Self-Excitation Concerns with Power Factor Correction on Induction Motors

Introduction

Very often power factor correction capacitors are applied to an induction (asynchronous) motor circuit to reduce the inductive or lagging current associated with the magnetizing current of the induction motor. In many applications (normally when the motor is large), a single power factor correction capacitor or filter will be applied to the load side terminals of the motor controller as illustrated in Figure 1 below. For this application, the capacitor is energized when the motor controller is closed (motor running). The benefit to this type of application is as follows:

- The reactive power requirements of the motor are only supplied when the motor is running. This effectively provides automatic control of power factor.
- Total equipment costs are reduced as the motor controller performs the capacitor switching function.
- The voltage profile to the motor is improved.

A major drawback to this type of capacitor application, however, is improper sizing of the capacitor can lead to motor failure; too large of a capacitor leads to self-excitation of the motor, which can result in motor insulation failure.

Self-excitation occurs when the capacitive reactive current from the capacitor is greater than the magnetizing current of the induction motor. When this occurs, excessive voltages can result on the terminals of the motor. This excessive voltage can cause insulation degradation and ultimately result in motor insulation failure. Figure 2 below illustrates a simplified circuit diagram for the disconnected capacitor and motor.

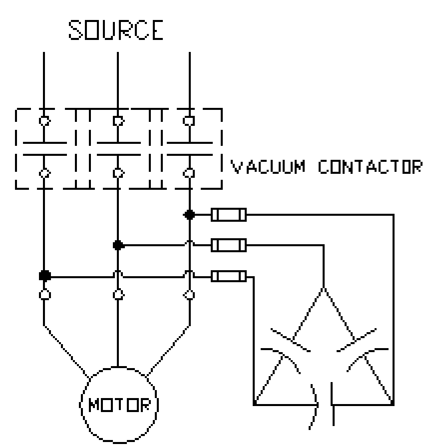

Figure 1 - Typical Power Factor Correction Capacitor Application On Induction Motor

Induction Motor Self-Excitation

To understand the phenomenon of self-excitation and why high voltage can occur, it must first be understood that when the motor is connected to the source with the motor controller closed, a rotating magnetic field is set up between the stator winding and the rotor winding of the induction motor (in the air-gap of the motor). This rotating magnetic field can be thought of as stored energy. When the motor is switched off, the stored energy still present in the air-gap of the motor begins to collapse and produce a current in the rotor winding. This rotor current induces a voltage on the stator winding and terminals of the motor which are disconnected (the motor becomes a generator). Because the motor has just been disconnected, it is still spinning due to its rotating inertial speed which will decrease in time. The decaying speed produces a subsequent voltage (and current flow through the capacitor) at a decaying frequency (starting at a value near 60 hertz). When the frequency of the motor terminal voltage equals the resonant frequency of the motor and capacitor reactance combination, high voltage may be produced. This high voltage can lead to insulation failure on the motor.

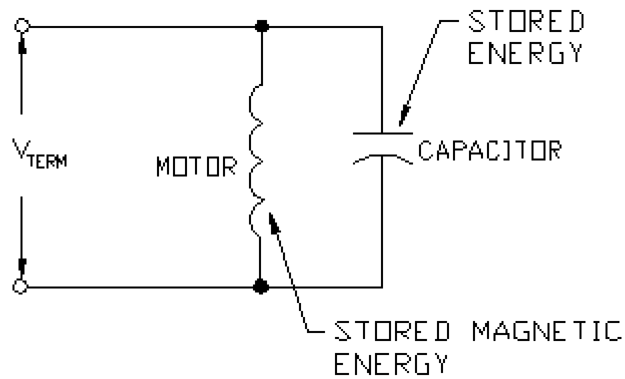

Figure 2 - Simplified Circuit Diagram for Motor Controller and Power Factor Correction Capacitors (Diagram Shown For Motor Controller in Open Position)

To create self-excitation, the capacitive reactance of the capacitor must be less than that of the motor reactance (this occurs when to large of a capacitor is chosen). This combination of reactance will result in a resonant frequency below 60 hertz (for the circuit in the above diagram). Therefore, as the motor slows in speed, the frequency of the motor terminal voltage will decrease from a value of near 60 hertz toward zero. When the motor's terminal voltage frequency passes through the resonant frequency setup between the capacitor reactance and the motor reactance, the terminal voltage will become very high, only limited by the properties of the iron. Depending on the inertia of the motor, this resonance (or high voltage) may be present for a considerable period of time.

On the other hand, if the capacitive reactance is greater than the motor magnetizing reactance (this occurs for a properly sized capacitor), the resonant frequency is greater than the motor speed (greater than 60 hertz). Under this condition, when the motor is disconnected, the frequency of the decaying terminal voltage will never correspond with the resonant frequency of the motor and capacitor reactance combination. Therefore, a high voltage condition will not occur.

Figure 3 below helps to illustrate how to large of a capacitor can result in an over voltage condition on the motor. The figure shows a plot of the capacitor and motor magnetizing voltage verses current waveforms. As can be seen, the motor magnetizing curve is sloped over, which is a characteristic of iron. The capacitor characteristic is a straight line. Two capacitor characteristics have been drawn on the plot, one which represents a properly sized capacitor, and one which represents an improperly sized capacitor (to large of a capacitor). The curve labeled "A" is sized properly because its capacitive current is less than that of the magnetizing current at nominal voltage. The curve labeled "B" is sized improperly because its capacitive current is greater than the magnetizing current at 1 per-unit voltage. When disconnected, the "B" curve in figure 3 shows a valid operating point at 140% voltage. This voltage may occur as the motor slows in speed and passes through its resonant frequency.

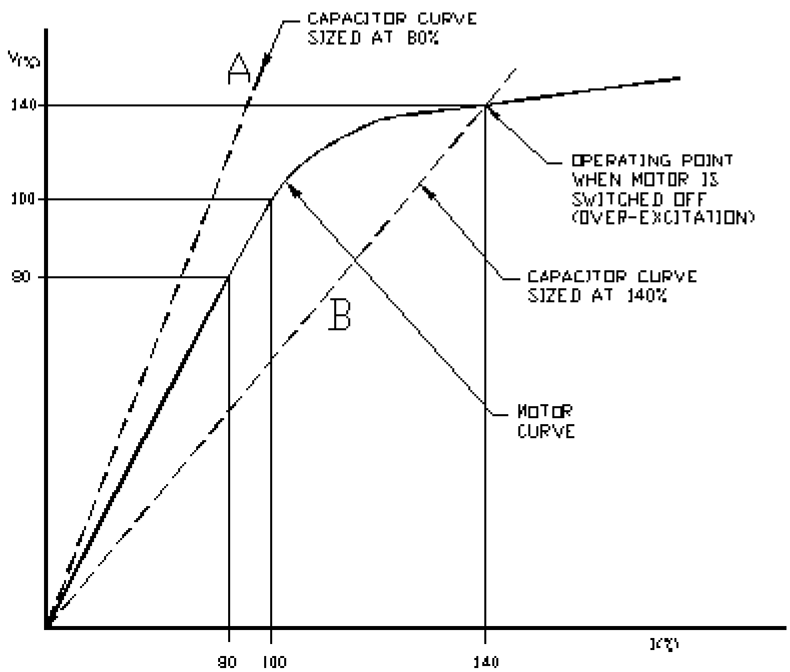

Figure 3 - Typical Motor Saturation Curve and Capacitor Characteristic Curves at a given frequency

Conclusions & Recommendations

When applying capacitors on terminals of motors, it is important that the capacitor be sized correctly. To large of a capacitor can cause self-excitation of the motor and lead to motor insulation failure.

NEPSI recommends using one of the following techniques when applying capacitors or harmonic filers directly on the terminals of an induction motor:

- Request a recommended kvar rating from the motor manufacturer.
- Size the capacitor at 80% of the no-load current rating (magnetizing current) of the motor. In no case should the rating be greater than 90%.
- Utilize recommended capacitor sizing tables induction motors. Motor tables, however, do not guarantee a properly sized capacitor and may not account for newer more efficient motor designs. The values published in these tables, have been found in many cases to be acceptable. If tables are utilized, NEPSI recommends the motor terminal voltage be checked on commissioning of the motor.
- Measure the no-load motor current and size the capacitor at 80% of the no-load current rating of the motor.

Northeast Power Systems, Inc.
66 Carey Road
Queensbury, New York 12804
Phone: 518-792-4776
Fax: 518-792-5767
E-mail: sales@nepsi.com
Website: www.nepsi.com