Powertech
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Project: 19765-26

March 22, 2010

Luis Elizalde
G&W Electric Co.
3500 West 127th Street
Blue Island
IL 60406
USA

Dear Luis,

Re: Test Report for Project 19765-26

Please find enclosed three copies of the following test report:

19765-26 **Test on Two Single-Phase 27kV, 12.5 kA rms-symmetrical, Vacuum Reclosers Catalog No. VIP188ER-12-SP, Manufactured by G&W Electric Co.**

If you have any questions or comments, please feel free to contact me directly at 1(604) 590-7486 or via e-mail at tom.stefanski@powertechlabs.com .

Yours truly,

for

Tom Stefanski, P.Eng.
Head of High Power Lab

Encls.

Test Report № 19765-26

The tests were performed in accordance with IEEE Standard C37.60-2003.

Manufacturer:	G&W Electric Company 3500 W. 127th Street Blue Island, IL, USA		
Project №:	#19765-26	**Test Dates:**	24-26 February 2010
Tested Devices:	Two Vacuum Reclosers. Units, #1 and #2.		
Manufacturer:	G&W Electric Company		
Catalog №:	VIP188ER-12-SP		
Rated Voltage:	27 kV_{rms}		
Rated Currents:	12.5 kA_{rms} interrupting; 800A_{rms} continuous		
Serial №:	Unit #1: 201002290003 Unit #2: 201002290004		
Control:	Schweitzer SEL-351RS Single-phase Recloser Control		
Tests performed:	• Unit #1; Rated Symmetrical Interrupting Current tests per Section 6.5 • Unit #2; Switching tests per Section 6.3, Table 9 • Units #1 and #2: • DC Resistance measurements before and after the tests • 60 Hz AC withstand test at 48 kV per Section 6.14 after the tests		
Test Witnesses:	Mr. Luis E. Elizalde Mr. Kennedy Darko Mr. Alex Bradley	G&W Electric G&W Electric SEL Schweitzer	
Remarks:	Identification of the tested unit was based on the nameplate information. The tests were performed in single-phase configurations at 27 kV_{rms}. The tested recloser passed all the tests performed.		

Tested by:

12 March 2010

T.Stefanski M.Sc., P. Eng.
Head of High Power Lab

Reviewed by:

J.A. Zawadzki M.Sc., P. Eng.
Director, Power Engineering Labs

TABLE OF CONTENTS

1.0 INTRODUCTION 4
2.0 SUMMARY OF TEST RESULTS 5
2.1. Rated Symmetrical Interrupting Current Tests 5
2.2. Load Switching Tests 6
2.3. Line Charging Tests 6
2.4. Cable Charging Tests 7
3.0 CONCLUSION 8

1.0 INTRODUCTION

A series of tests were performed at the High Power Laboratory of Powertech Labs Inc on two 27 kV, 12.5 kA_{rms} rated single-phase Vacuum Reclosers Catalog № VIP188ER-12-SP, Units #1 and #2, both manufactured by G&W Electric. The tests were performed in accordance with IEEE Standard C37.60-2003, Sections 6.3 and 6.5. All the tests were performed in single-phase configurations at 60 Hz.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025. The tests included in this report are within the scope of this accreditation. The results apply only to the samples tested.

The following tests were performed:

Unit #1:

Operating Duty Tests per Section 6.5, Table 6 and Table 10b:

- Tests at 12.6 kA_{rms} - 16 operations
- Tests at 6.85 kA_{rms} - 59 operations
- Tests at 2.48 kA_{rms} - 44 operations

Unit #2:

Switching Tests per Section 6.3 and Table 9:

- Load Switching tests at 808 A_{rms} – 10 operations
- Line Charging current tests at 5.10 A_{rms} - 20 operations
- Cable Charging current tests at 27.1 A_{rms} - 20 operations

The contact resistance of each switch was measured before and after the tests using a 100 A, Digital Low Resistance Ohmmeter, Megger Type DLRO 600.

After completion of the test program on each switch, a 60 second, 48 kV AC withstand test was performed in accordance with Section 6.2.3 of C37.60.

2.0 SUMMARY OF TEST RESULTS

All tests were performed at 60 Hz. As required by the standard, after each test sequence the normal frequency recovery voltage was held for one second across the switch. The contact resistance of each tested switch was measured before and after the tests using a 100 A, Digital Low Resistance Ohmmeter, Megger Type DLRO 600. The results of these measurements are shown in Table 1. The value of contact resistance measured after the tests was less than 200 % of that before the test sequence. After completion of the test program, each switch was subjected to a 60 second, 48 kV AC withstand test was performed in accordance with Section 6.2.3 of C37.60. The criteria of Section 6.14.1 were satisfied.

Photographs of the tested reclosers and the test setup are shown in Figures 17 to 22.

2.1. Rated Symmetrical Interrupting Current Tests

The tests were performed on Unit #1. The tests were performed per Section 6.5.4 and Table 6 of C37.60-2003. Before each of the operating duty tests, the source TRV was measured and adjusted in accordance with Table 10b) of the Standard. The TRV was adjusted using a current injection method. The tests were typically performed in an O-CO-CO-CO test sequence in the circuit shown in Figure 1.

a) Tests at 90 to 100 %.

• Test current	12.6 kA_{rms} (11.25 kA_{rms} to 12.5 kA_{rms} is required) [1)]
• X/R	18.0 (≥17 required)
• TRV peak	AF = 1.57 (≥ 1.54 is required)
• TRV rate of rise	t_3= 47.9 µs (≤ 51.4 µs is required)
• Number of operations performed	16.
• Typical test waveforms	Refer to Figures 4 to 6.

Note:
[1)] At the customer's request, all the 90-100% tests were performed with the current ≥100% of the interrupting rating.

b) Tests at 45 to 55 %.

• Test current	6.85 kA_{rms} (5.63 kA_{rms} to 6.87 kA_{rms} is required)
• X/R	9.6 (≥ 8 required)
• TRV peak	AF = 1.69 (AF ≥1.68 is required)
• TRV rate of rise	t_3 = 29.9 µs (≤ 29.9 µs is required)
• Number of operations performed	59
• Typical test waveforms	Refer to Figures 7 to 9.

c) Tests at 15 to 20 %

• Test current	2.48 kA_{rms} (1.88 kA_{rms} to 2.5 kA_{rms} is required)
• X/R	4.3 (≥ 4 required)
• TRV peak	AF = 1.81 (≥ 1.77 is required)
• TRV rate of rise	t_3 = 31.3 µs [1] (minimum achievable), (≤ 20.7 µs is required)
• Number of operations performed	44
• Typical test waveforms	Refer to Figures 10 to 12.

Note:
[1] The Standard allows the use of the shortest t_3 time that can be met (per the Note for Section 6.5.2)

2.2. Load Switching Tests

The tests were performed on Unit #2 in accordance with Section 6.3.2.1 of IEEE C37.60 and IEEE Standard 1247-1998.

• Test voltage	27 kV_{rms}
• Test current	808 A_{rms} (≥ 800 A_{rms} is required)
• Load power factor	0.71 (0.7 to 1.0 is required)
• Source impedance	10.5% (10% to 20% is required)
• Source X/R	6 (5 to 7 is required)
• TRV peak	E_S = 11 kV @290 µs (≥7.6 kV is required)
• Number of operations performed	10 x CO
• Test Circuit	Refer to Figure 2.
• Typical test waveforms	Refer to Figure 13.

2.3. Line Charging Tests

The tests were performed on Unit #2 in accordance with Section 6.3.2.2.2 of IEEE C37.60 and IEEE Standard 1247-1998.

• Test voltage	27 kV_{rms}
• Test current	5.10 A_{rms} (≥ 5 A_{rms} is required)
• Source impedance	same components as for the load switching tests
• Number of operations performed	20 x CO
• Test Circuit	Refer to Figure 3.
• Typical test waveforms	Refer to Figure 14.

2.4. Cable Charging Tests

The tests were performed on Unit #2 in accordance with Section 6.3.2.2.3 of IEEE C37.60 and IEEE Standard 1247-1998.

• Test voltage	27 kV_{rms}
• Test current	27.1 A_{rms} ($\geq$ 25 A_{rms} is required)
• Source impedance	same components as for the load switching tests
• Number of operations performed	20 x CO[1)]
• Test Circuit	Refer to Figure 3.
• Typical test waveform	Refer to Figures 15 and 16.

Note:

[1)] During two operations restrikes occurred after interruption. The transient voltage did not exceed 2.5 times the peak line-to-ground voltage during any of the above restrikes.

TABLE 1

Results of resistance measurements on Vacuum Reclosers Catalog VIP188ER-12-SP

Unit	When measured	Resistance (in μΩ)
1	Before tests	97.5
	After tests	102.5
2	Before tests	96.2
	After tests	97.0

3.0 CONCLUSION

Two 27 kV, 800 A_{rms}, 12.5 kA_{rms} rated single-phase Vacuum Reclosers Catalog № VIP188ER-12-SP, marked Unit #1 and Unit #2, manufactured by G&W Electric successfully performed the following tests:

Unit #1:

Operating Duty Tests per Section 6.5, Table 6 and Table 10b:

- Tests at 12.6 kA_{RMS} - 16 operations
- Tests at 6.85 kA_{RMS} - 59 operations
- Tests at 2.48 kA_{RMS} - 44 operations

The tested recloser passed all the tests performed. The tests were performed to qualify the device for a 27 kV, 12.5 kA_{RMS} rating.

Unit #2:

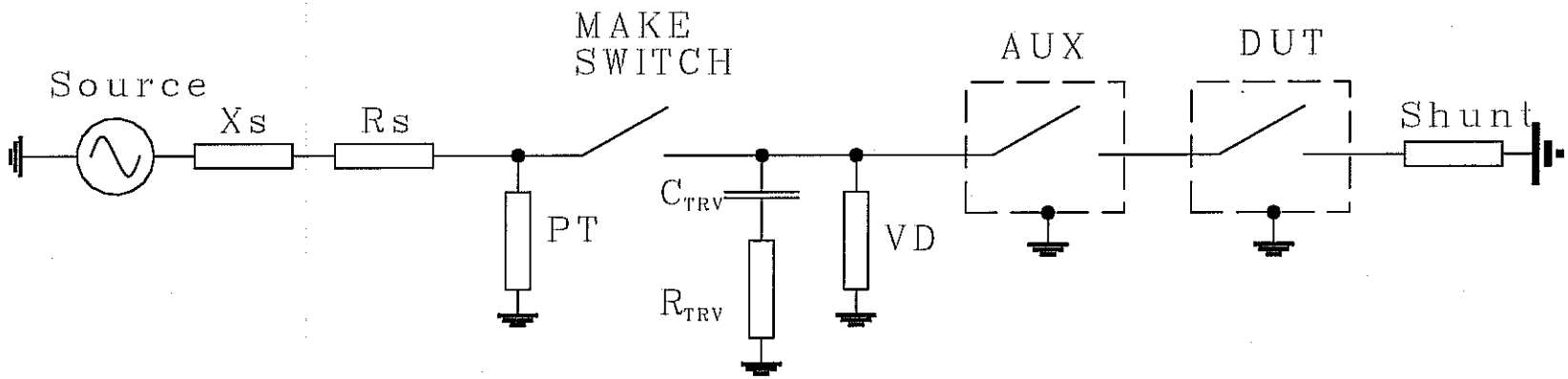
Switching Tests per Section 6.3 and Table 9:

- Load Switching tests at 808 A_{RMS} – 10 operations
- Line Charging current tests at 5.10 A_{RMS} - 20 operations
- Cable Charging current tests at 27.1 A_{RMS} - 20 operations

During two Cable Charging operations at 27.1 A_{rms}, restrikes occurred after interruption. The transient voltage did not exceed 2.5 times the peak line-to-ground voltage during any of the above restrikes.

All the above tests were performed at 60 Hz in accordance with IEEE Standard C37.60-2003.

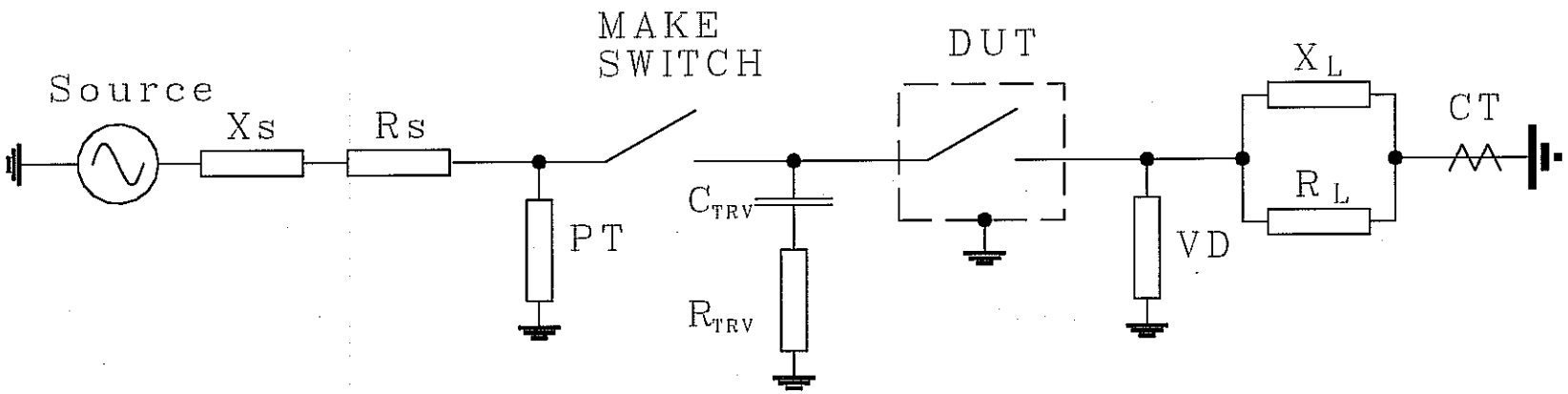
After completion of the test program, the tested reclosers passed a 60 second, 48 kV AC withstand test performed in accordance with Section 6.2.3. The value of contact resistance measured after the tests was less than 200 % of that before the test sequence. The criteria of Section 6.14.1 were satisfied.



Notes:

- X_S - source reactance
- R_S - source resistance
- PT - potential transformer
- C_{TRV}, R_{TRV} - TRV components
- VD - voltage divider
- AUX - auxiliary switch
- DUT - Tested recloser

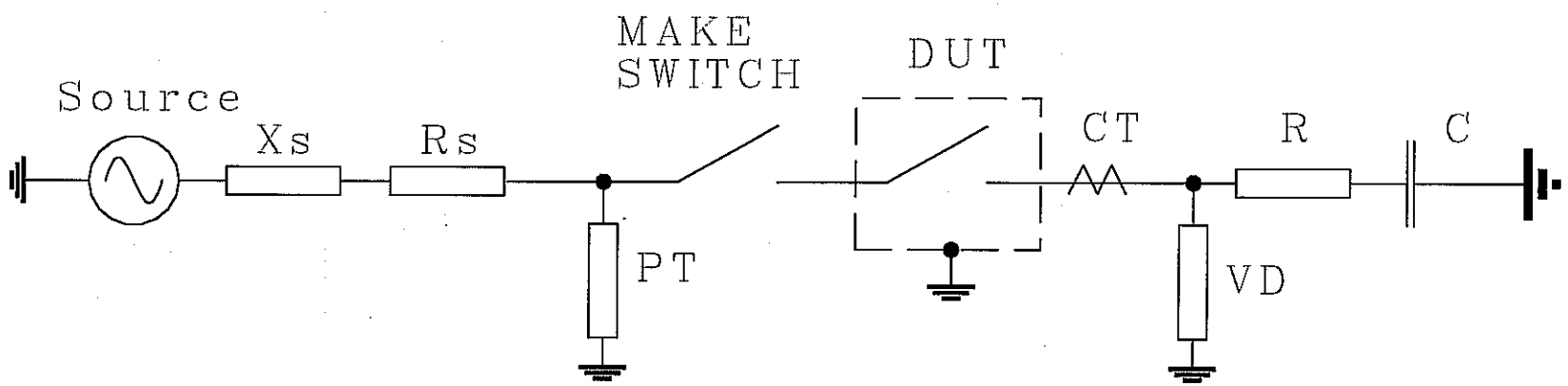
Figure 1. Test circuit for Operating Duty tests.



Notes:

- X_S - source reactance
- R_S - source resistance
- PT - potential transformer
- C_{TRV}, R_{TRV} - TRV components
- VD - voltage divider
- CT - current transformer
- DUT - Tested recloser
- X_L, R_L - load components

Figure 2. Test circuit for Load switching tests.



Notes:

- X_S - source reactance
- R_S - source resistance
- PT - potential transformer
- DUT - Tested recloser
- VD - voltage divider
- CT - current transformer
- R - series resistance
- C - load capacitance

Figure 3. Test circuit for Cable and Line Charging tests.

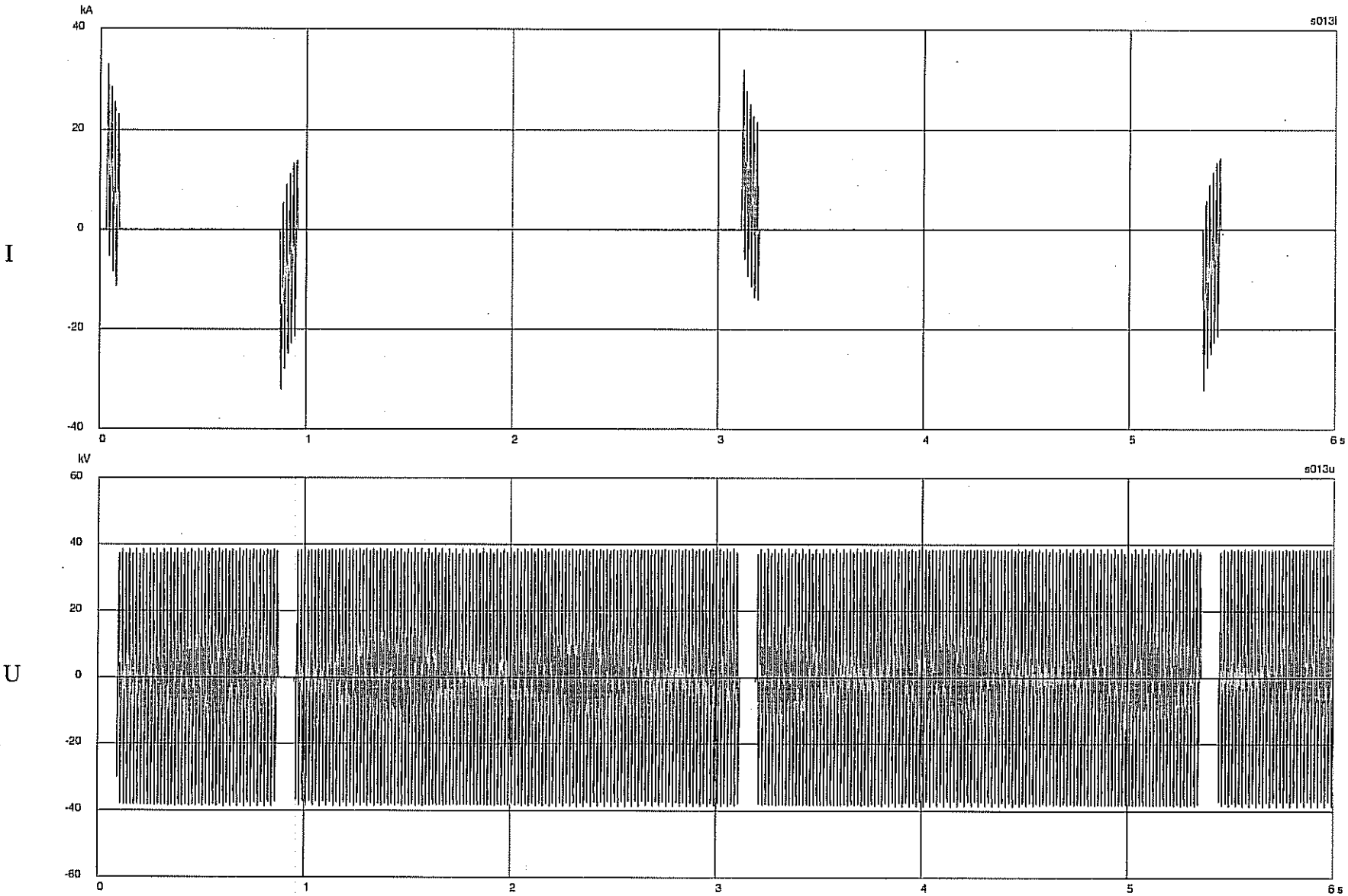


Figure 4. Typical 12.6 kA_{RMS} test. Overall waveform.

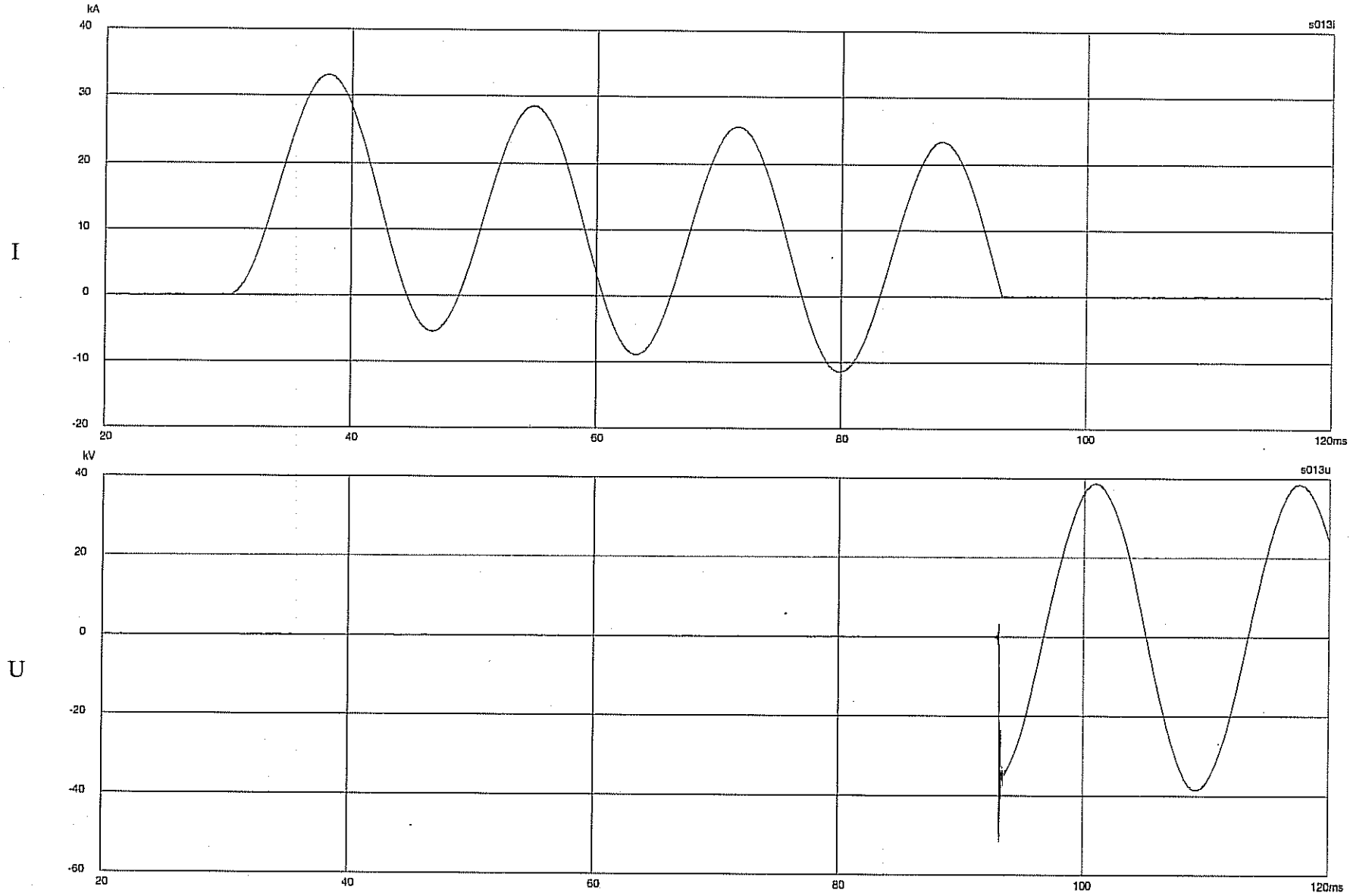


Figure 5. Typical 12.6 kA_{RMS} test. Opening operation.

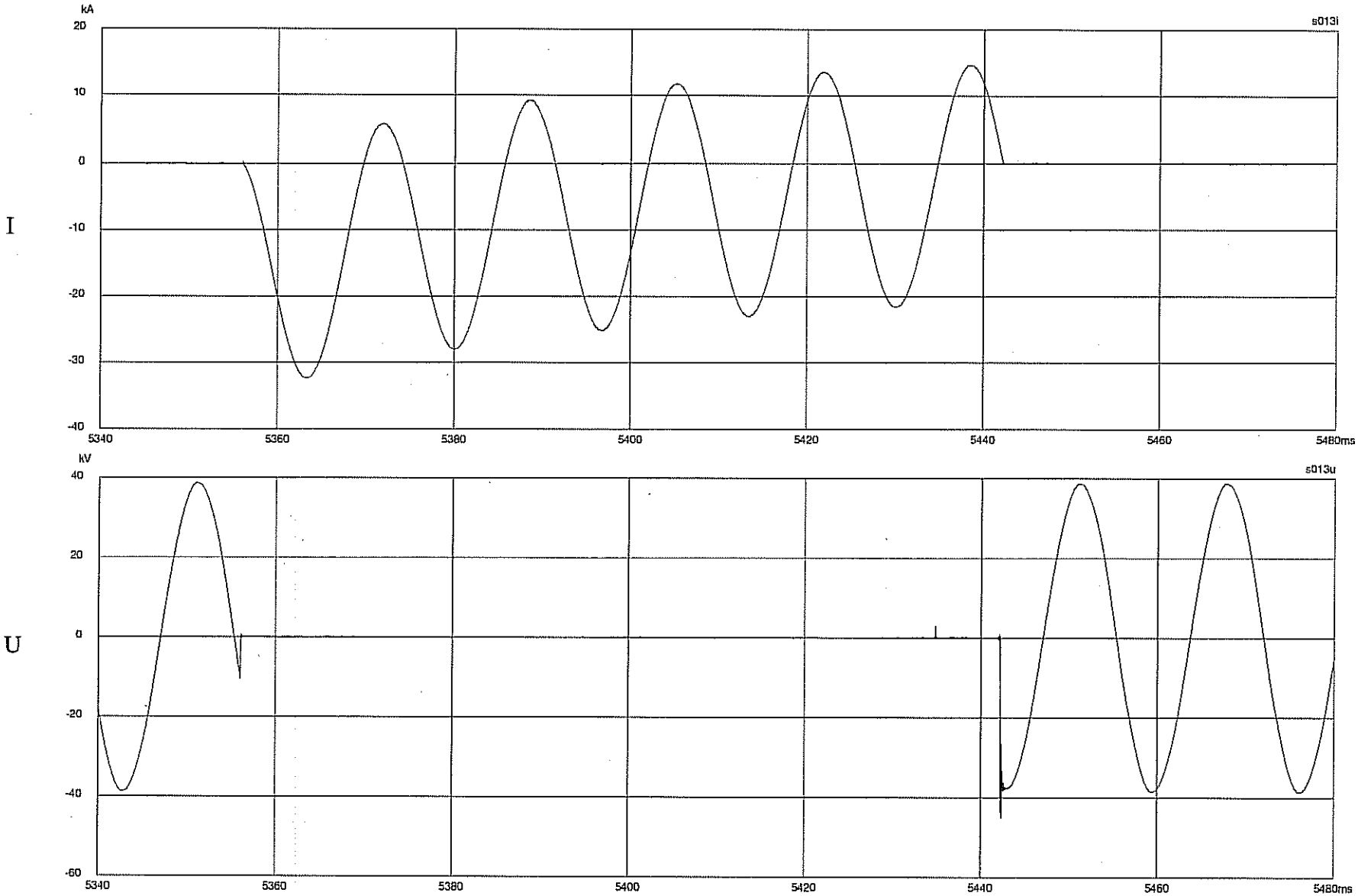


Figure 6. Typical 12.6 kA_{RMS} test. CO operation.

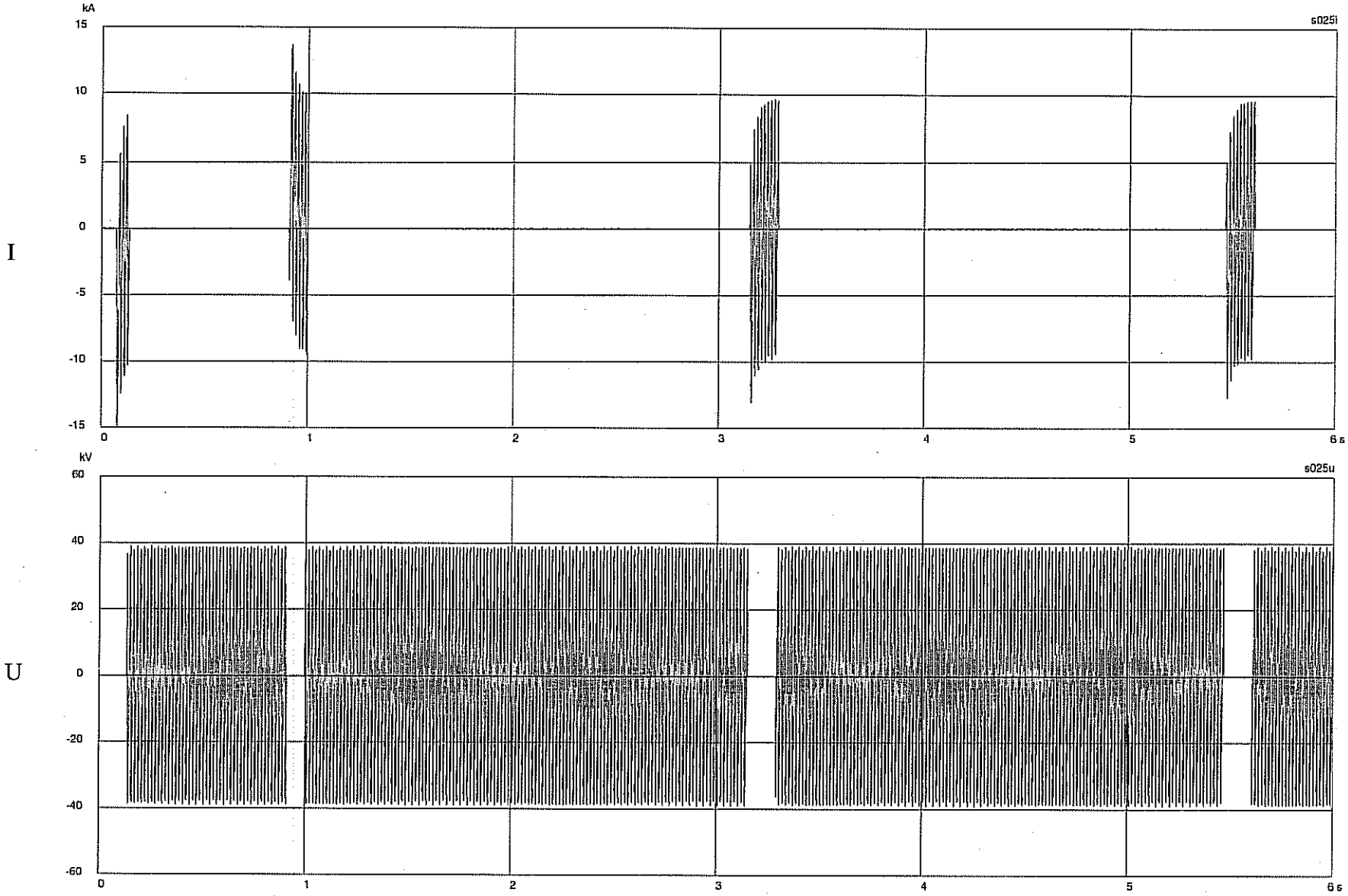


Figure 7. Typical 6.85 kA_{RMS} test. Overall waveform.

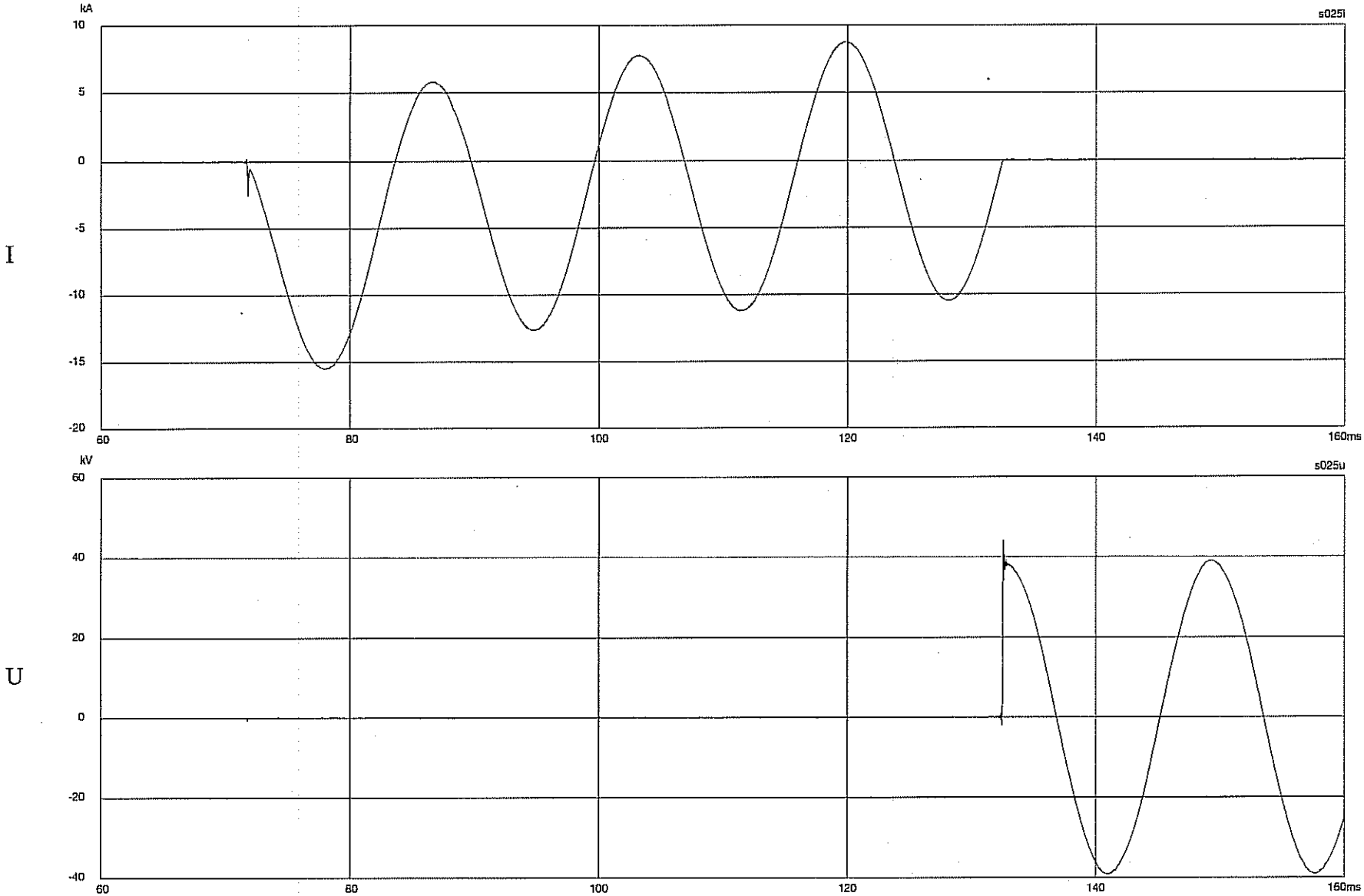


Figure 8. Typical 6.85 kA_{RMS} test. Opening operation.

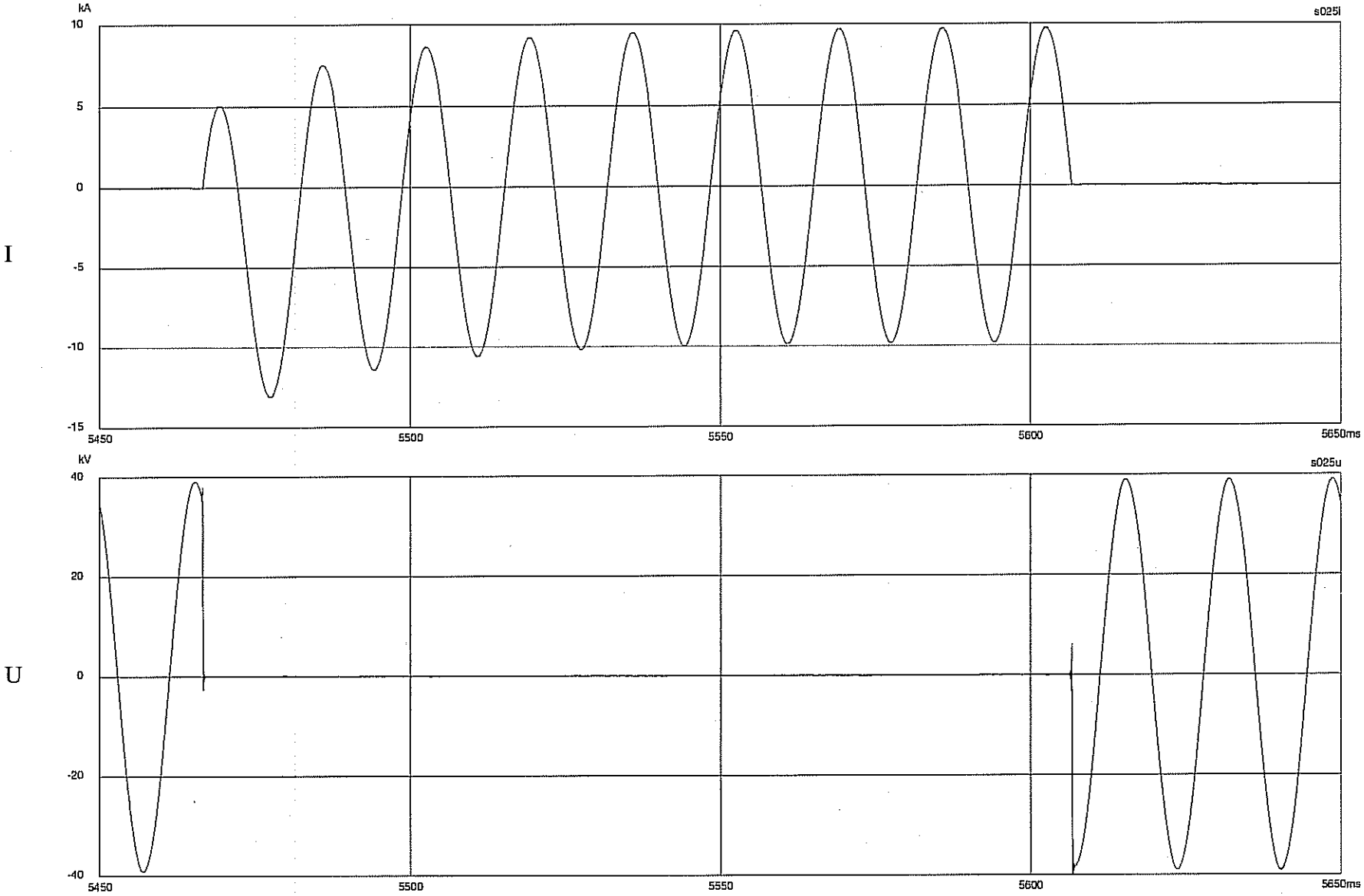


Figure 9. Typical 6.85 kA_{RMS} test. CO operation.

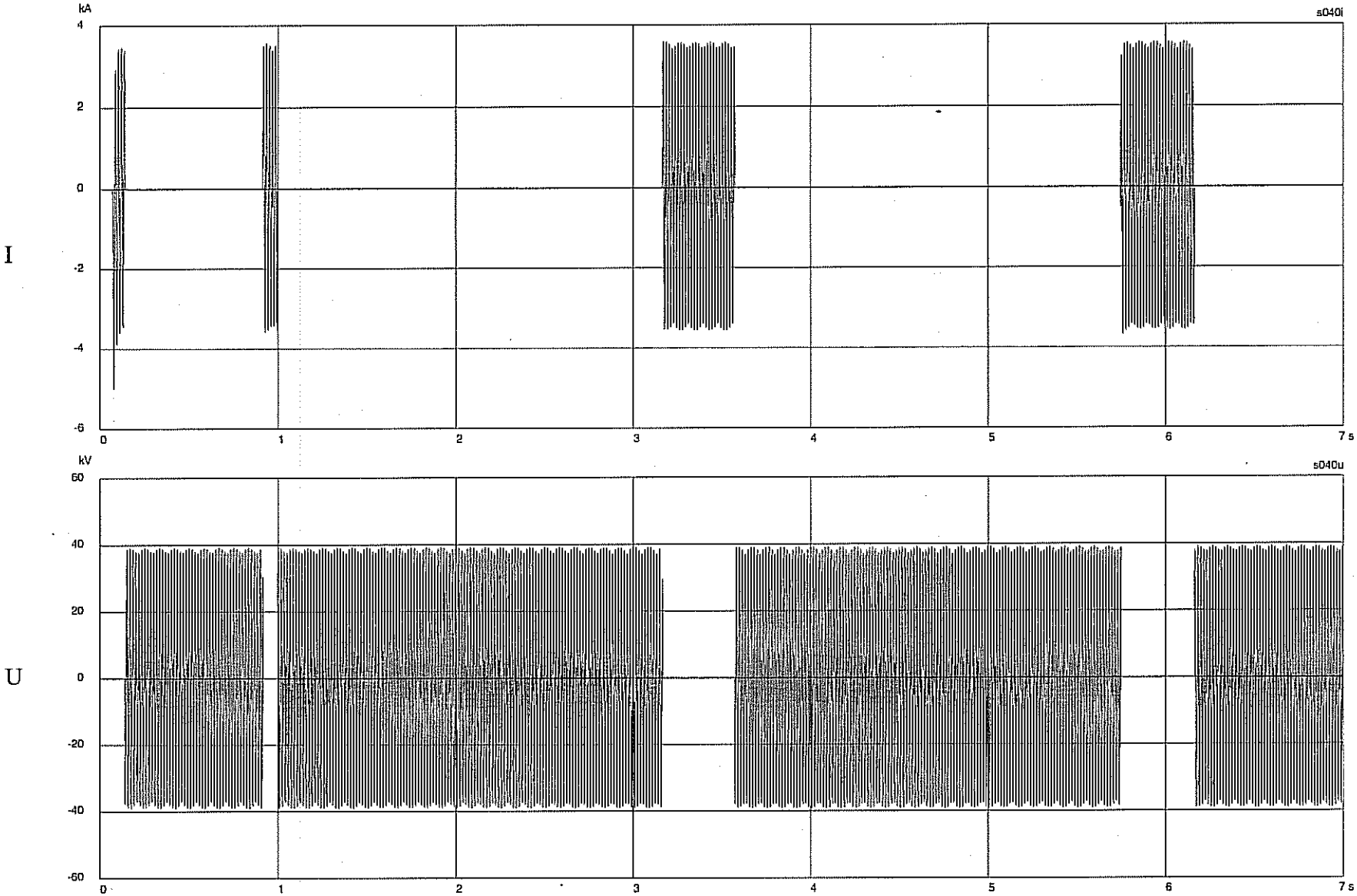


Figure 10. Typical 2.48 kA_{RMS} test. Overall waveform.

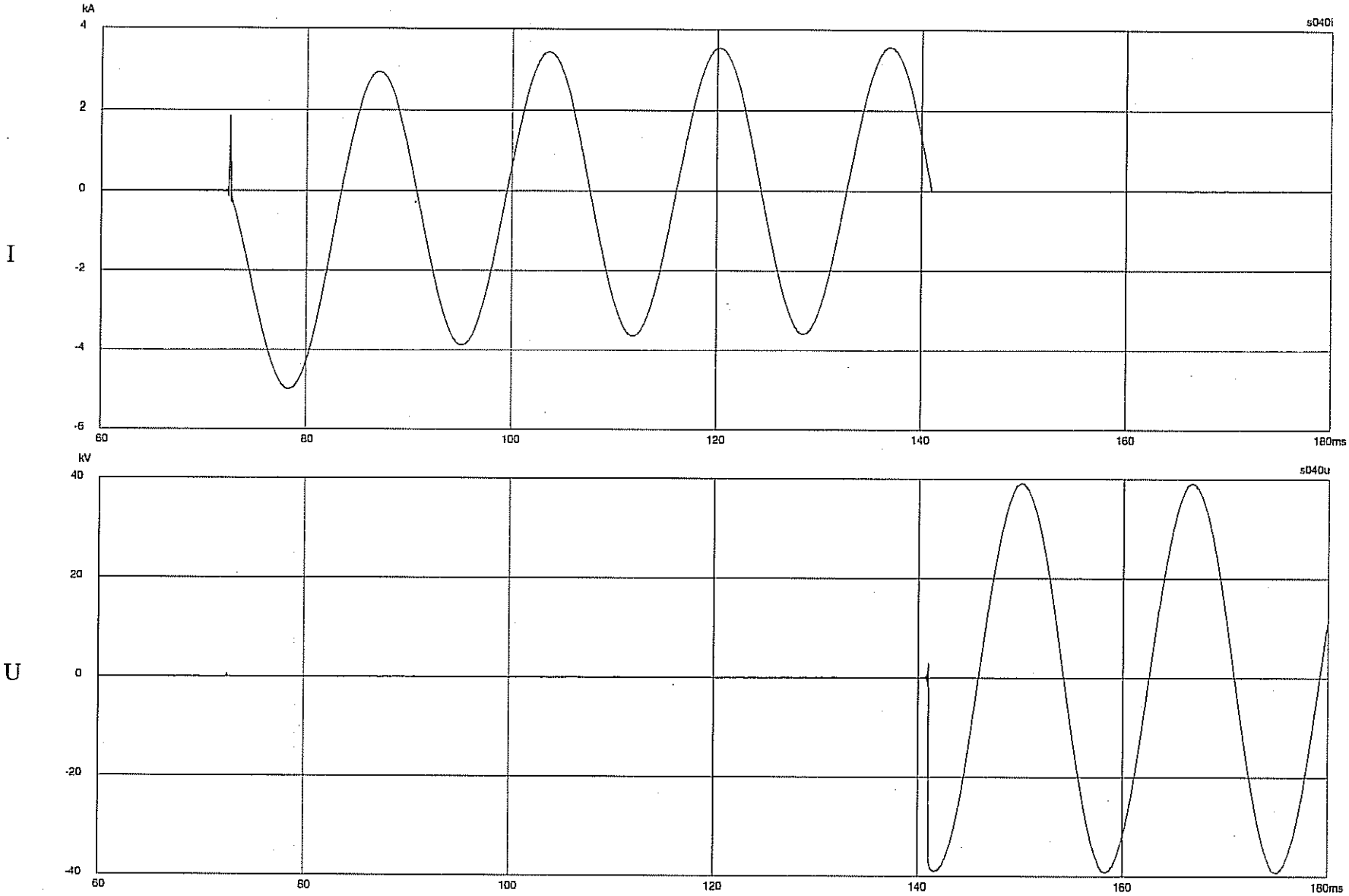


Figure 11. Typical 2.48 kA_{RMS} test. Opening operation.

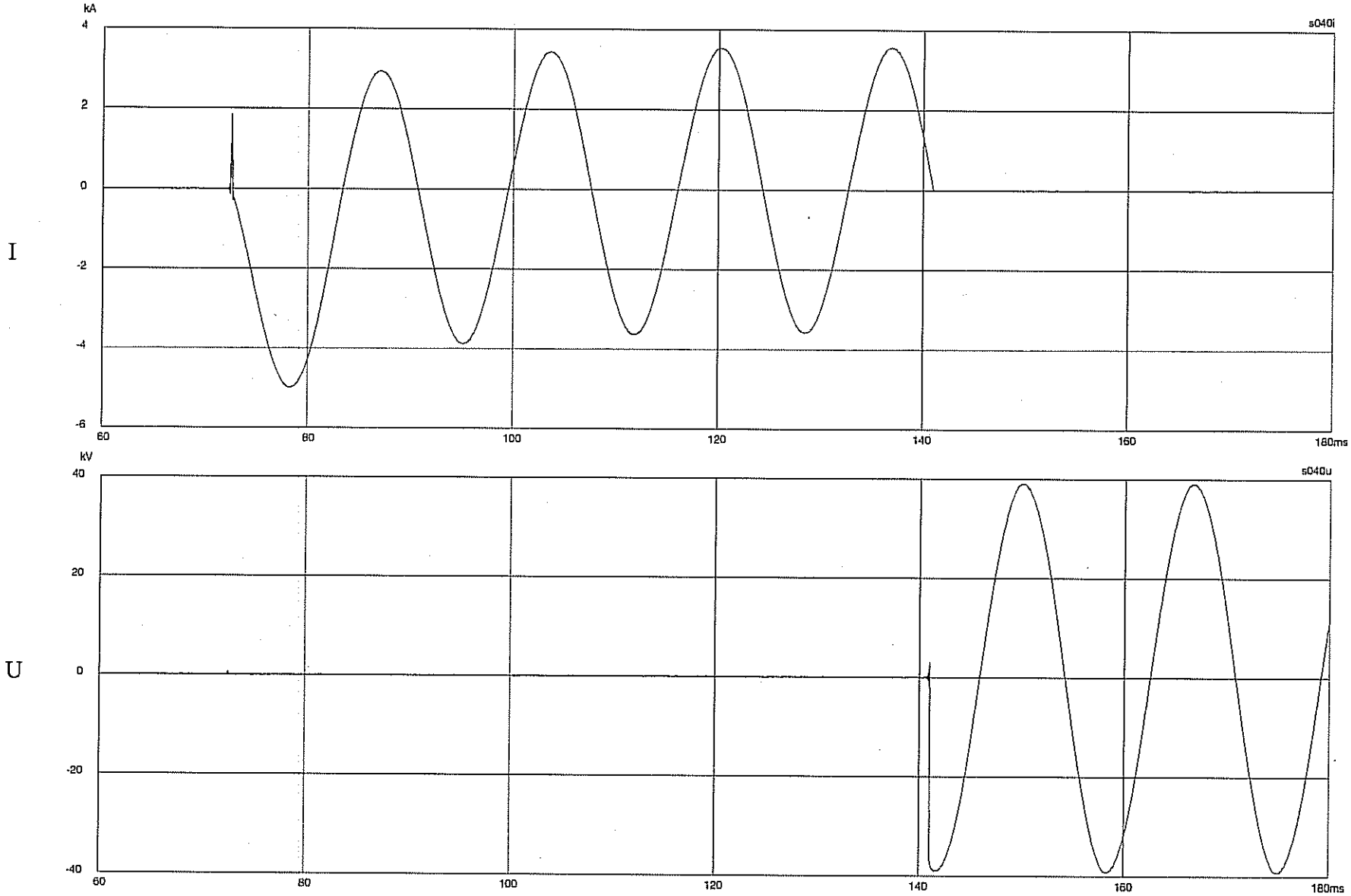


Figure 12. Typical 2.48 kA_{RMS} test. CO operation.

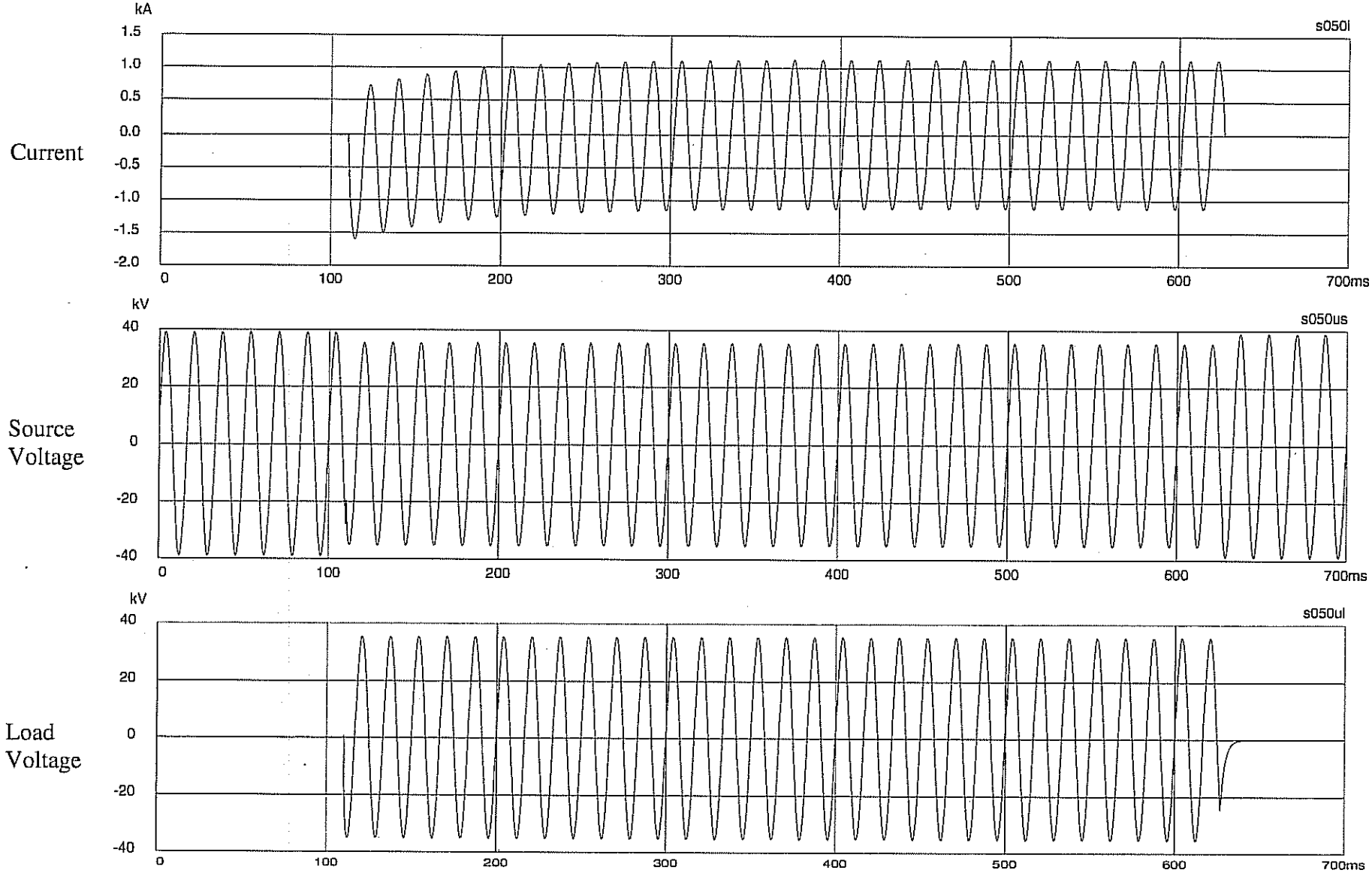


Figure 13. Typical load switching test

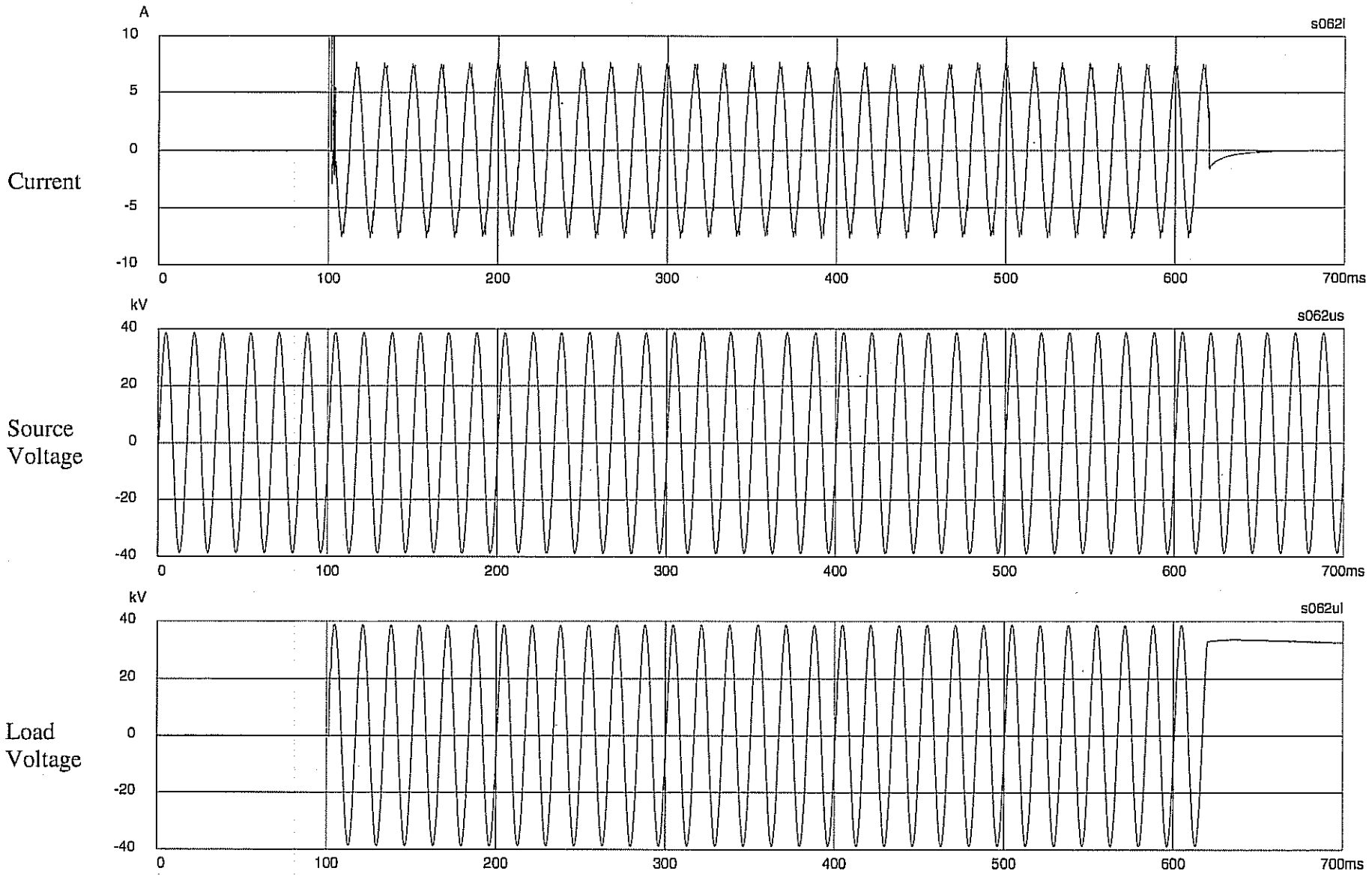


Figure 14. Typical line charging test.

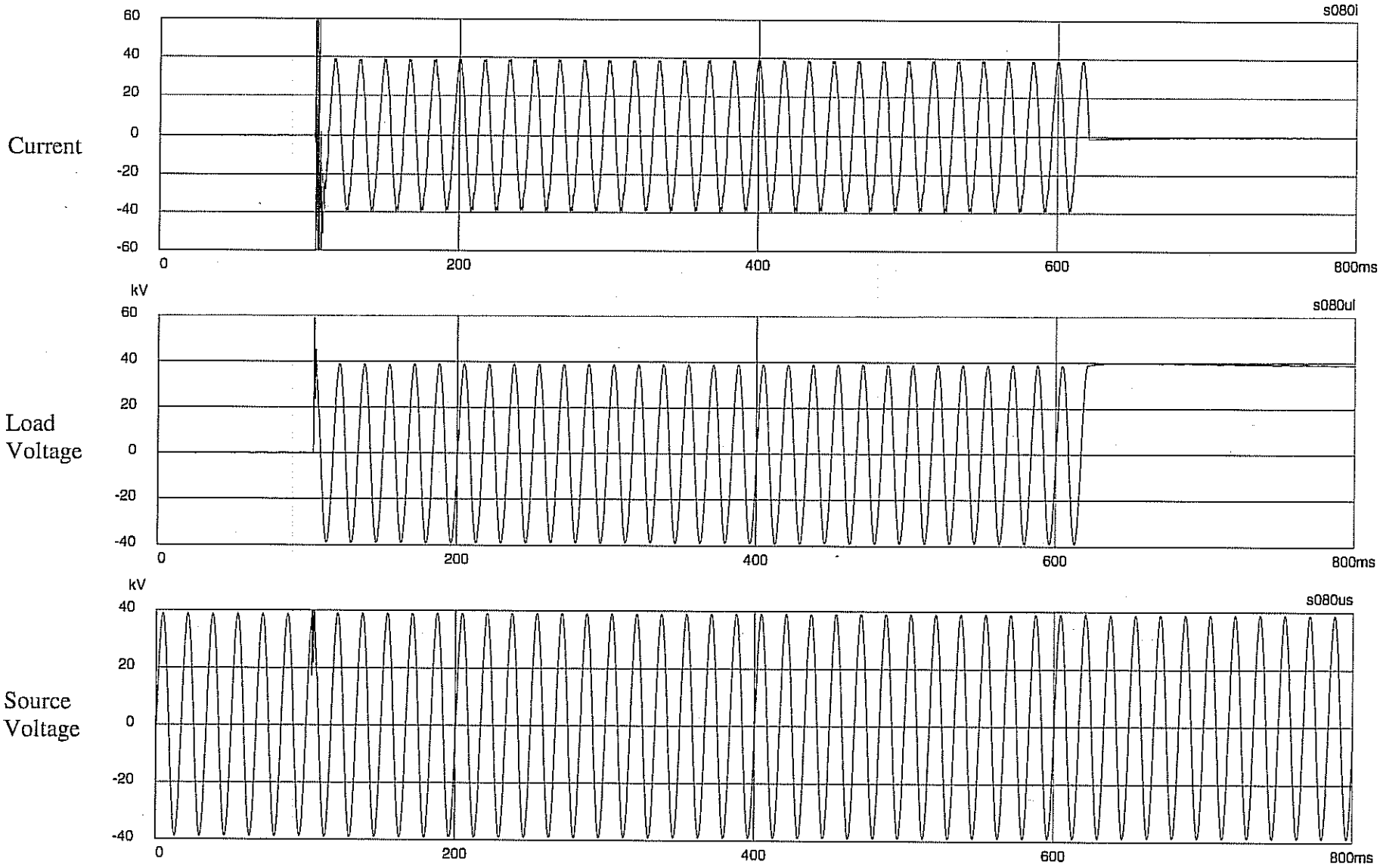


Figure 15. Typical cable charging test.

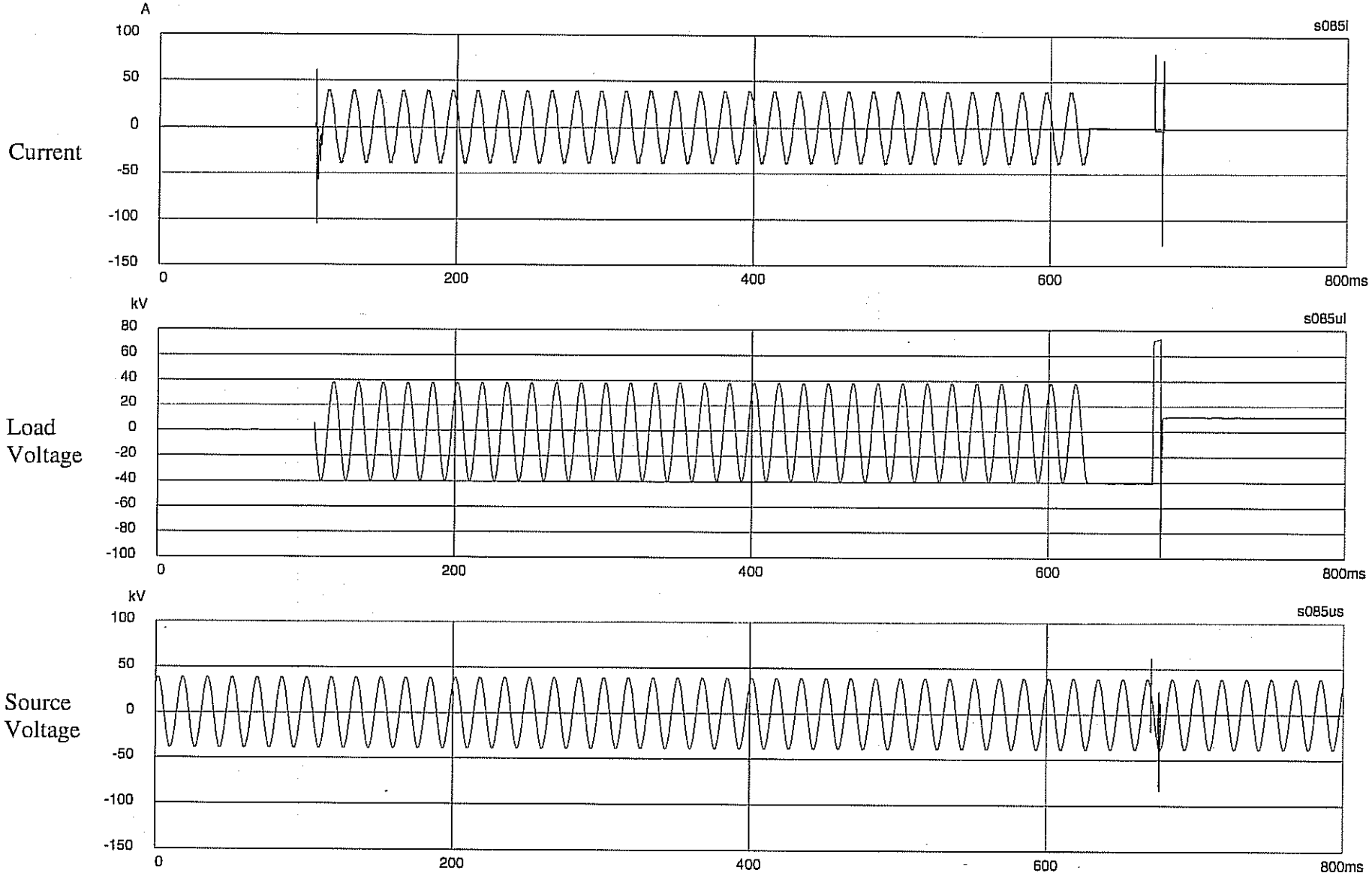


Figure 16. Cable charging test showing restrike.

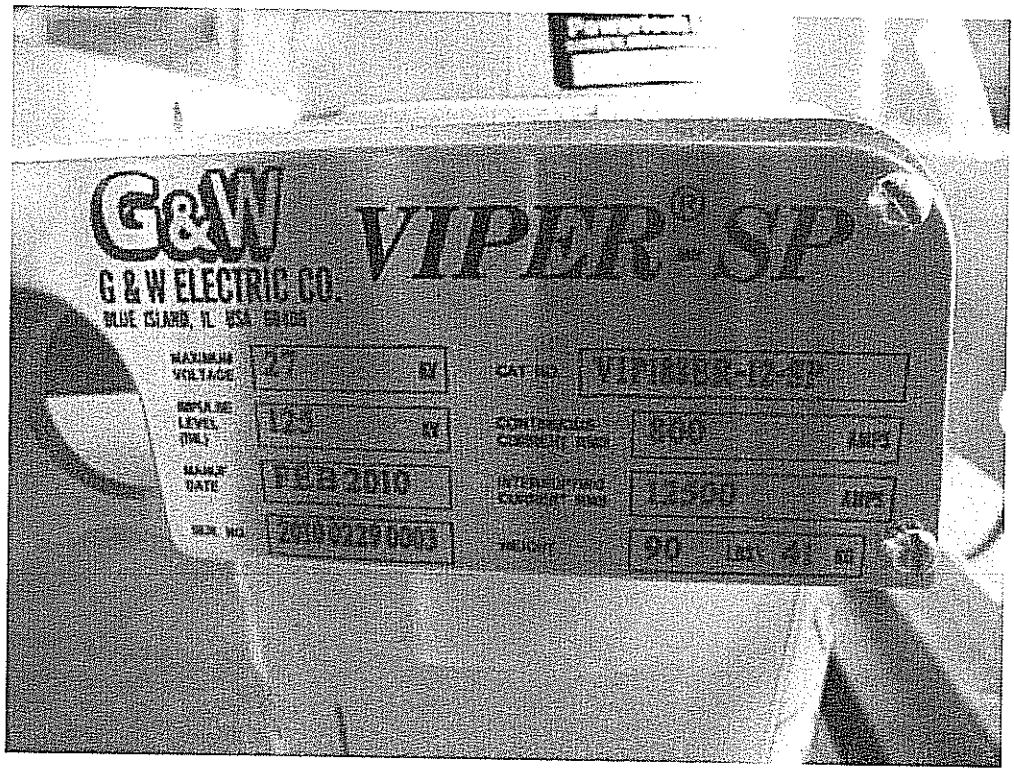


Figure 17. Recloser Unit #1 nameplate.

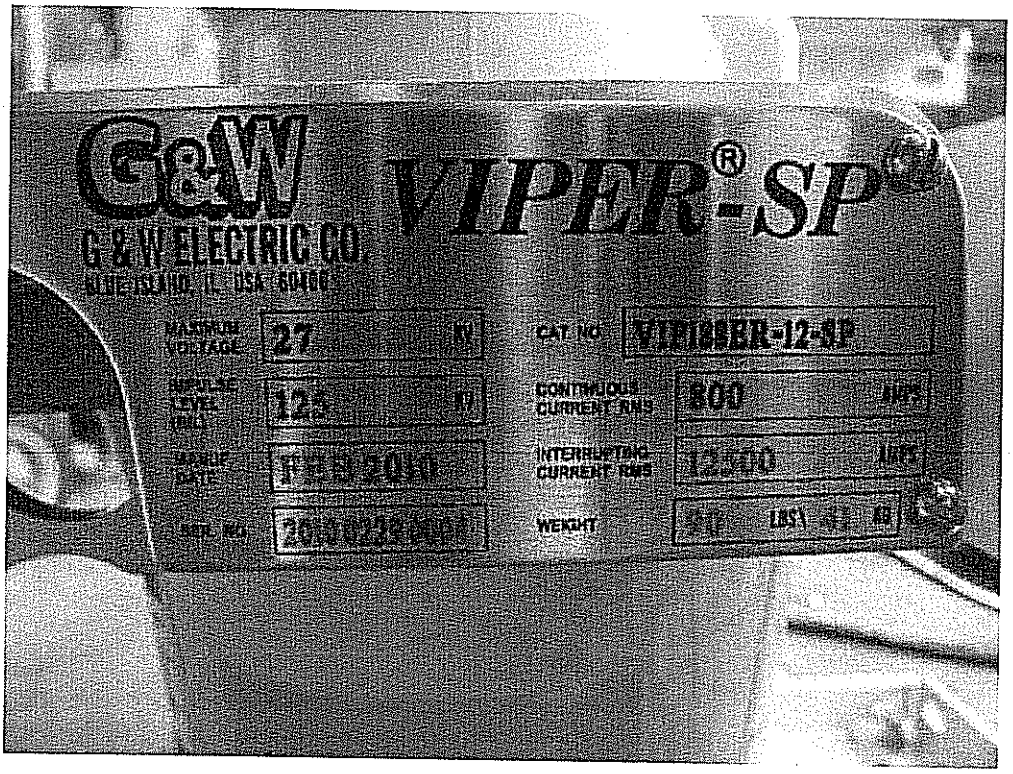


Figure 18. Recloser Unit #2 nameplate.

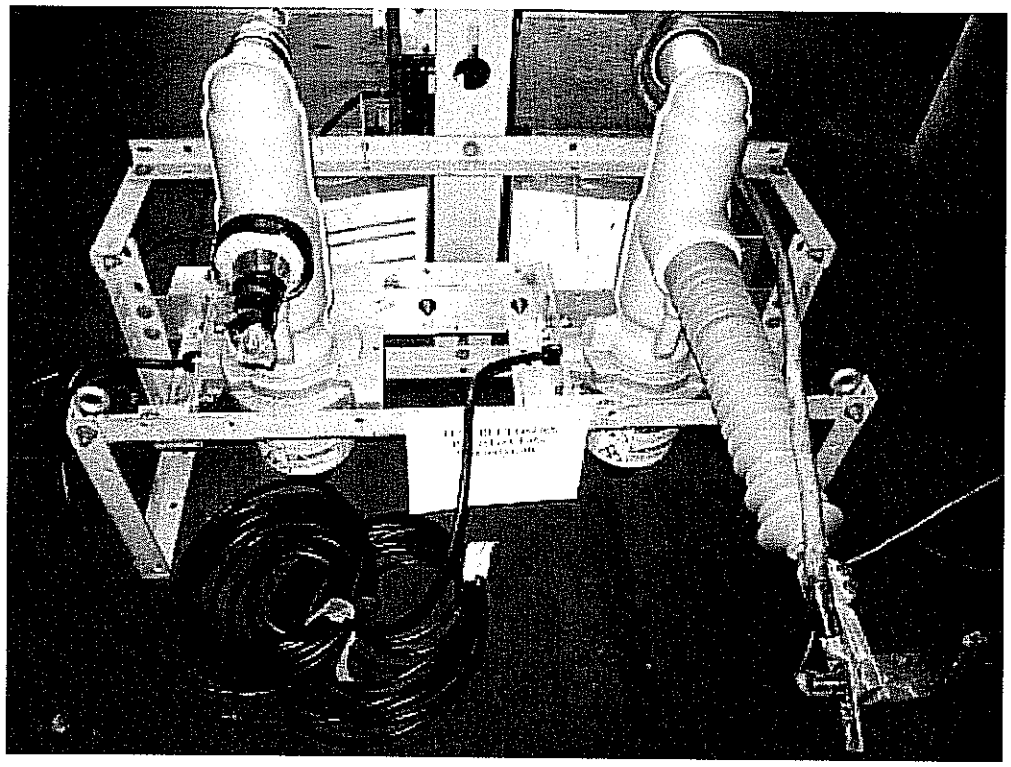


Figure 19. Overall view of tested Units #1 and #2.

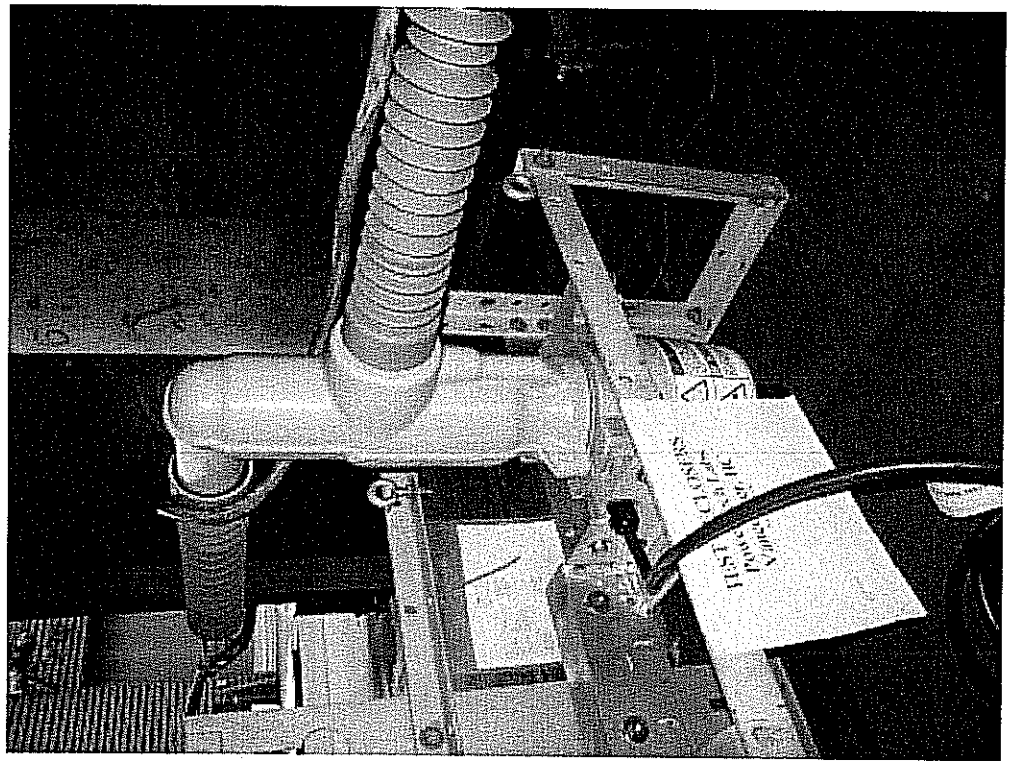


Figure 20. Overall view of tested recloser.

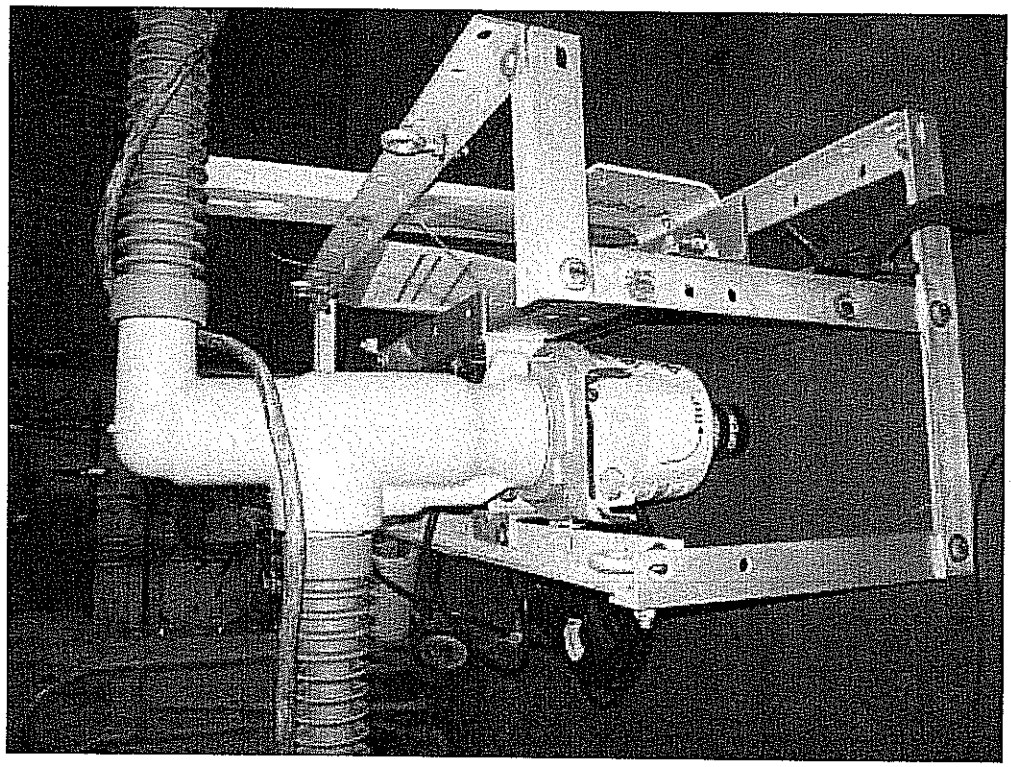


Figure 21. Overall view of tested recloser.

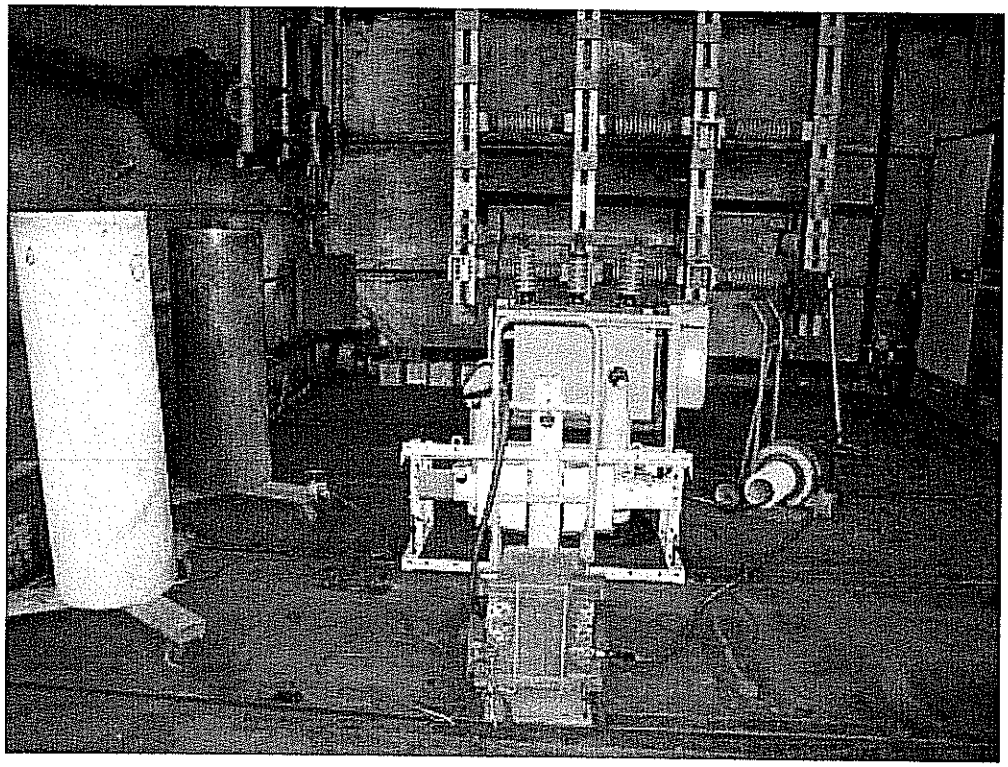


Figure 22. Overall view of test setup.

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12 March 2010

Suneetha Papupalli
G&W Electric Co.
3500 West 127th St
Blue Island
IL 60406
USA

Dear Suneetha,

Re: Test Reports for Project 19759-27

Please find enclosed 3 copies each of the following test reports:

- Recloser Controller Simulated Surge Arrester Operation
- Controller Oscillatory SWC
- Controller Fast Transient SWC

If you have any questions or comments, please contact me directly at (604) 590-7485, fax: (604)597-6656 or via e-mail: john.vandermaar@powertechlabs.com

Yours Sincerely,

for

John Vandermaar, P.Eng.
Manager, High Voltage Lab
Power Engineering Labs

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RECLOSER CONTROLLER SIMULATED SURGE ARRESTER OPERATION TEST REPORT

Client: G&W Electric Co., 3500 W. 127th Street, Blue Island IL, 60406

Test Date: February 24 - 25, 2010 | **Project:** 19759-27

Nameplate Data:

Single Phase Recloser Controller:

Manufacturer:	SEL
Model:	PROTO-351RS-02
Serial No.:	2010033533

Single Phase Switch:

Manufacturer:	G&W
Catalog No.:	VIP188ER-12-SP
Impulse level (BIL):	125 kV_{peak} Line-to-Ground
Rated voltage:	27 kV_{rms}
Rated current:	800 A_{rms} continuous/12.5 kA interrupting
Serial No.:	2010002290001

Test Witnesses: Luis Elizalde, G&W; Eric Pratt and Alex Bradley, SEL

Test Standard: IEEE Std C37.60-2003, Clause 6.13.2: "Simulated Surge Arrester Operation Test"

Atmospheric Conditions:

	Feb 24/10	Feb 25/10
Temperature	19.1 °C	19.2 °C
Relative humidity	37 %	41 %
Barometric pressure	747.5 mmHg	754.7 mmHg

Nominal Test Voltage and Current: 100 kV (125 kV * 0.8), 7 kA_{peak}

Test Configurations Tested (in accordance with the above standard):

A – 15 surges of positive polarity and 15 surges of negative polarity were applied to the source bushing with the switch open.
B – 15 surges of positive polarity and 15 surges of negative polarity were applied to the source bushing with the switch closed.
C – 15 surges of positive polarity and 15 surges of negative polarity were applied to the load bushing with the switch closed.
D - 15 surges of positive polarity and 15 surges of negative polarity were applied to a properly rated transformer with the recloser closed.
E- 15 surges of positive polarity and 15 surges of negative polarity were applied to a properly rated transformer with the recloser open.

Test Results: The controller and switch complied with the requirements of IEEE Std C37.60-2003, Clause 6.13.2, configurations A to E.

Remarks: The system passed with the addition of an external aluminium foil shield to the control cable.

Tested by:

12 MAR 2010

R.G. Pollock,
Senior Projects Specialist

Reviewed by:

12 Mar. '10

A.J. Vandermaar, P.Eng.
Manager, High Voltage Laboratory

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CONTROLLER OSCILLATORY SWC TEST REPORT

Client:	G&W Electric Co, Blue Island, IL 60406	
Test Date:	26 February 2010	**Project:** 19759-27
Nameplate Data: ***Controller:*** Manufacturer: Type: Serial No.: ***Single Phase Recloser Switch:*** Manufacturer: Type: Serial No.: Rated voltage: Rated current:	 SEL PROTO-351RS-02 2010033533 G&W VIP188ER-12SP 2010 0229 0001 27 kV_{rms}, 125 kV BIL 800 A_{rms} continuous, 12.5 kA interrupting	
Test Witness:	Luis Elizalde of G&W; Alex Bradley and Eric Pratt of SEL	
Test Standard:	IEEE C37.60-2003, Clause 6.13.1: "Oscillatory and fast transients surge tests"	
Atmospheric Conditions:	Temperature Relative humidity Barometric pressure	20.1 °C 47% 745.0 mmHg
Test Voltage:	2.5 kV_{peak}	
Test Procedure:	Test surge was applied to the control cable in common mode using a capacitive clamp and transverse mode through 1.5 mH coils. Test surge was applied to ac power input in common mode and transverse mode using an external coupling filter. The AC power supplied to the controller was 120 Volts, 60 Hz.	
Test Results:	The controller and recloser operated normally following the Oscillatory SWC Test performed in accordance with the test procedures as per the above document. The controller complied with requirements of "IEEE C37.60-2003, Clause 6.13.1".	
Remarks:	The system passed with the addition of an external aluminium foil shield to the control cable.	

Tested by:

12 MAR 2010

Robert G. Pollock
Senior Project Specialist

Approved by:

12 Mar. '10

A.J. Vandermaar, P.Eng.
Manager, High Voltage Laboratory

APPENDIX 1

Oscillatory SWC Waveform Validity Tests

(in accordance with IEEE Std C37.90.1-2002, Clause A.2)

Performed before the Oscillatory SWC Test

1. Measuring system feedthrough test

   Generator Output voltage 2.46 kV

   Feed through voltage 1.5 V (pass ≤ 1%)

2. Open circuit voltage waveform test

   Recorded waveforms – Figures 1 and 2.

3. Test Generator performance verification

Rise time of the first peak	83	ns	(60 to 90 ns – 10% to 90%)
Peak voltage level (no load)	2.27	kV	(2.25 to 2.5 kV when set to 2.5 kV)
Output impedance	225	Ω	(160 to 240 Ω)
Waveform envelope decay	4.98	µs	(4 to 6 µs to 50%)
Oscillation frequency	0.943	MHz	(0.9 to 1.1 MHz)
Repetition rate	8	bursts per period	(6-10 bursts per 16.7 mS)
Test duration	2.11	s	(2 to 2.2 s)

4. Test Pass X Test Fail _____

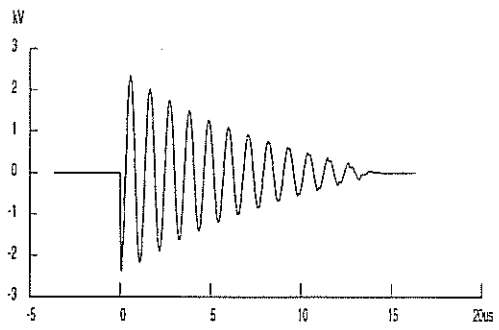

Figure 1

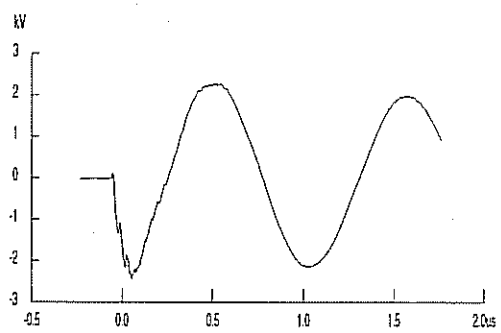

Figure 2

APPENDIX 2

Oscillatory SWC Waveform Validity Tests
(in accordance with IEEE Std C37.90.1-2002, Clause A.2)

Performed after the Oscillatory SWC Test

1. Measuring system feedthrough test

   Generator Output voltage 2.5 kV

   Feed through voltage 1.0 V (pass ≤ 1%)

2. Open circuit voltage waveform test

   Recorded waveforms – Figures 1 and 2.

3. Test Generator performance verification

Rise time of the first peak	80	ns	(60 to 90 ns – 10% to 90%)
Peak voltage level (no load)	2.5	kV	(2.25 to 2.5 kV when set to 2.5 kV)
Output impedance	195.7	Ω	(160 to 240 Ω)
Waveform envelope decay	5.44	µs	(4 to 6 µs to 50%)
Oscillation frequency	0.929	MHz	(0.9 to 1.1 MHz)
Repetition rate	8	bursts per period	(6-10 bursts per 16.7 mS)
Test duration	2.04	s	(2 to 2.2 s)

4. Test Pass X Test Fail _____

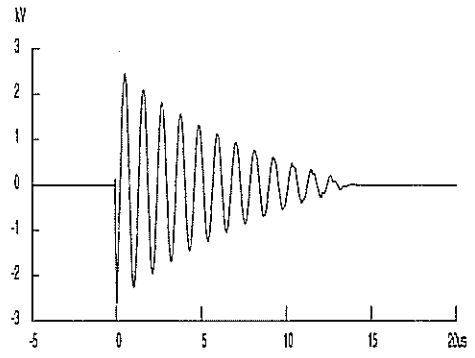

Figure 1

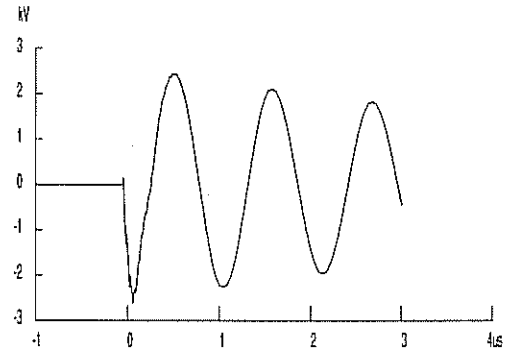

Figure 2