can occur at rated frequency in the case when motors are used with pulse-width-modulated PWM controls. For other frequencies the noise levels may be higher. [MG1-30. 2.2.6]

12.6 Resonances, Sound, Vibration

When an induction motor is operated from a control, torque ripple at various frequencies may exist over the operating speed range. Consideration should be given to identifying the frequency and amplitude of these torques and determining the possible effect upon the motor and the driven equipment. It is of particular importance that the equipment not be operated longer than momentarily at a speed where a resonant condition exists between the torsional system and the electrical system (i.e., the motor electrical torque). For example, if the inverter is of the six-step type then a sixth harmonic torque ripple is created which would vary from 36 to 360 hertz when the motor is operated over the frequency range of 6 to 60 hertz. At low speeds, such torque ripple may be apparent as observable oscillations of the shaft speed or as torque and speed pulsations (usually termed "cogging"). It is also possible that some speeds within the operating range may correspond to the natural mechanical frequencies of the load or support structure and operation other than momentarily could be damaging to the motor and or load and should be avoided at those speeds. [MG1-30. 2.2.7]

12.7 Voltage Stress

When operated under usual service conditions the following voltage limit values at the motor terminals should be observed. [MG1-30. 2.2.8]

$V_{peak} \leq 1kV$

Rise time $\geq 2\mu s$

12.8 Power Factor Correction

The use of power capacitors for power factor correction on the load side of an electronic control connected to an induction motor is not recommended. {MG1-30. 2.2.9]

12.9 Operation in Hazardous (Classified) Locations

WARNING: Motors operated from adjustable frequency or adjustable voltage power supplies or both, should not be used in any Division 1 hazardous (classified) locations unless the motor is identified on the nameplate as acceptable for such operation when used in Division 1 hazardous (classified) locations

For motors to be used in any Division 2 hazardous (classified) locations, the motor manufacturer should be consulted.

Failure to comply with this warning could result in an unsafe installation that could cause damage to property or serious injury or death to personnel, or both. [MG1-30. 2.2.10]