

PQ News

December 2007

Newsletter for EPRI Program 1, PQ Knowledge (PS1D)

During a Voltage Sag, a Coil Hold-In Device Keeps Current Flowing Through a Motor Controller to Keep the Motor On



The Effects of Holding in a Motor Starter during a Voltage Sag

Question

Via EPRI's PQ Knowledge (PQK) Power Quality Hotline, a PQK funder and one of his industrial customers asked EPRI engineers how "holding in" a control circuit and motor contactor during a voltage sag would effect his customer's motor. Could the approach lead to motor electrical or mechanical problems?

Introduction

A proven method for keeping an industrial process up and running through a typical voltage sag involves providing power conditioning for the associated control circuits. Through EPRI's power quality research and hundreds of service-related power quality testing and power quality auditing jobs, this approach has been proven effective many times over. By keeping the machine or process controller and associated control circuits protected from the voltage sag, the system can ride-through many of the events that would have normally led to process shutdowns. A typical approach for conditioning a PLC and associated motor-control circuit is shown in Figure 1.

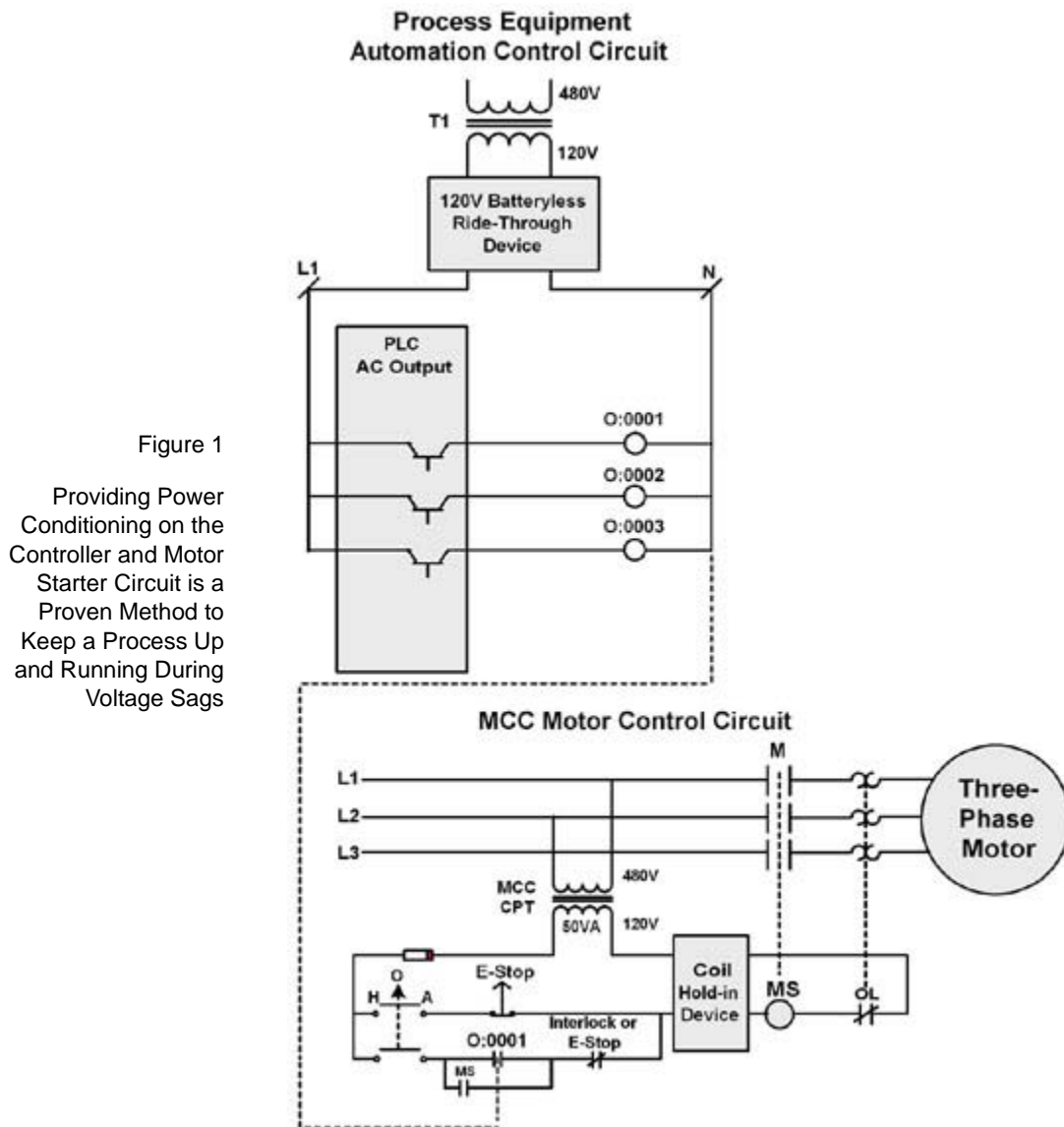


Figure 1

Providing Power Conditioning on the Controller and Motor Starter Circuit is a Proven Method to Keep a Process Up and Running During Voltage Sags

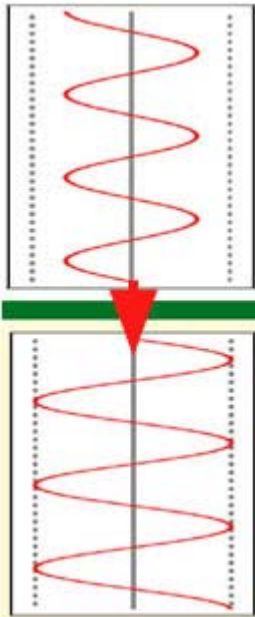
Devices That Hold in a Motor Control Circuit May Effect the Motor

If the control voltage is protected from a voltage sag, then the motor starter will remain energized during the event and the voltage and the motor terminals will remain in-phase with the supply voltage. This Hotline Call of the Month addresses the associated effects of keeping the control voltage maintained and the motor starter engaged during a voltage sag.

Simulation

In order to demonstrate the effects of voltage sags on induction motors, EPRI modeled a direct line-fed induction motor influenced by voltage sag. In order to accurately replicate the transient response of the motor, a dynamic motor model using d-q transformation [1] was modeled in MATLAB/SIMULINK. A 3-HP motor with the following parameters was modeled [2]:

Power: 3 HP/2.4 kW
 Voltage: 460 V (L-L, RMS)
 Frequency: 60 Hz
 Full Load Current: 4 A
 Full Load Speed: 1750 RPM
 Number of Poles: 4
 Full Load Efficiency: 88.5%
 Full Load Power Factor: 80.0%



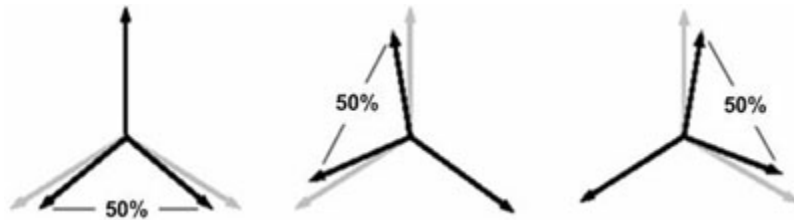
The effect of Type C voltage sag (as specified in standard IEC61000-4-34) on the motor was studied. The parameters of the sag used in this example are as follows:

- VAB (L-L voltage) sag: 50% of nominal L-L voltage
- VA (Phase A voltage): 66.1% of nominal phase L-N voltage
- VB (Phase B voltage): 66.1% of nominal phase L-N voltage
- Phase A angle: -19.1 degrees
- Phase B angle: -100.9 degrees
- Phase C angle: -240 degrees
- Sag duration: 12 cycles

The simulation used a constant load torque (6.32 Nm) of 50% of the nominal full load torque (12.64 Nm), as shown in Figure 2.

Figure 2

Simulated Motors Were Tested with Sags from Phase to Phase, According to IEC61000-4-34



Findings

Figure 3 shows a sag to 50% from phase A to phase B and the response of the torque. Figure 4 shows the response of the motor current and speed during the same event. The results of the simulation show that the motor torque begins oscillating during the sag, with peak values comparable to the starting torque of the motor. The average value of this oscillating torque is the sum of a positive torque component caused by the positively rotating sequence components and a negative torque component created by the negative sequence components that arise due to the unbalance on the three phases. No significant change in speed results except for some oscillations. However, because the motor load is constant, the stator currents increase to compensate the decrease in the voltage during the sag.

Figure 3
The Torque of the Simulated Induction Motor Oscillated During the Applied Voltage Sags

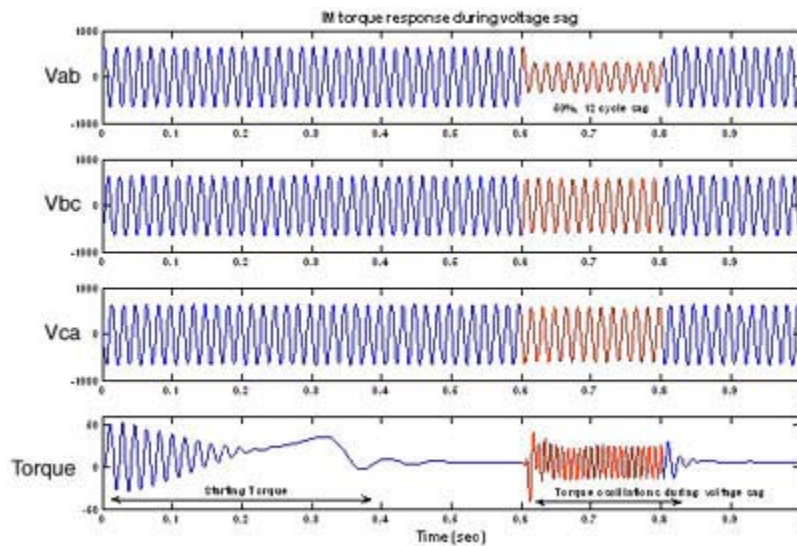
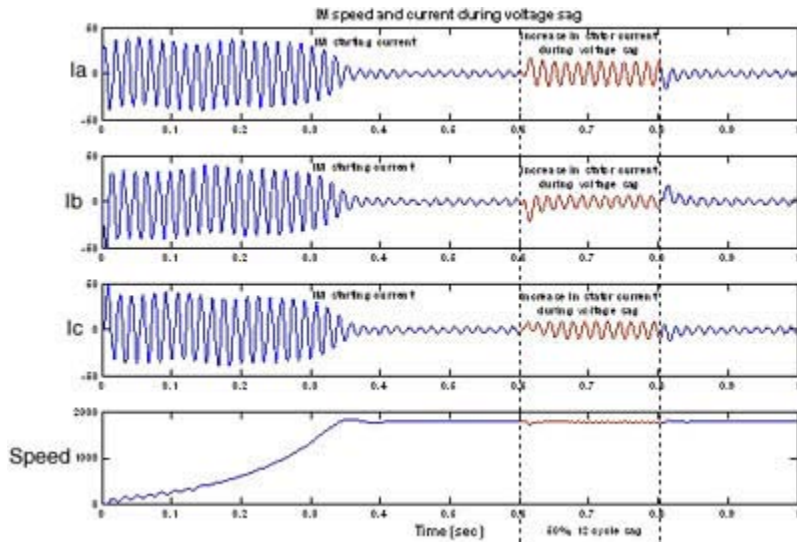


Figure 4
The Speed of the Motor Did Not Change Appreciably During the Simulation



Conclusion

To summarize, it can be stated that voltage sags cause significant torque pulsations that could be detrimental to the structural integrity of the rotor structure and shaft. A significant increase in the stator currents could cause an increase in winding temperature resulting in insulation failure. However, it is important to note that the voltage sag is a short-term transient event and the modeling shows that the torque and current transients experienced during voltage sags are less severe than those experienced by the motor at start up. Hence, it is unlikely that single voltage sag can cause enough torque oscillation or motor heating to decrease the life of a motor. However, motors subject to repetitive sags could see their life deteriorate in the long run.

While the detrimental effects of unbalances (long-duration voltage sags) and frequent motor restarts on electric motor life has been well researched, the effect of repetitive short-duration voltage sags on electric motors is still unknown. Frequent voltage sags may cause repetitive stress on the windings (through higher peak inrush currents) and rotor structure (due to the pulsating nature of the torque during sags), and may even result in insulation deterioration. However, the extent of this deterioration is yet to be ascertained. The effect of loading on the magnitude of torque oscillations is another area that must be investigated through future EPRI research.

The Effects of Repetitive Short-Duration Voltage Sags on Electric Motors Is Unknown



References and Further Reading

[1] D. W. Novotny and T. A. Lipo, *Vector Control and Dynamics of AC Drives (Monographs in Electrical and Electronic Engineering)*. Oxford University Press, USA, ISBN: 0198564392, 1996.

[2] N. Mohan, *Advanced Electric Drives: Analysis, Control and Modeling Using SIMULINK*. MNPERE, ISBN: 0-9715292-0-5, 2001.

[3] Paul C. Krause, Oleg Wasynczuk, and Scott D. Sudhoff, *Analysis of Electric Machinery and Drive Systems*. Institute of Electrical & Electronics Engineers, ISBN: 0780311019, 1995.

[4] IEC 61000-4-34, *Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests for Equipment with Input Current More Than 16A per Phase*. CDV, July 2004.

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The EPRI Program 1, PQ Knowledge (PS1D) Power Quality Hotline is provided as a service to all PQ Knowledge (PQK) funders. There are a number of ways to submit a question to the PQK Hotline, including:

Email: PQHotline@epri.com

Telephone: 1-800-832-7322

Online through the PQ Online Resource Center at www.MyPQ.net

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