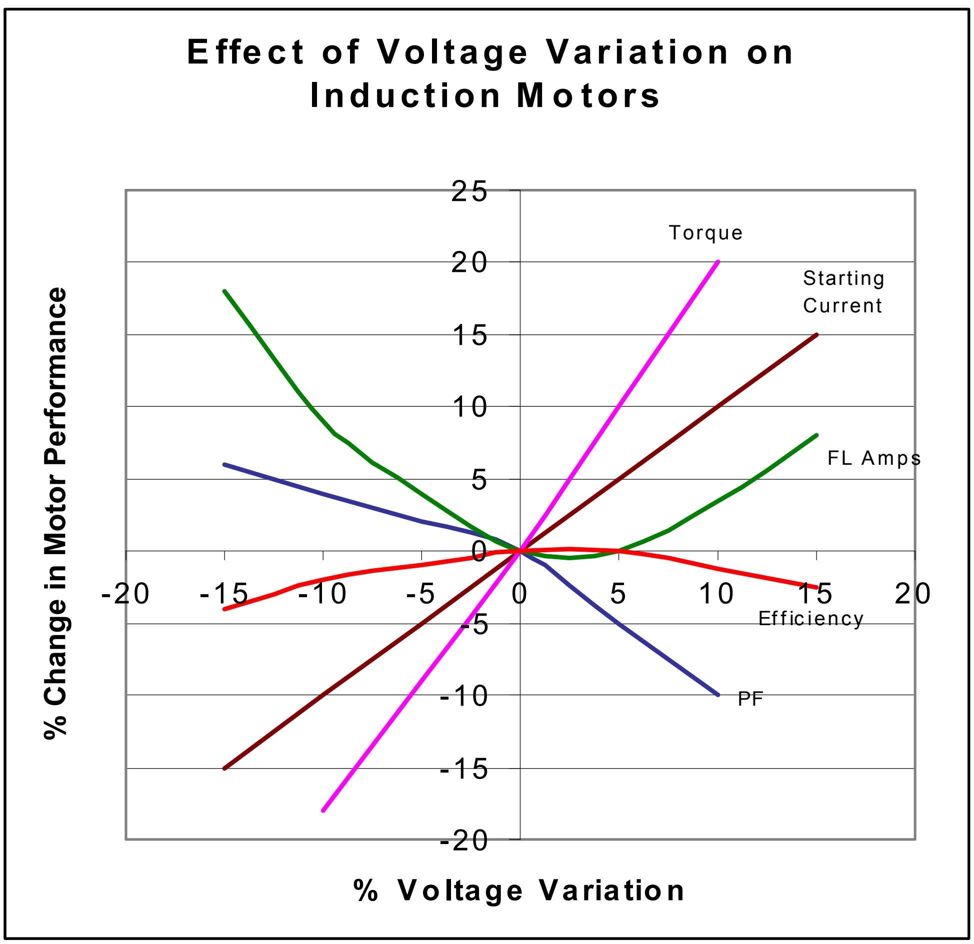
Effects of Voltage and Frequency

Effect of Voltage Variation

Polyphase induction motors are normally designed to give satisfactory performance on a line voltage of up to 10% above or 10% below the rated value per NEMA MG1-12.42. Depending on the design of the motor, voltage variation causes effects as summarized on the table below. The information is based on frequency being held constant.

Voltage	Starting and Max. Torque	Synchro-nous Speed	% Slip	Full Load Speed	Full Load Eff'y	Full Load PF	Full Load Current	Locked Rotor Current	Temp. Rise @ Full Load	Max. Overload Capacity	Magnetic Noise (No load)
110%	Increase 21%	No change	Decrease 17%	Increase 1%	Increase 0-1 point	Decrease 2-8 points	Decrease 0-7%	Increase 10-14%	Decrease 4-6°C	Increase 21%	Increase slightly
90%	Decrease 21%	No change	Increase 23%	Decrease 1%	Decrease 1-3 points	Increase 1-3 points	Increase 10-12%	Decrease 10-12%	Increase 4-8°C	Decrease 19%	Decrease slightly

The following chart graphically shows the effects of voltage on various motor parameters.



Effect of Frequency Variation

Motors built in accordance to NEMA standards are designed to operate successfully at rated load and at rated voltage with a variation in the frequency of up to 5% above or below the rated frequency (MG1-12.42). The information in the following table is based on voltage being held constant.

Freq.	Starting and Max. Torque	Synchro-nous Speed	% Slip	Full Load Speed	Full Load Eff'y	Full Load PF	Full Load Current	Locked Rotor Current	Temp. Rise @ Full Load	Max. Overload Capacity	Magnetic Noise (No load)
105%	Decrease 10%	Increase 11%	Practically No Change	Increase 5%	Slight Increase	Slight Increase	Decrease Slightly	Decrease 5-6%	Decrease Slightly	Decrease Slightly	Decrease Slightly
95%	Increase 11%	Decrease 10%	Practically No Change	Decrease 5%	Slight Decrease	Slight Decrease	Increase Slightly	Increase 5-6%	Increase Slightly	Increase Slightly	Increase Slightly

Effect of Voltage and Frequency Variation

When both voltage and frequency are changed at the same time, a motor can operate successfully if the voltage ÷ frequency (volts/Hz) ratio is kept constant. For example, if a 460V, 60Hz motor is operated at 380V, 50Hz the motor will be able to provide full rated torque. (There will be a slight increase in temperature due to reduced fan speed.) The motor will rotate at $5/6^{th}$ of the speed. Since HP = (T x RPM) ÷ 5250 the output HP will be $5/6^{th}$ as much as the 60Hz nameplate indicates. This means that to produce full HP, the torque output must increase by $6/5^{th}$. Some motors, because they run cooler than the rating of the insulation, may be able to successfully produce the full HP rating of the motor (but at a higher temperature rise). The Toolbox contains an Excel spread sheet titled “50Hz Temp Rise 1-12-98” that calculates the expected 50Hz temperature rise at full HP loading.

Effect of Voltage Unbalance

The percent voltage unbalance is defined as: 100 times the sum of the deviation of the three phases from average without regard to sign, divided by twice the average voltage.

For example, a 220V system with phase voltages of 215, 221 & 224 would have a voltage unbalance of:

$$\frac{(220 - 215) + (221 - 220) + (224 - 220)}{2 \times 220} \times 100 = 2.27\%$$

When voltage unbalance increases, locked rotor torque reduces slightly. Speed does not change appreciably but does decrease slightly. Temperature rise, however, increases dramatically. Although there are no hard and fast rules, the tendency is that the percentage increase in temperature rise is usually twice the square of the percentage of voltage unbalance. For example, if a motor is subjected to a 4% voltage imbalance, the resulting temperature increase will be approximately:

$$2 \times (4\%)^2 = 32\%$$

The Toolbox has a file named “Voltage Derating Factor.xls” which shows the Voltage Unbalance Derating curve as defined by NEMA.