Allen Bradley Standard Drives Application Note

Measuring High Frequency High Voltage Transients Using Tektronix P5200 Differential Isolation Amplifiers

Inverter Output Voltage Measurement

The line to line output voltage $V_{\|}$ from a variable speed AC Pulse Width Modulated (PWM) drive containing IGBT semiconductors is a pulse waveform with a peak value equal to the DC bus level with transition fast rising / falling pulse edges ranging from 50 ns to 400 ns. The nominal DC bus level for 480V and 575V systems are 650 Vdc and 800 Vdc while under high input line voltage conditions the DC bus is 712 Vdc and 850 Vdc respectively. A single P5200 differential amplifier, connected line to line at the inverter output, has enough bandwidth and a maximum rated peak voltage of 1300 Vmax to accurately measure these fast rise times and peak voltages for 480V & 575V systems directly at the drive output.

Measurement Problems at the Motor Terminals

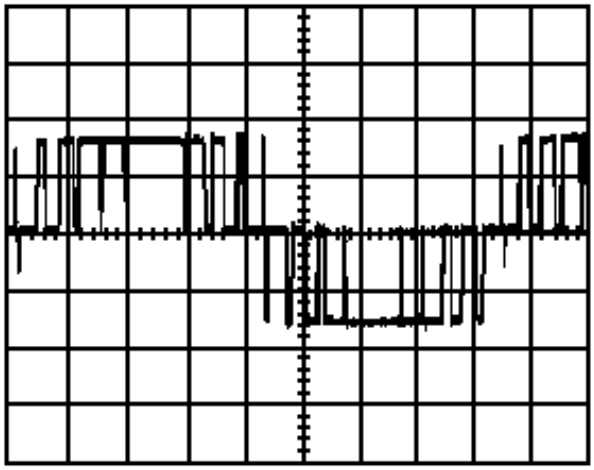
Reflected wave issues may create transient voltage peaks of twice the DC bus (2 per unit or 2 pu) on the AC motor line to line terminals on every pulse width fast rising edge, even for motor cable distances of 30 feet. Transient motor voltage peaks increase with the addition of cable length until three times the DC bus (3 pu) may possibly occur across the motor terminals for motor cable distances of 600 feet using 1305 & 1336+ drives. As seen from the table below, all the peak motor voltages are above the Tektronix P5200 maximum limit when a single unit is connected across the line to line motor terminals. Each P5200 costs about $ 350.

System Input Volts	480 VAC	480 VAC+10%	575 VAC	575 VAC+10%
Motor line to line peak voltages				
DC bus	650	715	800	850
2 pu	1300	1430	1600	1700
3 pu	1900	2145	2400	2550
Motor line to ground peak voltages				
Vbus/2	325	357	400	425
2 pu * (Vbus/2)	650	715	800	850
3 pu * (Vbus/2)	975	1072	1200	1275

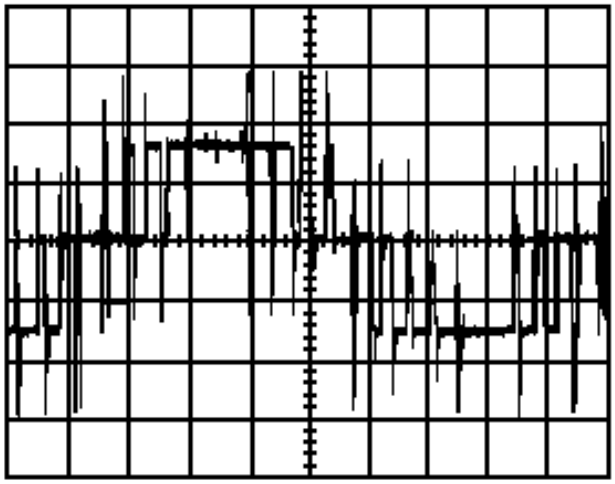
One solution is to use a Oregon Differential Amplifier. This instrument accurately measures 50 ns pulses to 3,400 Volts peak and is the best instrument used in the Mequon Development Lab. However, it costs $3,500 per channel, requires a Tek Mainframe power supply type unit, and is rather bulky to carry around for field use. Another method tried was to use a wye configuration resistor divider network connected across the motor terminals but this has been found to create erroneous results with fast rising high voltage transients due to the resistance's interacting with probe capacitance's.

Proposed Motor Terminal Measurement Technique: The peak line to ground voltage at the drive output is approximately the DC bus voltage divided by 2. The peak line to ground voltage at the motor terminals follows the same "pu ringup" voltage factor as the line to line condition, namely 2 pu @ around 30 ft cable distances and 3 pu @ 600 ft motor cable distances. Thus, as seen in the table above, a Tek P5200 can accurately measure motor line to ground voltages. Line to line motor voltages may be measured using *two P5200* and a scope capable of subtracting channel (1) & (2) waveforms. A P5200 is connected from each phase to motor ground stud, with the red positive lead on the phase conductor and the black minus lead on frame ground. Thus, the scope channels read phase A voltage Va to ground (V_{ag}) and phase B voltage to ground (V_{bg}). By definition the line to line V_{ab} motor voltage is $V_{ab} = V_{ag} - V_{bg}$. Thus, the correct line to line voltage may be displayed by subtracting channel (1) - Channel (2). A demonstration of these waveforms is shown on attached pages.

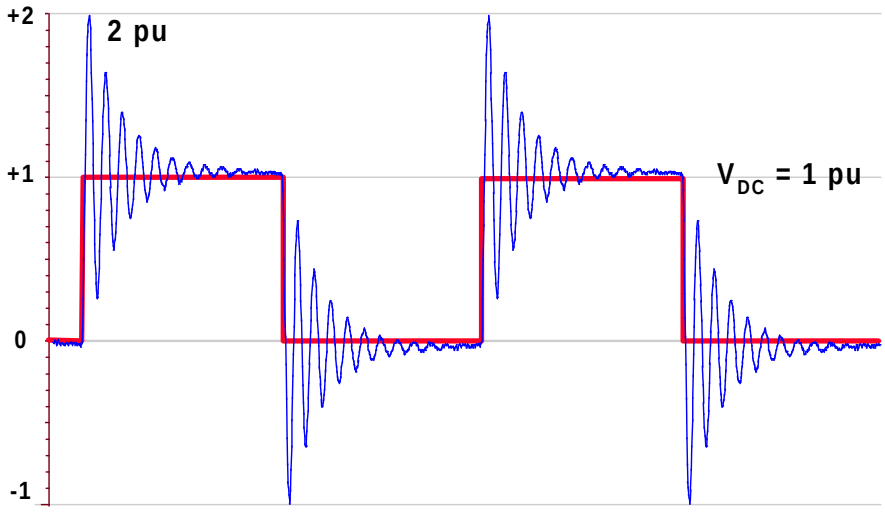
Conclusion: Two P5200 ($700) and a Math scope can measure up to 2,550 Volt line to line motor transients on 480V & 575 V systems with 600 ft drive -motor Cable lengths on 1305 & 1336+ drives.



V_{LL} PWM Output Voltage at the Drive



V_{LL} PWM Output Voltage at the Motor



Expanded Pulse Voltage

Measuring High Voltage High Frequency Transients Utilizing the Tektronix P5200
Date: February 21, 1996

Summary:

The purpose of this test was to determine if the Tektronix P5200 will be able to accurately measure the line-line motor voltage for 460V and 575V IGBT drive applications. This was accomplished by measuring the line-ground motor voltages for two phases and then subtracting them using the oscilloscope's math function. This voltage was then be compared with waveform obtained by Oregon Analog Tools. The results can be seen in figures 2-3 in the Test Data section.

Test Drive:

1336S 460V 125HP AC Drive. Cat# 1336S-B125-AA-EN-HA2-L6 SN# MEAA4YQ4

Test Motor:

General Electric 460V 100HP AC Motor. SN# 0D075603/F

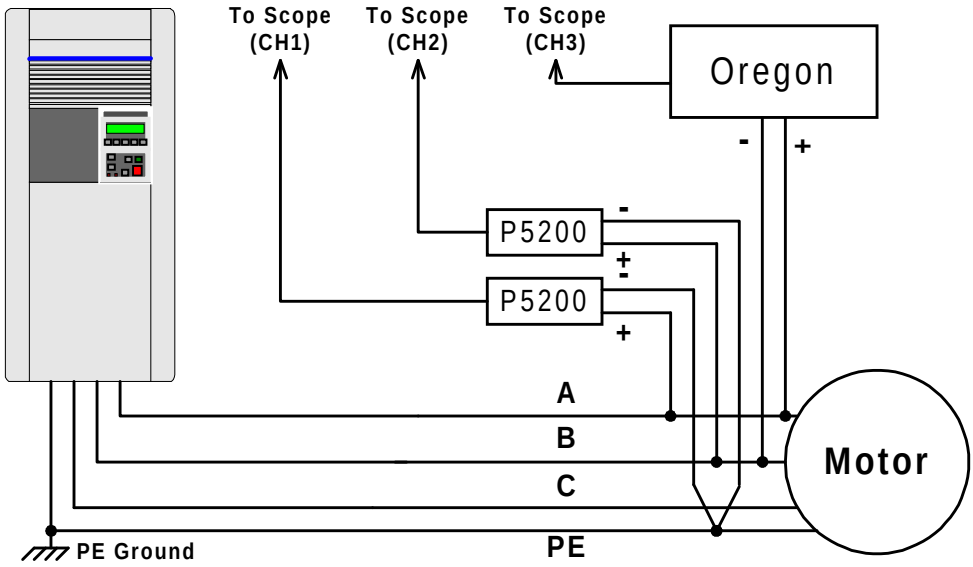
Test Equipment:

Tektronix TDS544A SN# H700388 Electro Rent Calibrated 10/31/95
Tektronix P5200 Differential Voltage Probe SN# B010788 Calibrated 7/11/95
Tektronix P5200 Differential Voltage Probe SN# B010246 Calibrated 7/11/95
Oregon Analog Tools Z2M Differential Amplifier BD# 2016 Calibrated 6/1/95

Test Procedure:

1.) Configure the test drive for the test motor using the 1336 manual recommendations.
2.) Connect the test probes to the motor as shown in figure 1.
3.) Set up the oscilloscope. Channels one and two for the P5200, and channel three for the Oregon.
4.) Set the math function on the scope to subtract channels one and two (CH1 - CH2).
5.) Measure and compare the line-line motor voltage using the Tektronix P5200's and the Oregon Analog Tools.

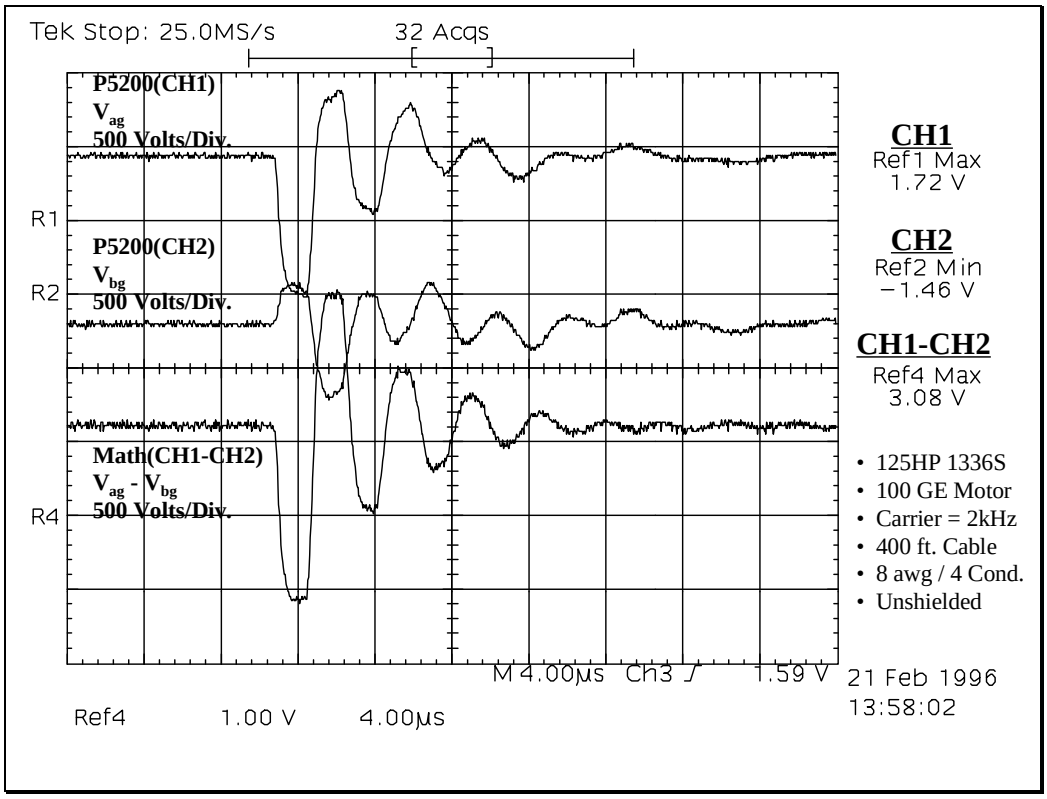
Equipment Setup


To Scope
(CH1)
To Scope
(CH2)
To Scope
(CH3)
Oregon
-
+
P5200
-
+
P5200
-
+
A
B
C
PE
Motor
PE Ground

(figure 1)

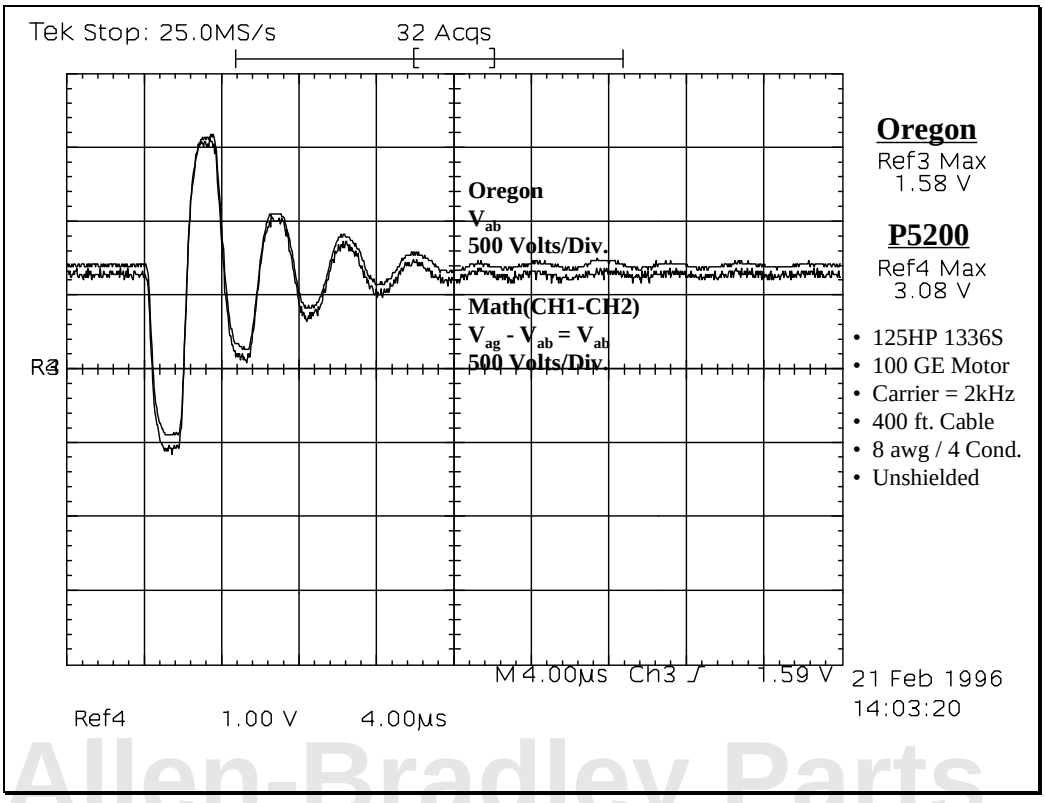
Test Data:

P5200 Waveforms / Math Waveform



(figure 2)

Oregon vs. P5200



(figure 3)