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GLEN CANYON 230-KV SHUNT CAPACITOR AND 345-KV AUTOTRANSFORMER SWITCHING TRANSIENT FIELD TESTS

September 1990

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16. ABSTRACT

This document contains the results of the Glen Canyon Switchyard 230-kilovolt shunt capacitor and 345-kilovolt autotransformer switching transient field tests conducted by the Bureau of Reclamation from August 28 to September 2, 1989. These tests were conducted to determine if routine switching of four new 50-megavar, 230-kilovolt shunt capacitor banks in various combinations would produce undesired transient disturbances to the power system or station relaying. Glen Canyon Dam is located on the Colorado River near Page, Arizona.

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by

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Electric Power Branch
Research and Laboratory Services Division
Denver Office
Denver, Colorado

September 1990

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

Mission: As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

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INTRODUCTION

The Glen Canyon 230-kilovolt switchyard tests were conducted from August 28 to September 2, 1989, and data reduction and analysis have been completed. The August 1989 field test procedure is included as an appendix to this report. Due to power circuit breaker misoperations experienced during these tests, capacitor switching tests 5 and 9 of series I were omitted. A partial single-line diagram of the Glen Canyon Switchyard is given in figure 1.

CONCLUSIONS

The field tests and records provide the following observations and conclusions:

- The largest capacitor bank switching transient phase and neutral currents occurred, as anticipated, during the back-to-back switching tests. This corresponds to tests 3 and 8 of series I. These currents reached peak magnitudes of more than 6 kiloamperes at a natural frequency of 5.5 kilohertz.

- The most severe 230-kilovolt bus transient overvoltage observed (154 percent rated peak phase-to-neutral voltage) occurred during test 3, series I, where one capacitor bank was energized with one other bank on-line. Note, however, that energizing one or two banks with no other banks on-line produced nearly as high transient overvoltages (138 percent and 144 percent for tests 1 and 2).

- Measured step-and-touch potentials at capacitor bank PZ7B and the west corner of the switchyard were less than 100 volts peak for all tests. This indicates that the switchyard ground mat design is adequate for the short-time transient currents generated during capacitor switching operations.

- The transient voltages measured across the 50/51 and 87B4 relay phase A current transformer secondary burdens at circuit breaker JZ7C were less than 40 volts peak for all tests.

- Energizing autotransformer KU5A from the 230-kilovolt system caused noticeable high-frequency transient currents to appear in the phase and neutral leads of energized capacitors (see fig. 17 for example). These high-frequency transient currents were not severe enough to cause the capacitor unbalance protective relaying to misoperate.

- Several capacitor switching operations produced transient disturbances severe enough to cause 230-kilovolt circuit breakers 8082 and 8186 to incorrectly trip open. The tripping occurred during tests 6 and 7 of series I when one or two capacitor banks were energized on the west bus with two banks connected to the east bus. During these tests, peak switching transient currents on the 230-kilovolt bus ranged from 2,600 to 4,800 amperes at 1,200 to 1,480 hertz for tests 6 and 7, respectively.

- The circuit breaker pole current conduction process can be clearly observed during the closing operation of PCB JZ7C, as evident in figures 2 and 4 for tests 1 and 2, series I. As the breaker contacts traveled to close the gap, an arc established in the individual poles as the power system phase-to-neutral voltage (voltage across the gap) in each phase approached a crest. Each pole, therefore, began to conduct at a different time determined by the voltage stress across the gap as the contacts met. The time elapsed from initiation of the first pole conduction to the last during these tests was generally 3 milliseconds, or about the minimum time required for each of the three phases to pass through a voltage crest at 60 hertz. Pole restrikes can be observed in instances where current interruption is evident, caused by insufficient voltage across the contact gap to sustain the arc.

INSTRUMENTATION AND FIELD TEST SETUP

Figure 1 indicates connection points of the test instrumentation to the power system and the positive current references. CVACCT's (current-to-voltage air core current transformers) were located at capacitor bank PZ7B and at the neutral bushing of autotransformer KU5A to monitor three-phase capacitor currents and autotransformer neutral current. RCS's (resistor current shunts) were inserted in the metering current transformers at the control building to monitor autotransformer KU5A three-phase currents. FCECT's (ferrite core electronic current transformers) were installed at power circuit breaker JZ7C to measure three-phase currents. At the same location, PIA (potential isolation amplifiers) were wired to monitor transient voltages across relays 87B4 and 50/51 current transformer secondary burdens. BTP (bushing tap potential) devices were installed on the 230-kilovolt system bushings at autotransformer KU5B to monitor phase-to-ground voltage in each phase. Step-and-touch potential probes, shown as Vs and Vt in figure 1, were used to monitor the high-frequency transient response of the station ground mat.

The instrumentation was designed for optimum frequency response (minimum gain and phase angle error) over a range of 60 hertz to 10 kilohertz. This frequency range was chosen based on an electromagnetic transients program study done by WAPA (Western Area Power Administration) for these switching tests. The amplitude frequency response is flat to within 0 to -10 percent gain error for the current instrumentation, and to within 0 to -2 percent for the voltage instrumentation. The phase angle shift is linear with frequency, with a maximum phase shift of 10° and 35° at 10 kilohertz for the current and voltage instrumentation, respectively.

The instrumentation and connection schemes were carefully designed to minimize the effects of ground loops and stray pickup from within the 230-kilovolt switchyard. Noise reduction techniques using instrumentation and cable shielding, single-point grounding, and fiber optic isolation were employed to reduce the coupling in the high-noise environment of the capacitor switchyard. However, it is evident form these field data and laboratory tests that noise is present with the valid power system signals. The data must be interpreted with the caution stated below.

DATA SUMMARY

Results of the series I capacitor bank switching transient tests are given in figures 2 through 15. Results of the series II transformer magnetizing current inrush tests are presented in figures 16 through 21. On these figures, legends are used to point out salient features such as circuit breaker poles closing, pole restrikes, switchyard bus overvoltages, frequencies generated in the transient, etc. In cases where the frequency varies during the transient period due to system nonlinearities, ranges rather than single values are given. Also indicated are instrument-related phenomena such as instrument signal cable ringing and stray noise pickup. It was determined in the laboratory that all recorded signals with frequencies on the order of 30 kilohertz and higher are due to cable ringing. Further tests of the instrumentation helped to identify stray pickup signals, and these are indicated in some of the traces. The signal chart zero line has been drawn and indicated for cases where it does not coincide with the center line of the recorded waveform. This offset is the result of nonideal instrument amplifier response to large power system transients. However, if the amplifier does not saturate, the a-c data riding on the offset can be scaled with the reconstructed zero line.

Excluding the capacitor bank 230-kilovolt circuit breakers, all the 230- and 345-kilovolt switchyard circuit breakers were closed at the time these tests were conducted. Generators on-line during these tests were as follows:

Test No.	Glen Canyon generators on-line
Series I	
1	1, 2, 3, 4, 5, 6, 7, 8,
2	1, 2, 3, 4, 5, 6, 7*, 8
3	1, 2, 3, 4, 5, 6, 7*, 8
4	1, 2, 3, 4, 5, 6, 7*, 8
6	1, 2, 3, 4, 6, 7, 8*
7	1, 2, 3, 4, 5, 6, 7*, 8
8	1, 2, 3, 4, 6, 7, 8*
Series II	
1	1, 2, 3, 4, 5, 6, 7, 8
2	1, 2, 3, 4, 5, 6, 7, 8
3	1, 2, 3, 4, 5, 6, 7, 8
4	1, 2, 3, 4, 5, 6, 7, 8
5	1, 2, 3, 4, 5, 6, 7, 8

* Machine was running as synchronous condenser.

RESULTS

Figure 2 shows traces of switching transient currents and voltages produced when 230-kilovolt capacitor bank PZ7B was energized with no other banks on-line (series I, test 1). The highest capacitor bank transient current occurred in phase B, reaching about 1600 amperes peak. The resulting peak transient overvoltage on that phase was 133 percent rated peak phase-to-neutral voltage. Note that the highest transient overvoltage occurred in phase A at 138 percent. A pole restrike occurred on phase B of circuit breaker JZ7C, resulting in a voltage discontinuity of approximately 25 kilovolts. Capacitor switching transient currents ranged in frequencies from 720 to 1020 hertz for the phase currents and 660 to 720 hertz for the neutral current. Figure 3 shows the corresponding phase and neutral current traces for autotransformer KU5A. It also shows the 230-kilovolt bus voltage of phase A taken at east bus capacitor voltage transformer VZ7A. Notice that the amplitude response of this device has a significant attenuation at high frequencies when compared to the 230-kilovolt bushing tap potential traces in figure 2.

Energization of two capacitor banks (PZ7A and PZ7B) with no other banks on-line (series I, test 2) yielded similar magnitude transient phase currents but a larger neutral current as shown in figure 4. Overvoltages on the 230-kilovolt bus were also slightly larger than the previous test, reaching 144 percent rated peak phase-to-neutral voltage. Current interruption and restrike of the phase C pole of circuit breaker JZ7C is clearly evident in the current traces. As predicted in electromagnetic transient program studies performed by WAPA, the capacitor transient currents consisted of a low-order oscillation at 600 hertz and a high order of oscillation at 5.5 kilohertz, as can be seen in these traces. The higher frequency is superimposed on the lower frequency. Figure 4A is a time-expanded version of figure 4 that clearly shows the high frequency component. Autotransformer KU5A phase and neutral current traces are given in figure 5.

Results of tests 3 and 8 of series 1 are shown in figures 6 and 14, respectively. For test 3, capacitor bank PZ7B was energized with only PZ7A on-line. For test 8, the same capacitor bank (PZ7B) was energized but with PZ7A, PZ8A, and PZ8B on-line. In (close) agreement with the western electromagnetic transients program study predictions, these back-to-back capacitor bank switching tests produced transient peak currents up to 6.6 kiloamperes in magnitude and 5.5 kilohertz frequency of oscillation in both cases. Figures 6A and 14A are time expansion versions of the current traces for PZ7B. Figure 8 shows phases B and C current traces for test 3 (repeat) using more sensitive current scales, thus allowing one to observe the 60-hertz steady-state load current that is almost unnoticeable in figure 6. Large peak transient overvoltages, about 155 percent rated peak phase-to-neutral voltage, were recorded on the 230-kilovolt bus for test 3 (repeat). For test 8, in spite of the high transient currents measured, the overvoltage was only 119 percent. Figures 7 and 15 show autotransformer KU5A current traces for tests 3 and 8, respectively.

The remainder of the series I test data shown in figures 9 through 15 are for various combinations of capacitor bank(s) energized from the 230-kilovolt west bus, with bank(s) connected to the 230-kilovolt east bus. As expected, the transient switching currents observed in all the tests with capacitor bank(s) connected to the east bus are larger than without capacitors on the east bus, but are lower than observed for the back-to-back bank switching tests on the west bus. The reason for these lower transient currents lies in the 4-millihenry series current limiting reactors connecting both capacitor bank systems to the 230-kilovolt buses. Frequencies of transient capacitor currents range between 1200 and 1700 hertz. A very small high-frequency component of 5.5 kilohertz also appears in test 7 when two capacitor banks were energized on the 230-kilovolt west bus with two banks connected to the east bus. The interaction of banks on the same bus (without 4-millihenry current limiting series reactors) generates this high-frequency oscillation, the same as observed for the back-to-back bank switching tests. The highest peak transient bus overvoltage of these three tests occurred during test 6 (133 percent rated peak phase-to-neutral voltage).

Strip chart traces of autotransformer KU5A magnetizing inrush currents with no capacitor banks on-line (test 1, series II) and with all four banks on-line (test 5, series II) are given in figures 16 and 21, respectively. The inrush current traces shown in these figures are representative of all the series II field test data. Typically, it took 10 seconds for the inrush current to die out to 10 percent of its initial peak value.

In general, the steady-state capacitor bank load currents recorded at capacitor bank PZ7B and circuit breaker JZ7C for the series II tests show harmonic distortion. The distinguishable harmonic components varied for different tests. The 11th harmonic was the most prominent in test 2, the 7th in test 3, and the 5th in tests 4 and 5. The capacitor bank PZ7B neutral current trace for test 5 shows a 9th harmonic component. In all cases when autotransformer KU5A was energized, the current distortion increased. During test 5, the PZ7B neutral current increased about 15 times when interrupter switch WZ5C was closed. A very noticeable distortion in the 230-kilovolt bus voltage resulted in this test.

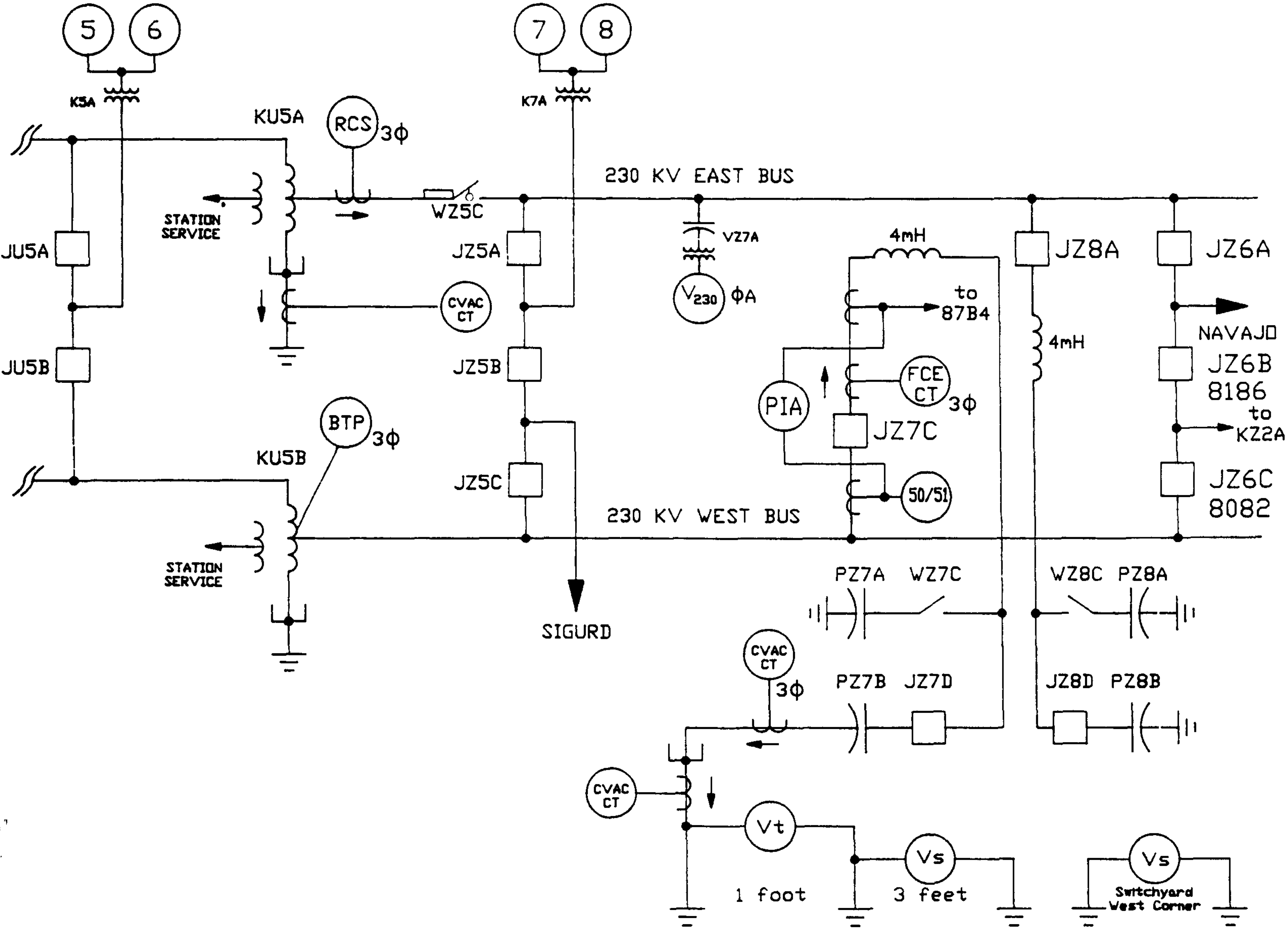


Figure 1. - Partial single-line diagram of the Glen Canyon Switchyard and test instrumentation.

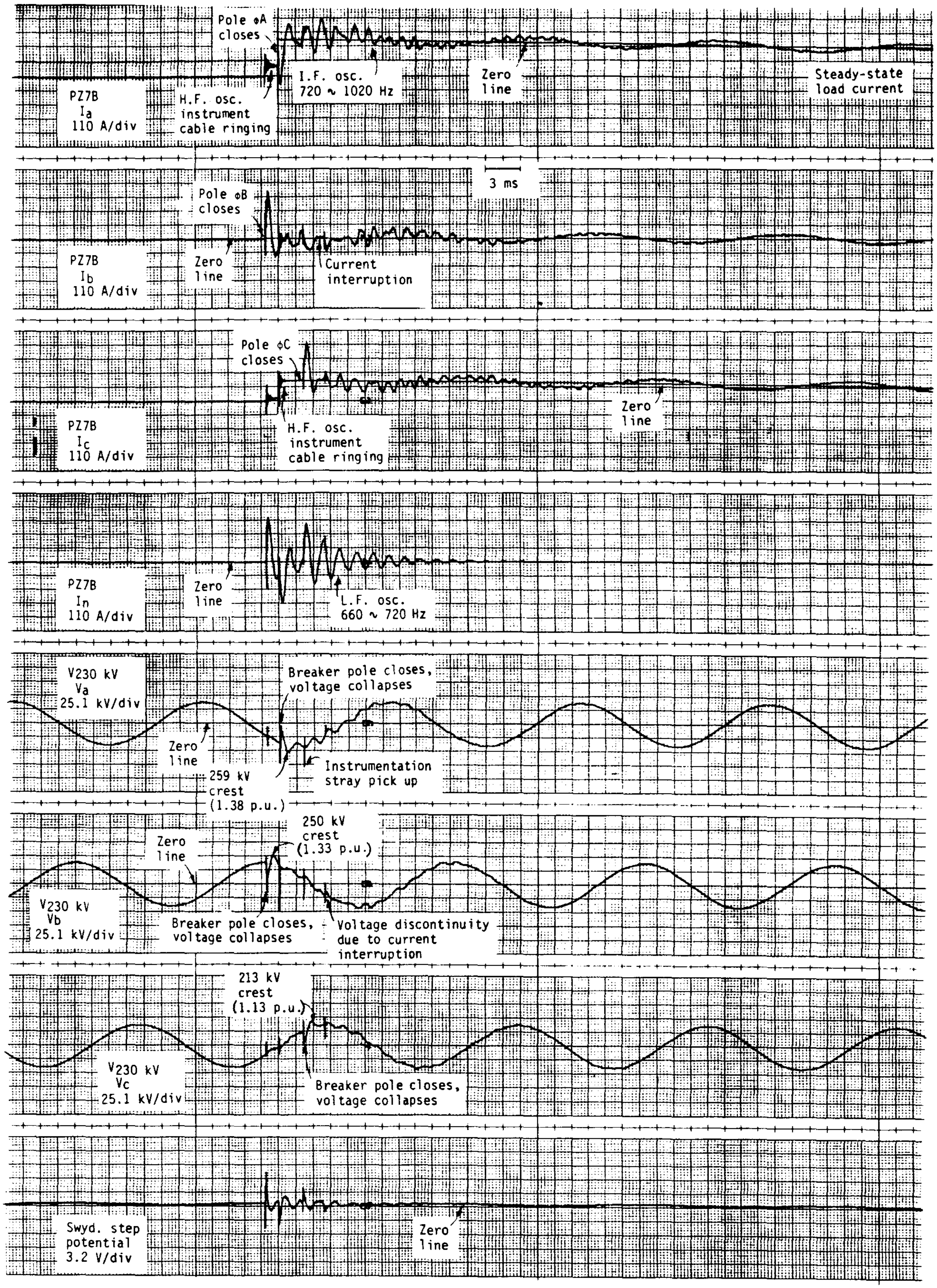


Figure 2. - Series I, test 1: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. No other banks on-line.

Figure 2. - Series I, test 1: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. No other banks on-line. - Continued

Figure 3. - Series I, test 1: digital electronic strip chart traces of transformer KU5A 230-kV side voltage and currents when capacitor bank PZ7B energized. No other banks on-line.

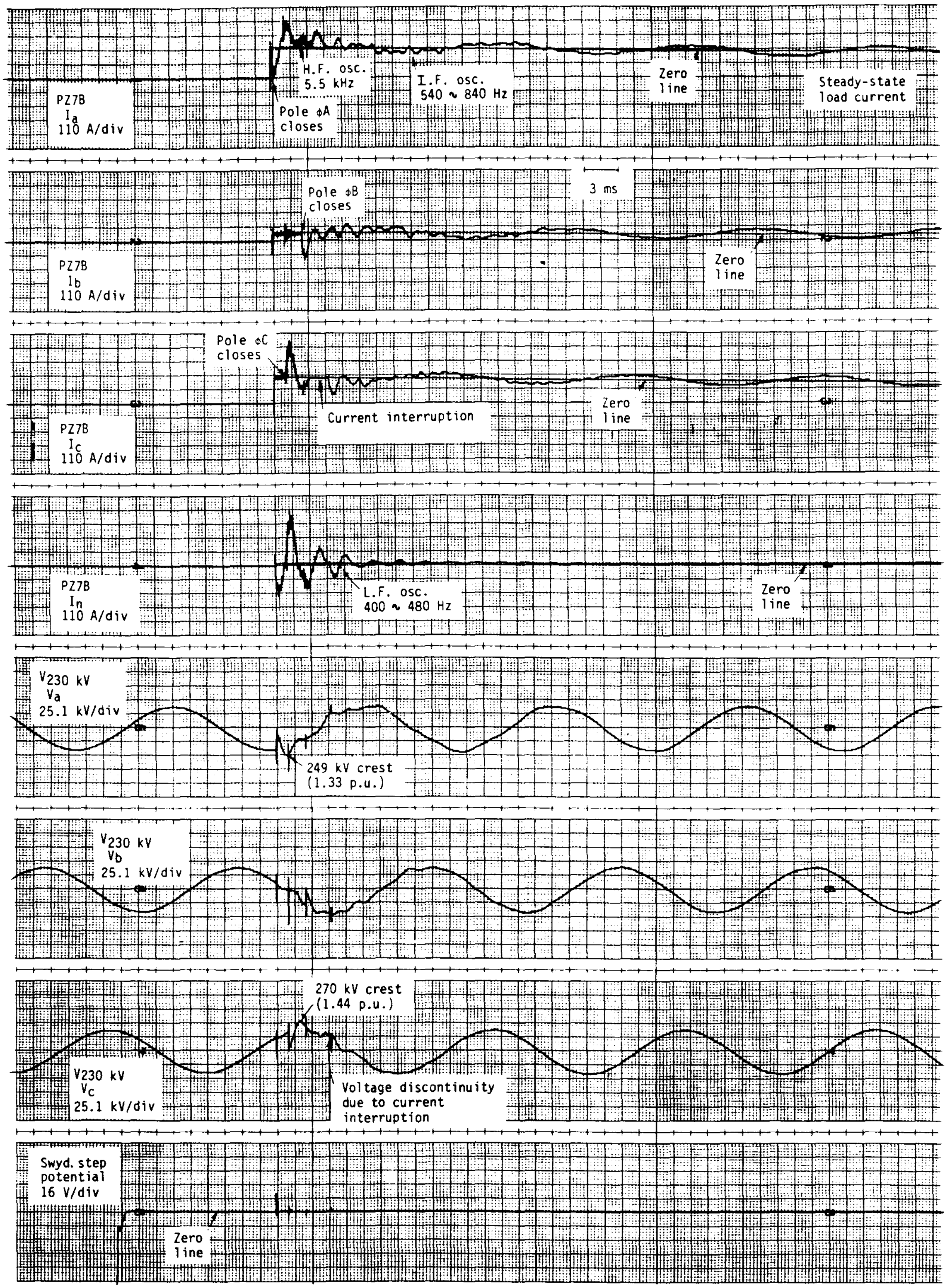


Figure 4. - Series I, test 2: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor banks PZ7A and PZ7B energized. No other banks on-line.

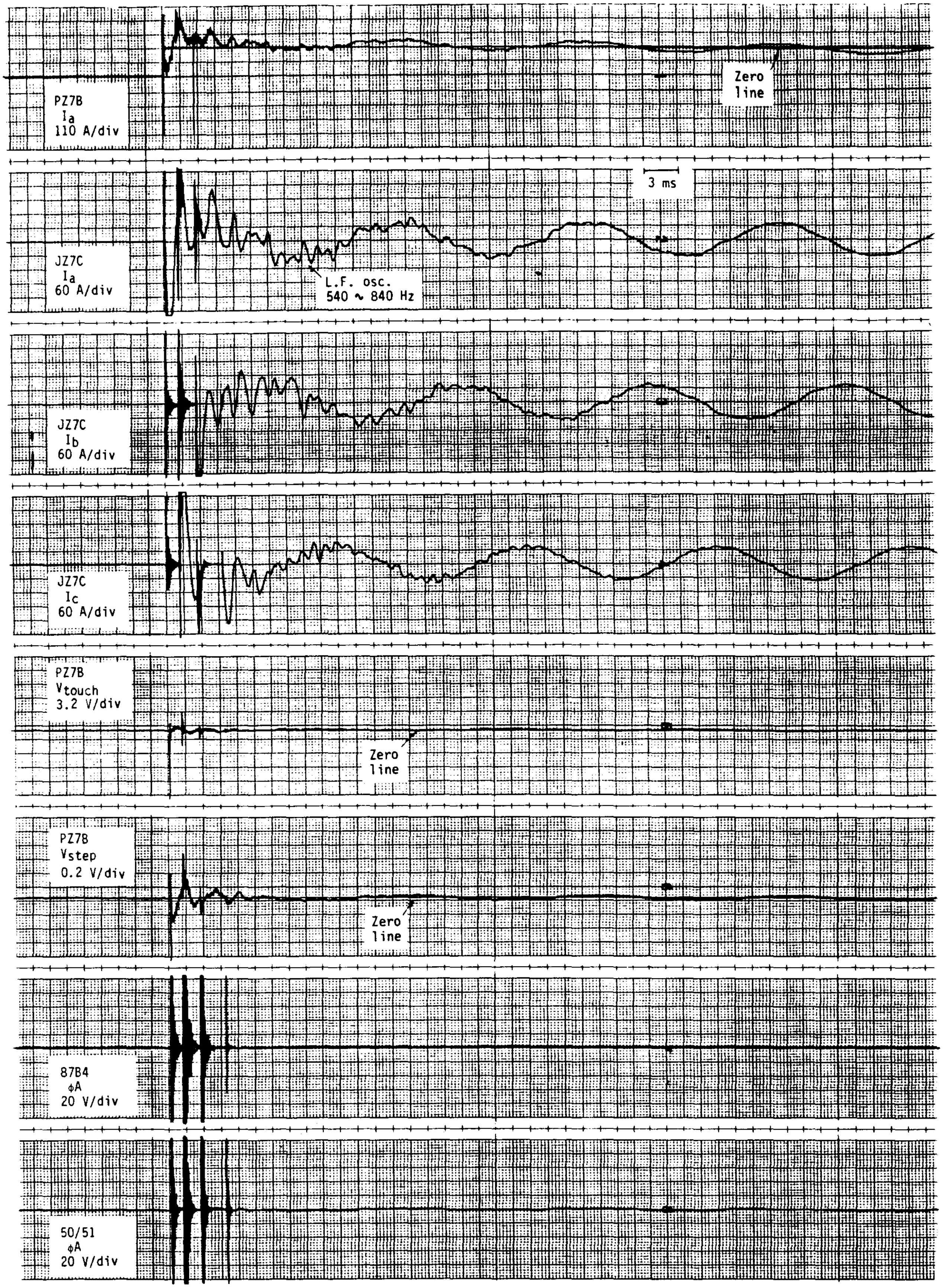


Figure 4. - Series I, test 2: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor banks PZ7A and PZ7B energized. No other banks on-line. - Continued

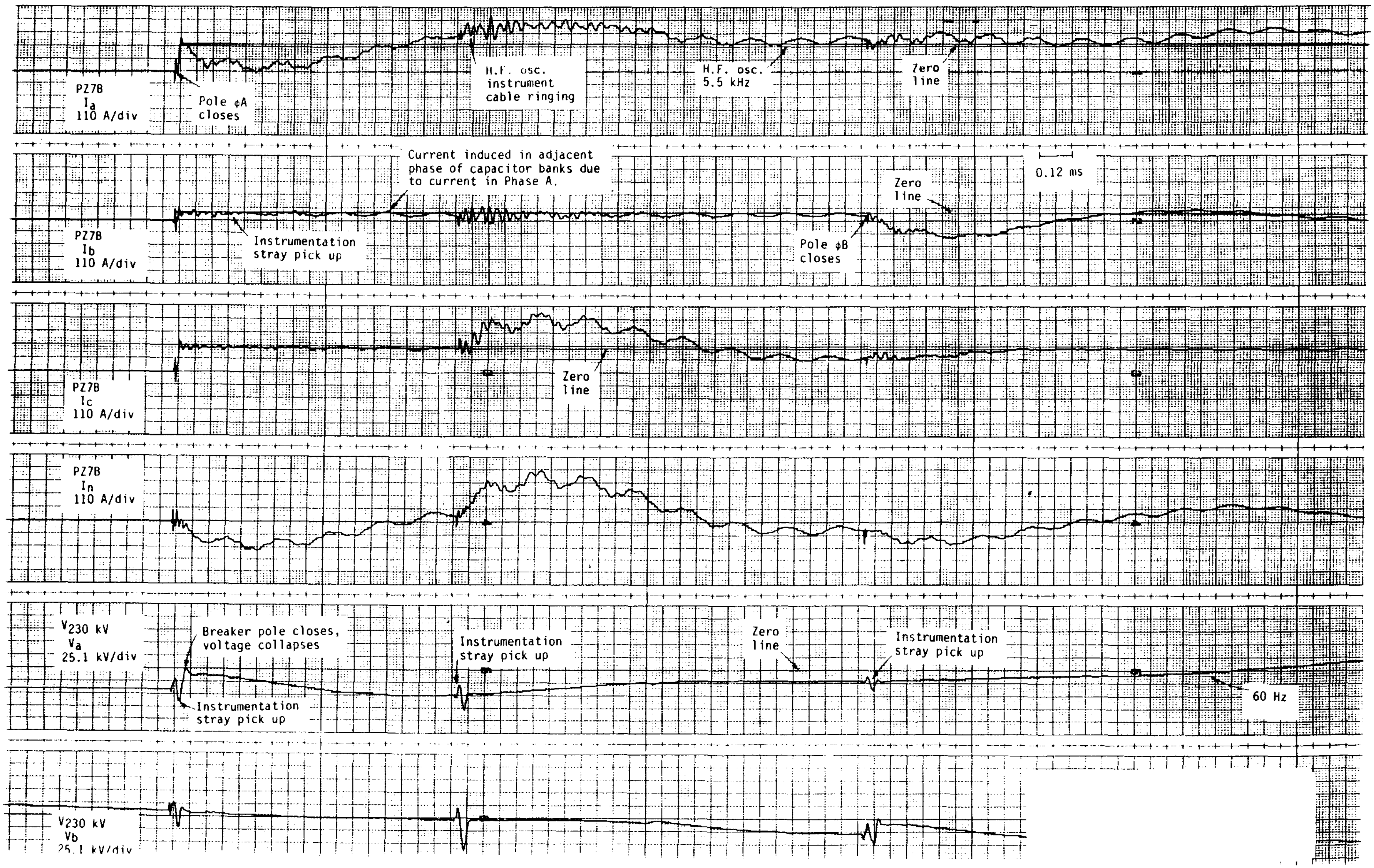


Figure 4A. - Series I, test 2: time expansion of capacitor banks PZ7B currents and 230-kV bus voltage strip chart traces shown in figure 4.

Figure 5. - Series I, test 2: digital electronic strip chart traces of transformer KU5A 230-kV side voltage and currents when capacitor bank PZ7A and PZ7B energized. No other banks on-line.

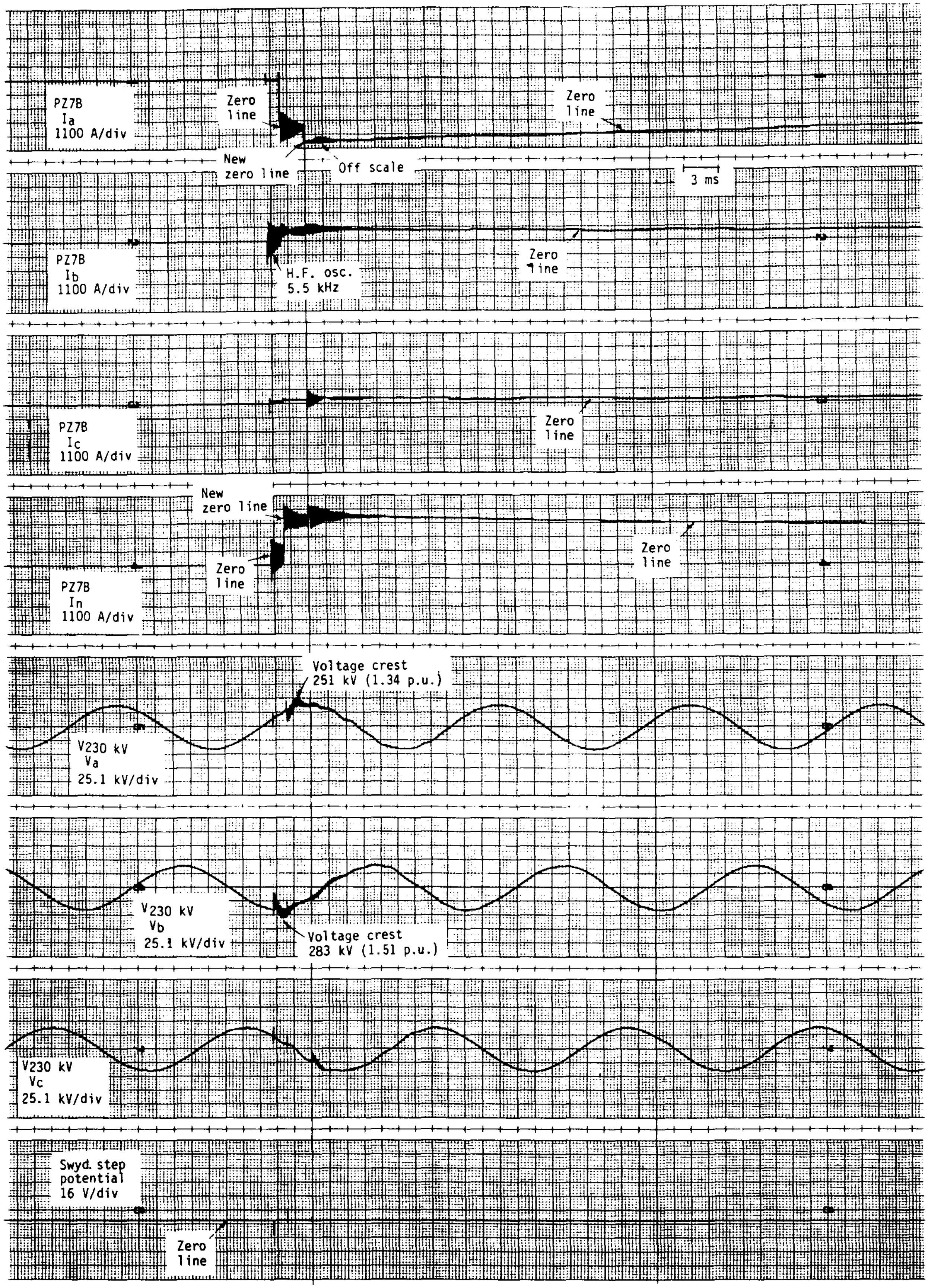


Figure 6. - Series I, test 3: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor bank PZ7A on-line.

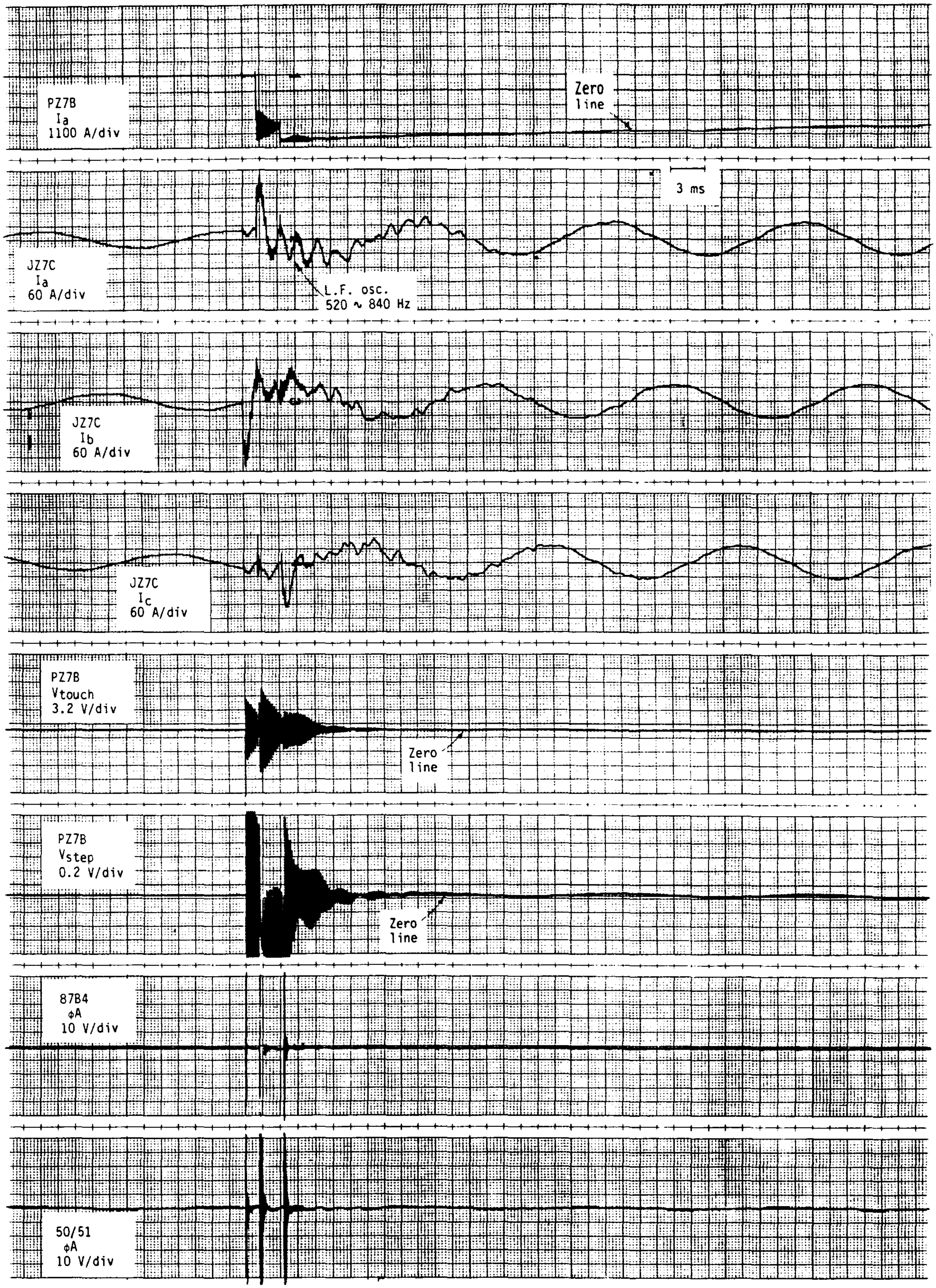


Figure 6. - Series I, test 3: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor bank PZ7A on-line. - Continued

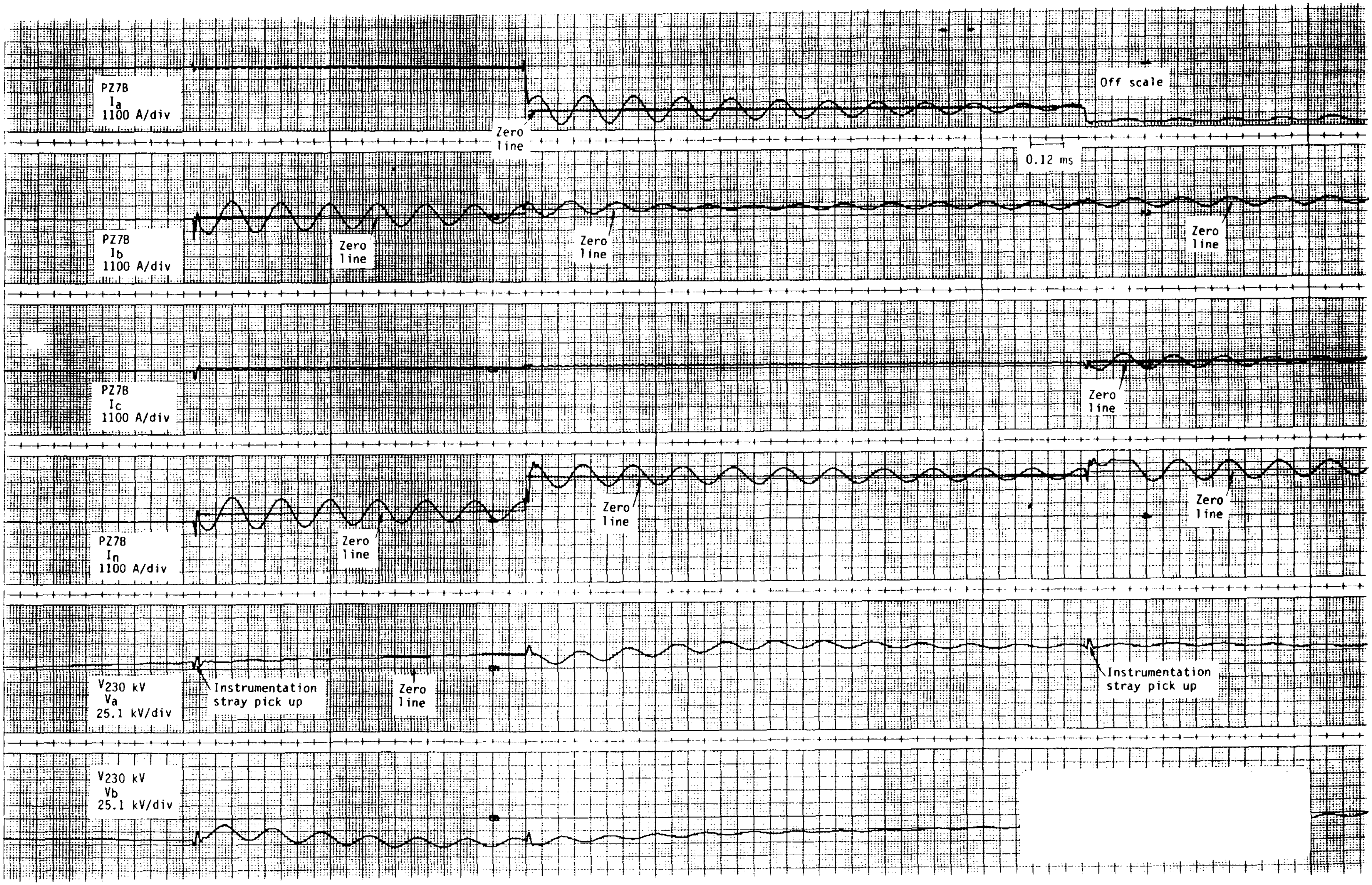


Figure 6A. - Series I, test 3: time expansion of capacitor bank PZ7B strip chart currents and 230-kV bus voltage traces shown in figure 6.

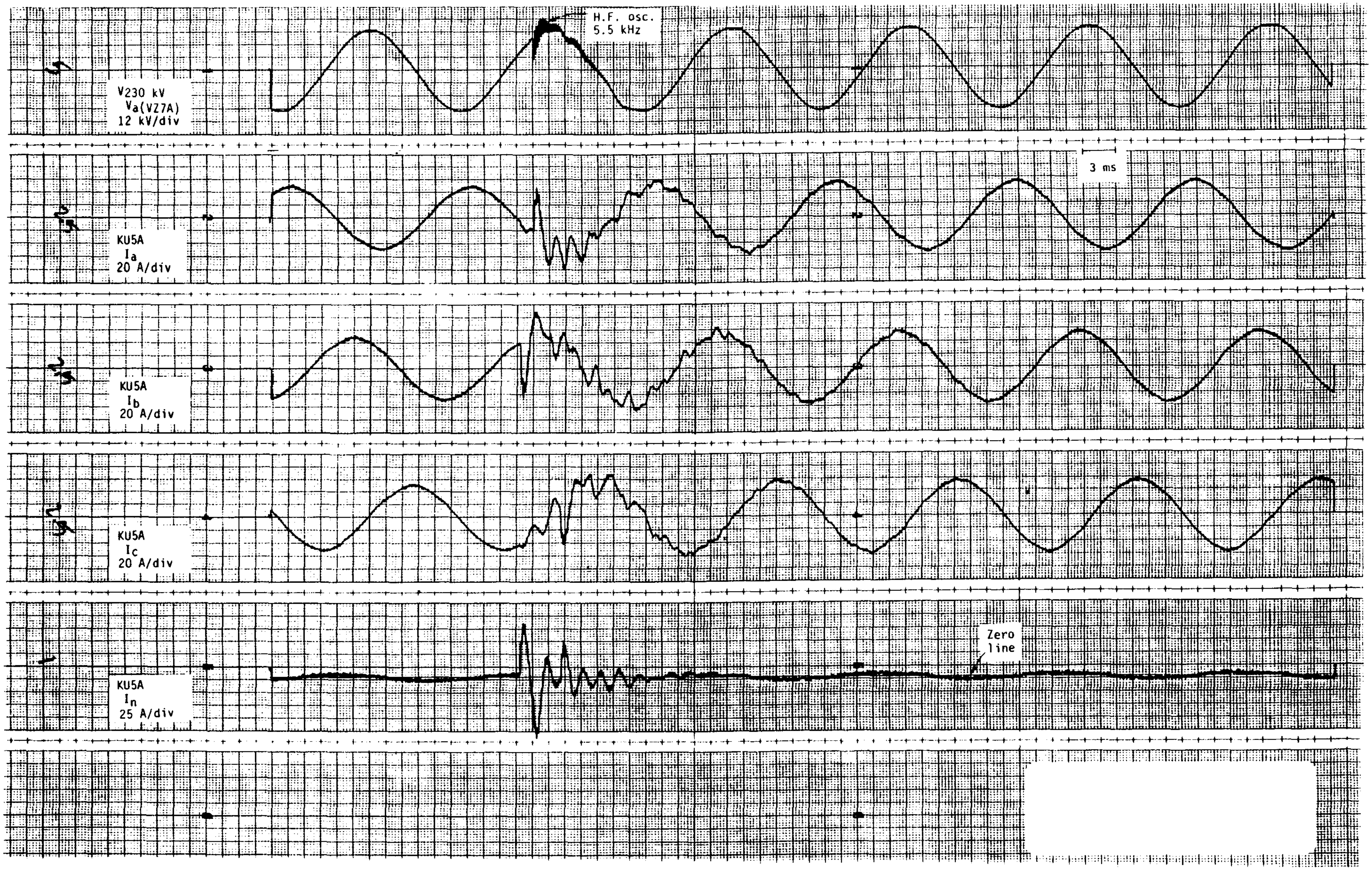


Figure 7. - Series I, test 3: digital electronic strip chart traces of transformer KU5A 230-kV side voltage and currents when capacitor bank PZ7B energized. No other banks on-line.

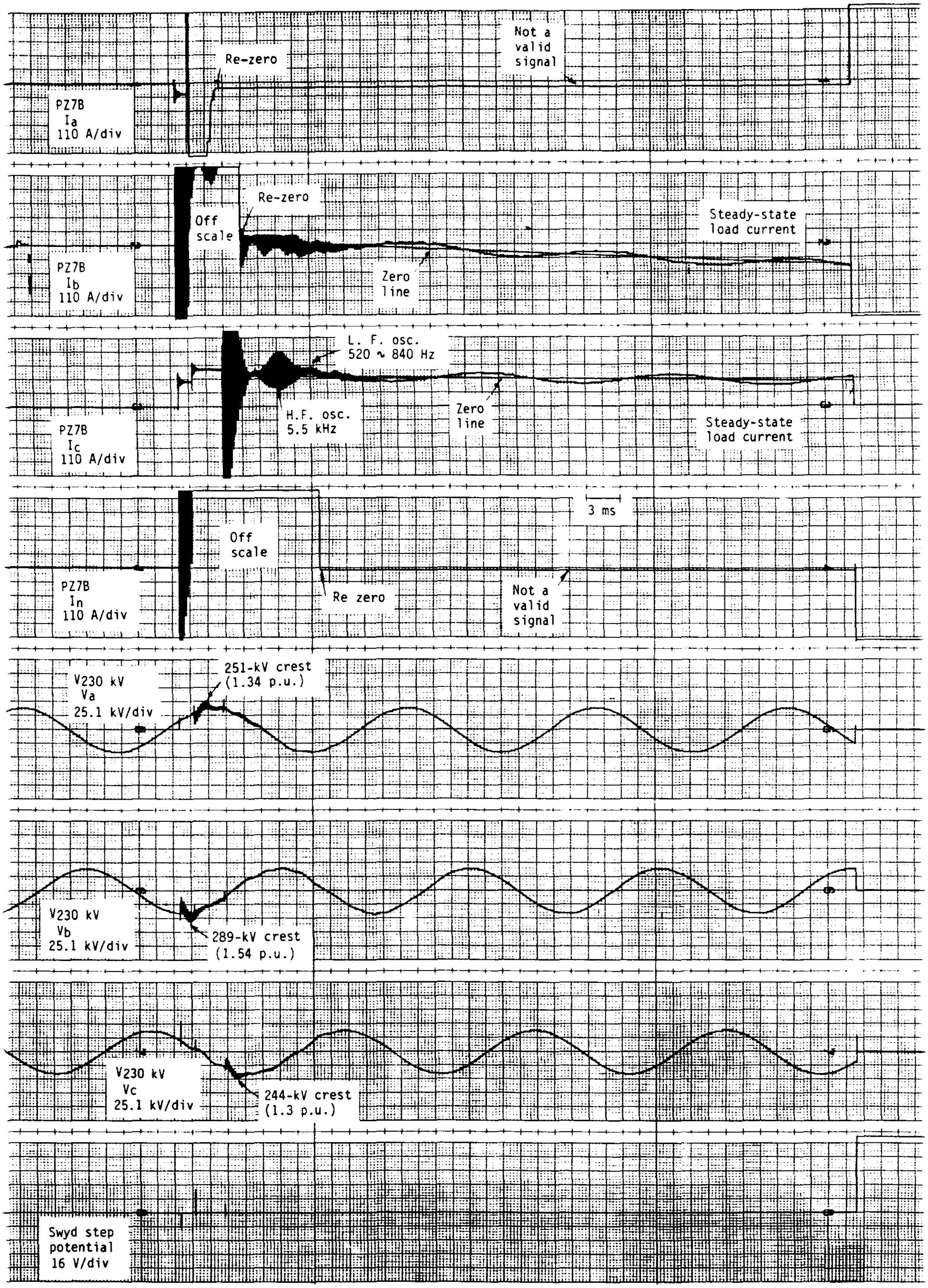


Figure 8. - Series I, test 3 (repeat): digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor bank PZ7A on-line. Note that a more sensitive scale than for previous test 3 was used for the capacitor currents.

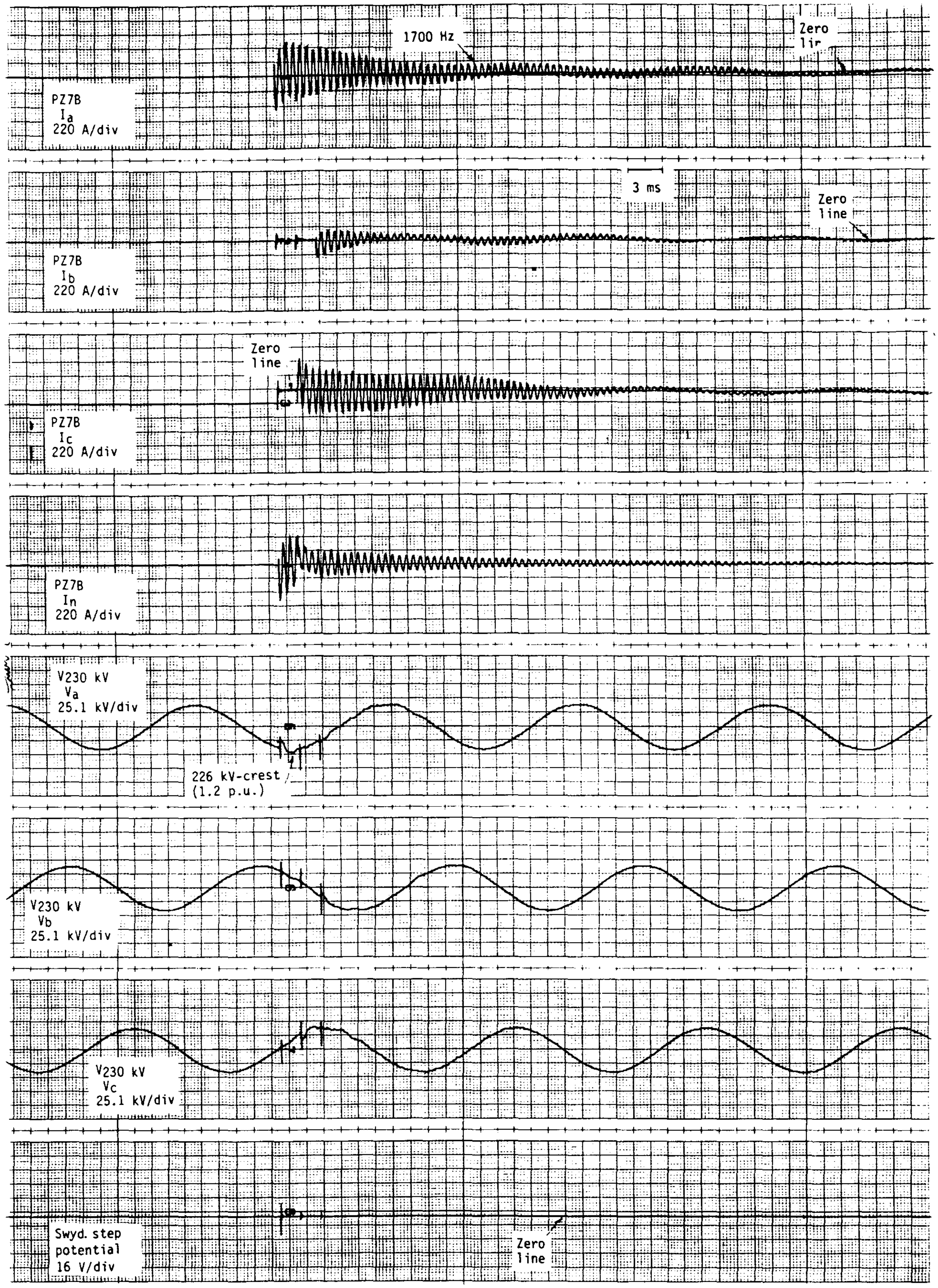


Figure 9. - Series I, test 4: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor bank PZ8A on-line.

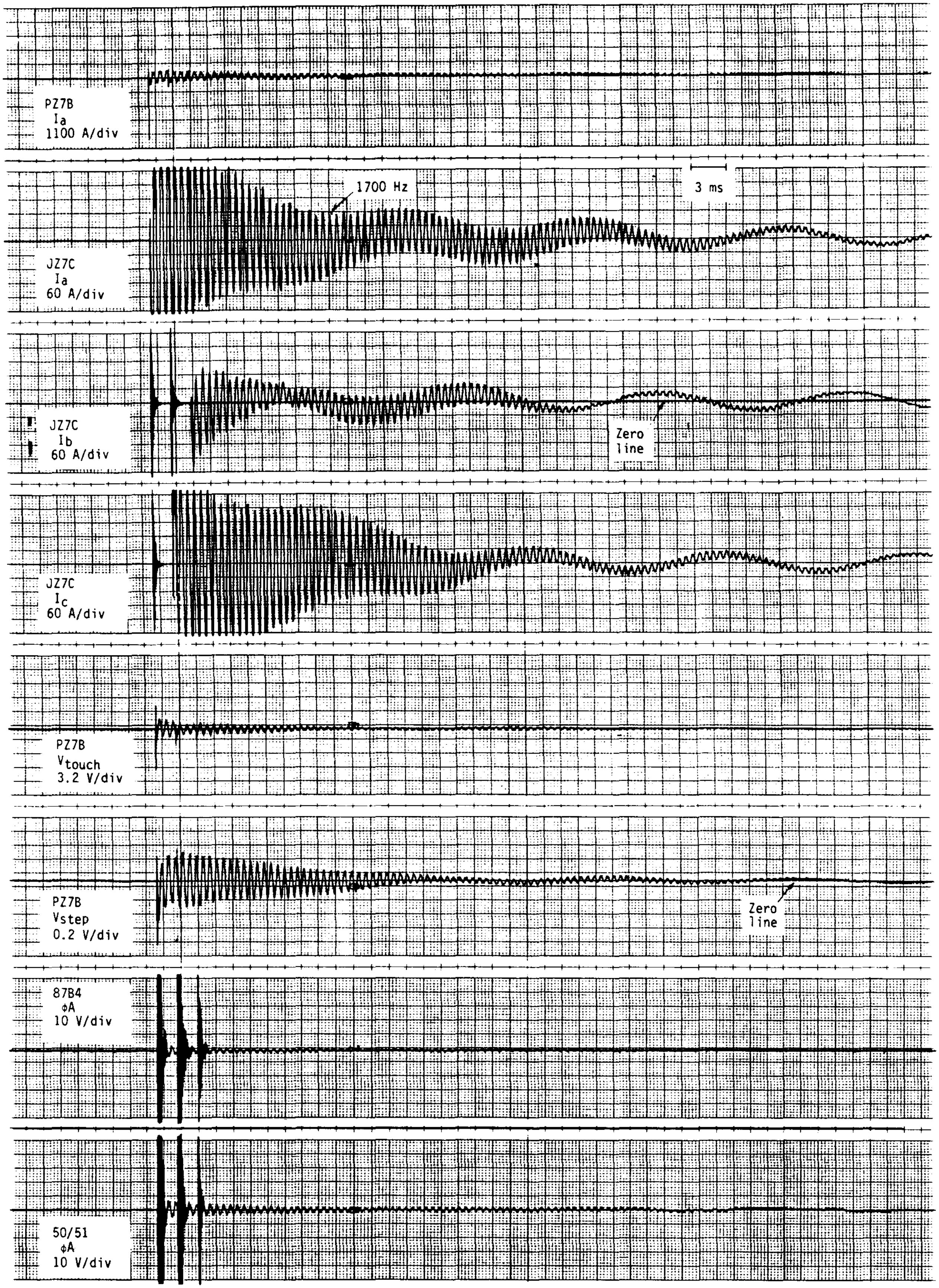


Figure 9. - Series I, test 4: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor bank PZ8A on-line. - Continued

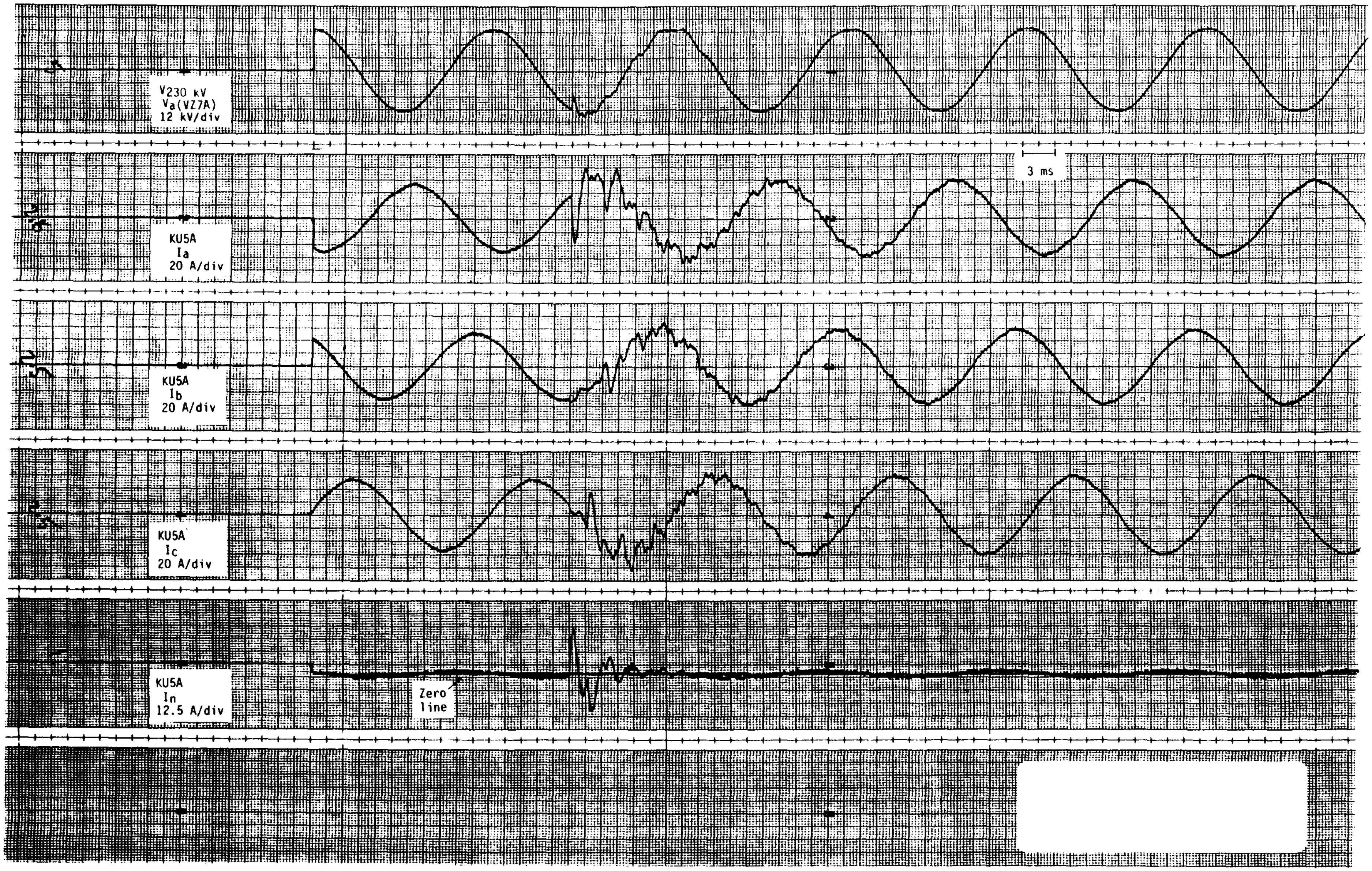


Figure 10. - Series I, test 4: digital electronic strip chart traces of transformer KU5A 230-kV side voltage and currents when capacitor bank PZ7B energized. Capacitor bank PZ8A on-line.

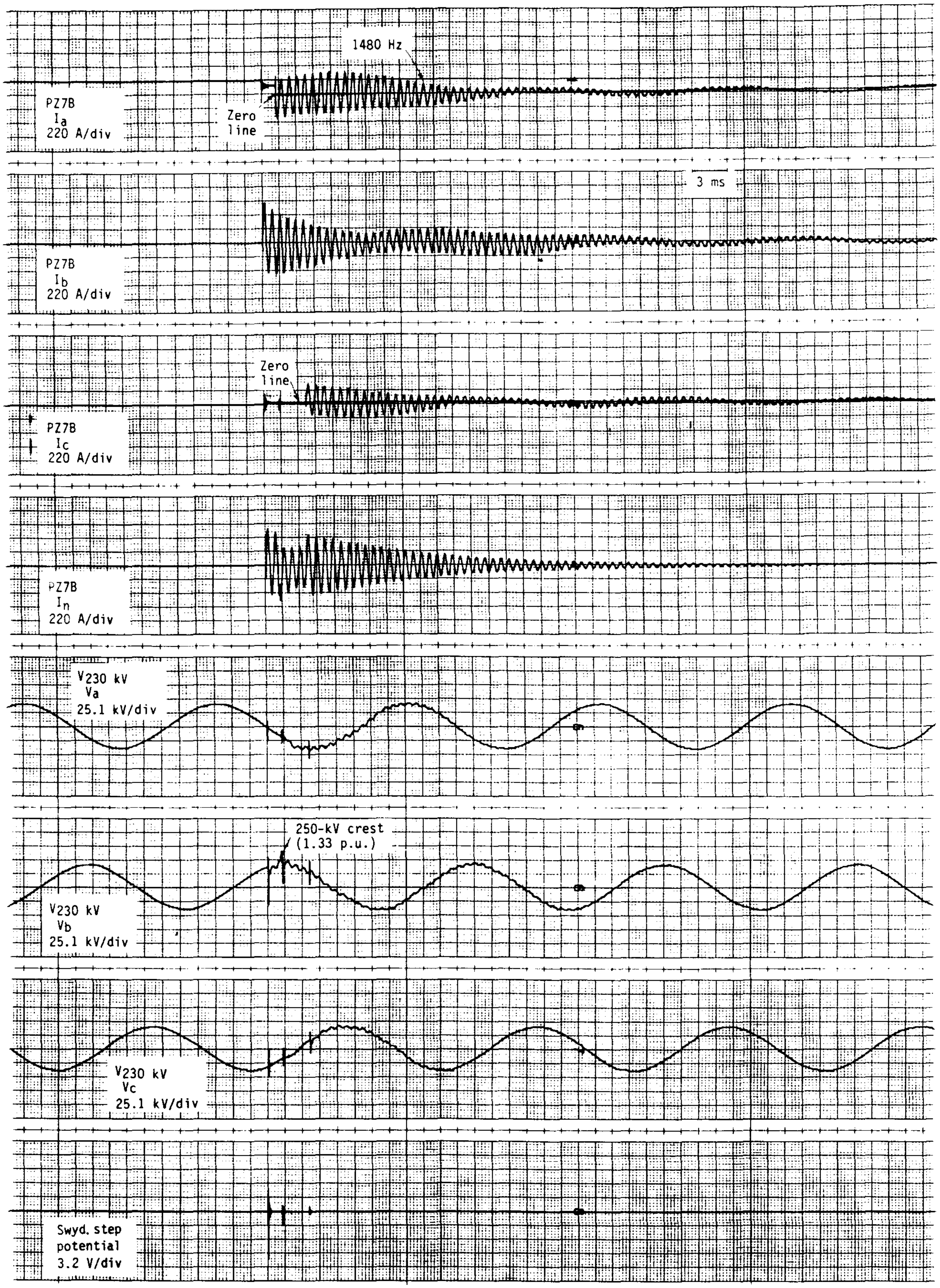


Figure 11. - Series I, test 6: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor banks PZ8A and PZ8B on line.

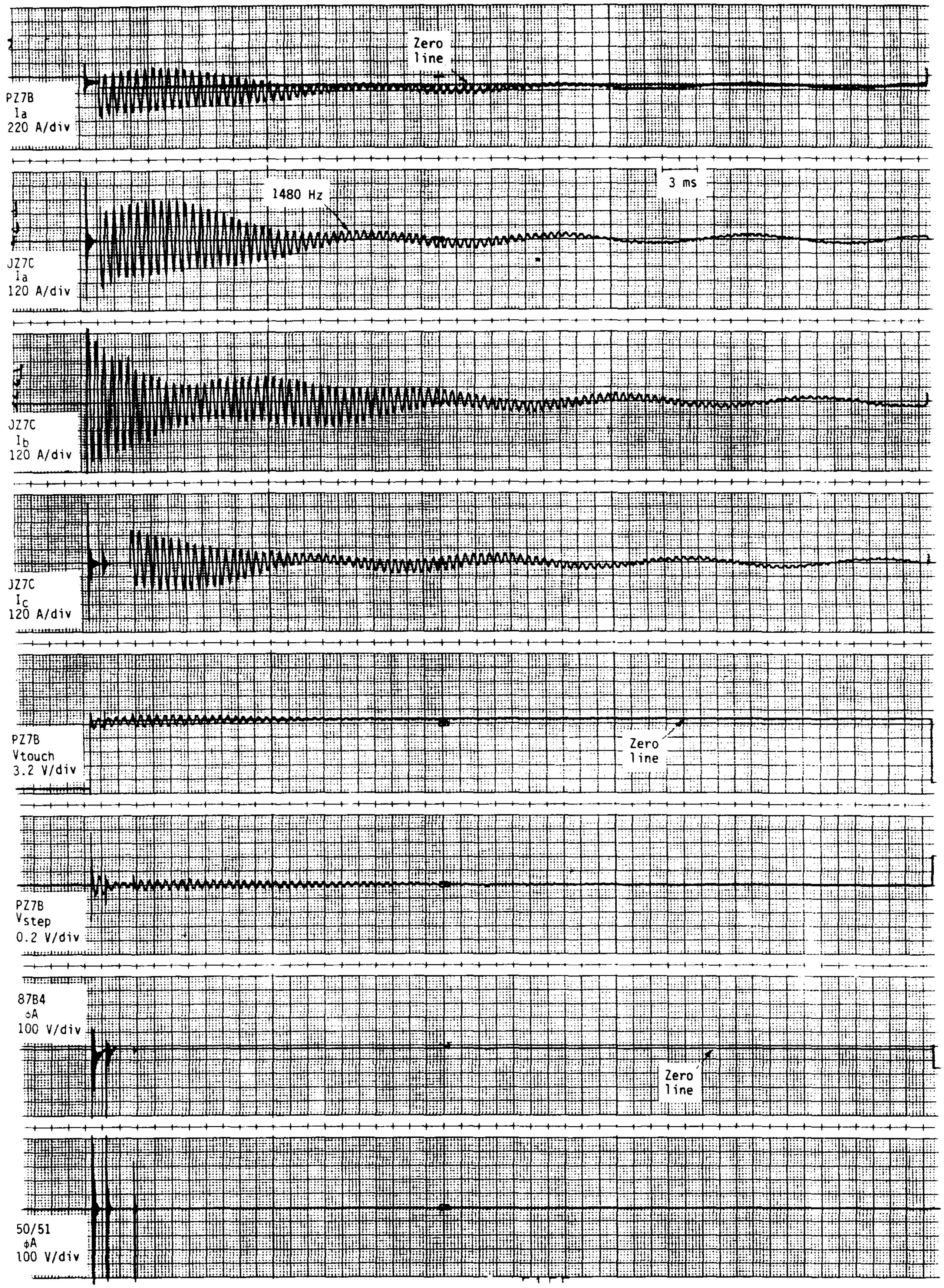


Figure 11. - Series I, test 6: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor banks PZ8A and PZ8B on line. - Continued

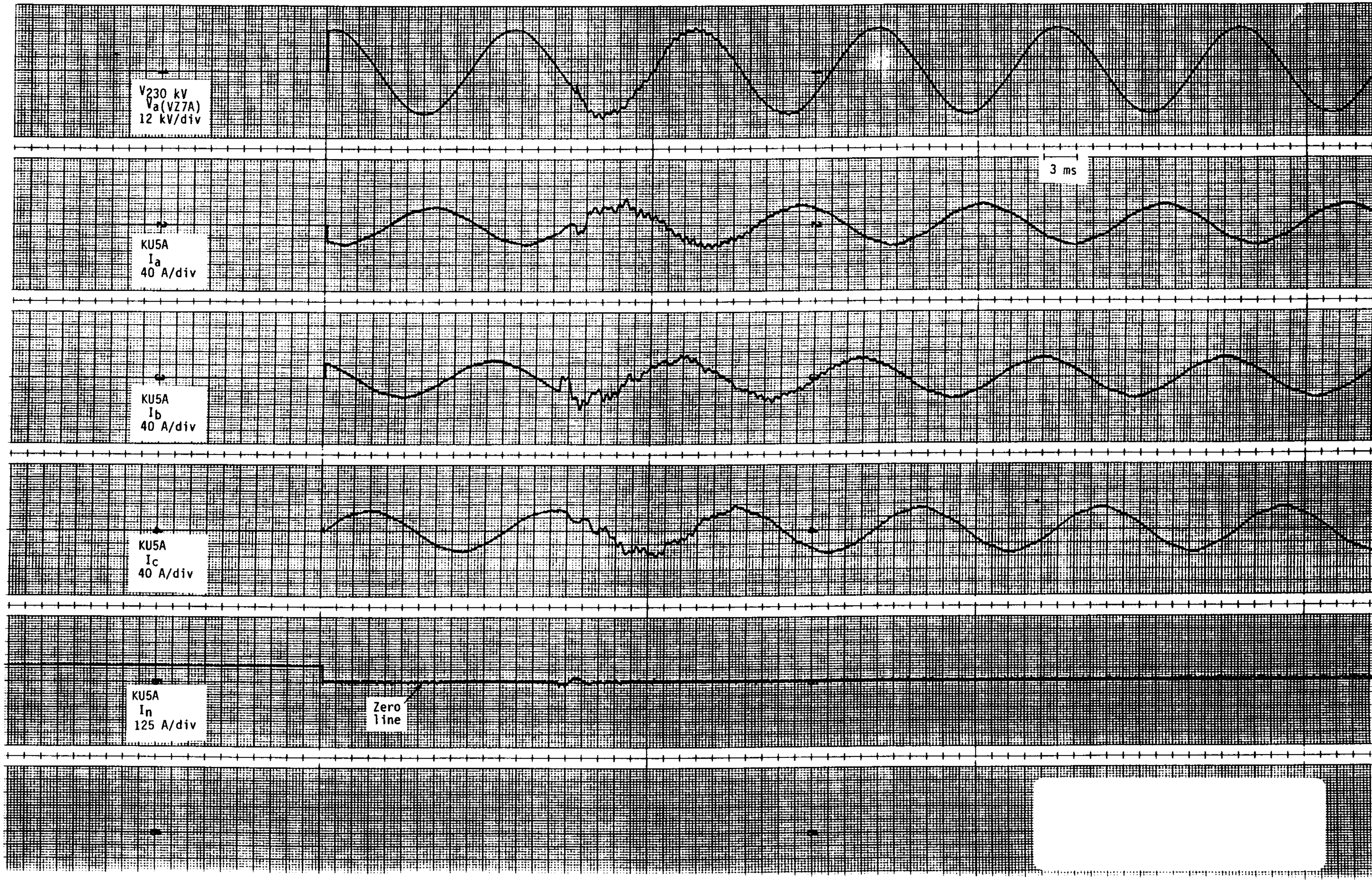


Figure 12. - Series I, test 6: digital electronic strip chart traces of transformer KU5A 230-kV side voltage and currents when capacitor bank PZ7B energized. Capacitor bank PZ7B energized. Capacitor banks PZ8A and PZ8B on-line.

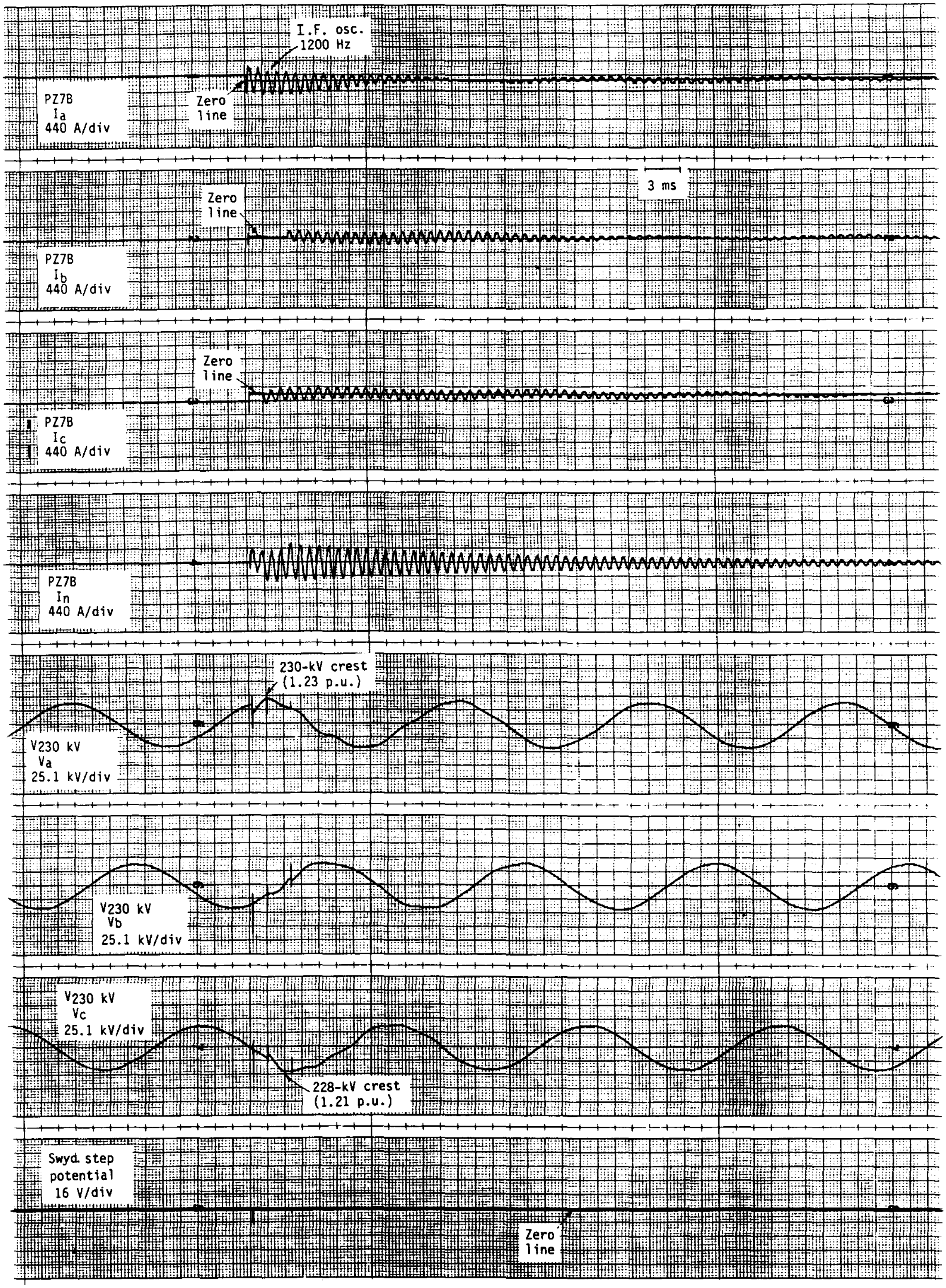


Figure 13. - Series I, test 7: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor banks PZ7A and PZ7B energized. Capacitor banks PZ8A and PZ8B on-line.

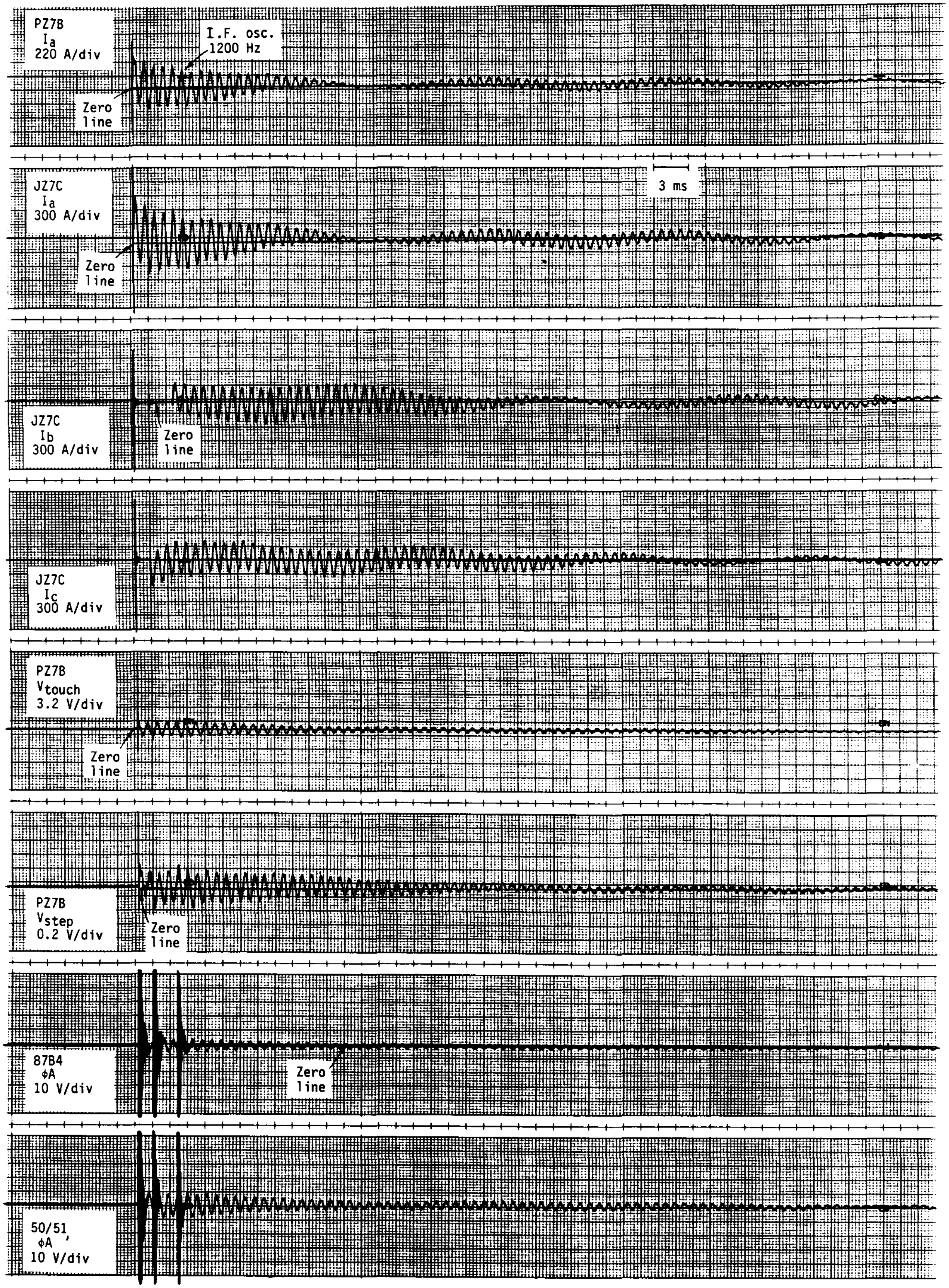


Figure 13. - Series I, test 7: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor banks PZ7A and PZ7B energized. Capacitor banks PZ8A and PZ8B on-line. - Continued

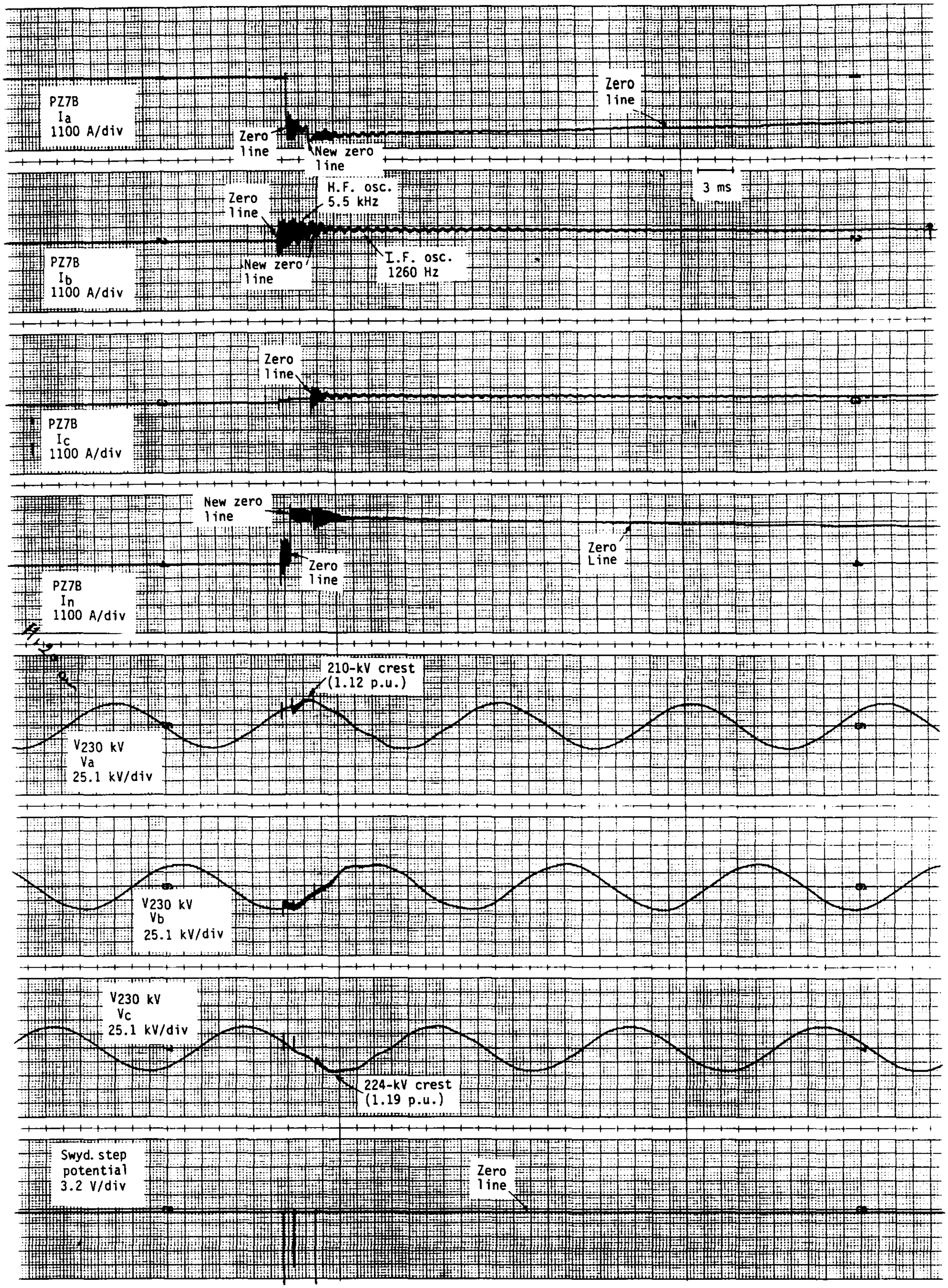


Figure 14. - Series 1, test 8: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor banks PZ7A, PZ8A, and PZ8B on-line.

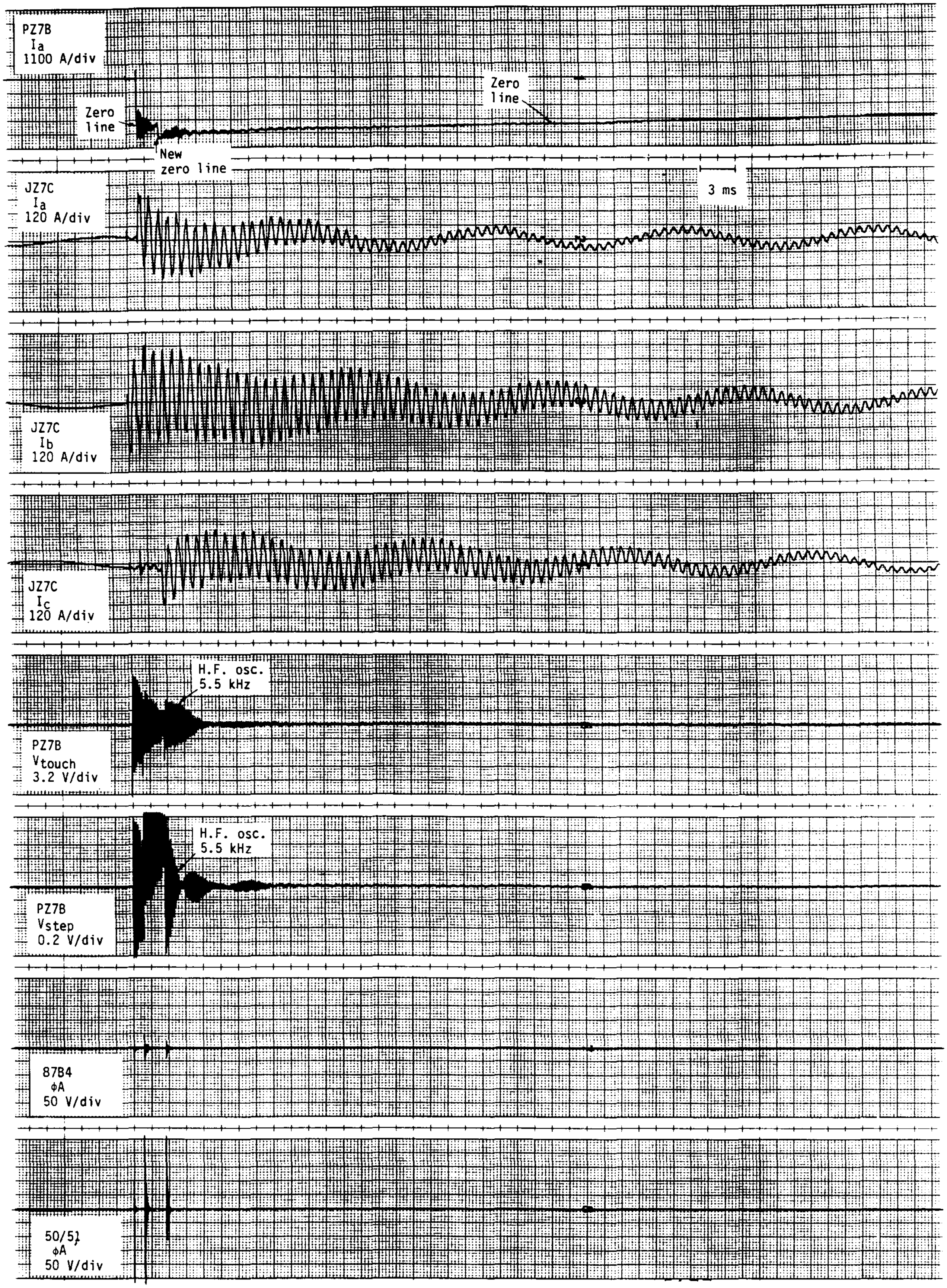


Figure 14. - Series 1, test 8: digital electronic strip chart traces of switching transient currents and voltages produced when 230-kV capacitor bank PZ7B energized. Capacitor banks PZ7A, PZ8A, and PZ8B on-line. - Continued

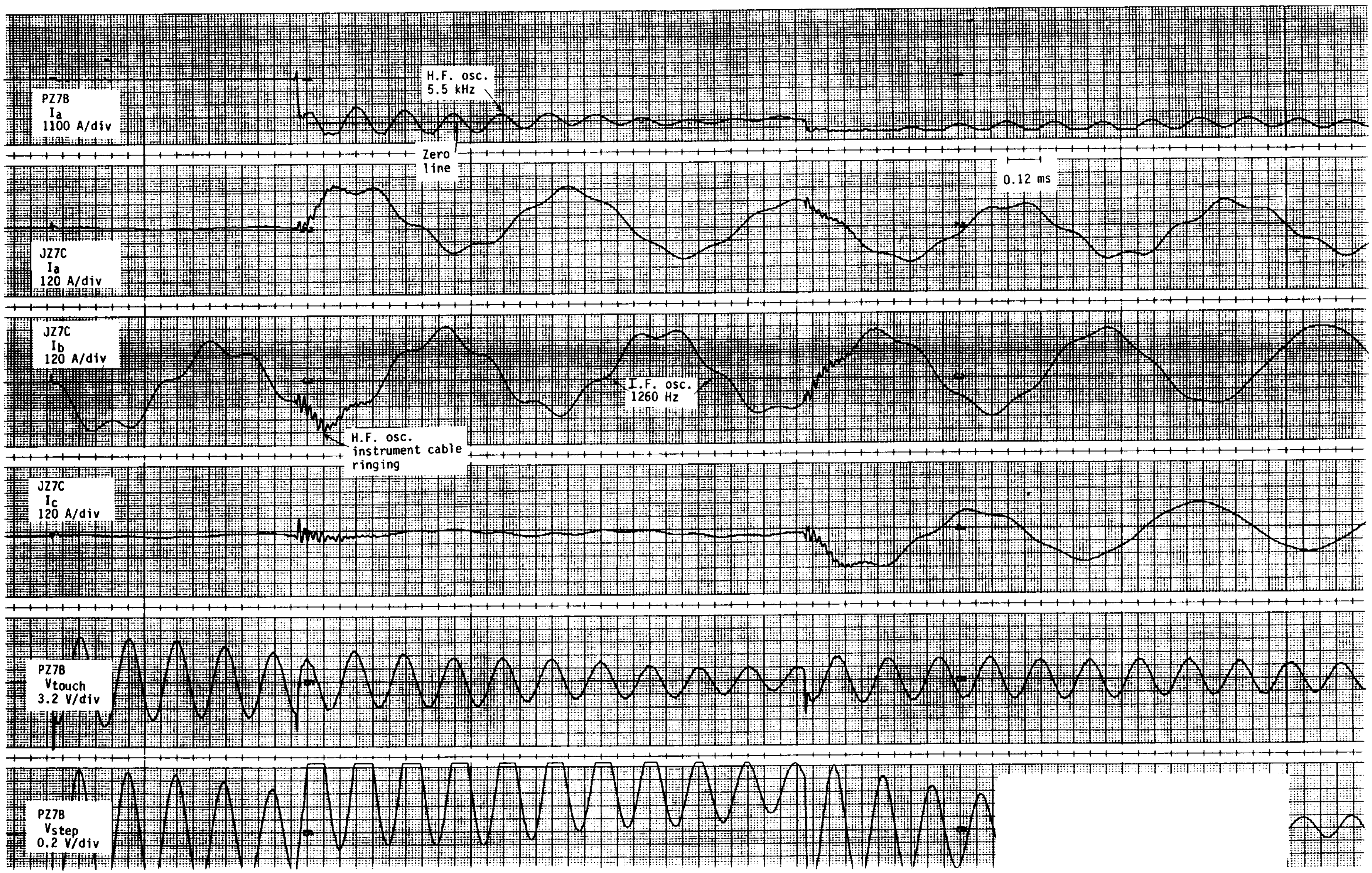


Figure 14A. - Series I, test 8: time expansion of capacitor bank PZ7B currents and 230-kV bus voltage strip chart traces shown in figure 14.

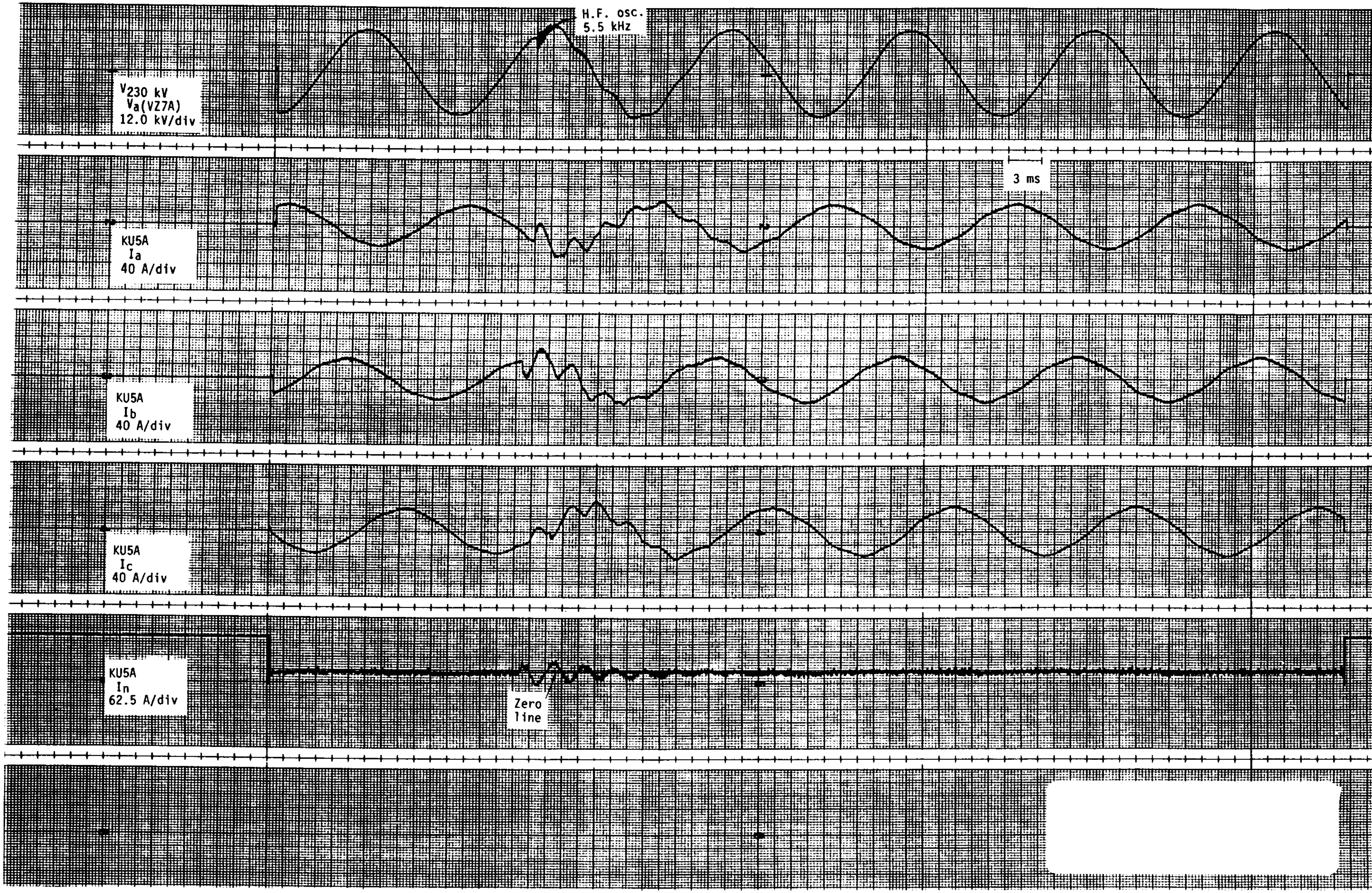


Figure 15. - Series I, test 8: digital electronic strip chart traces of transformer KU5A 230-kV side voltage and currents when capacitor bank PZ7B energized. Capacitor banks PZ7A, PZ8A, and PZ8B on-line.

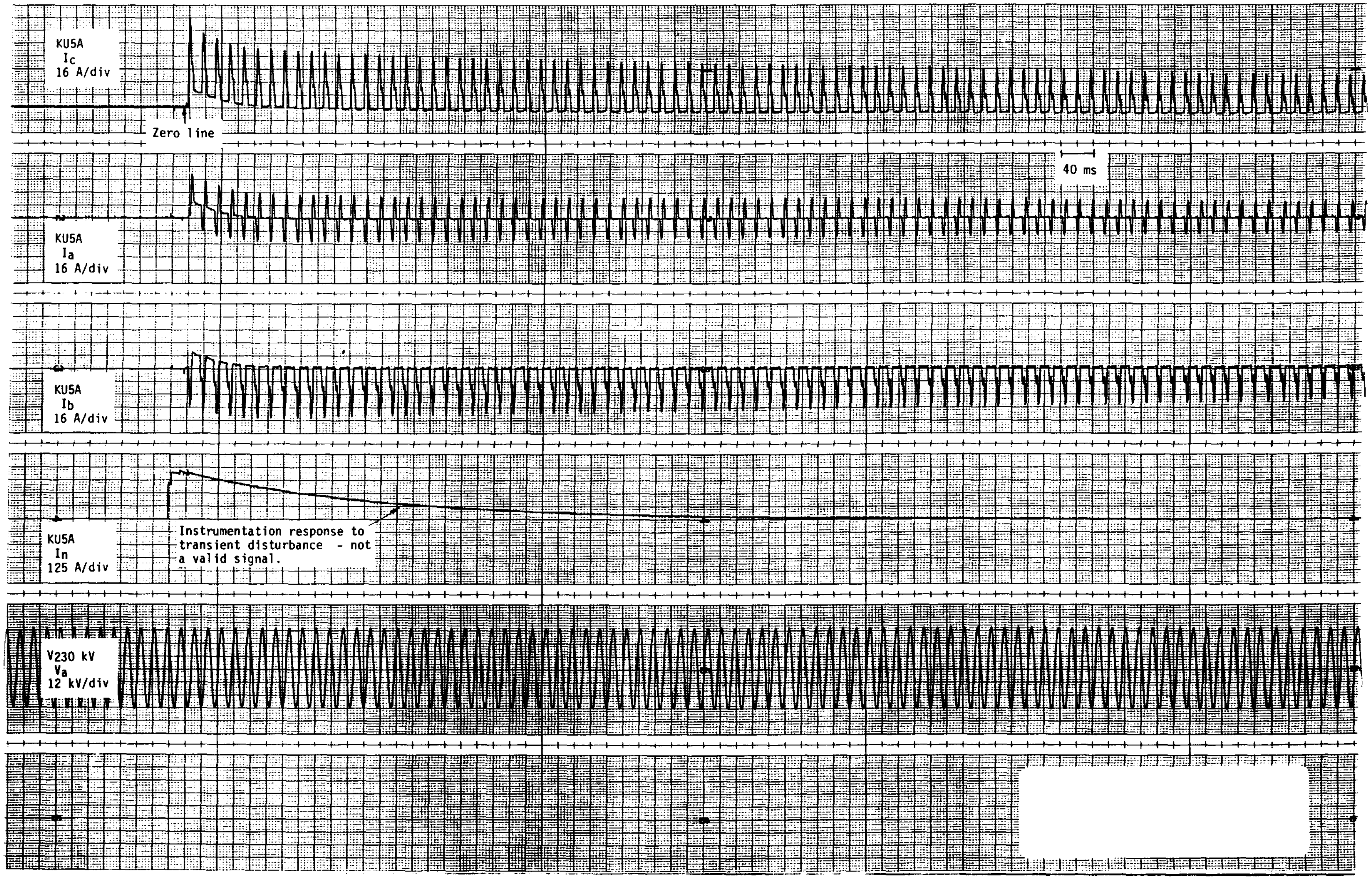


Figure 16. - Series II, test 1: digital electronic strip chart traces of transformer KU5A inrush currents when energized from 230-kV system. No capacitor banks on-line.

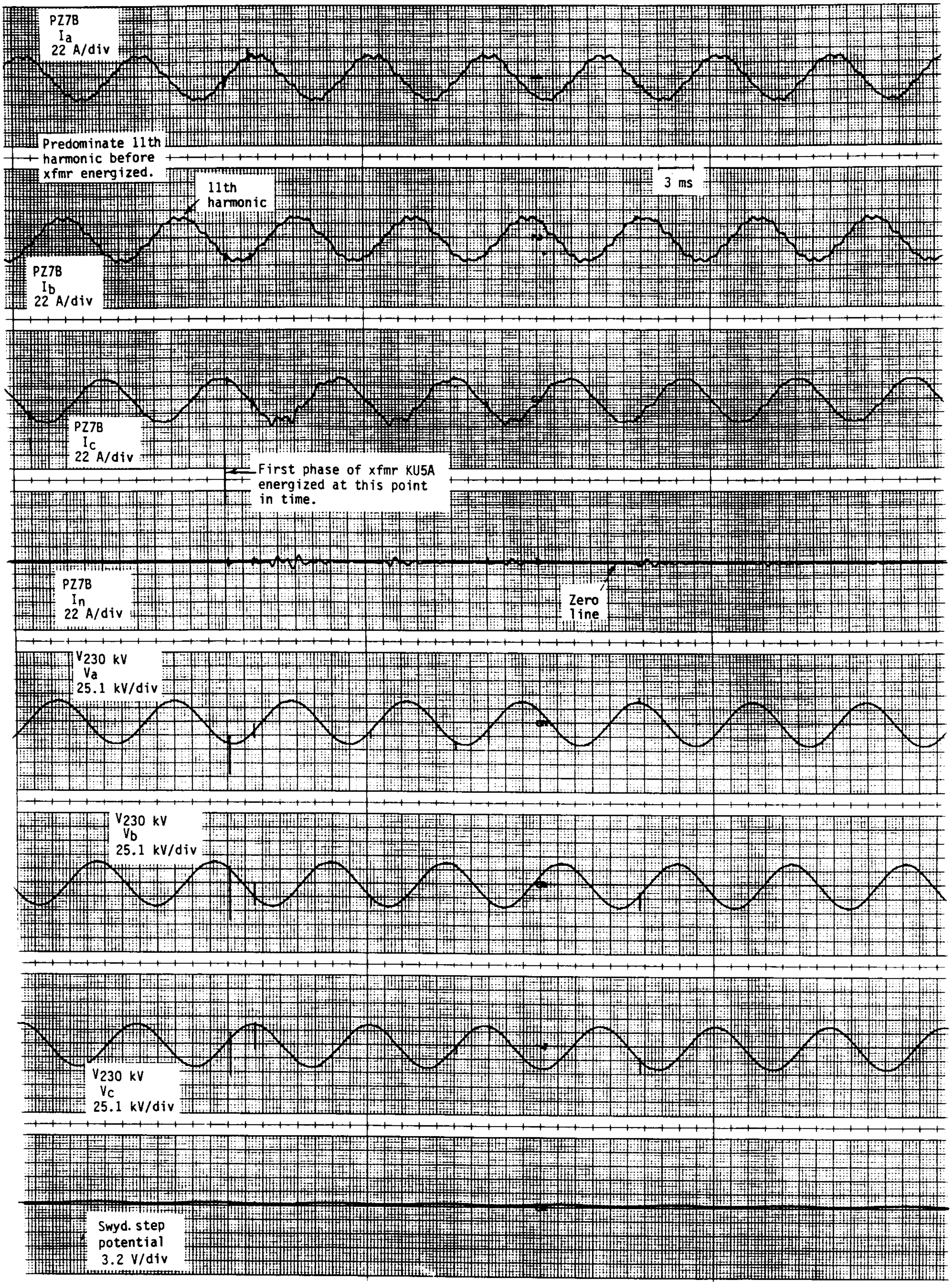


Figure 17. - Series II, test 2: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor bank PZ7B on-line.

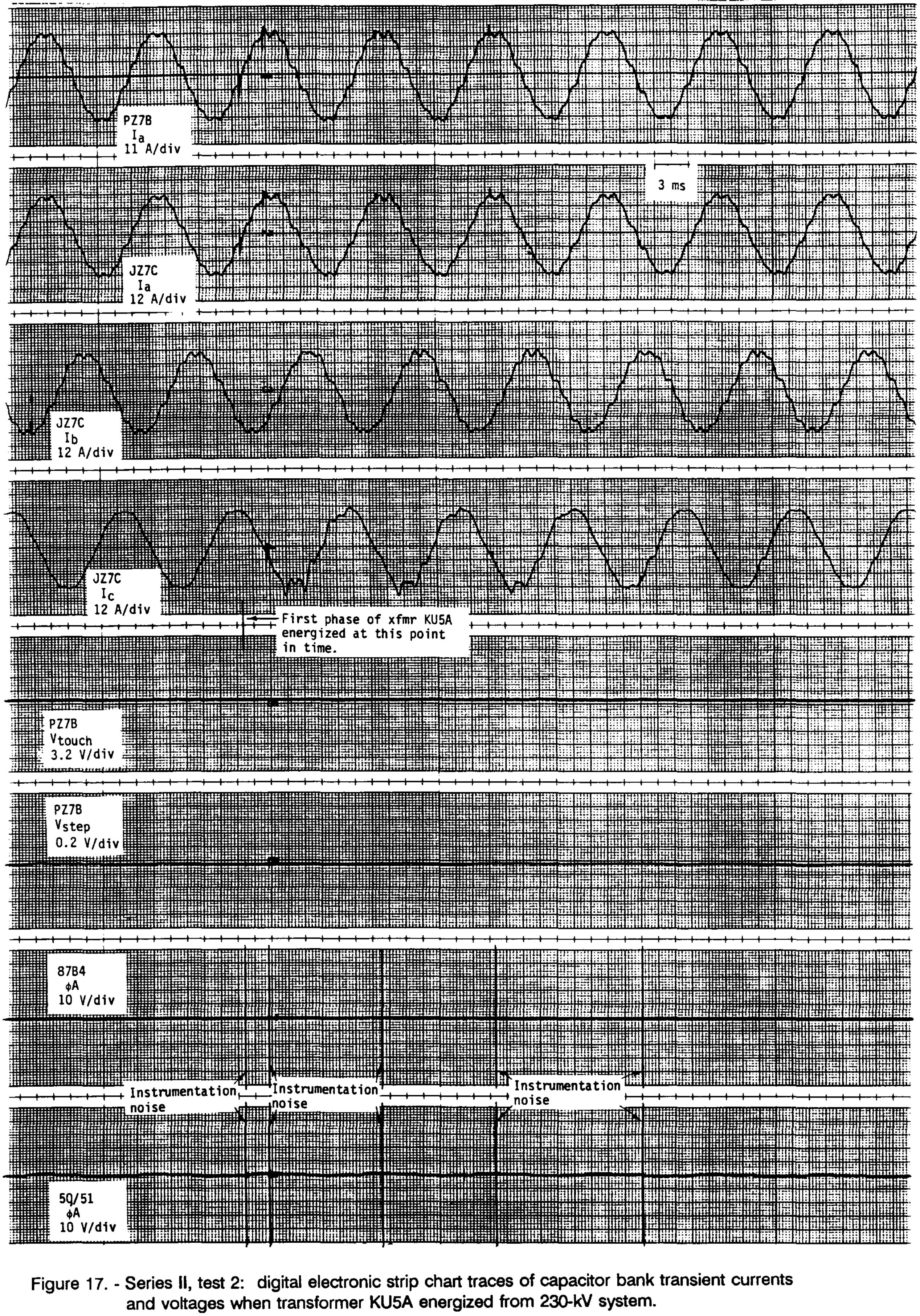


Figure 17. - Series II, test 2: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor bank PZ7B on-line. - Continued

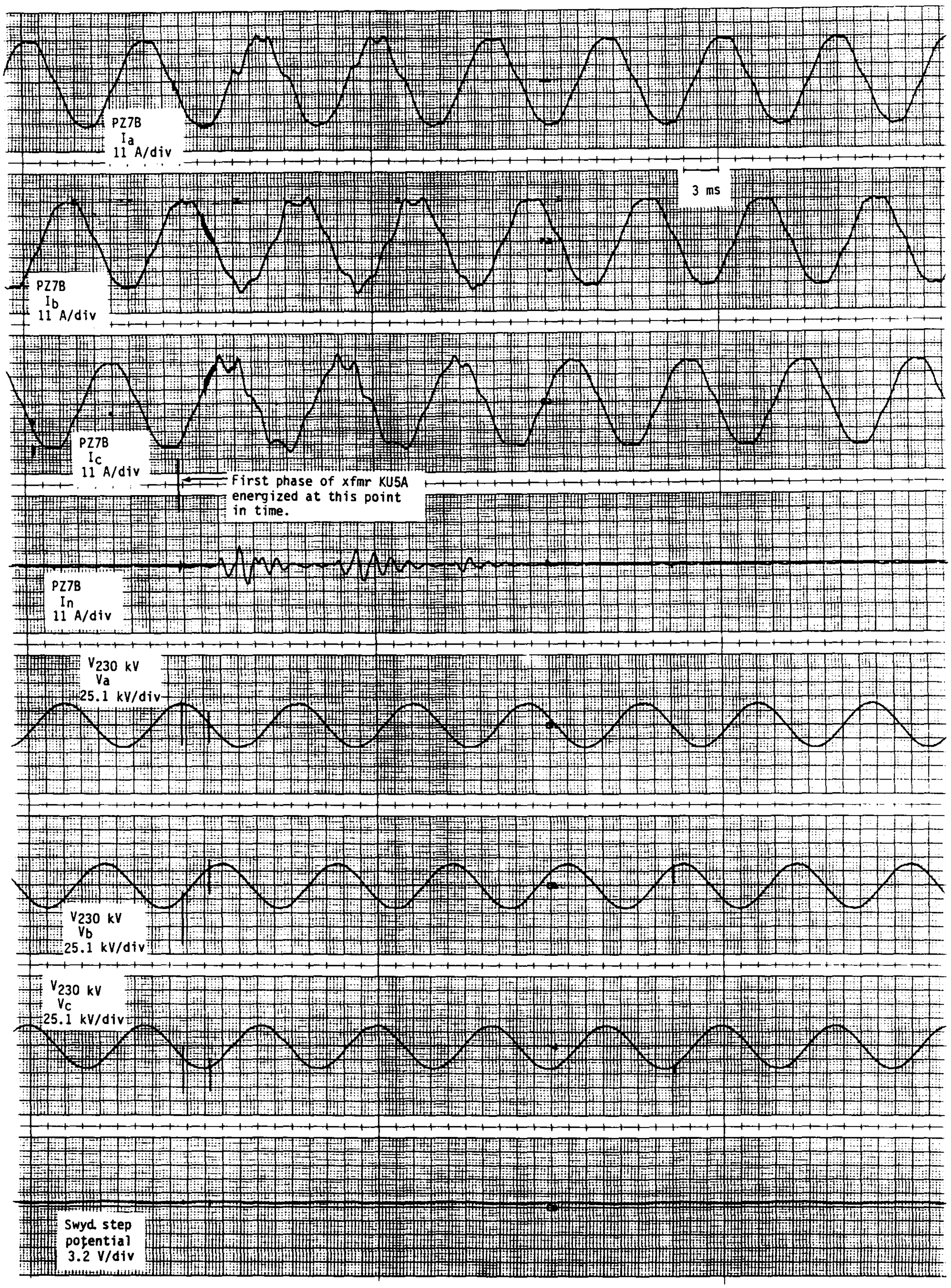


Figure 18. - Series II, test 3: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor banks PZ7A and PZ7B on-line.

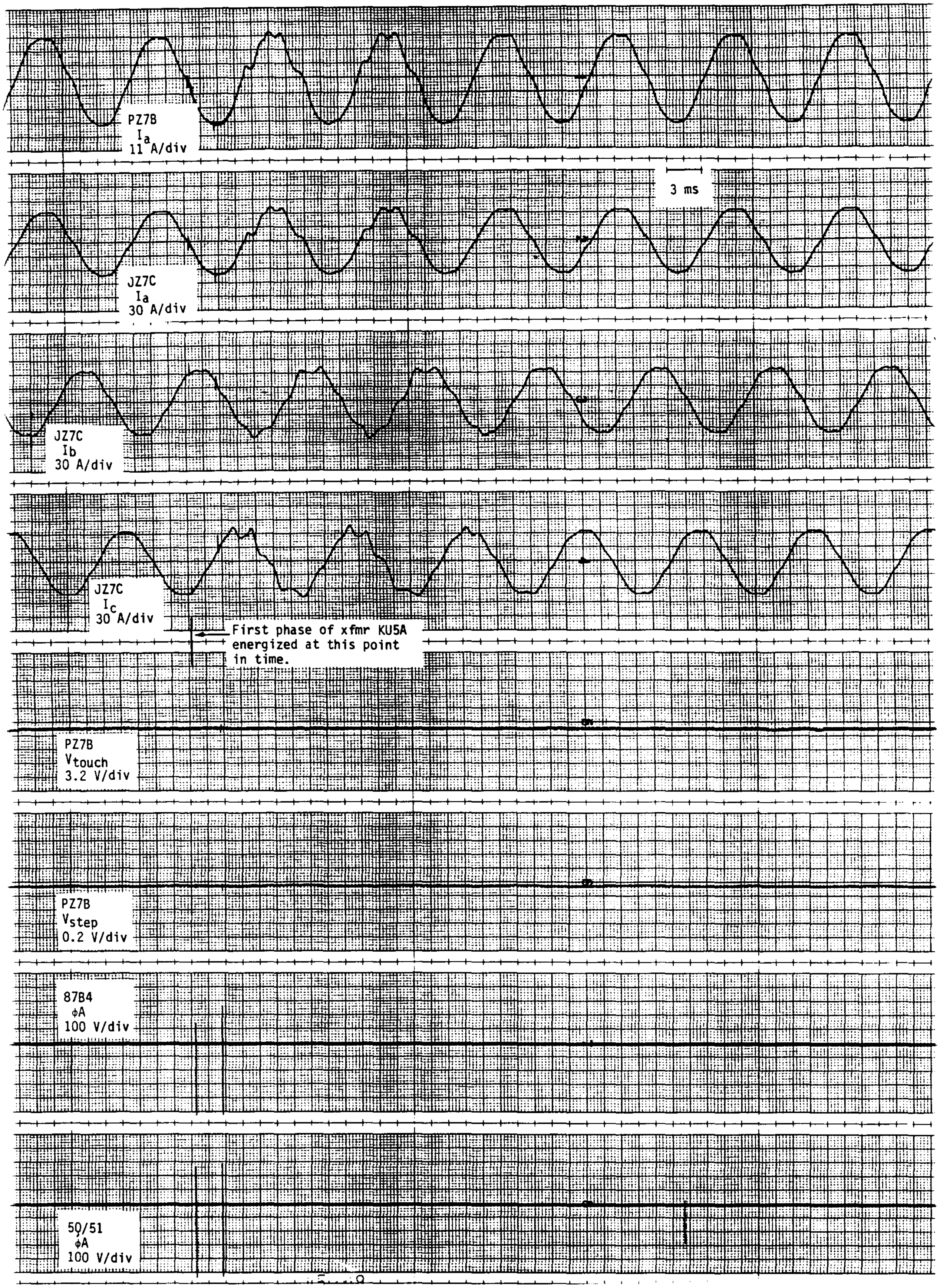


Figure 18. - Series II, test 3: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor banks PZ7A and PZ7B on-line. - Continued

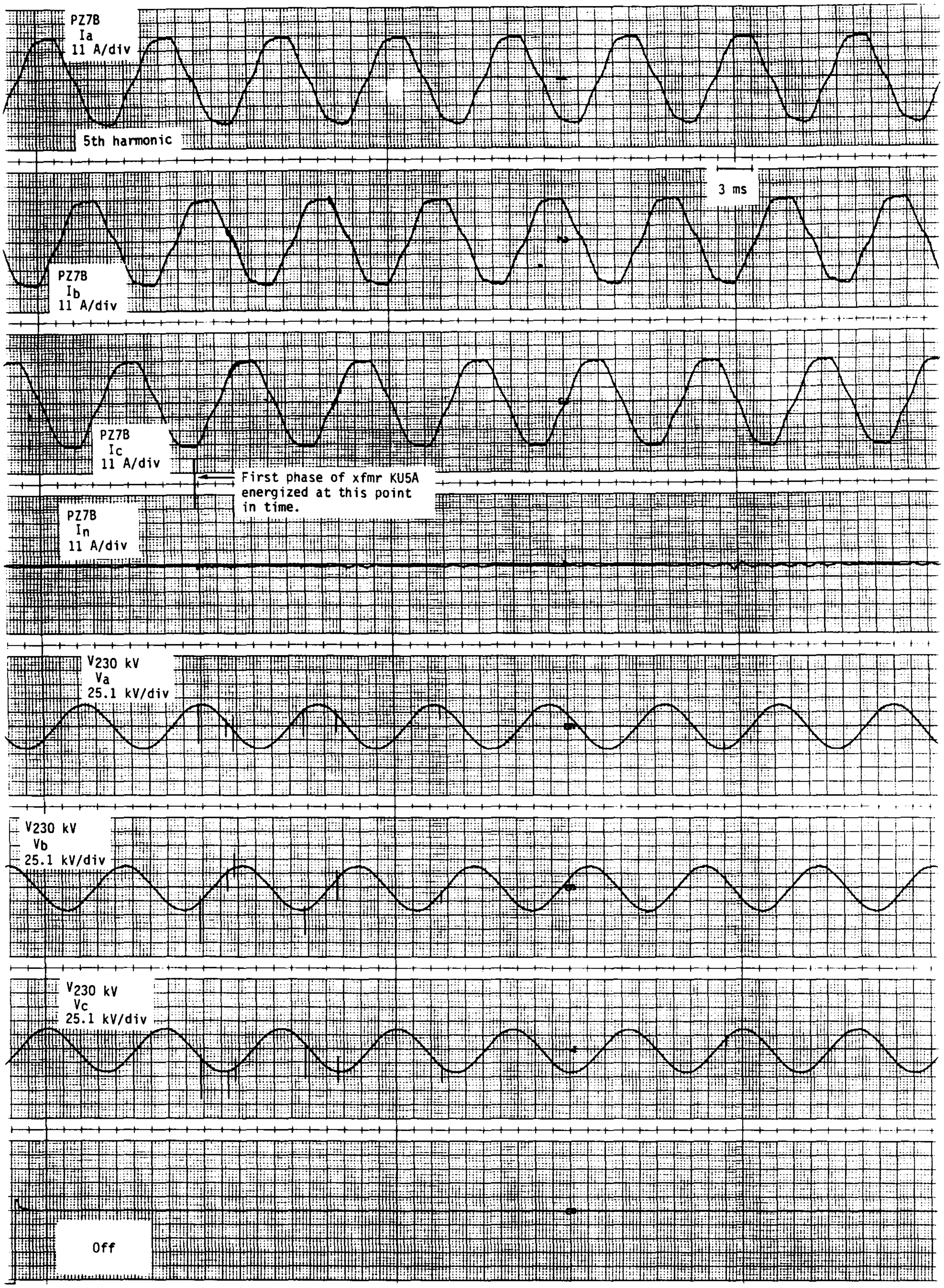


Figure 19. - Series II, test 4: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor banks PZ7A, PZ7B, and PZ8A on-line.

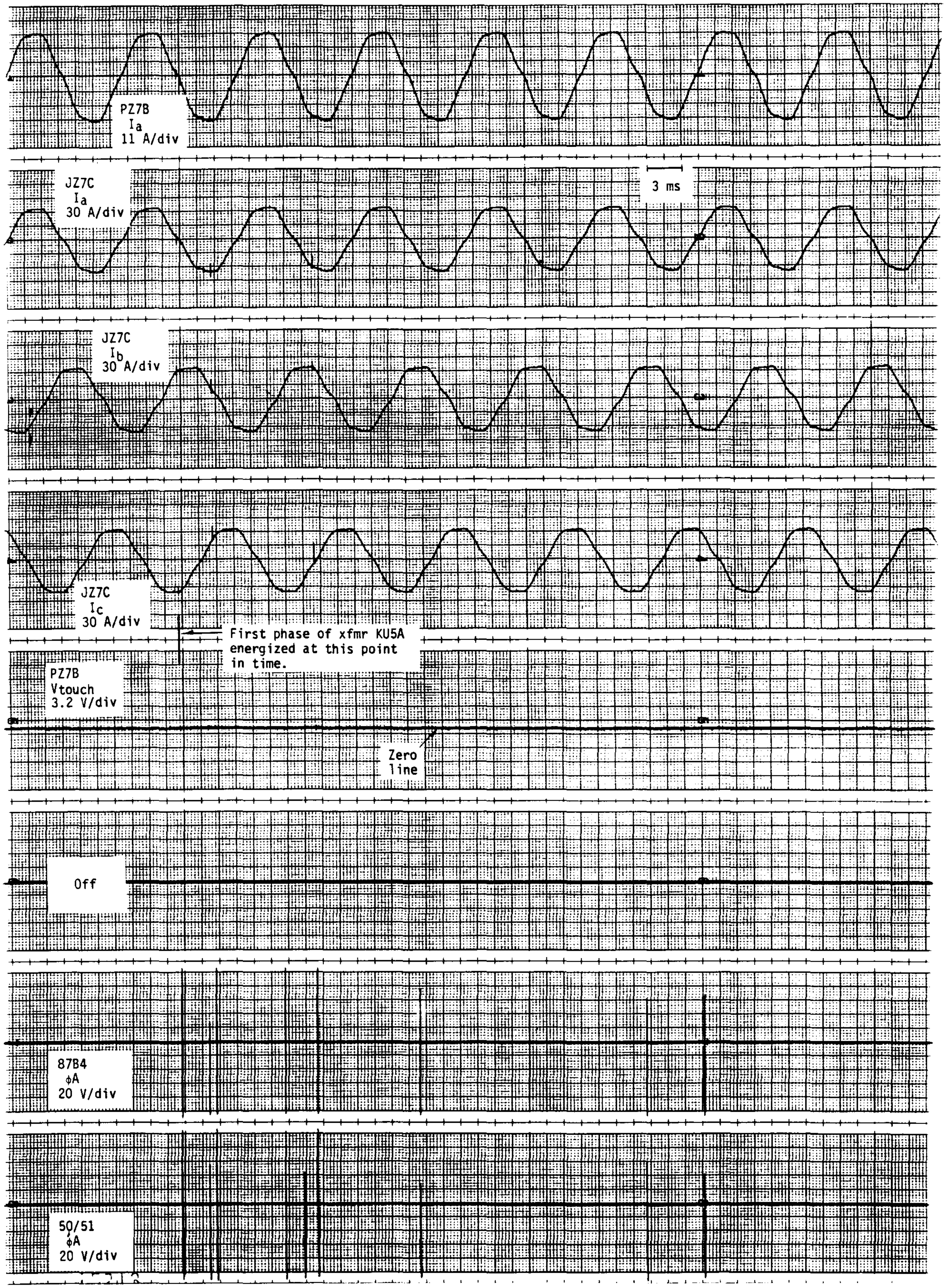


Figure 19. - Series II, test 4: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor banks PZ7A, PZ7B, and PZ8A on-line. - Continued

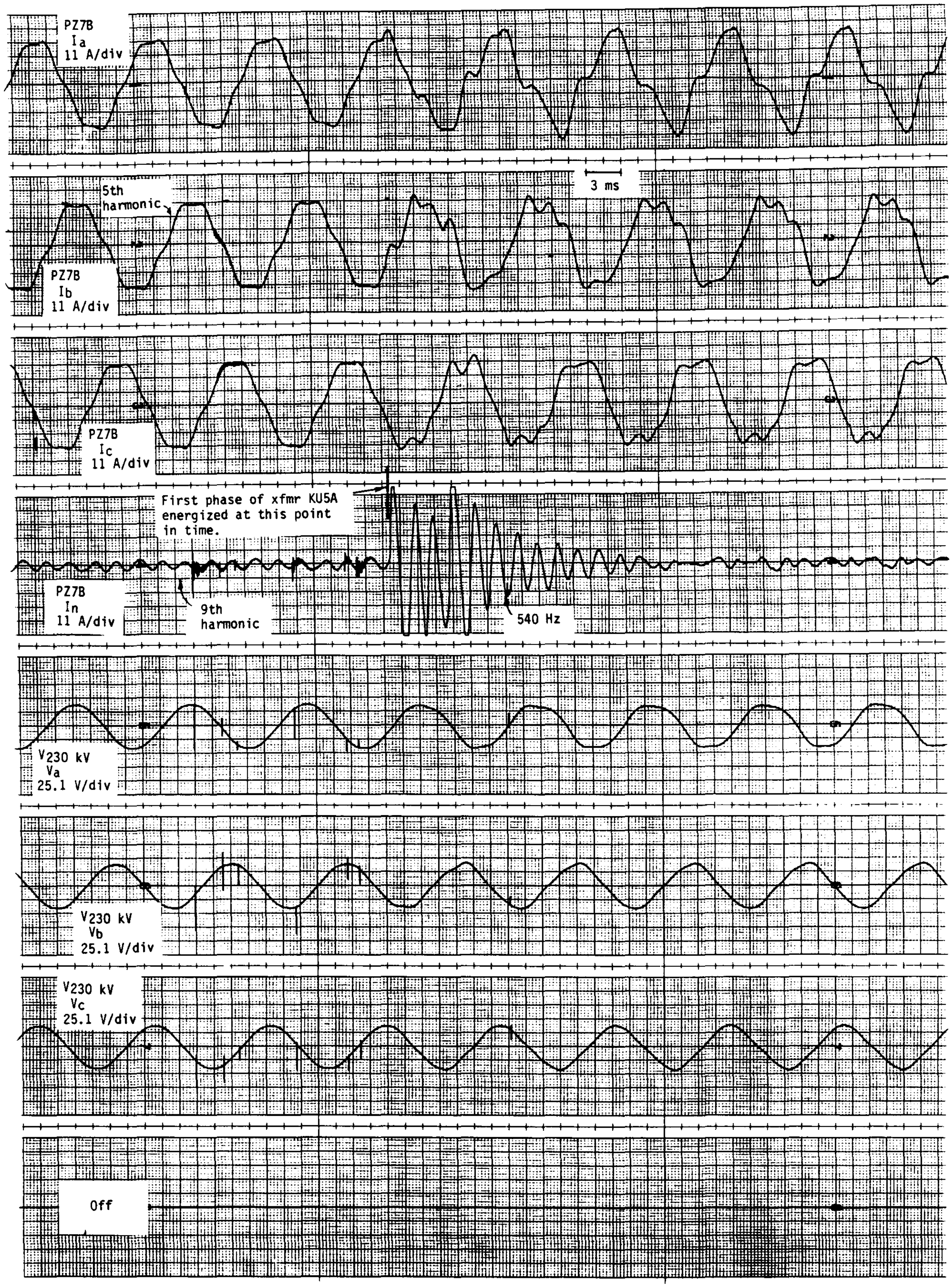


Figure 20. - Series II, test 5: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor banks PZ7A, PZ7B, PZ8A, and PZ8B on-line.

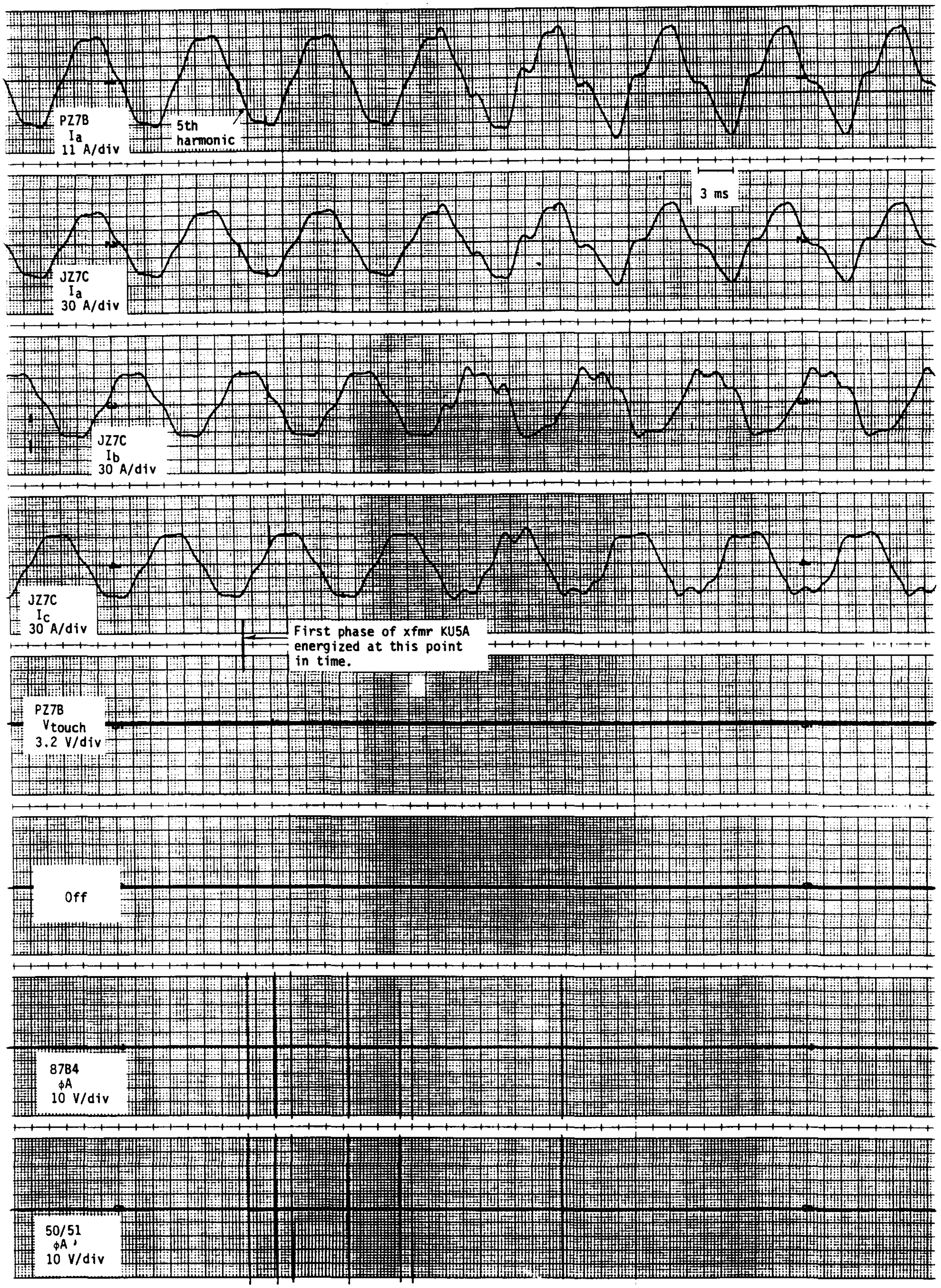


Figure 20. - Series II , test 5: digital electronic strip chart traces of capacitor bank transient currents and voltages when transformer KU5A energized from 230-kV system. Capacitor banks PZ7A, PZ7B, PZ8A, and PZ8B on-line. - Continued

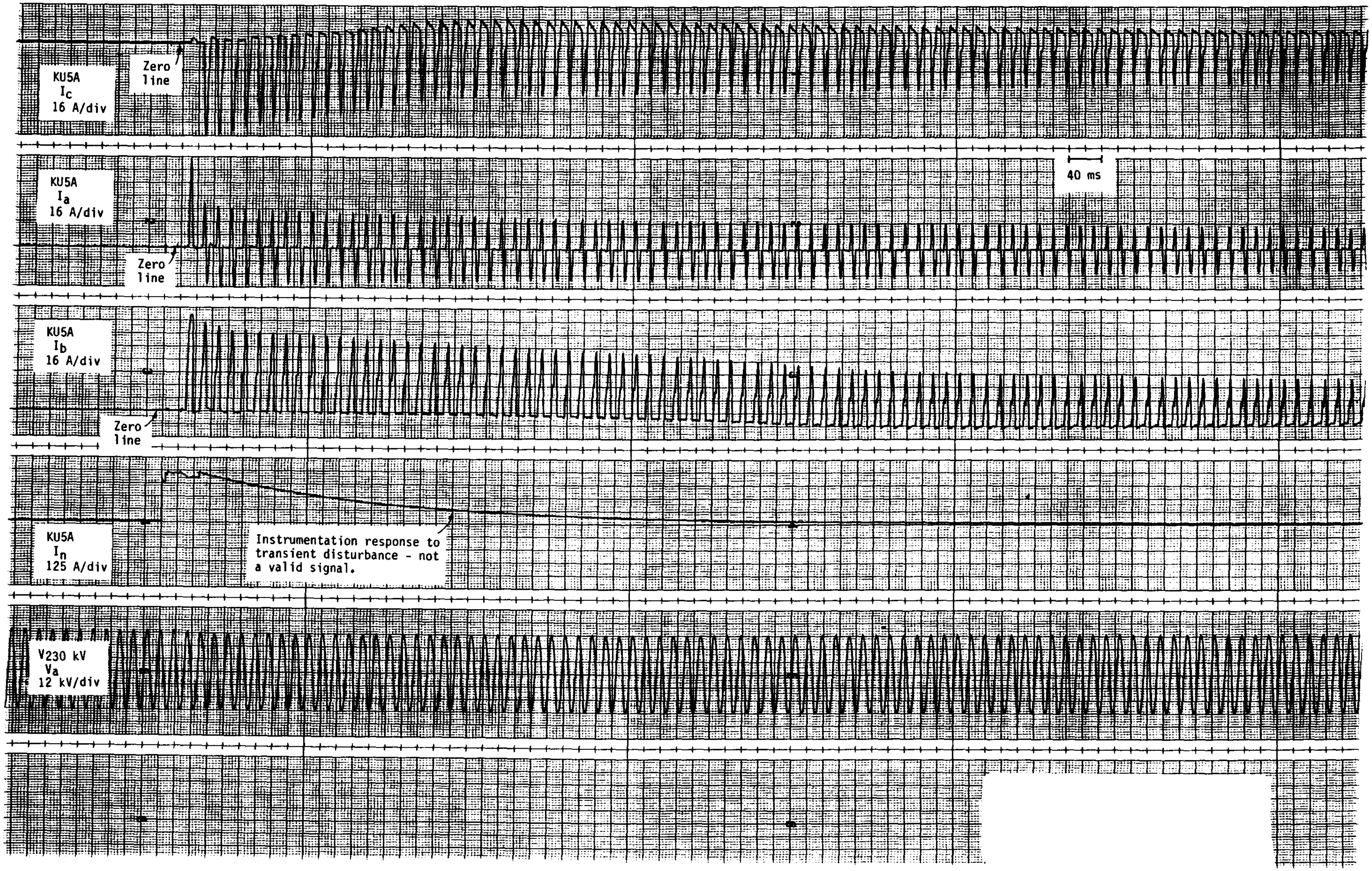


Figure 21. - Series II, test 5: digital electronic strip chart traces of transformer KU5A inrush currents when energized from 230-kV system. Capacitor banks PZ7A, PZ7B, PZ8A, and PZ8B on-line.

APPENDIX

Test Procedure

Glen Canyon Switchyard
230-kV Shunt Capacitor Bank Field Tests

August 1989

Purpose

The purpose of this field test is to measure switching transient voltages and currents generated in the 230-kilovolt yard when various combinations of the four 50-megavar capacitor banks and a 345-/230-kilovolt autotransformer are energized. Induced currents and voltages in instrument transformer secondary and control cable circuits, and the high-frequency transient response of the station ground mat will also be monitored. The following two test series have been developed by Reclamation in response to the Western Area Power Administration (Western) field test proposal, copy attached, from A2330.

Description of Test Series

Series I: Capacitor Bank Switching Transient Tests - This test series will measure various transient voltages and currents developed in the switchyard when the banks are energized in the following combinations. The electrical circuits to be monitored for these tests are listed in the Instrumentation section. During these tests, the switchyard should be in a normal switching configuration with all 345- and 230-kilovolt power circuits energized and the maximum number of generators on-line at Glen Canyon Powerplant (at speed-no-load as required). The generators will be used as necessary to control voltage during these tests.

Test No.	Cap. Bank(s) Energized	Circuit Breaker Closed	Cap. Bank(s) On-line
1	PZ7B	JZ7C	None
2	PZ7A & PZ7B	JZ7C	None
3	PZ7B	JZ7D	PZ7A
4	PZ7B	JZ7C	PZ8A
5	PZ8B	JZ8D	PZ7B & PZ8A
6	PZ7B	JZ7C	PZ8A & PZ8B
7	PZ7A & PZ7B	JZ7C	PZ8A & PZ8B
8	PZ7B	JZ7D	PZ7A, PZ8A, PZ8B
9	PZ7A & PZ7B	JZ7C	PZ8A

Series II: Transformer Magnetizing Current Inrush Tests - This test series will measure transformer and capacitor bank inrush currents when 345-/230-/25-kilovolt autotransformer KU5A is energized from the 230-kilovolt system. Interrupter switch WZ5C will energize the autotransformer with the 345-kilovolt high-voltage and 25-kilovolt tertiary windings disconnected from the power system. During these tests, the 345-, 230-, and 25-kilovolt systems will be interconnected only through autotransformer KU5B. Western must ensure that the switching and loading conditions on the various voltage rated systems and station service are appropriate for autotransformer KU5A out of service. The electrical circuits to be monitored for these tests are similar for series I and are listed in the Instrumentation section. Autotransformer KU5A will be energized with the following capacitor banks on-line:

Test No.	Transformer Energized	Int. Sw. Closed	Cap. Bank(s) On-line
1	KU5A	WZ5C	None
2	KU5A	WZ5C	PZ7B
3	KU5A	WZ5C	PZ7A, PZ7B
4	KU5A	WZ5C	PZ7A, PZ7B, PZ8A
5	KU5A	WZ5C	PZ7A, PZ7B, PZ8A, PZ8B

Instrumentation

The following instrumentation will be provided by Reclamation and installed by the Reclamation Denver Office test crew with the assistance of Western. All instrumentation listed below will be operational for both test series.

Type Instrument	Instrument Location	Point of Connection	No. of Recording Channels
I to V air core CT	PZ7B	Ia,Ib,Ic,In	4
ferrite core electronic CT	JZ7C	spare CT's Ia,Ib,Ic	3
230-kV bushing tap potential	KU5B	Va,Vb,Vc	3
step and touch potential probes	PZ7B	3-foot step and touch V	2
step potential probe	swyd. corner	3-foot step V	1
potential iso. amp.	JZ7C	87B4 CT phase A	1
potential iso. amp	JZ7C	50/51 CT phase A	1
CT current shunt	control bldg.	KU5A Ia,Ib,Ic	3
I to V air core CT	KU5A	neutral bushing In	1

In addition, Western will provide recording instrumentation suitable for monitoring transient voltages generated in control cables terminated in the control building. The Denver Office test crew will assist with the installation and operation of this equipment.

Test Schedule

The following test schedule gives the approximate time required to set up and perform these tests. Western should have all materials and equipment described in the Materials and Equipment section on hand as required. All clearances and switching procedures required should be prepared in advance where necessary to expedite the testing.

Sunday, August 27 - Denver test crew leaves Denver with test van and equipment.

Monday, August 28 - Test van arrives at Page, Arizona. Additional Denver test crew and Western personnel fly to Page. Discuss details of testing activities, safety and clearance procedures, switchyard modifications, etc. in the afternoon.

Tuesday and Wednesday, August 29 and 30 - Set up test instrumentation and monitoring equipment. Capacitor bank PZ7B and autotransformers KU5A and KU5B must be deenergized/grounded and on clearance status while instrumentation is installed on this equipment. The transformers can be removed from service one at a time and reenergized after the work is completed. Perform initial test instrument function and calibration checks.

A Western electrician and personnel who can place clearances and personal protective grounds must be available to assist the Denver test crew beginning Tuesday, August 29, continuing until test equipment is removed from the yard on Friday, September 1.

Thursday, August 31 - Final test instrument calibration. Perform series I and II tests. Tests to be conducted during daytime hours.

Friday, September 1 - To be used to either complete testing or as backup in case of delays or bad weather. Disconnect and pack test instrumentation. Test van leaves Page for Denver. Denver test crew and Western personnel return flight to Denver in late afternoon.

Materials and Equipment

The Denver test crew will provide all test equipment and materials required for monitoring and recording the signals listed in the Instrumentation section. All wire and cable required for connection to the switchyard will also be provided.

Western will provide the recording instrumentation for monitoring control cable transient voltages in the control building. The Denver test crew will assist with the installation and operation of this equipment. The test van will require 240-volts a-c, single-phase power which can be obtained from an unused 30-amp circuit breaker in cabinet DZA. Western should provide approximately 175 feet of No. 10 AWG, 2/c cable to power the van from this cabinet when located at the northwest end of the cable trench in the shunt capacitor yard. Western should also provide all personal protective grounding cable and hardware required for deenergized and grounded clearance work on capacitor bank PZ7B and autotransformers KU5A and KU5B.

Communications

These tests will require coordination and/or communication between the following locations: instrument test van in shunt cap. switchyard, test crew, switchyard control building, powerplant, and the Montrose dispatch center. Western will provide two-way radios for communication between the test crew and van, and the control building. Switchyard power equipment under test will be locally controlled from the control building during all setup and testing activities. During actual test data recording, power equipment under test will be energized by voice countdown from the test van.

Western will provide a person designated as the test coordinator who will be responsible for obtaining and/or writing the proper clearance and switching procedures necessary to perform these tests. The test coordinator will also observe test and equipment status and supervise all test activities involving clearances and interaction with the powerplant and dispatch center. The Denver test crew will work with the test coordinator in directing the testing activities.

A2330, P. Krause

Field Tests of the Glen Canyon Shunt Capacitor Banks

L2000, L. Nelson

The addition of the four 230-kV, 50,000 kvar shunt capacitor banks at Glen Canyon will be complete by August, 1989. The switching of these banks will result in high frequency currents and voltages on the Glen Canyon 230-kV bus which could impact the operation of the protective relays. Therefore, we recommend that additional monitoring devices be connected to measure the high frequency currents and voltages associated with shunt capacitor bank switching during the commissioning tests.

No system short circuits will be required for the tests, only energization of the capacitor bank, energization of one 345/230-kV transformer, and back-to-back switching of the capacitor banks. The tests will enable measurements to be recorded relating to the following items:

1) Shunt capacitor bank switching results in large, high frequency currents through the current transformers(CTs) resulting in possible high voltages in the secondary circuit. The high voltages are a result of the increased burden presented to the CT by the various components connected to the secondary circuit. Measurements can be made to confirm that the secondary burden does not cause excessive voltages on the CT, or elements in the secondary circuit (cable, relays, transducers, meters, etc).

2) Large voltage spikes can also develop during shunt capacitor switching. The phase-to-phase magnitude is of interest because of the stress this can place on three phase transformer windings. The first capacitor bank to be energized usually produces the largest phase-to-phase stress on the transformer.

3) Transformer energization can cause excessive harmonic currents in the neutral of shunt capacitor banks. The harmonic currents may cause the capacitor bank unbalance protection to misoperate.

4) During back-to-back capacitor bank switching, large high frequency currents flow between the neutrals of the individual capacitor banks. The ground mat is designed to provide safe step and touch potentials at 60 Hz, but the step and touch potentials associated with the high frequency capacitor currents may differ.

Data obtained during the commissioning tests will determine if any additional measures are required for proper control, protection, or operation of the shunt capacitor banks. In addition, the results will aid in design of future shunt capacitor installations

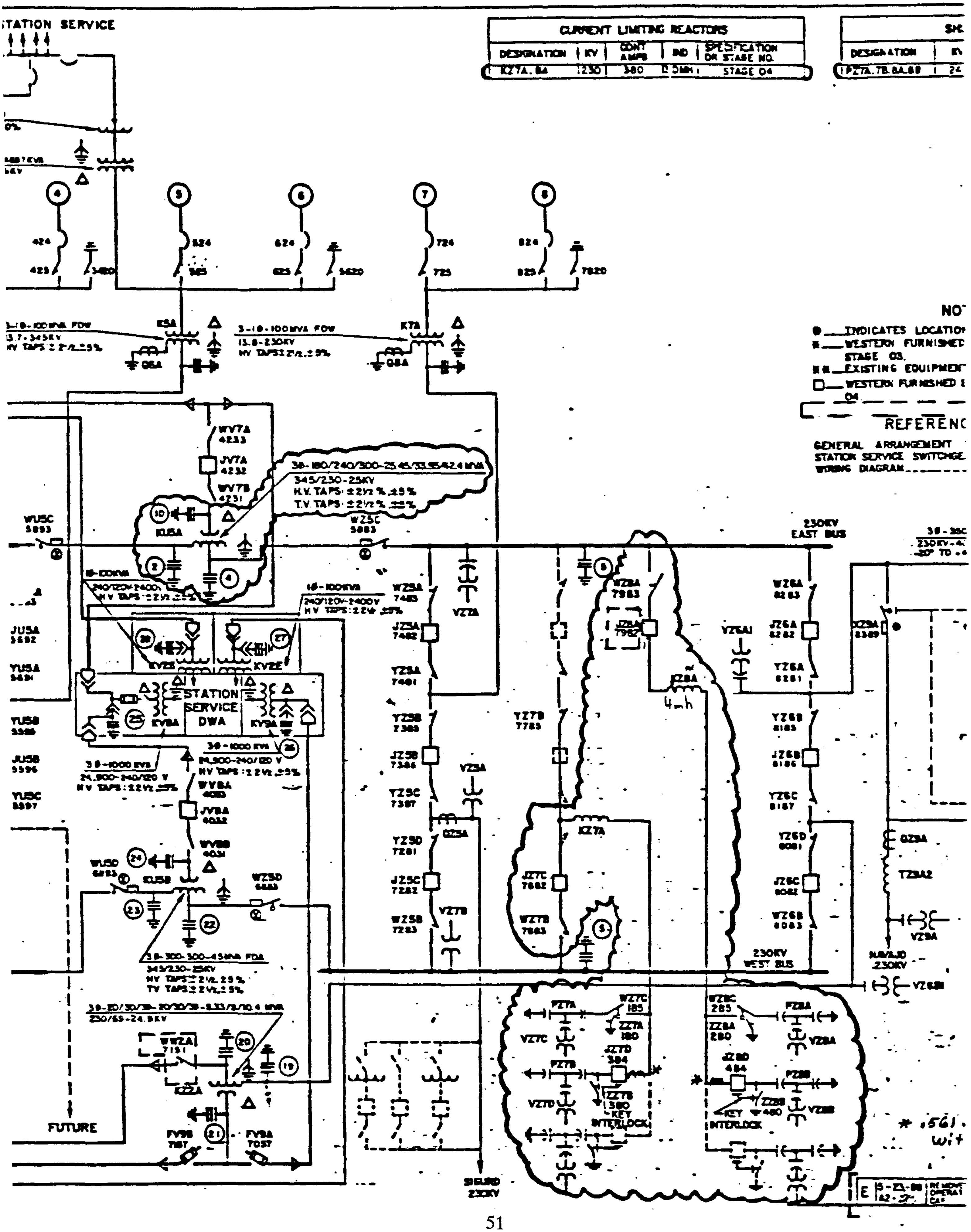
A2330 will provide coordination within Headquarters and with the Bureau of Reclamation Labs for special instrumentation that may be required. If you have any questions please call Joel Bladow at FTS 327-7572.

Gorden T. McCone
Director, Division of
System Engineering

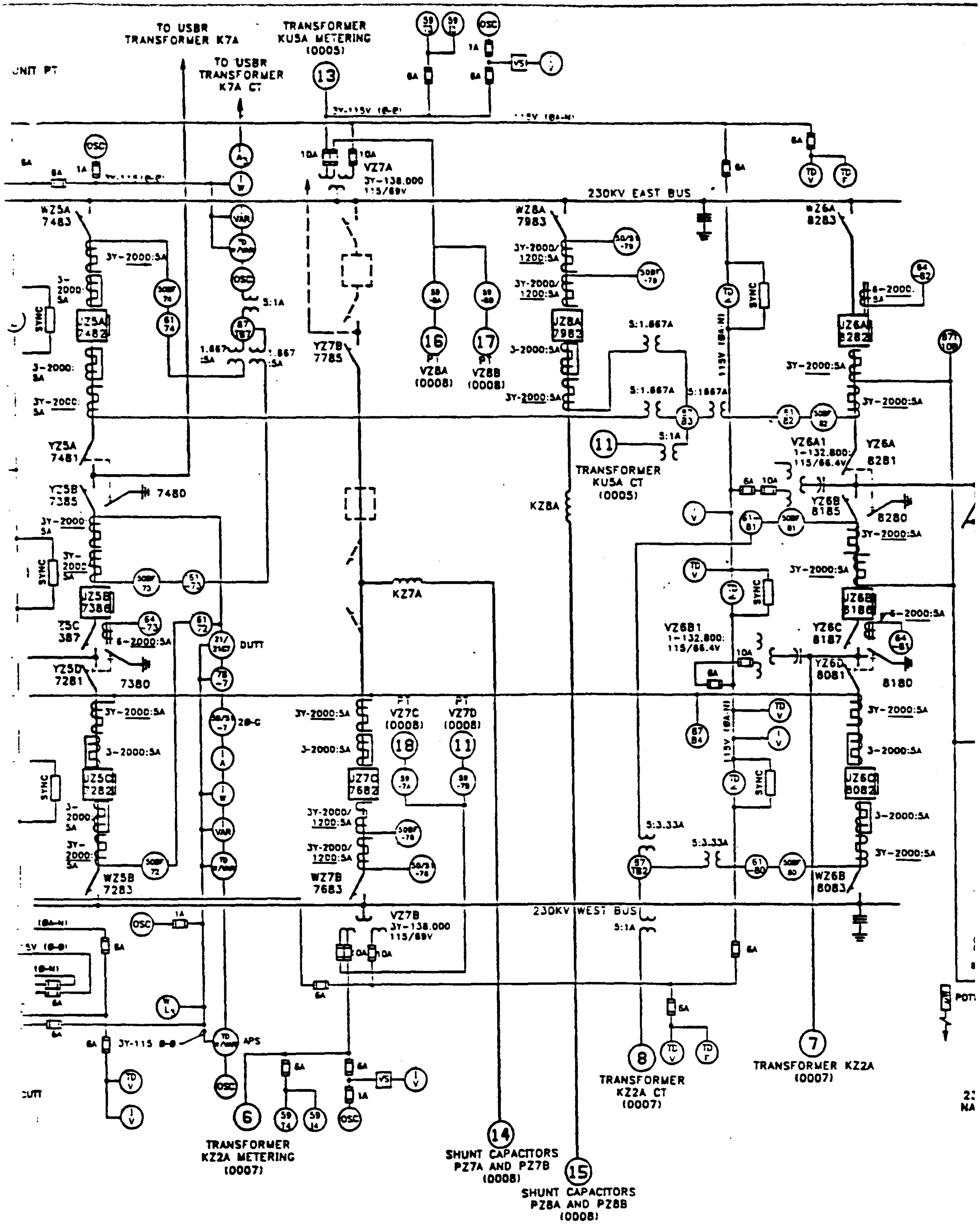
CC:
A2100 G. Birney
M0000 L. Eilts

bcc:
A2000
A2110
A2130
A2300
A2330

A2330:JBladow:X7572:2/3/89



STATION SERVICE
CURRENT LIMITING REACTORS
DESIGNATION | KV | CONT AMPS | IND | SPECIFICATION OR STAGE NO.
KZ7A, 8A | 230 | 380 | 5MH | STAGE 04
DESIGNATION | KV
PZ7A, 7B, 8A, 8B | 24
NOTES
INDICATES LOCATION
WESTERN FURNISHED STAGE 03.
EXISTING EQUIPMENT
WESTERN FURNISHED 04.
REFERENCE
GENERAL ARRANGEMENT
STATION SERVICE SWITCHGEAR
WIRING DIAGRAM
3-1Φ-100MVA FOW
13.8-230KV
HV TAPS ±2½,±5%
3Φ-180/240/300-25.45/33.95/42.4 MVA
345/230-25KV
H.V. TAPS ±2½%,±5%
T.V. TAPS ±2½%,±5%
230KV EAST BUS
230KV WEST BUS
STATION SERVICE DWA
3Φ-1000 KVA
24,900-240/120 V
HV TAPS ±2½,±5%
3Φ-300-300-45MVA FOA
345/230-25KV
HV TAPS ±2½,±5%
TV TAPS ±2½,±5%
FUTURE
SIGURD 230KV
NAVAJO 230KV
KEY INTERLOCK
4mh


TO USBR TRANSFORMER K7A
TRANSFORMER KU5A METERING (0005)
TO USBR TRANSFORMER K7A CT
UNIT PT
13
VZ7A 3Y-138,000 115/69V
230KV EAST BUS
WZ5A 7483
WZ8A 7983
WZ6A 8283
UZ5A 7482
UZ8A 7983
UZ6A 8282
YZ7B 7785
16 PT VZ8A (0008)
17 PT VZ8B (0008)
11 TRANSFORMER KU5A CT (0005)
YZ5A 7481
VZ6A1 1-132,800: 115/66.4V
YZ6A 8281
YZ5B 7385
7480
KZ8A
YZ6B 8185
8280
UZ5B 7386
KZ7A
UZ6B 8186
DUTT
VZ6B1 1-132,800: 115/66.4V
YZ6C 8187
YZ5D 7281
7380
YZ6D 8081
8180
PT VZ7C (0008)
PT VZ7D (0008)
18
11
UZ5C 7282
UZ7C 7682
UZ6C 8082
WZ5B 7283
WZ7B 7683
WZ6B 8083
230KV WEST BUS
VZ7B 3Y-138,000 115/69V
APS
8 TRANSFORMER KZ2A CT (0007)
7 TRANSFORMER KZ2A (0007)
6 TRANSFORMER KZ2A METERING (0007)
14 SHUNT CAPACITORS PZ7A AND PZ7B (0008)
15 SHUNT CAPACITORS PZ8A AND PZ8B (0008)

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.