Elwood High Performance Motors

Transient Voltage Evaluation White Paper

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1. Purpose

To measure and characterize voltage transients occurring in a closed loop servo application. Data gathered herewith utilized Elwood explosion proof (XP) servo motors controlled by Rockwell Kinetix 5700 drives. In extreme cases, voltage transients have been attributed to causing phase-phase shorted motor winding failures in Elwood XP motors in as little as a few weeks after installation.

2. Equipment

1) Motor: M431-NNNB-9T08
2) Drive: 2198-P070, 2198-D012-ERS3, 2198-D006-ERS3
3) Cable: 2090-CSBM1DE-18AA40
4) Oscilloscope (Tektronix TDS 2004C)
5) 2500V probe, 100x (Tek P5100)

3. Objectives

1) Inspect application. Verify motor power and feedback connections, grounds, shielding, minimize excess cable lengths.
2) Obtain scope readings at motor.

3) Document Vmax and dV/dt
4) Install 1321-3R2-B line reactor at output of drive and observe dv/dt and peak voltages

4. Setup

Oscilloscope connections must be made at the motor. Elwood XP motors conveniently utilize a junction box where flying lead to extension wire cabling is accessible. U and V motor phases were connected to CH1 and CH2 of the oscilloscope respectively (Figure 1). Scope CH1 and CH2 ground leads were left floating and scope 120V power utilized a ground isolator. The scope MATH function was used to add CH1 and CH2 which resulted in a single observable scope trace. Triggering was not allowed on MATH scope trace, so CH1 was used. Trigger settings were Rising Edge type with DC coupling.

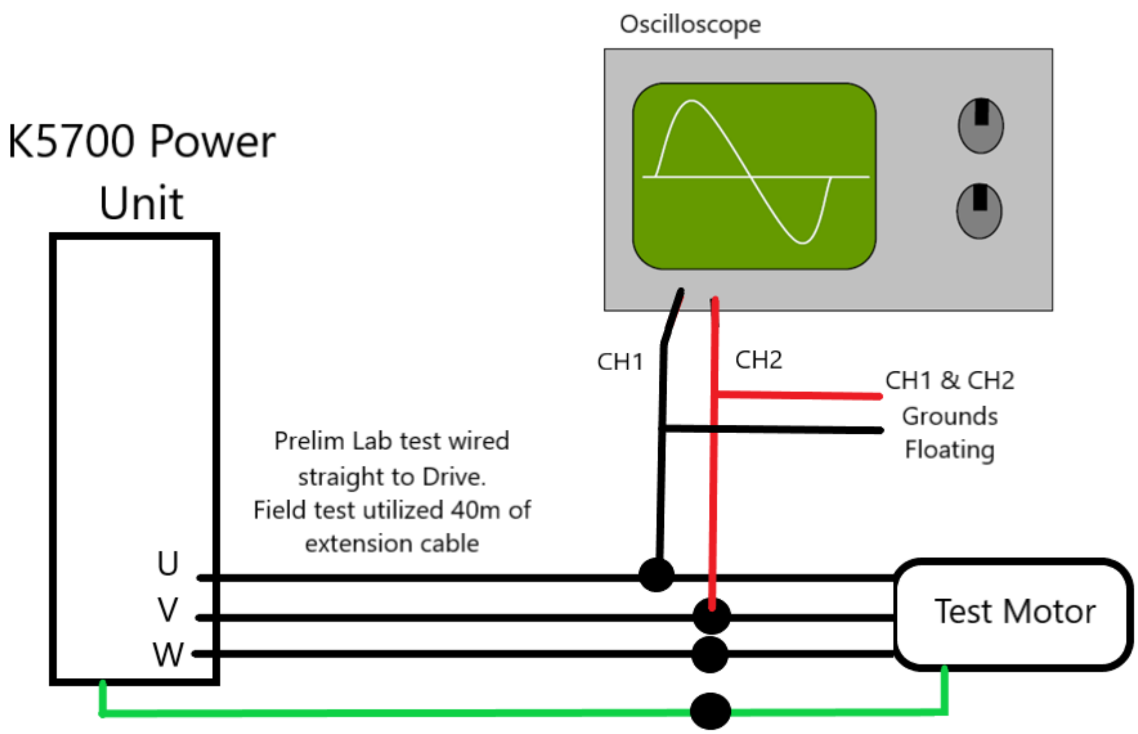
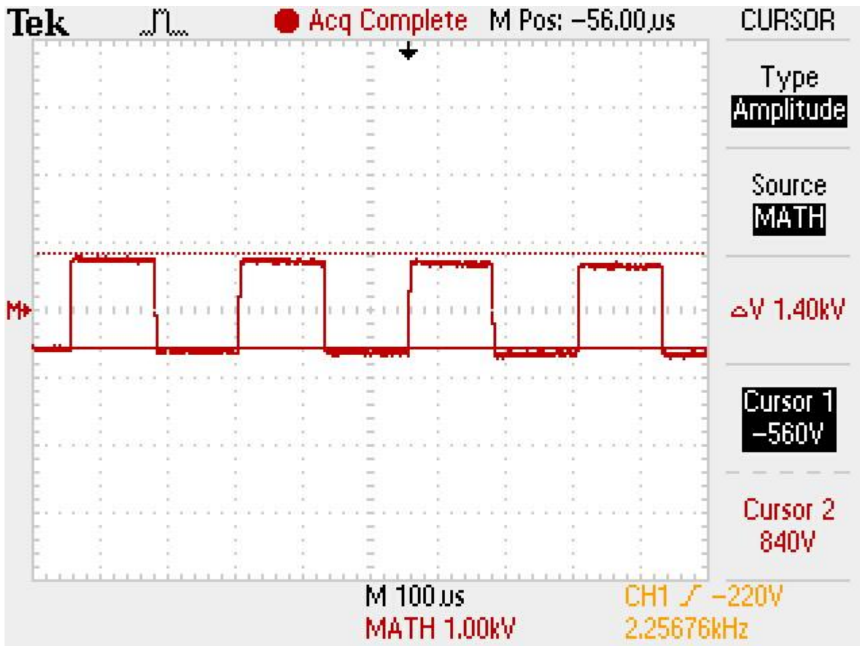
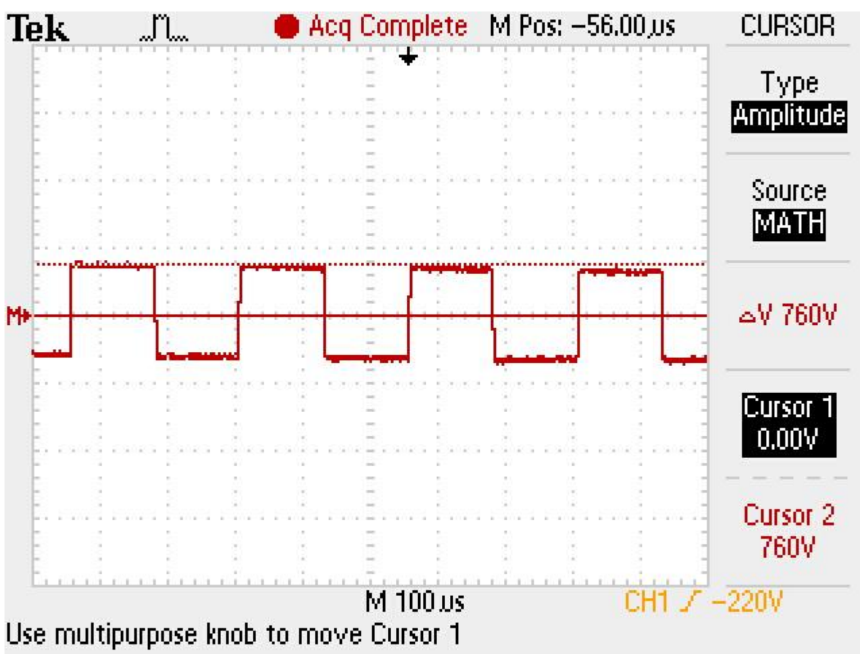


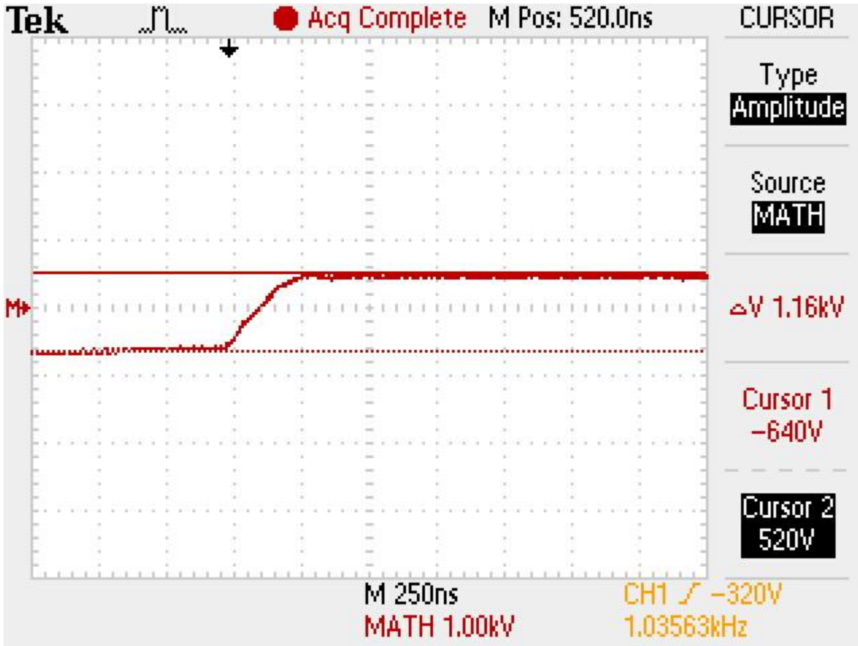
Figure 1

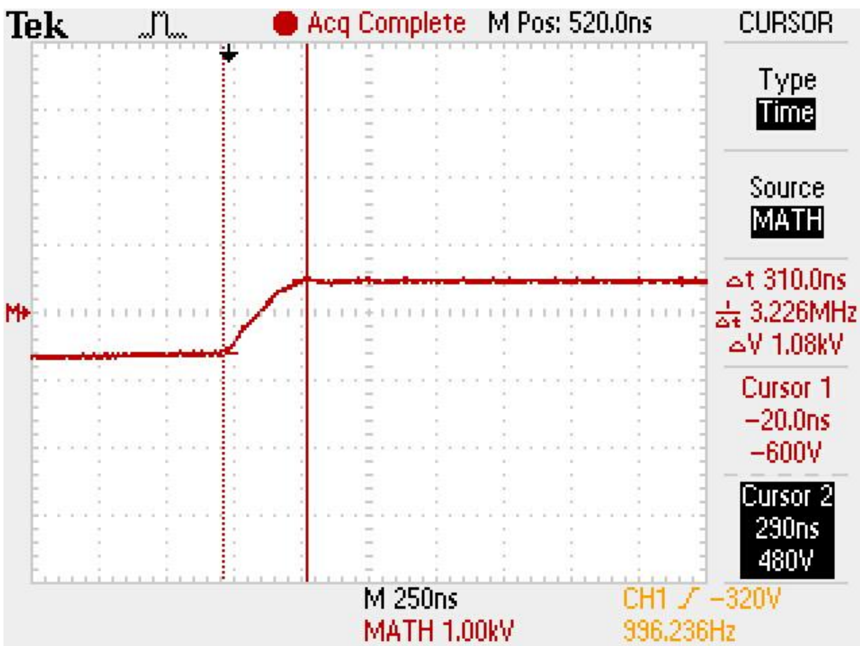
5. Elwood Preliminary Factory Test

Scope images below are of a M431-NNN0-AT08 motor and K5700 drive with 2198-P031 power unit. Motor was wired directly to drive power output UVW. No transient voltage spikes observed.









$$\frac{dV}{dt} = 1000V \times \frac{1.16kV}{0.310\mu s} = 3741.93\frac{V}{\mu sec}$$

6. Data and Results

Field test data was taken on primary screw feed motor (M431-NNNB-9T08) of a bottling machine with K5700 drive (2198-P070 power unit) and 40 meter cable (2090-CSBM1DE-18AA40). Test connections were made by opening motor end junction box and connecting to U and V phases to CH1 and CH2 of the oscilloscope (see “Setup” section for full description). Shield and ground connections were found to be adequate. 2090 cable was finished by Rockwell with shields terminated to drive. Excess cable was looped in conduit above drive cabinet (Figure 2). This cable should be pulled and trimmed down to reduce overall cable length in order to lower voltage transients.

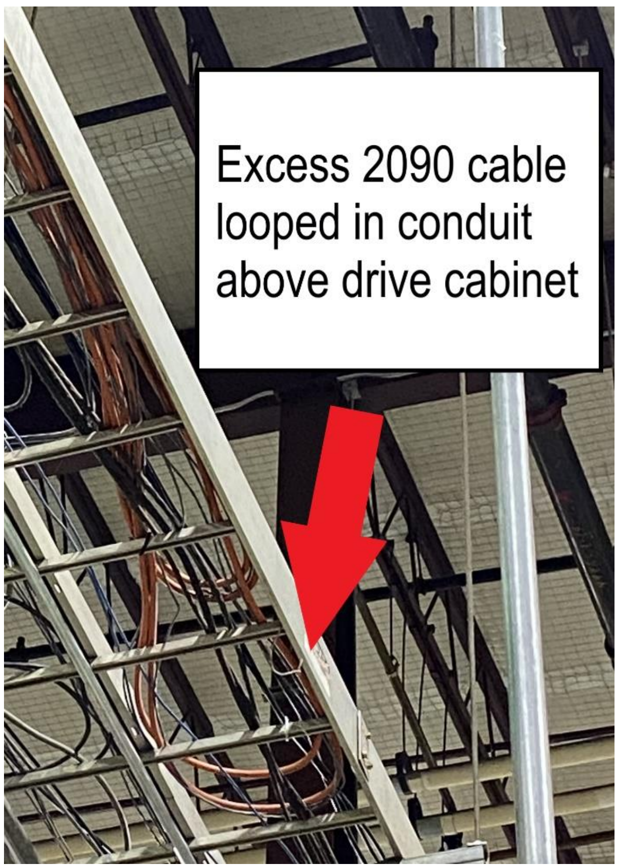


Figure 2

Initial scope images taken with existing motor, drive, and cable setup. Vpk observed to be at least 2.36kV (Figure 3).

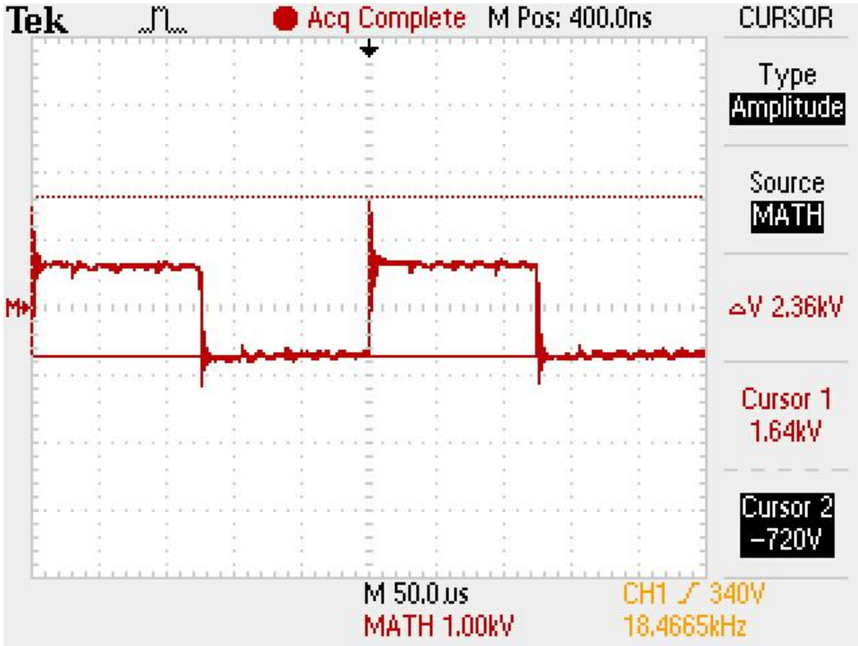


Figure 3

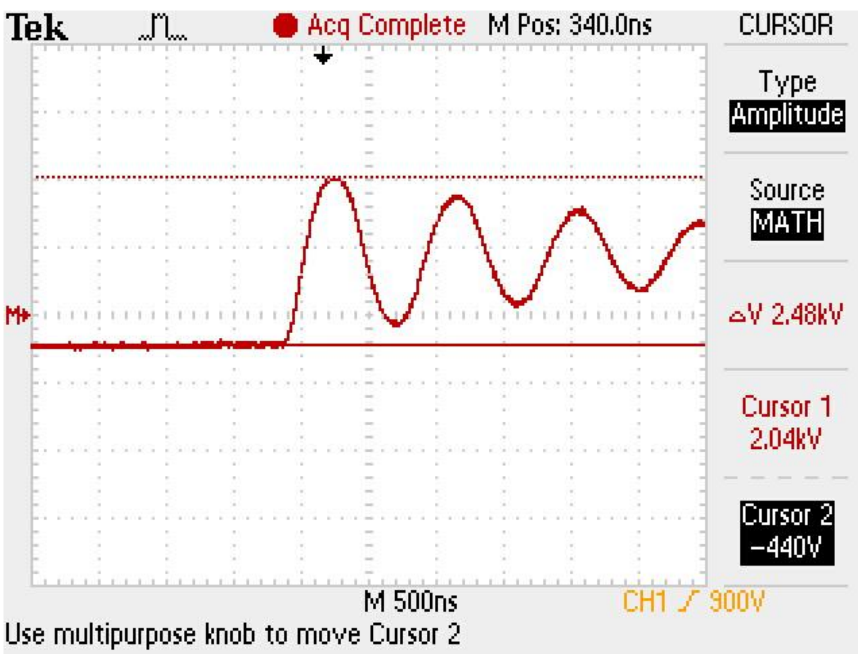


Figure 4

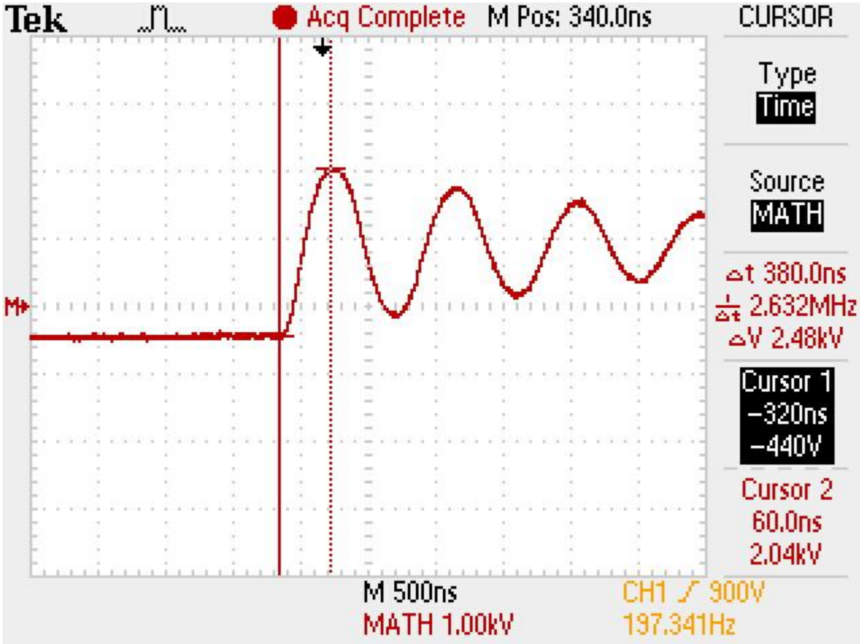
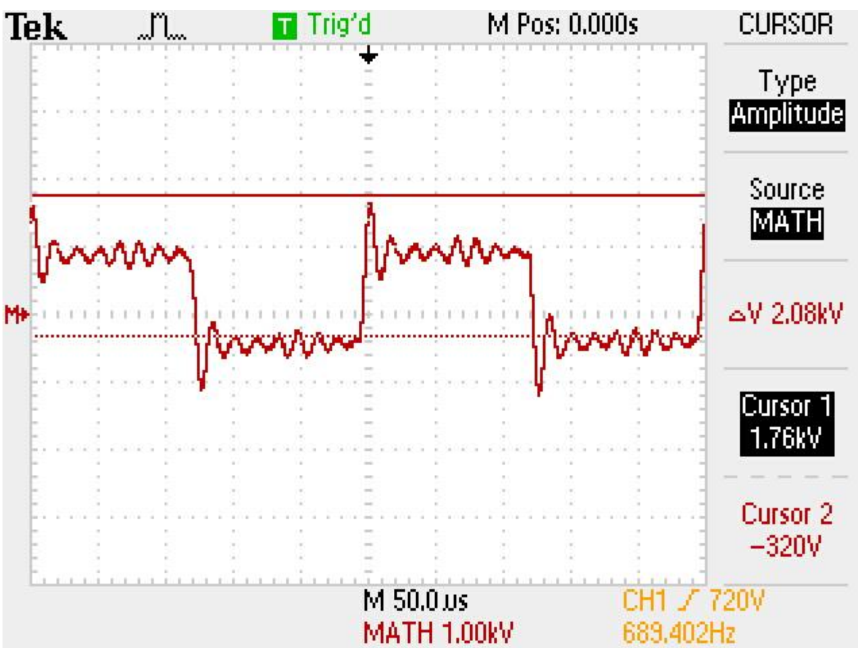


Figure 5

dV/dt calculated from Figure 4 and Figure 5 cursor values.

$$\frac{dV}{dt} = 1000V \times \frac{2.48kV}{0.38\mu s} = 6526.31\frac{V}{\mu sec}$$

Following scope images were taken after a 1321-3R2-B line reactor was installed at drive output.



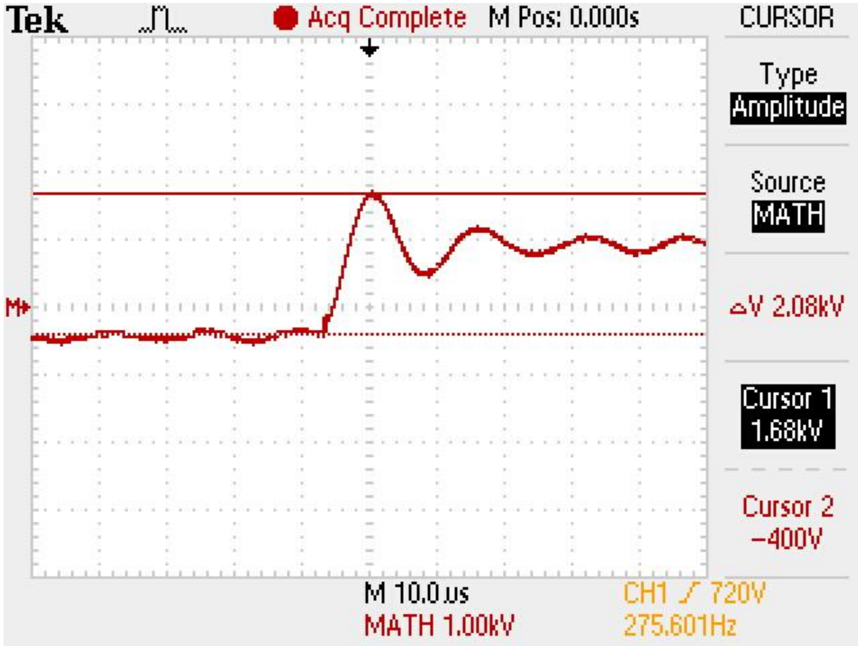


Figure 6

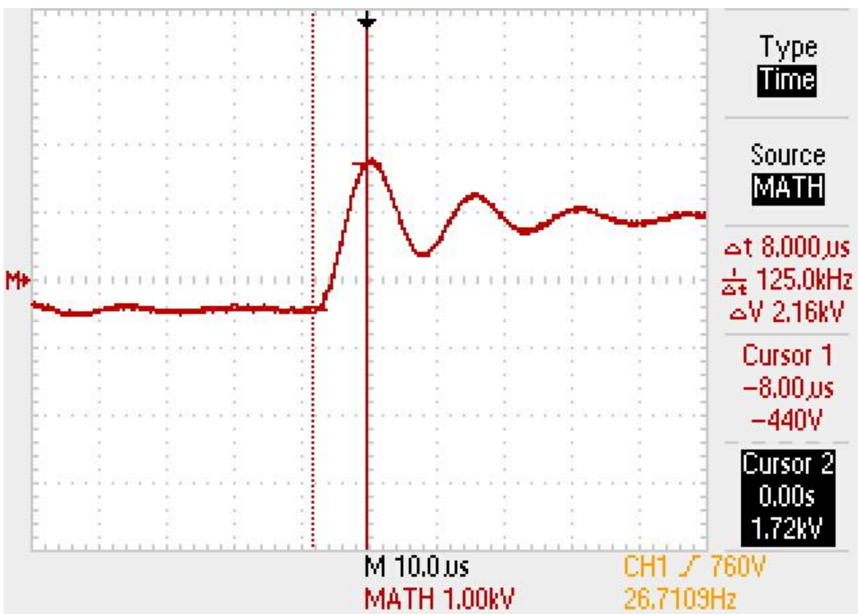


Figure 7

dV/dt calculated from Figure 6 and Figure 7 cursor values.

$$\frac{dV}{dt} = 1000V \times \frac{2.08kV}{8.0\mu s} = 260\frac{V}{\mu sec}$$

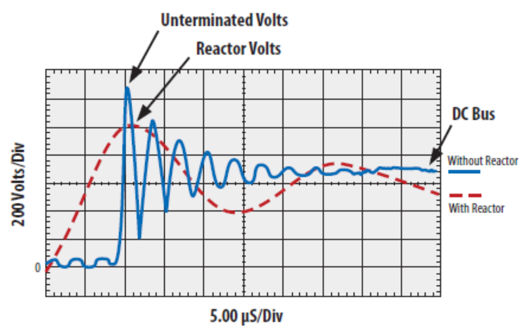
7. Conclusion

Initial setup test values yielded peak voltages of 2360V and dV/dt of 6526.31 V/ µsec. Peak voltage and rate of voltage change at these levels will contribute to phase-phase motor failures. The 1321-3R2-B line reactor lowered peak voltage by 300-400V, and reduced dV/dt by a factor of over 25x. Customer could install 1321-RWR reflected wave reduction devices to further lower peak voltages. The 1321-RWR utilizes a resistor along with the inductor. The 1321-RWR devices are more expensive and have a larger footprint than the 1321-3R, however the added resistor further dampens the wave. A negative impact on motor performance due to the addition of a reactor-resistor type device requires adjustment to motor parameters. In a Rockwell application, the motor flux saturation tables would be adjusted. Rockwell's 1321 documentation further discusses these devices (see link in supported documents section).

Motor Protection

Allen-Bradley load reactors can help protect motors from high peak voltages.

For IGBT drive applications with long drive-to-motor lead lengths, Allen-Bradley load reactors can help protect against fast dv/dt rise times.

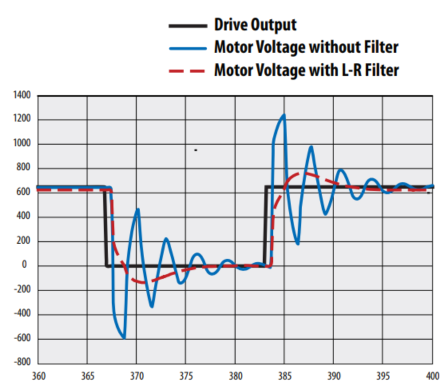


1321-3R Line Reactor

Motor Protection

Allen-Bradley Reflective Wave Reduction devices can help protect motors from high peak voltages.

For IGBT drive applications with long drive-to-motor lead lengths, Allen-Bradley RWR devices can help protect against fast dv/dt rise times.



1321-RWR Reflected Wave Reduction device

8. Transient Voltage and Motor Ratings

Voltage rise time and peak voltage levels for continuous operation in 480v motors is defined in NEMA MG1 Part 31.40.4.2, 1998. (FIGURE 8 is from NEMA MG1 Part 31.40.4.2, 1998.) Using this standard, maximum voltage should be ≤ 1488VPK (zero-to-peak line-to-line), and the rise time of the voltage recorded at the motor should be ≥ 0.1 micro seconds (per FIGURE 8).

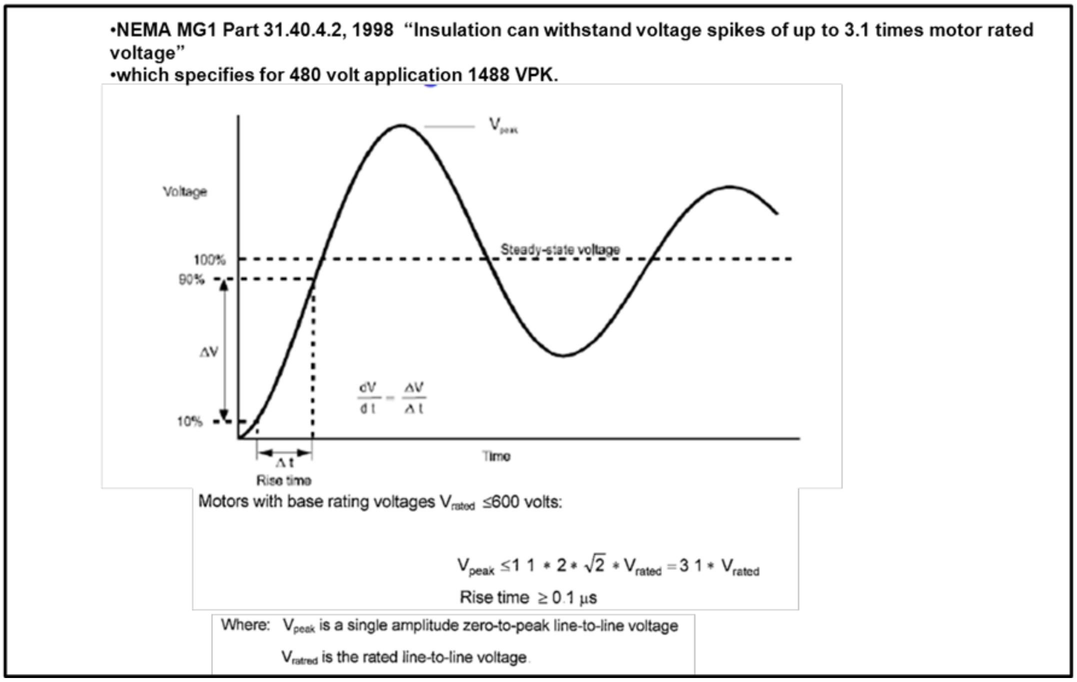


Figure 8: NEMA MG1 Part 31

Original application measured peak voltage and rise time were high. After adding the line reactor, voltage was still slightly high, but rise time fell into a safe range (Figure 9). Original values gathered per Figure 10, values with line reactor gathered per Figure 11.

	Standard Values: NEMA MG1 Part 31.40.4.2, 1998	Original Application Values	Values With Line Reactor
Vpeak	1488V max	2480V	2080V
Rise Time	0.1μs min	0.05μs	4μs

Figure 9

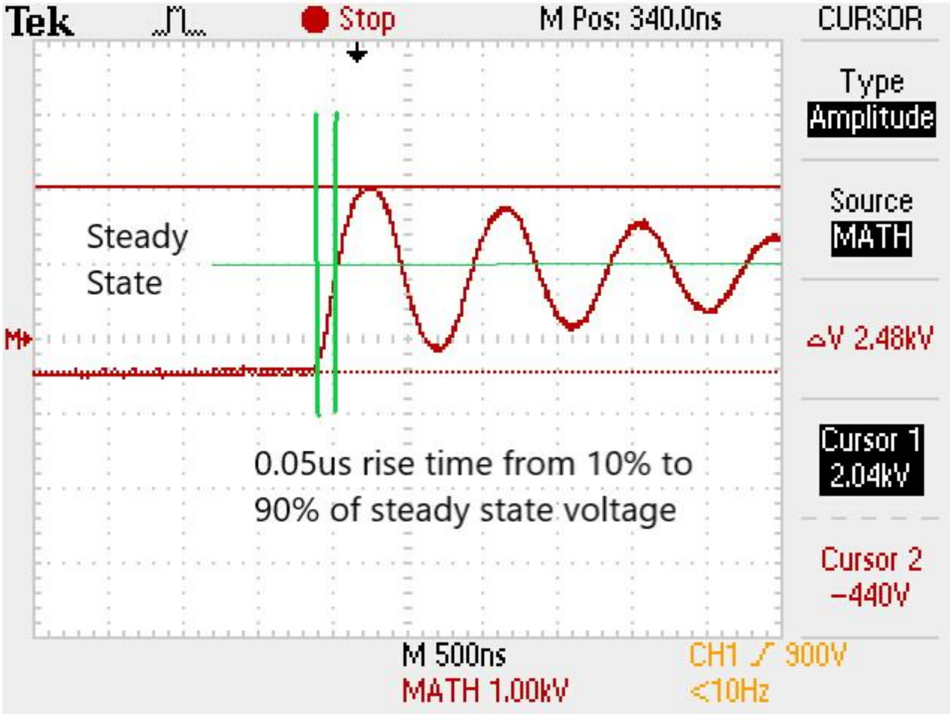


Figure 10

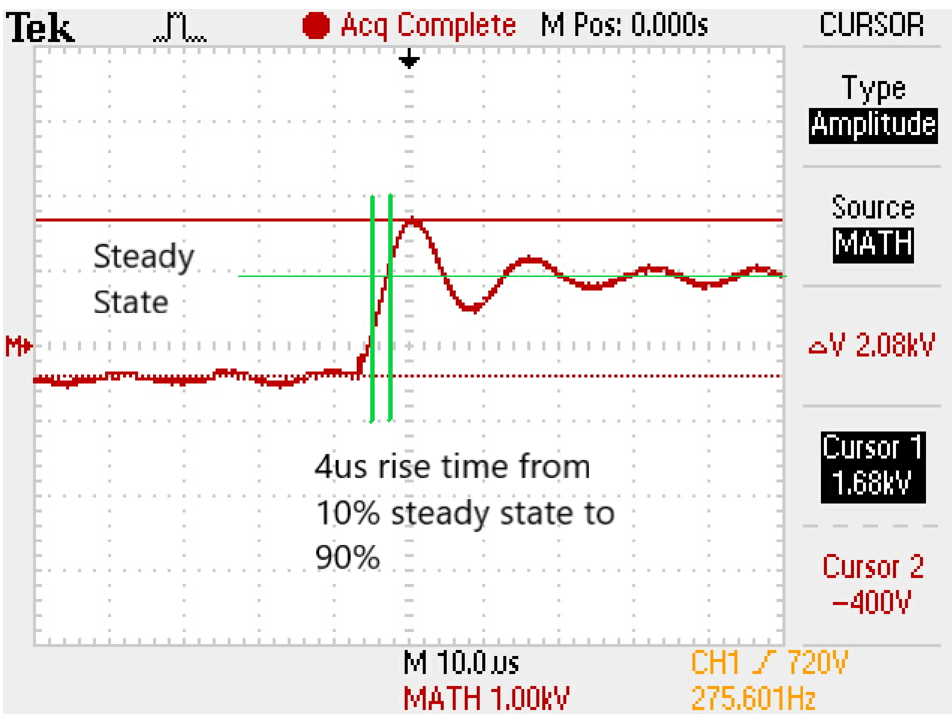


Figure 11

9. Supporting Documents

https://literature.rockwellautomation.com/idc/groups/literature/documents/td/1321-td001_-en-p.pdf

Rockwell Application Test Document (contained in zip folder)

Reliance Trainsent Document (contained in zip folder)

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