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SHUTTLE ELECTRICAL POWER ANALYSIS PROGRAM (SEPAP) DISTRIBUTION CIRCUIT ANALYSIS REPORT

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National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
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SHUTTLE ELECTRICAL POWER ANALYSIS PROGRAM (SEPAP) DISTRIBUTION CIRCUIT ANALYSIS REPORT

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CONTENTS

FIGURES

Figure		Page
3-9	On-orbit operations, Aft Bus C	4-24
3-10	On-orbit operations, Inverters	4-25
4-1	De-orbit through GSE connect, Main Bus A .	4-28
4-2	De-orbit through GSE connect, Main Bus B .	4-29
4-3	De-orbit through GSE connect, Main Bus C .	4-30
4-4	De-orbit through GSE connect, Forward Bus A	4-31
4-5	De-orbit through GSE connect, Forward Bus B	4-32
4-6	De-orbit through GSE connect, Forward Bus C	4-33
4-7	De-orbit through GSE connect, Aft Bus A . .	4-34
4-8	De-orbit through GSE connect, Aft Bus B . .	4-35
4-9	De-orbit through GSE connect, Aft Bus C . .	4-36
4-10	De-orbit through GSE connect, Inverters . .	4-37

TABLES

1.0 SUMMARY

This report is an analysis and evaluation of the operating parameters of the Shuttle electrical power distribution circuit under load conditions encountered during a normal Sortie Mission 2. Component data was obtained from the NASA/JSC Baseline Electrical Equipment List, dated October 22, 1974. The RI/SD Power Analysis document, dated October 8, 1974, was used as the baseline for determining the active components during each phase of the mission. The data was provided as input to a computer program which contained the math models for simulating the distribution network, the fuel cell, and the inverter. The computer output analysis was evaluated to determine if the system parameters (voltage, current, and power) met the operating requirements as defined by the appropriate specification documents and system design. The evaluation indicates that the Orbiter distribution system is capable of handling the load requirements, under present component load values, without exhibiting any out-of-tolerance parameters. It should be noted that the analysis did not contain payload loads. But, in a quick look evaluation utilizing maximum payload specification loads for each phase, the distribution system should be capable of providing electrical power to the payload without any parameters exceeding design limits. Also, this analysis was based on a normal operating distribution system with no intent on analyzing the system based on a distribution system anomally. A point of concern in this area is the total power required during the first 4 minutes of ascent. Total Orbiter power at liftoff is 26.7 kilowatts and if a fuel cell should fail, switching its load through the bus tie to an operational fuel cell would drive the power requirements of the fuel cell over the maximum design limit of 12 kilowatts.

Further evaluation is required to determine what action should be followed in this case. Peak load during de-orbit is 20.6 kw, thus no major load distribution modifications should be required for this time period. Another point of concern is the suspected inverter overload condition during the ascent phase of the mission. The report does not address the problem since this overload condition, which exists on one phase of one inverter array, is due to a transient condition resulting from the startup of the RCS door motors. The SEPAP program is presently not able to perform transient analysis, but program modifications have been initiated to include this capability for future electrical power distribution evaluations.

Future evaluations will be made as component information is updated. Also, detailed evaluations will be performed to include payload loads, contingency planning, and transient analysis.

2.0 INTRODUCTION

This report contains an evaluation of the data obtained from an analysis of the Shuttle electrical power distribution system during a typical Sortie 2 Mission with special attention focused on the main periods of liftoff and landing. The Shuttle Electrical Power Analysis Program (SEPAP) provides NASA/JSC with a database containing information on the electrical characteristics of the Shuttle components, the energy sources and the distribution circuit. It has the capability of developing a mission power profile and conducting distribution circuit analyses solving for bus voltage, branch currents and fuel cell power requirements. A description of the approach utilized is provided and the conclusions that are drawn from an evaluation of the data is included.

2.1 PURPOSE

The purpose of this analysis effort was to determine the voltage at each distribution bus, fuel cell peak and continued power requirements, inverter loads and main branch currents. Based on this information, conclusions can be made regarding load distribution, wire sizing, circuit breaker protection, and fuel cell and inverter power output requirements. Although the data is preliminary due to the status of the information on which the calculations are based, some indication of the adequacy of the system design at this point in the program can be determined.

2.2 GROUND RULES AND ASSUMPTIONS

The RI/SD Power Profile Analysis document, dated October 8, 1974, was used to determine the operational aspects of each component on the Shuttle Orbiter. The average power percent values listed for each component for each mission phase were used to determine the number of identical components that were "ON" and the time duration for each component for that phase. The NASA/JSC Space Shuttle System Baseline Reference Missions Volume II - Mission 2 document, dated May 29, 1974, provided the sequence of major events within a mission phase. The NASA/JSC Electrical Equipment Database, dated October 18, 1974, was used to obtain component data. A few modifications were incorporated to reflect later information. In addition, the distribution circuit database utilized by SEPAP was developed from the preliminary Main DC Power Distribution Subsystem Schematic Diagram (VS70-760301), dated August 2, 1974.

The following ground rules and assumptions were used in performing this analysis:

(a) No payload loads were included.

(b) Orbiter display and control equipment were "all up" during liftoff in case of mission abort.

(c) Inverter DC power requirements were calculated as Power In = 1.25 x Power Out (80% inverter efficiency).

(d) Heater cycling was based on RI/SD data.

(e) RCS thruster cycles were not included because of the random, short time duration of each firing.

(f) Three fuel cell operation was assumed during the mission.

(g) Line resistance data was taken from information received from RI/SD on October 31, 1974.

(h) The 32-cell gold platinum catalyst fuel cell operational characteristics were used.

(i) Assumed equal load distribution for each inverter array.

2.3 GENERAL APPROACH

The computer program used to generate the circuit analysis data is based on a nodal solution program developed and utilized during the Apollo missions. The program has been updated to reflect the Shuttle electrical power distribution network and contains models of the fuel cell and the inverter. The power distribution system busses and subbusses are identified as nodes and the electrical components are identified as loads connected between circuit nodes. A simplified schematic of the Shuttle Orbiter distribution circuit utilized by SEPAP is included in figure 1. By defining the power status of each component through an input timeline, a circuit solution is derived for each time point. The Sortie Mission 2 sequence of major events is included for information in table 1.

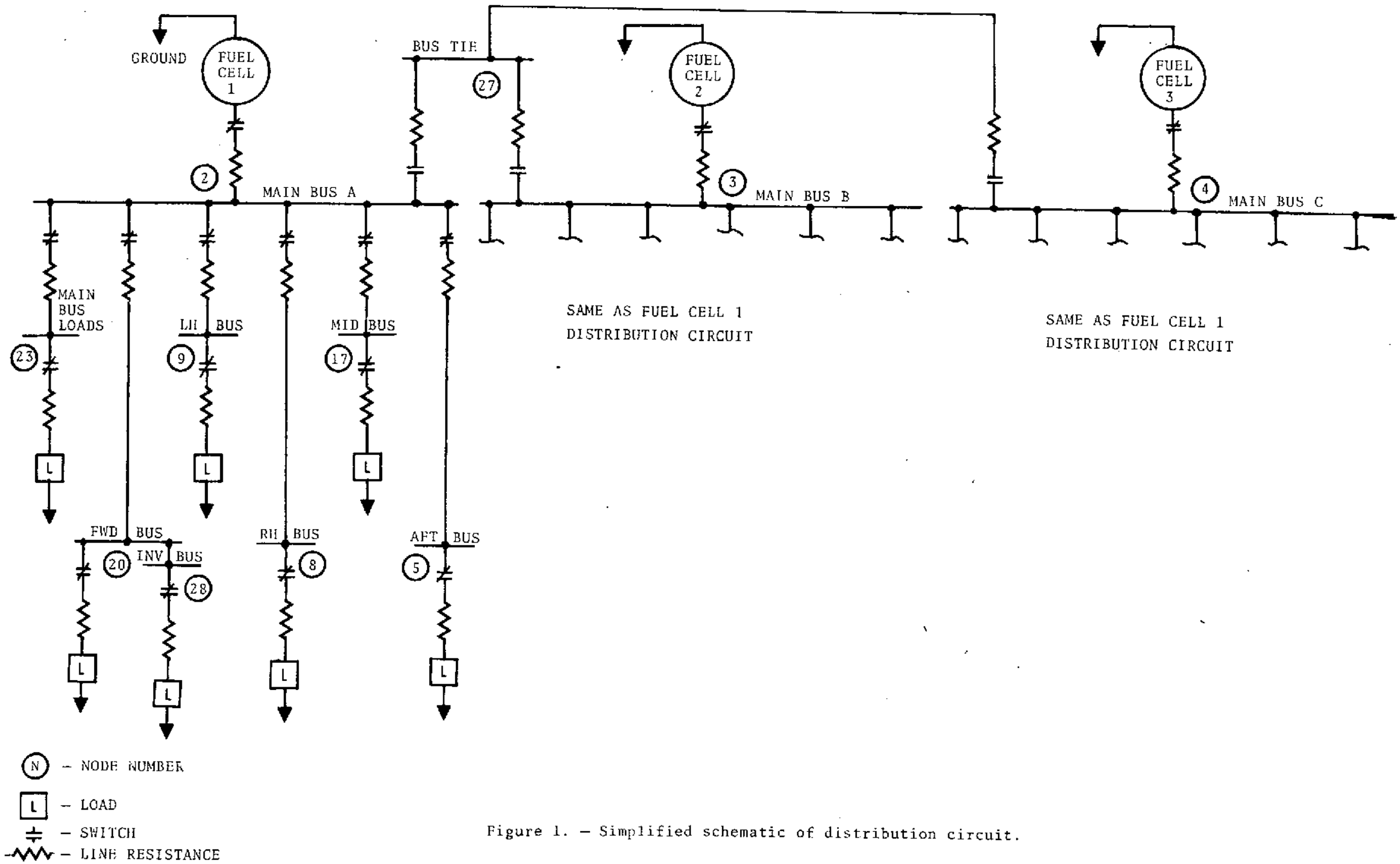


Figure 1. – Simplified schematic of distribution circuit.

TABLE 1. – SORTIE MISSION 2 SEQUENCE OF EVENTS

EVENT	GET HR:MIN:SEC	FIG.2,3, &4 TIME HR:MIN:SEC
Start Final Countdown	-00:10:00	00:00:00
Liftoff	00:00:00	00:10:00
Launch Umbilical Doors Closed	00:00:05	00:10:05
SRB Jettison	00:02:04	00:12:04
Main Engine Cutoff	00:08:24	00:18:24
RCS Doors Open	00:08:25	00:18:25
E/T Jettison	00:08:51	00:18:51
OMS Burn	00:08:56	00:18:56
OMS Cutoff	00:09:55	00:19:55
Payload/Startracker Doors Open	00:09:56	00:19:56
OMS Circularization Maneuver	00:24:28	00:34:28
OMS Cutoff	00:25:18	00:35:18
OMS Height Adjust Maneuver	19:12:51	19:22:51
OMS Cutoff	19:17:24	19:27:24
TPI OMS Burn	23:07:10	23:17:10
OMS Cutoff	23:07:21	23:17:21
Docking with Satellite	24:50:00	25:00:00
Refurbish Operations	26:10:00	26:20:00
Separation	46:10:00	46:20:00
Orbital Adjustment OMS Burn	48:59:07	49:09:07
OMS Cutoff	49:00:41	49:10:41
Begin Sortie Operations	51:10:00	51:20:00
End Sortie Operations	149:10:00	149:20:00
De-Orbit OMS Burn	165:20:00	165:30:00
OMS Cutoff	165:23:00	165:33:00
Entry	166:34:02	166:44:02
Final Approach	166:37:20	166:47:20
Touchdown	166:40:00	166:50:00
Stop-Roll	166:42:00	166:52:00
GSE Connect	166:55:00	167:05:00

3.0 DISCUSSION AND EVALUATION

3.1 GENERAL

For this report, the analysis data was generated by executing two computer runs to complete the mission timeline. The first run covers the period between "countdown" starting at T-10 minutes to the end of "Sortie Experiment Operations Day 1" (T+75 hours 20 minutes). The second run includes the time period beginning "Sortie Experiment Operations Day 5" at T+147 hours 20 minutes and ending at "GSE Connect" (T+167 hours 5 minutes). "Sortie Experiment Operations Days 2, 3, and 4 are similar to Day 1, thus eliminating the need to analyze that portion of the mission timeline. Plots of the power/voltage profiles for main, forward, and aft busses for the mission duration are included in figures 2, 3, and 4. It should be pointed out that power to the payload has not been included in the analysis. The present power allowances for the payload as detailed in the specifications requirements are:

1. Ascent and Descent payload power consumption is to be a maximum 1000 watts average.
2. During on-orbit periods power consumption is to be:
   A. 7000 watts maximum except for peaks up to 12,000 watts (15 minutes for 3-hour period) if one fuel cell is dedicated to payload.
   B. 5000 watts maximum except for peaks up to 8000 watts (2 minutes for 3-hour period) if payload shares a fuel cell with the Orbiter.

3.2 DETAILED EVALUATION

For discussion and evaluation, the mission has been segmented into three phases and these are:

1. Countdown through circularization.
2. On-orbit operations.
3. De-orbit through GSE connect.

Each phase is presented in the following paragraphs. The detailed data is available for review if required.

3.2.1 Countdown through Circularization

During this time period the Shuttle is launched from Kennedy Space Center (KSC) and orbit insertion (100 by 50 n.mi.) occurs 9 minutes 55 seconds after liftoff. After a coast period to apogee, an OMS burn occurs to circularize the orbit. Also, during the coast period payload and startracker doors are sequentially opened and the Orbiter is reconfigured for on-orbit operations. Figure 2 and table 2 present and summarize the analysis data for this time period. The peak load on a distribution bus that occurs during this time period is 9.7 kw for 6 seconds on Main Bus B. This load is well within the design limits defined for the system of 12 kw for 15 minutes. The total peak load at liftoff is approximately 26.8 kw for 6 seconds, then drops to about 25 kw for the next 4 minutes 15 seconds before total power drops below 24 kw. This could be a potential problem area if a fuel cell failure should occur during this time causing power loads on remaining fuel cells to exceed 12 kw. The average power required for this phase is approximately 6.13 kw for each of the fuel cells with the specification limit set at 7.0 kw for an extended time period. No power overload is presently exhibited during this phase and the system is capable of handling the additional payload power and still remain within the margin.

All Main Bus voltages fluctuate within the operational limits set for the fuel cells (27.5 to 32.5 VDC). Maximum voltage level (31.2 VDC) occurs on Main Bus C and the minimum level (28.7 VDC) occurs on Main Bus A. In addition, there is a small (0.05V @ 352A) voltage drop due to feeder line resistance from fuel cell to main bus. At the component interfaces, the minimum voltage has been specified to be 24.0 VDC for maintaining component continuous operation. Allowing for a 2.1 voltage drop (RI/SD design value) between the distribution bus and the component interface, the minimum voltage level at the distribution bus should be 26.1 VDC. In reviewing table 2-1, the lowest voltage on a bus occurs on AFT Bus B with a voltage level of 28.2 VDC. At this time point, the current to the AFT Bus is approximately 99.3 amps with a voltage drop of almost .5 volts from Main Bus to the AFT Bus. This occurs at the peak load period of liftoff, thus there presently exist sufficient margin in the design for the present load conditions. The maximum current through each bus feed has been calculated and are presented in table 2-1. The feeder line from fuel cell No. 2 to Main Bus B carries the largest ampere (amps) load which is 338.0 amps. Fuel cell design is based on a maximum overload capacity of 545 amp for 1 minute. The distribution branch from Main Bus A to AFT Bus A carries 202.8 amps and the branch from Main Bus A to AFT Bus A carries 105.3 amps. In both cases, the branch consists of parallel wires with a circuit breaker on each wire. The circuit breaker ratings are:

1. Main Bus to Fwd Bus – 225 amps

2. Main Bus to AFT Bus – 225 amps

This points out that with the loss of one line normal operation would continue with no detrimental effects to the distribution system. The only noticeable effect to the system would be a small increase in the voltage drop between the Main Bus and the Distribution Bus. In future analyses, current values to other distribution busses will be determined and compared with circuit breaker ratings and configuration.

The individual inverter array DC power requirements for this time period are profiled on figure 2-10 and estimated inverter VA outputs are presented in table 2-2. Design values for inverter array output capability are:

RATING	% FULL LOAD	RATING – VA
Continuous	100%	2250
30 Min. Overload	150%	3375
2 Min. Overload	200%	4500

Considering an average component Power Factor (PF) of 0.9, peak values and continuous inverter loads fall within the inverter array design limits. Maximum peak value is 3.3 kVA with a duration of 6 seconds. The maximum continuous VA output is at 128 percent of rated full load for approximately 13.5 minutes. After reviewing the analysis data, no problems are evident under a normal operating system. Future analyses will contain transient data and individual inverter load evaluations where suspected problems may exist.

3.2.2 On-Orbit Operations

This mission phase is divided into two major operations. The first is a rendezvous, dock, and refurbishment of an orbiting element which occurs in the first 50 hours of the mission phase. The remaining on-orbit time of approximately 98 hours is utilized by the payload specialists to perform the scheduled sortie experiments. Several OMS burns are required during the on-orbit operations to adjust the orbit for rendezvousing with the satellite and for establishing the desired orbit for the sortie experiments. Figure 3 and table 3 present and summarize the analysis data for this time period.

Peak power on Main Bus A is 8.7 kw, and this falls well within the design limits of 12 kw. The average power required is approximately 4.1 kw for each fuel cell. No power overload is presently exhibited during this phase but further analysis is required to determine if the system is capable of handling the added payload power requirements and still remain within the system design limits. In future evaluations, the load distribution will be reviewed with payload power requirements included to ensure no single fuel cell overload condition exists. The large variations in power on Main Busses A, B, and C (figs. 3-1, 3-2, and 3-3) are due to cyclic heaters on the Orbiter. The cycle period is for 90 minutes and the percent "ON" for each component is based on RI/SD data.

All bus voltages are within the design limits of the distribution system and no problems are foreseen with present loading requirements. Maximum current values are less than those exhibited during the launch phase. The inverter array

DC power requirements for this time period are profiled on figure 3-10 and estimated inverter VA outputs are presented in table 3-2. After reviewing the analysis data, no problems are evident under normal operating conditions.

3.2.3 De-Orbit Through GSE Connect

At approximately 149 hours the payload specialists close out the sortie experiments and preparation begins for reentry. Orbiter doors are closed and the de-orbit burn occurs at 165.507 hours. Touchdown is at 166.833 hours with a 2 minute rollout and 13 more minutes before GSE connect. Figure 4 and table 4 present and summarize the analysis data for this time period.

The peak load on a distribution bus that occurs during this time period is 9.1 kw on Main Bus A. Again, the system is capable of handling this load. The average power for each fuel cell is approximately 4.66 kw and adding the payload power requirements per the payload specification, no problem of system overload is foreseen. All bus voltages are within the operational design limits of the distribution system. Maximum current values are less than those exhibited during the launch phase. The inverter array DC power requirements for this time period are profiled on figure 4-10 and estimated inverter VA outputs are presented in table 4-2. After reviewing the analysis data, no problems are evident under normal operating conditions. Peak total fuel cell power is 20.6 kw, thus no major load distribution modifications should be required if one fuel cell failed. At GSE connect the Orbiter total power load is approximately 15 kw. Forty-four percent of the load is attributed to the three hydraulic fluid circulation motor pumps which are "ON" at this time to cool the hydraulic fluid.

4.0 EVALUATION SUMMARY

The information presented in the preceding paragraphs provides an indication of the distribution system operational characteristics for a typical Shuttle mission. Payload requirements and their effect on the power distribution system were not considered in the analysis data. However, the power and voltage profile displayed in figures 2, 3, and 4 provides a realistic indication of the system requirements and can be used to evaluate system operating parameters versus specification and design requirements. Tables 2, 3, and 4 present the parameter values that can be evaluated to ensure overload and under-voltage conditions are avoided by design or by procedural control.

The data obtained in this analysis effort should be evaluated with due consideration for the preliminary nature of the input parameters. Further analyses will be conducted as more accurate data is received from the contractors related to component power characteristics and bus assignments.

TABLE 2-1. – ANALYSIS DATA SUMMARY, COUNTDOWN THROUGH INSERTION, DC BUS REQUIREMENTS

BUS	POWER (KILOWATTS)			VOLTAGE		MAX BUS CURRENT (AMPS)	APPROX. AVERAGE POWER (KW)
	MIN	MAX	MAX-TIME (MIN:SEC)	MIN	MAX		
MAIN A	6.3	8.9	02:17	28.9	29.8	308.0	7.6
MAIN B	3.8	9.7	00:06	28.7	30.7	338.0	6.0
MAIN C	2.7	8.4	00:06	29.1	31.2	288.7	4.8
FWD A	3.8	5.8	00:06	28.6	29.6	202.8	4.6
FWD B	2.4	5.0	00:03	28.4	30.6	176.1	3.5
FWD C	1.5	3.8	00:03	28.9	31.2	131.5	2.2
AFT A	0.5	3.0	01:30	28.5	29.6	105.3	1.5
AFT B	0.6	2.8	00:30	28.2	30.6	99.3	1.3
AFT C	0.4	2.0	00:06	28.8	31.2	69.4	1.0

PEAK FUEL CELL POWER

1. 26.8 kw for 6 seconds.
2. 25.0 kw for 4 minutes 30 seconds.
3. Below 24.0 kw remainder of the time.

TABLE 2-2. — ANALYSIS DATA SUMMARY, COUNTDOWN THROUGH INSERTION, INVERTER REQUIREMENTS

INVERTER ARRAY	DC WATTS (PF=1.00)		MAX KVA WITH AVERAGE PF AT		TIME DURATION FOR POWER ABOVE:					
					2250 VA		3375 VA		4500 VA	
	MAX (KW)	AVERAGE DC PWR (KW)	1.00 PF	0.90 PF	1.00	0.90	1.00	0.90	1.00	0.90
BUS A	3.7	2.4	3.0	3.3	13:30	13:30	-0-	-0-	-0-	-0-
BUS B	3.1	1.7	2.5	2.8	02:00	08:00	-0-	-0-	-0-	-0-
BUS C	2.6	1.2	2.1	2.3	00:00	00:00	-0-	-0-	-0-	-0-

DC WATTS = AC POWER x 1.25 (INVERTER EFFICIENCY OF 80%)

AC POWER = (V-A) (PF), WHERE V-A = VOLT-AMPERE REQUIREMENTS OF THE INVERTER ARRAY
AND PF = COMPONENT POWER FACTOR

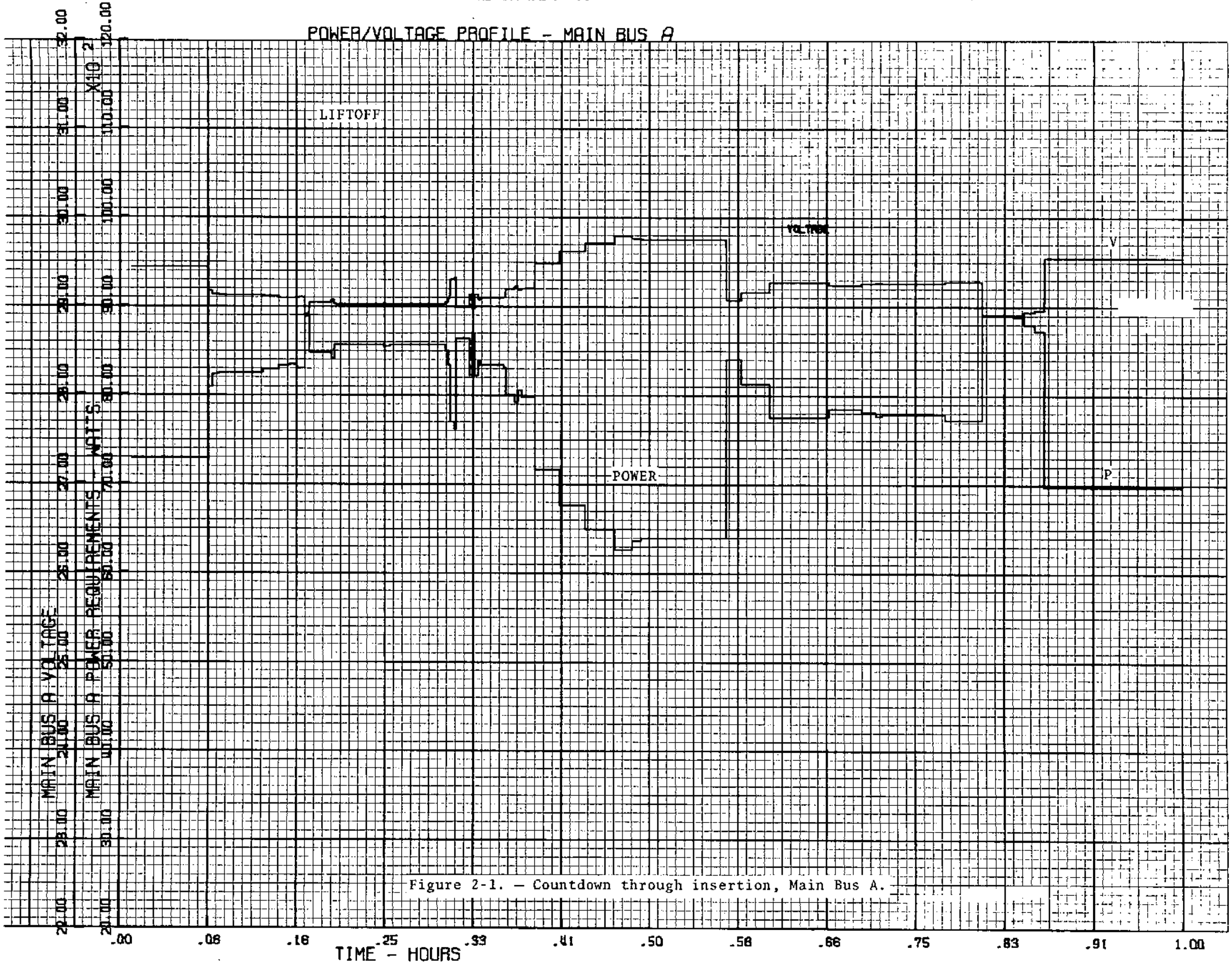


Figure 2-1. — Countdown through insertion, Main Bus A.

4-4

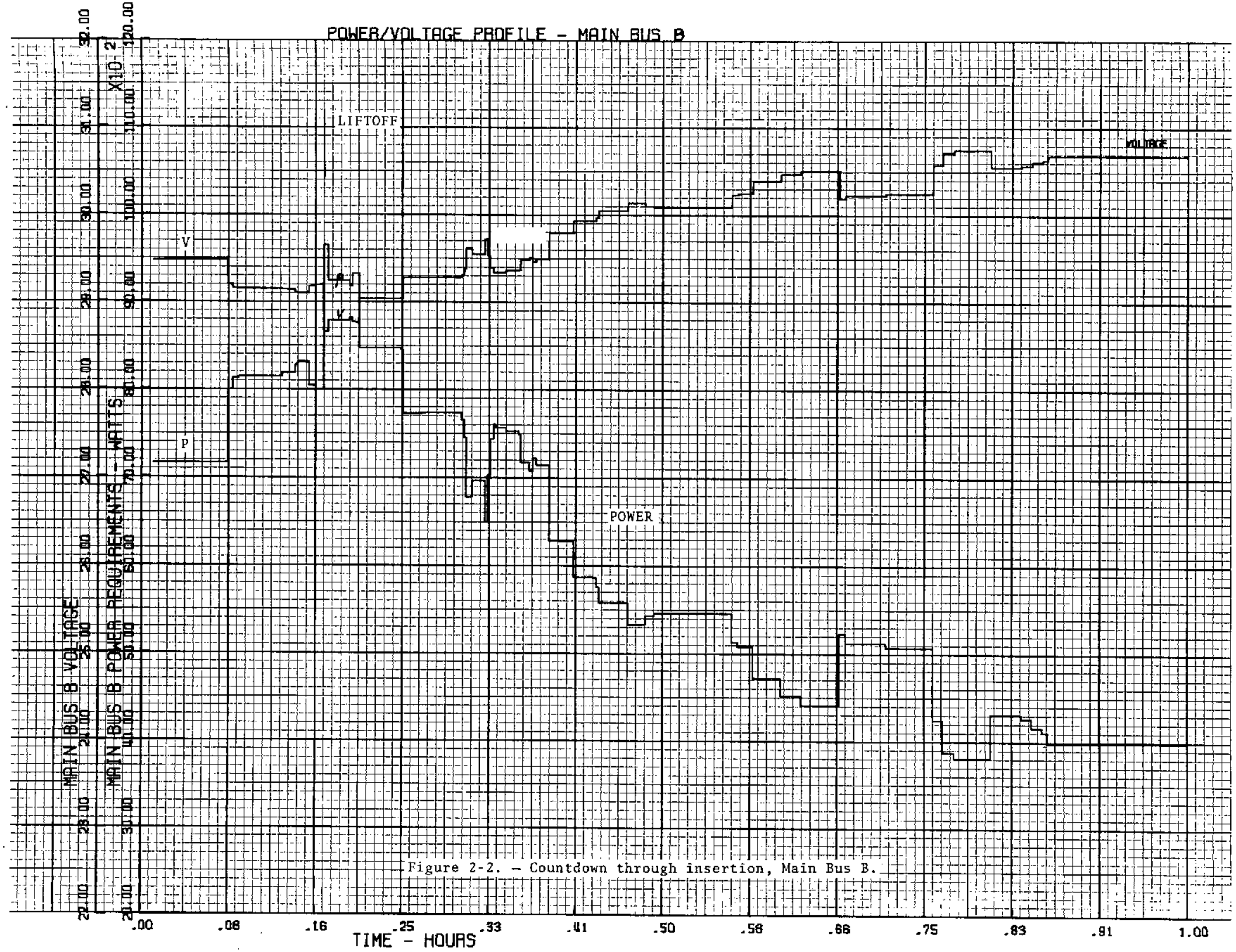


Figure 2-2. – Countdown through insertion, Main Bus B.

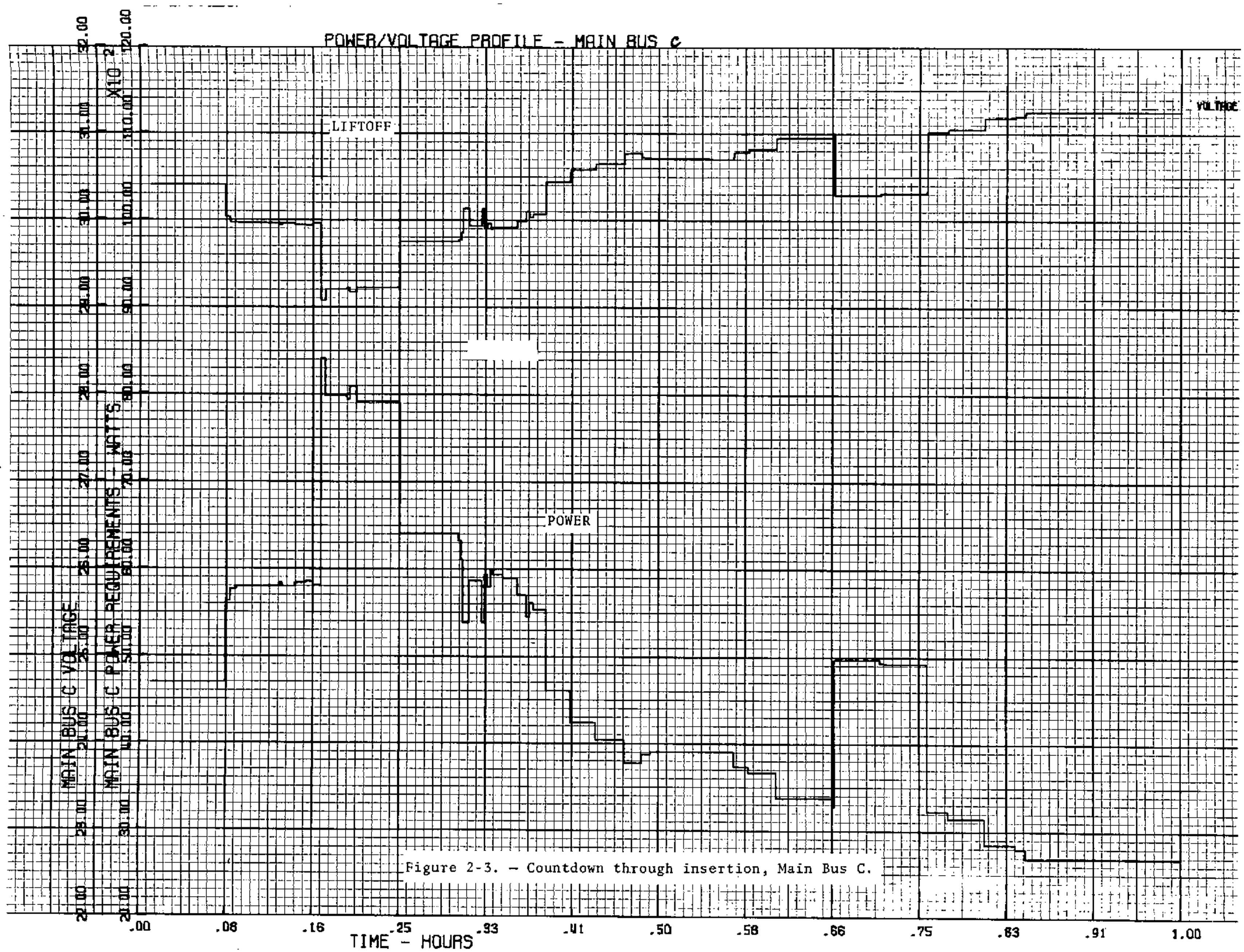


Figure 2-3. — Countdown through insertion, Main Bus C.

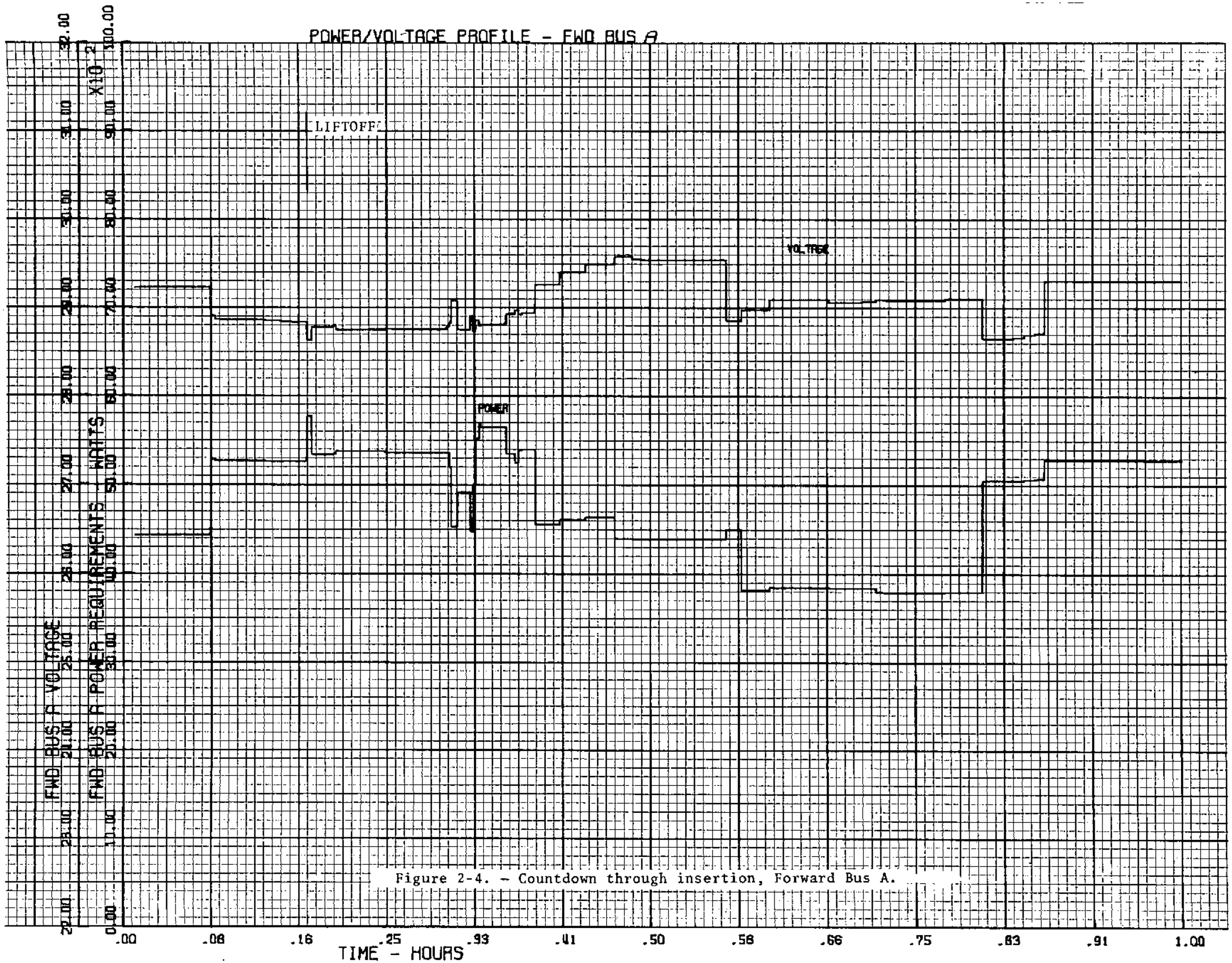


Figure 2-4. - Countdown through insertion, Forward Bus A.

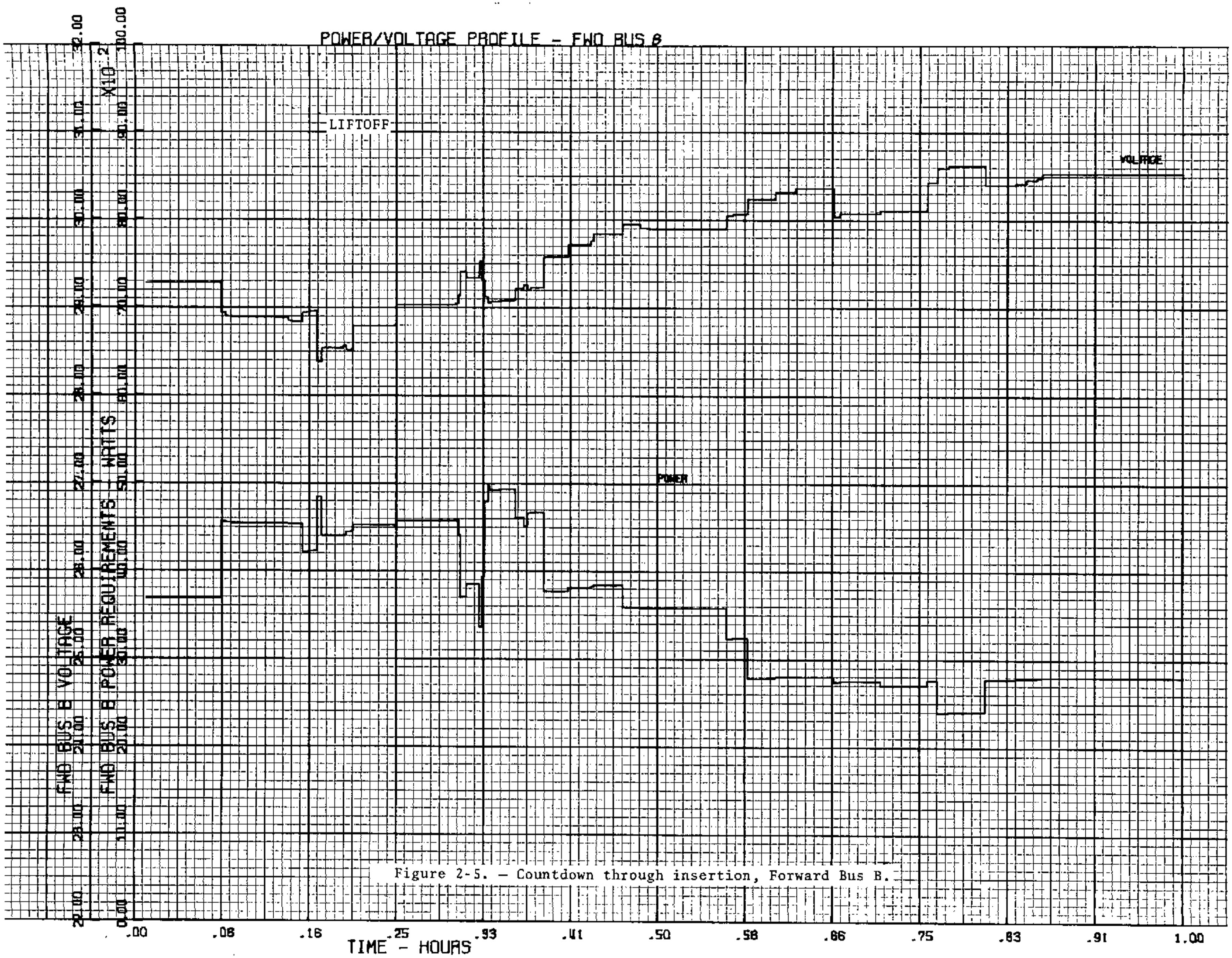


Figure 2-5. — Countdown through insertion, Forward Bus B.

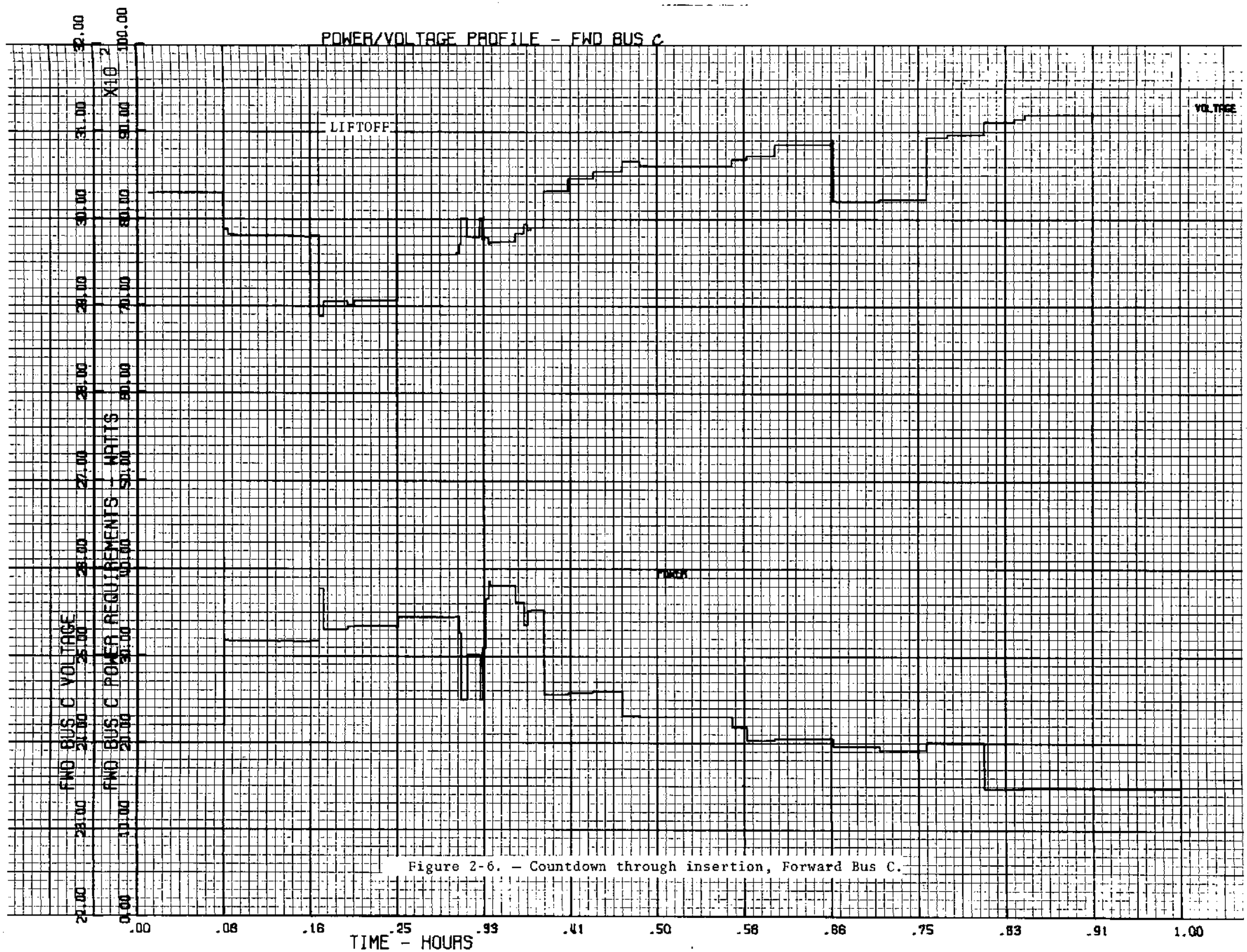


Figure 2-6. — Countdown through insertion, Forward Bus C.

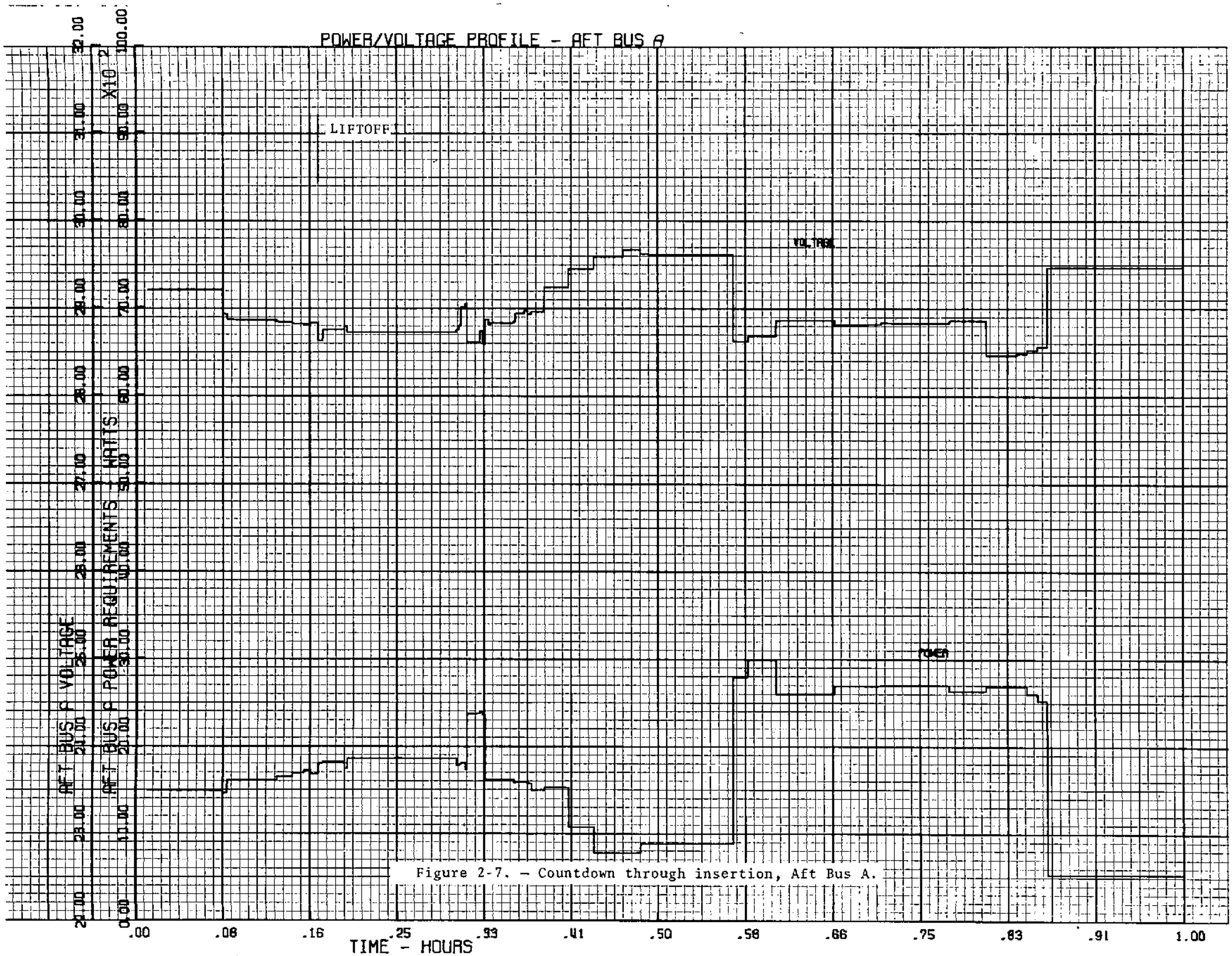


Figure 2-7. — Countdown through insertion, Aft Bus A.

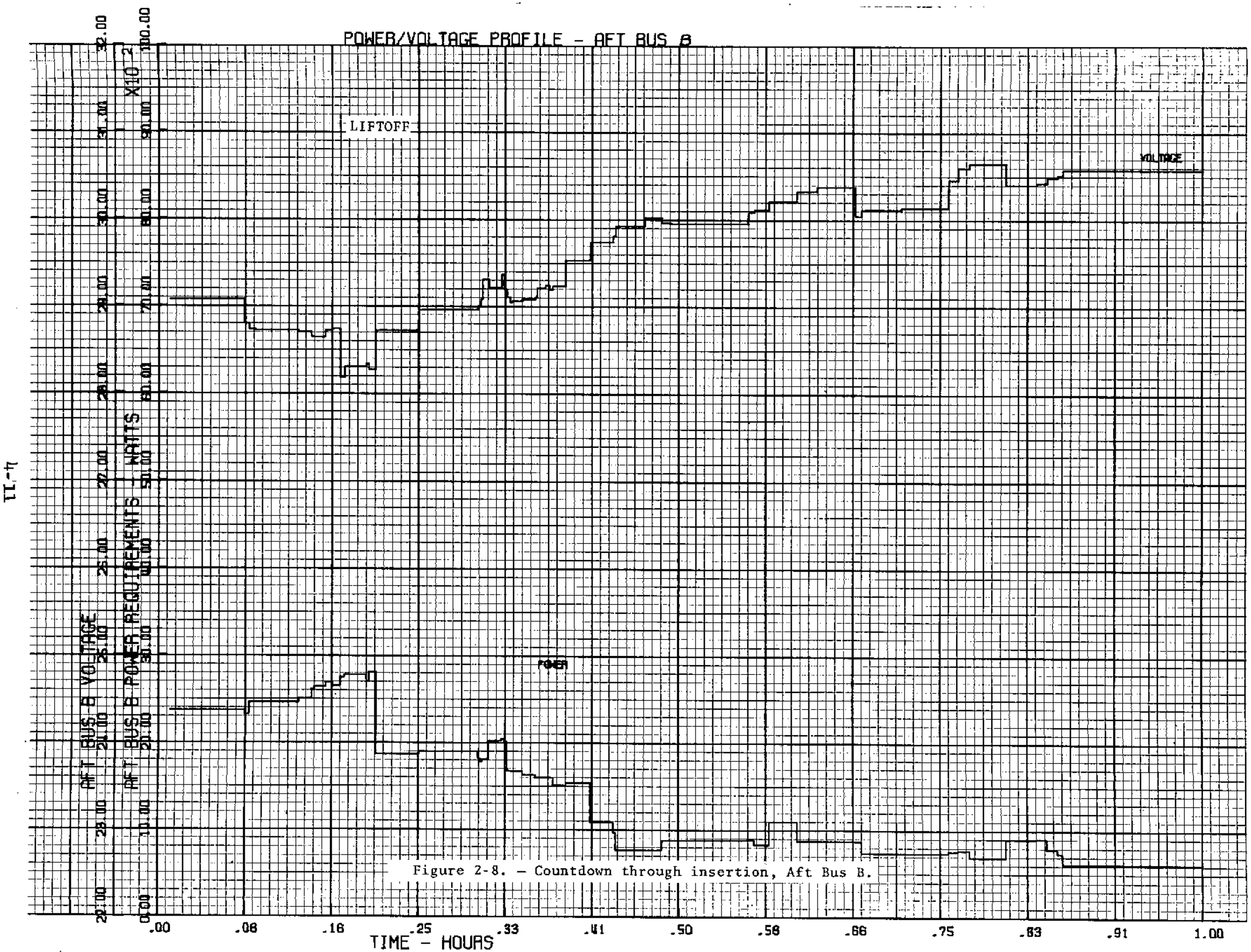


Figure 2-8. — Countdown through insertion, Aft Bus B.

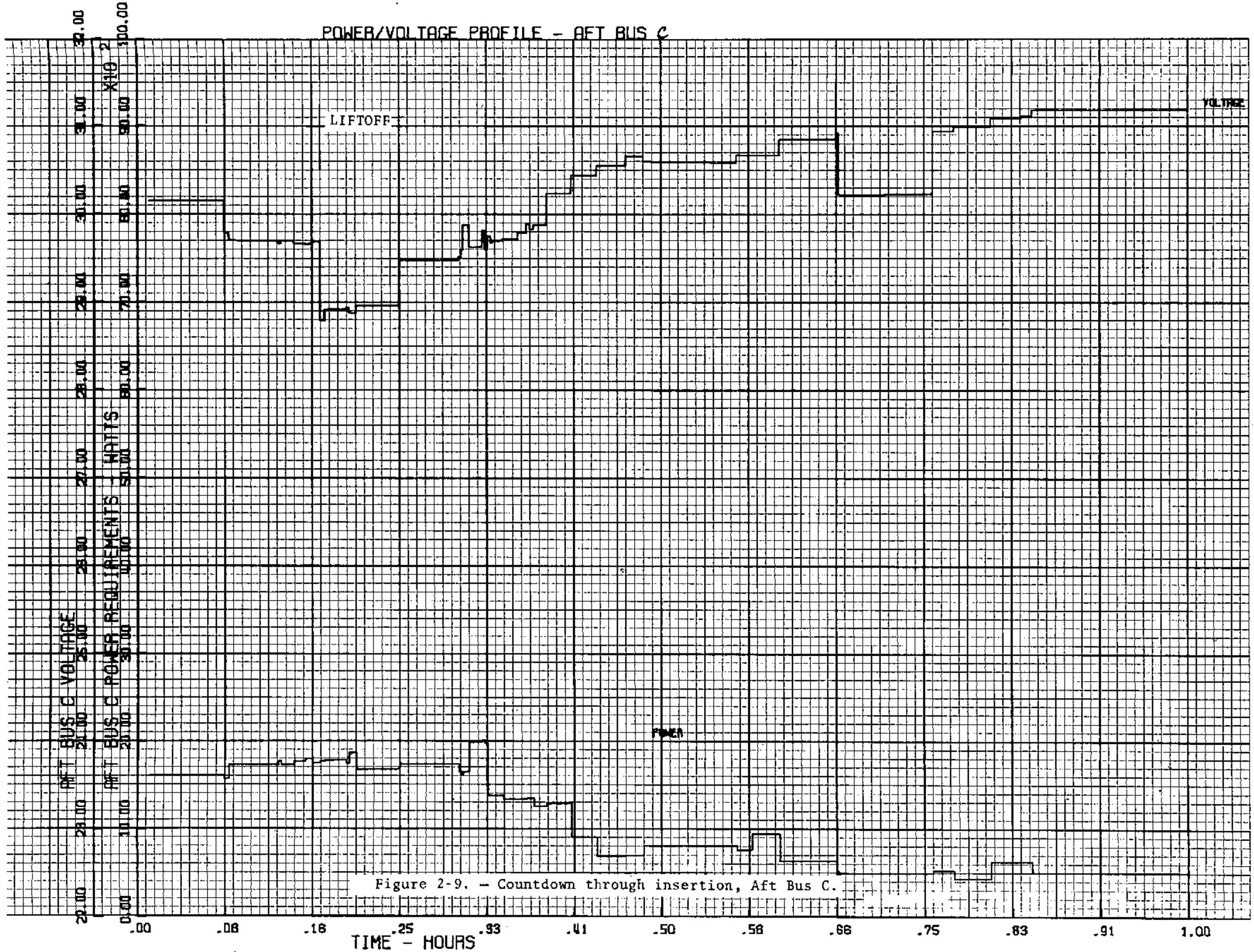


Figure 2-9. — Countdown through insertion, Aft Bus C.

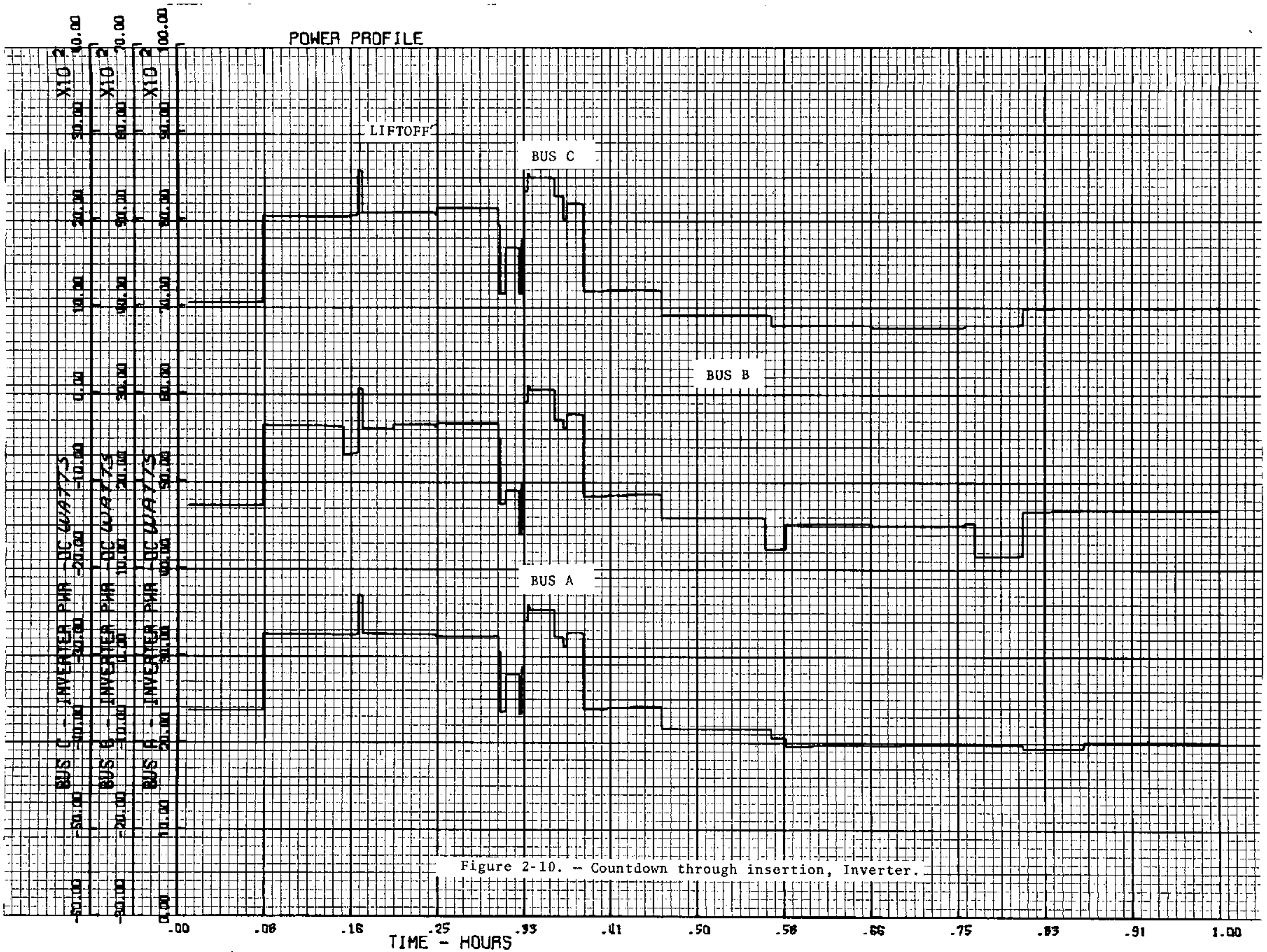


Figure 2-10. — Countdown through insertion, Inverter.

TABLE 3-1. – ANALYSIS DATA SUMMARY, ON-ORBIT OPERATIONS, DC BUS REQUIREMENTS

BUS	POWER (KILOWATTS)			VOLTAGE		MAX BUS CURRENT (AMPS)	APPROX. AVERAGE POWER (KW)
	MIN	MAX	MAX-TIME (MIN:SEC)	MIN	MAX		
MAIN A	4.3	8.7	10:00	28.6	30.6	304.2	5.0
MAIN B	3.4	7.2	01:00	29.5	31.0	244.1	4.2
MAIN C	2.0	8.6	02:00	29.0	31.8	296.6	2.9
FWD A	3.4	5.6	10:00	28.3	30.4	204.5	3.9
FWD B	2.5	3.6	10:00	29.3	30.8	122.9	2.8
FWD C	1.0	3.2	00:10	28.9	31.8	110.7	1.4
AFT A	0.3	3.4	00:10	28.2	30.5	120.6	0.6
AFT B	0.3	3.0	00:10	29.0	30.9	103.4	0.6
AFT C	0.2	2.8	01:00	28.6	31.8	97.9	0.6

PEAK FUEL CELL POWER

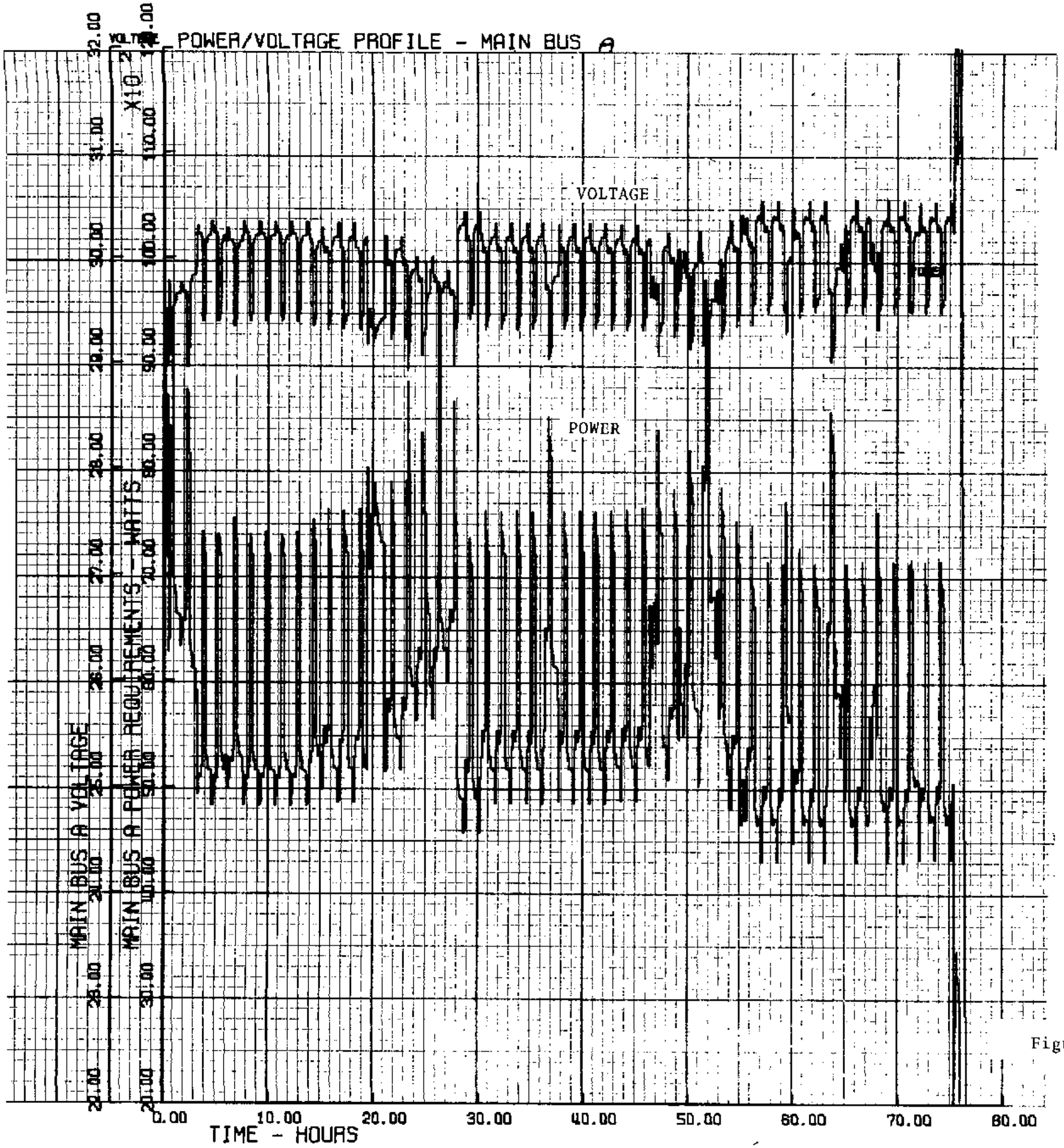
Remained below 24 KW throughout mission phase.

TABLE 3-2. — ANALYSIS DATA SUMMARY, ON-ORBIT OPERATIONS, INVERTER REQUIREMENTS

INVERTER ARRAY	DC WATTS (PF=1.00)		MAX KVA WITH AVERAGE PF AT		TIME DURATION FOR POWER ABOVE:					
					2250 VA		3350 VA		4500 VA	
	MAX (KW)	AVERAGE DC PWR (KW)	1.00 PF	0.90 PF	1.00	0.90	1.00	0.90	1.00	0.90
BUS A	2.4	2.1	1.9	2.1	-0-	-0-	-0-	-0-	-0-	-0-
BUS B	2.3	1.5	1.8	2.0	-0-	-0-	-0-	-0-	-0-	-0-
BUS C	1.8	0.8	1.4	1.6	-0-	-0-	-0-	-0-	-0-	-0-

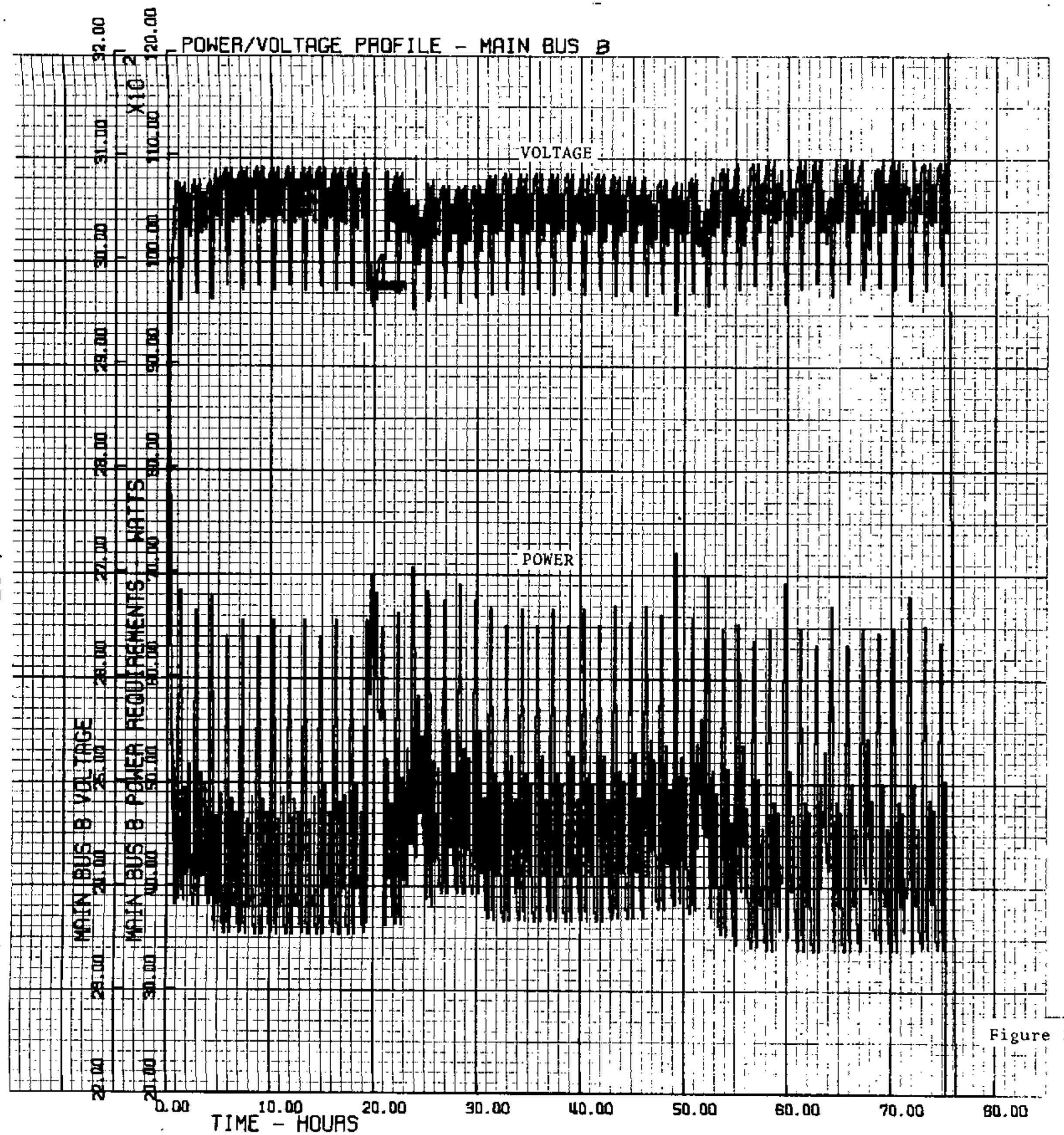
DC WATTS = AC POWER x 1.25 (INVERTER EFFICIENCY OF 80%)

AC POWER = (V-A) (PF), WHERE V-A = VOLT-AMPERE REQUIREMENTS OF THE INVERTER ARRAY
AND PF = COMPONENT POWER FACTOR



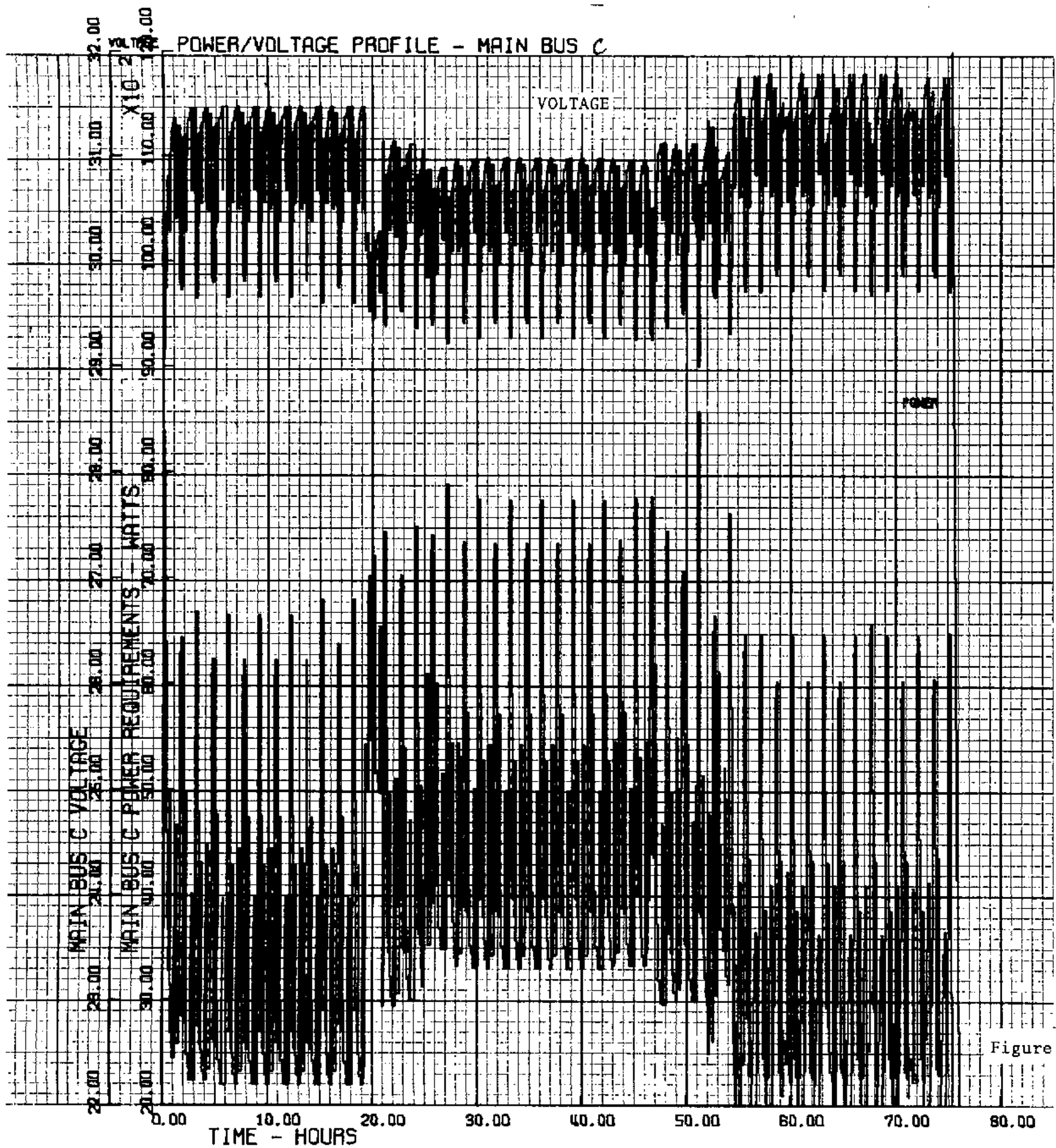
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-1. – On-orbit operations, Main Bus A.



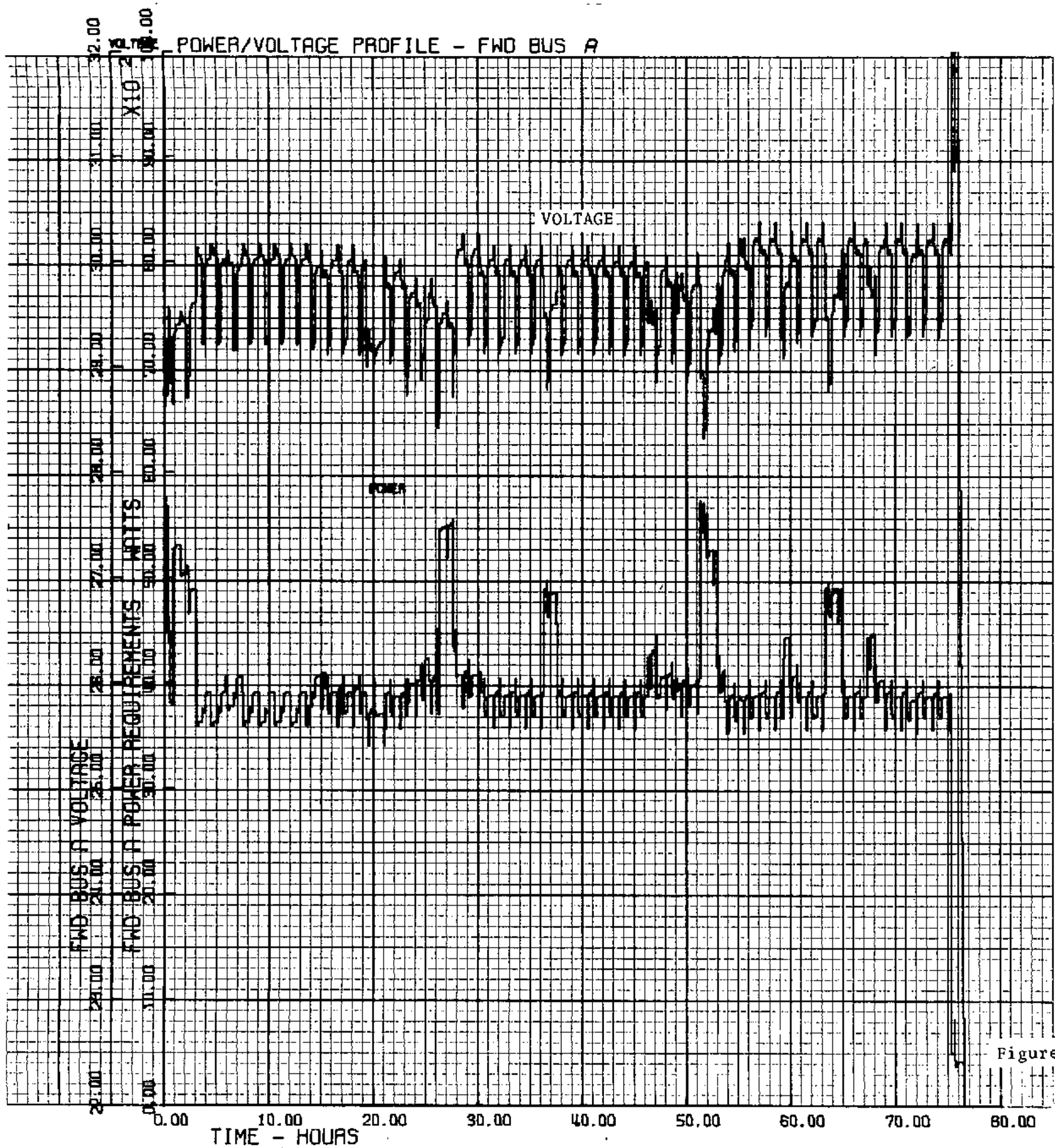
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-2. – On-orbit operations, Main Bus B.



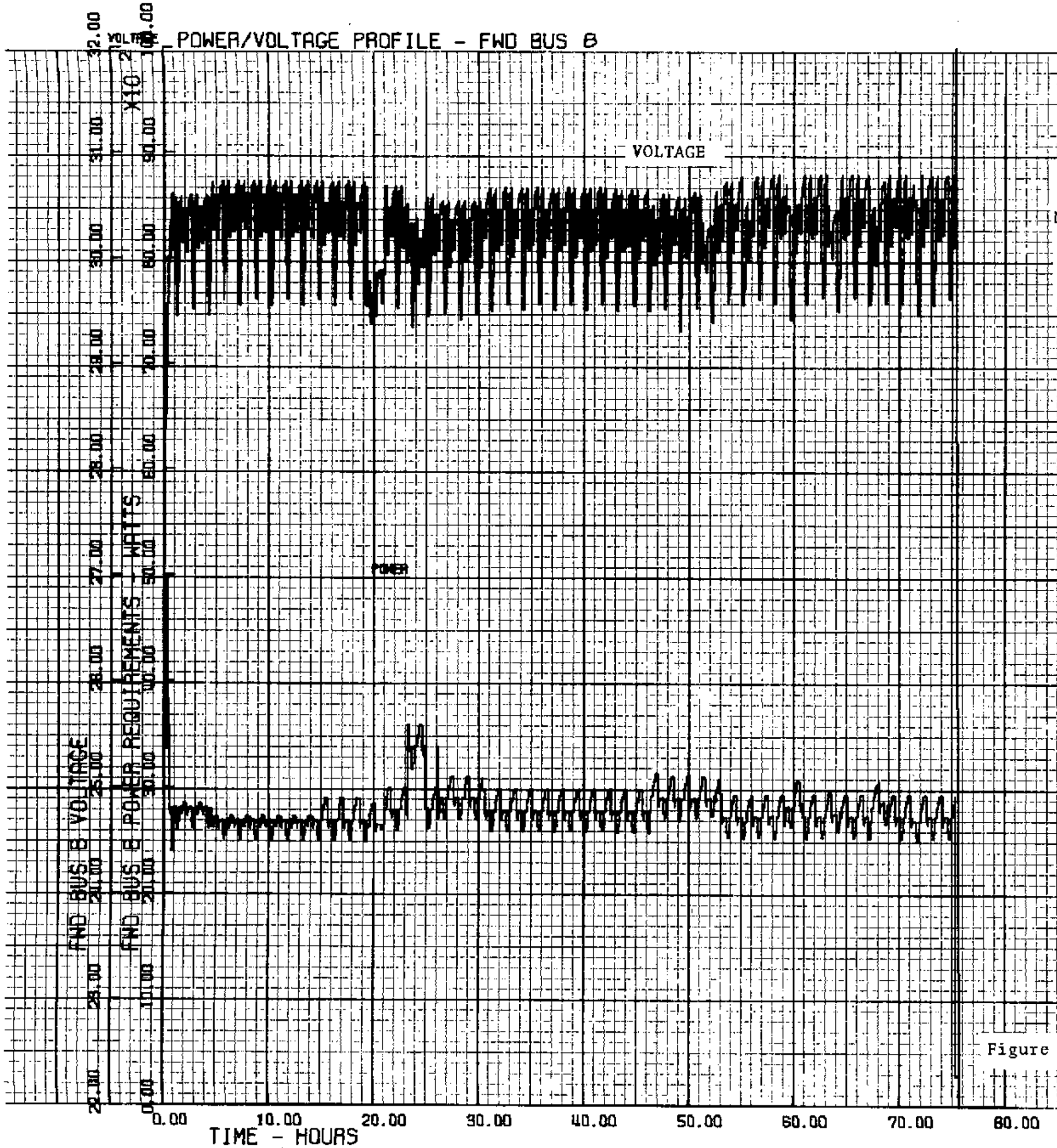
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-3. – On-orbit operations, Main Bus C.



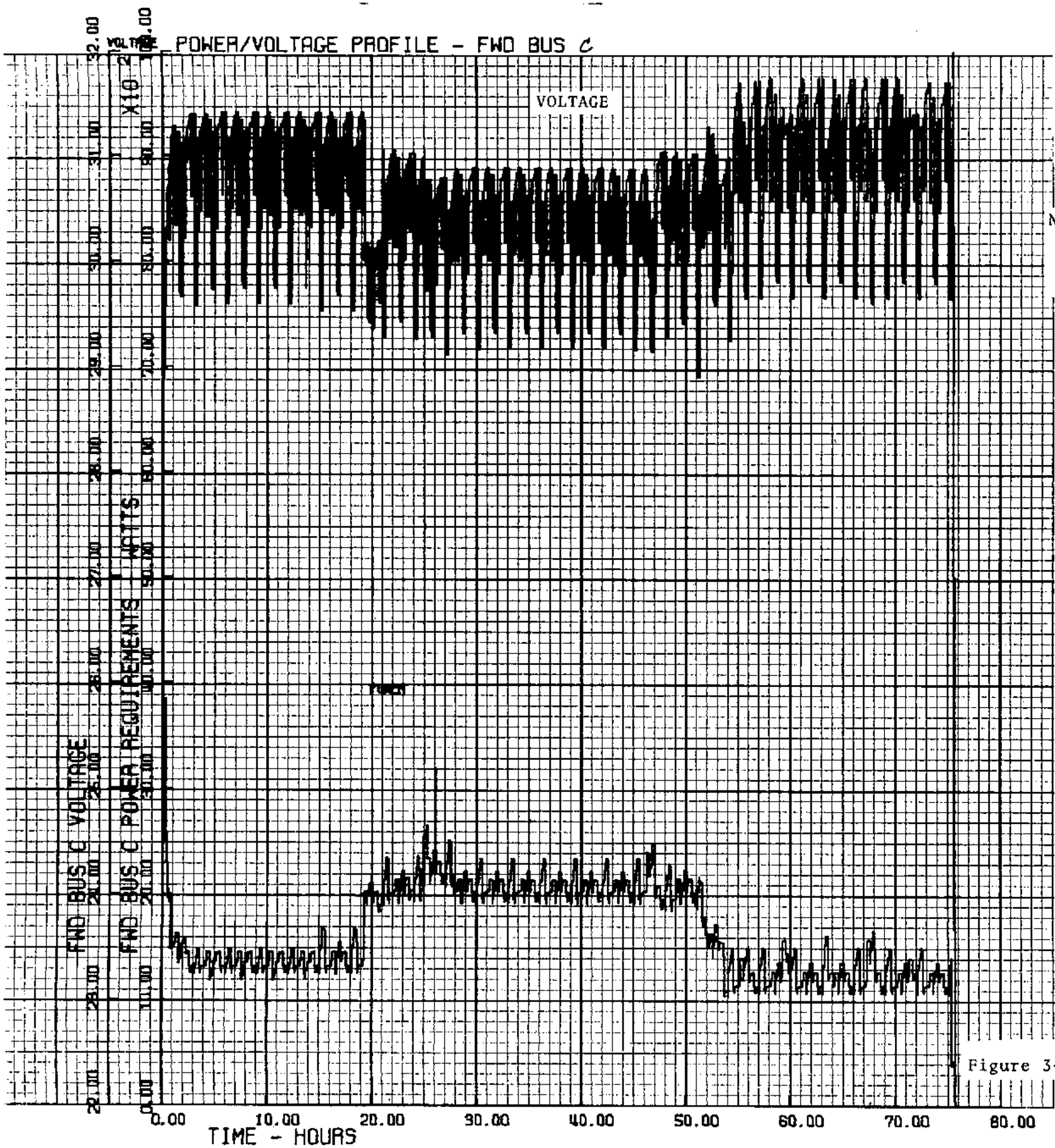
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-4. – On-orbit operations, Forward Bus A.



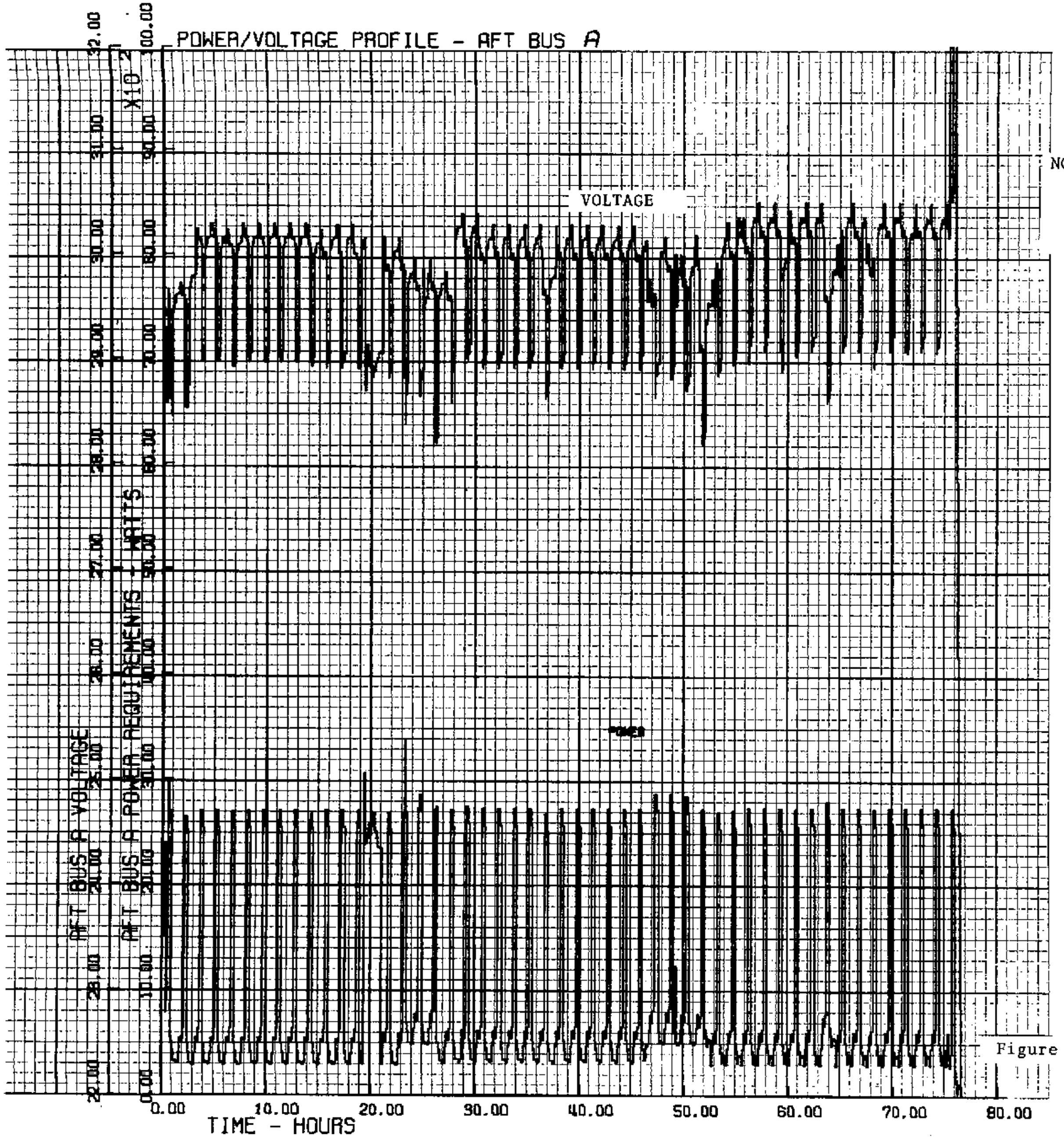
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-5. — On-orbit operations, Forward Bus B.



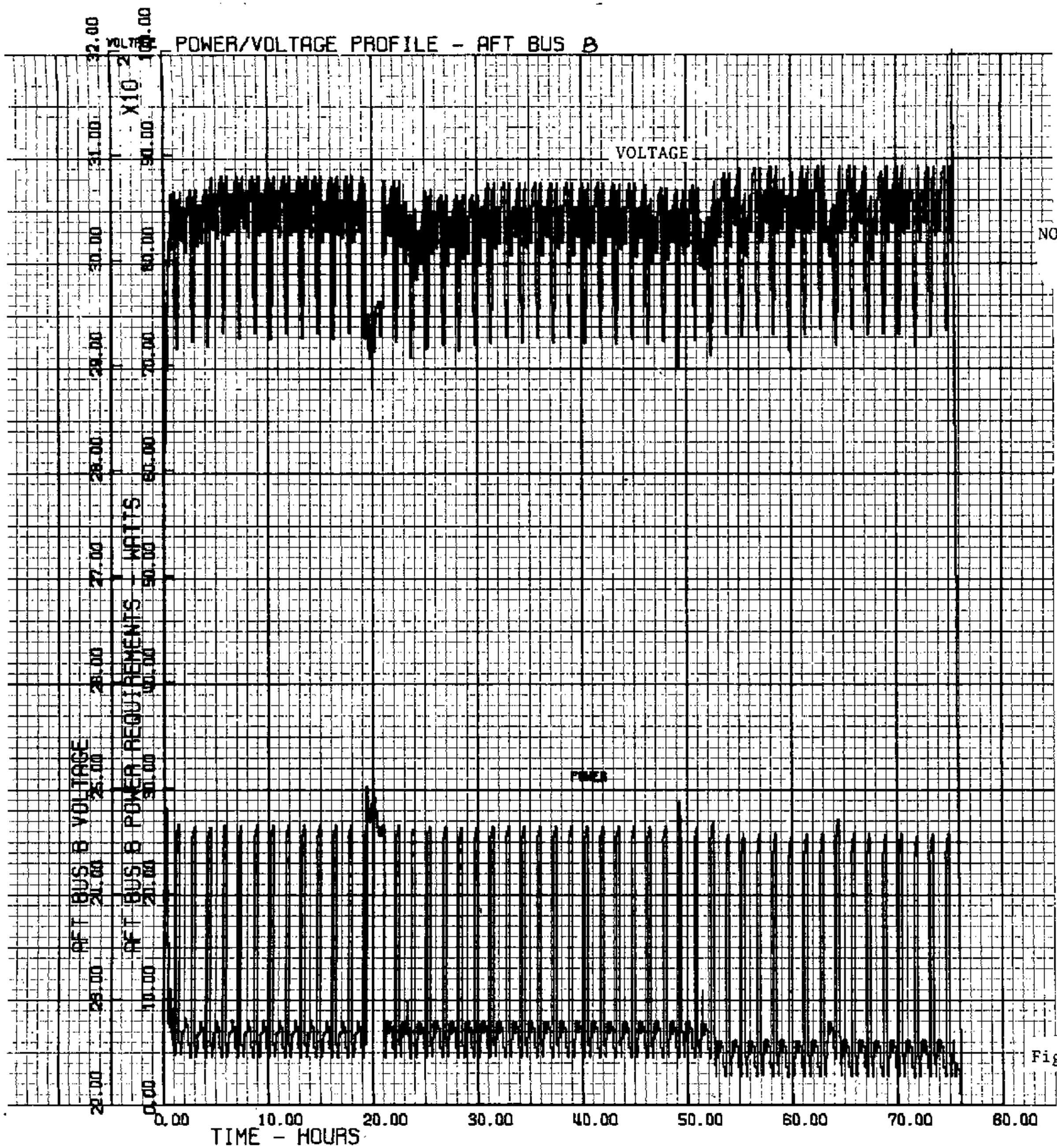
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-6. — On-orbit operations, Forward Bus C.



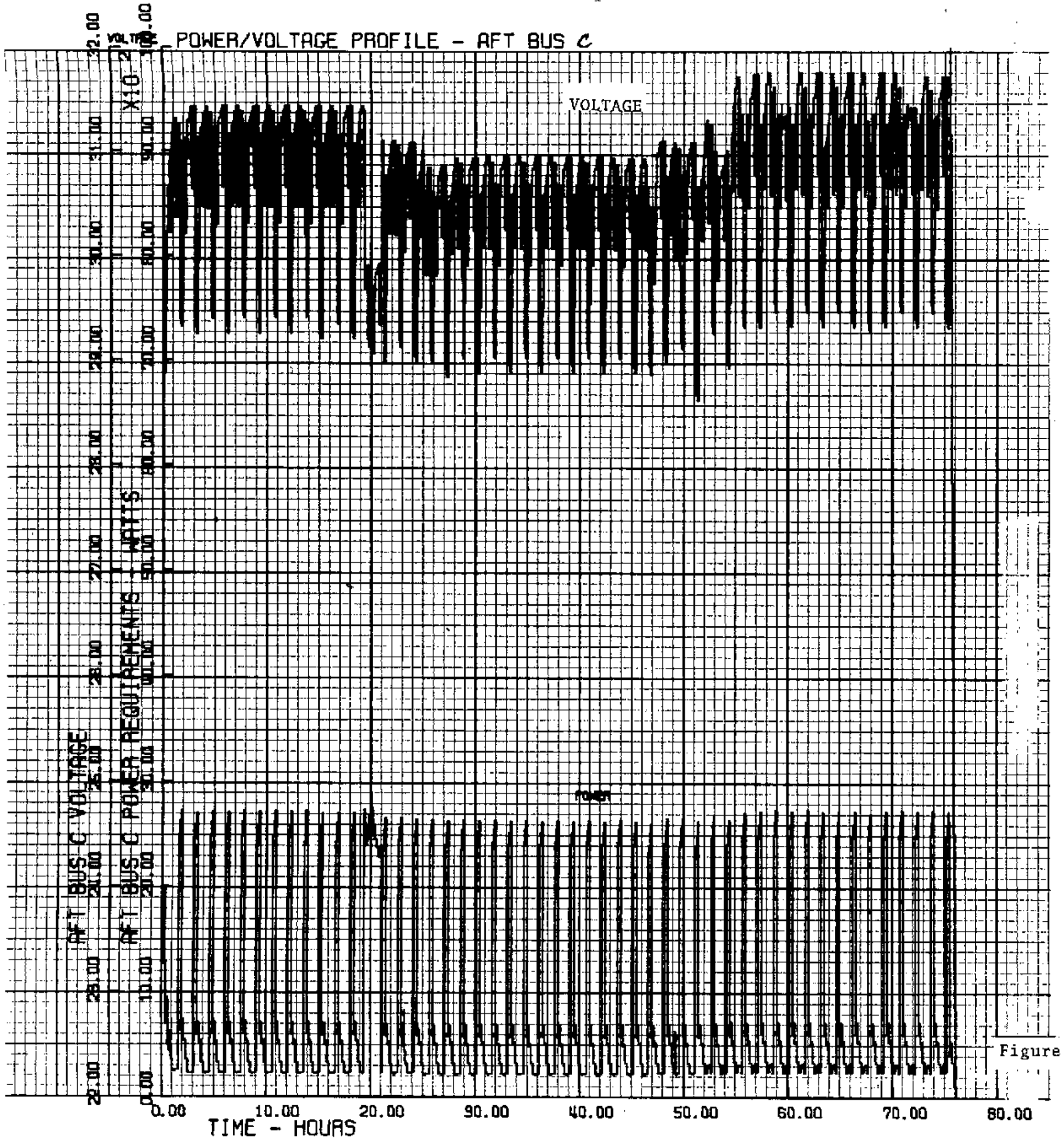
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-7. – On-orbit operations, Aft Bus A.



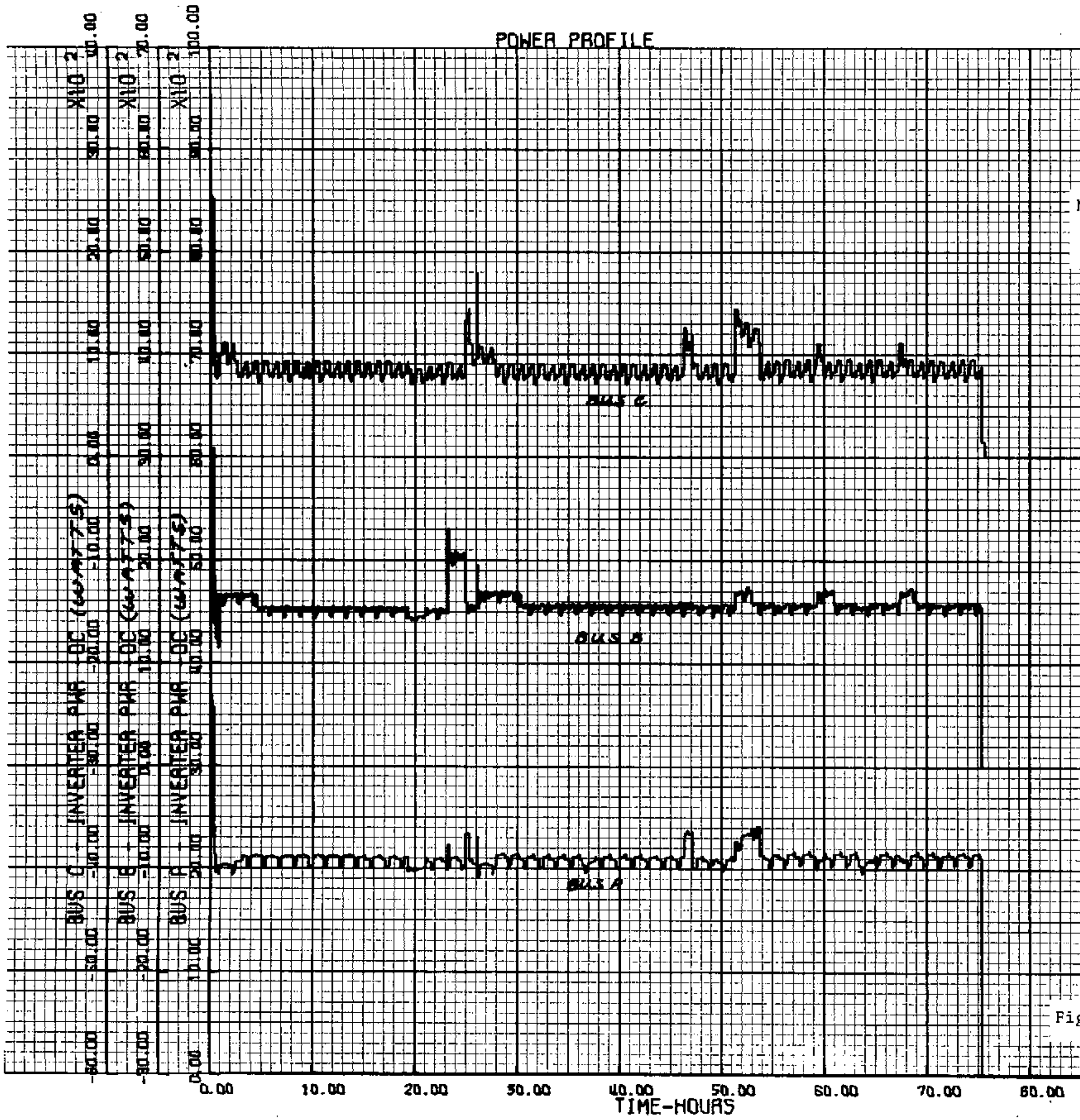
NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-8. — On-orbit operations, Aft Bus B.



NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-9. – On-orbit operations, Aft Bus C.



NOTE: THE 24-HOUR PROFILE BETWEEN 51 HOURS AND 75 HOURS IS REPEATED FOR THE NEXT 74 HOURS.

Figure 3-10. – On-orbit operations, Inverters.

TABLE 4-1. – ANALYSIS DATA SUMMARY, DE-ORBIT THROUGH GSE CONNECT, DC BUS REQUIREMENTS

BUS	POWER (KILOWATTS)			VOLTAGE		MAX BUS CURRENT (AMPS)	APPROX. AVERAGE POWER (KW)
	MIN	MAX	MAX-TIME (MIN:SEC)	MIN	MAX		
MAIN A	4.0	9.1	00:10	28.9	30.4	314.9	6.1
MAIN B	2.8	7.6	00:10	29.3	30.7	259.4	5.0
MAIN C	2.0	7.4	02:56	29.4	32.0	251.7	3.5
FWD A	3.5	5.5	12:00	28.6	30.2	192.3	4.0
FWD B	2.7	5.1	00:10	29.1	30.6	175.3	3.2
FWD C	.9	3.0	00:10	29.4	32.0	102.0	1.2
AFT A	.5	2.9	05:00	28.4	30.3	102.1	0.8
AFT B	.4	2.7	04:00	28.9	30.7	93.4	0.9
AFT C	.3	3.1	04:00	29.0	32.0	106.9	0.7

PEAK FUEL CELL POWER

Remained below 24 KW throughout mission phase.

TABLE 4-2. — ANALYSIS DATA SUMMARY, DE-ORBIT THROUGH GSE CONNECT, INVERTER REQUIREMENTS

INVERTER ARRAY	DC WATTS (PF=1.00)		MAX KVA WITH AVERAGE PF AT		TIME DURATION FOR POWER ABOVE:					
					2250 VA		3350 VA		4500 VA	
	MAX (KW)	AVERAGE DC PWR (KW)	1.00 PF	0.90 PF	1.00	0.90	1.00	0.90	1.00	0.90
BUS A	3.1	2.1	2.5	2.8	00:10	00:10	-0-	-0-	-0-	-0-
BUS B	2.8	1.7	2.2	2.5	00:10	00:10	-0-	-0-	-0-	-0-
BUS C	1.8	.7	1.4	1.6	-0-	-0-	-0-	-0-	-0-	-0-

DC WATTS = AC POWER x 1.25 (INVERTER EFFICIENCY OF 80%)

AC POWER = (V-A) (PF), WHERE V-A = VOLT-AMPERE REQUIREMENTS OF THE INVERTER ARRAY
AND PF = COMPONENT POWER FACTOR

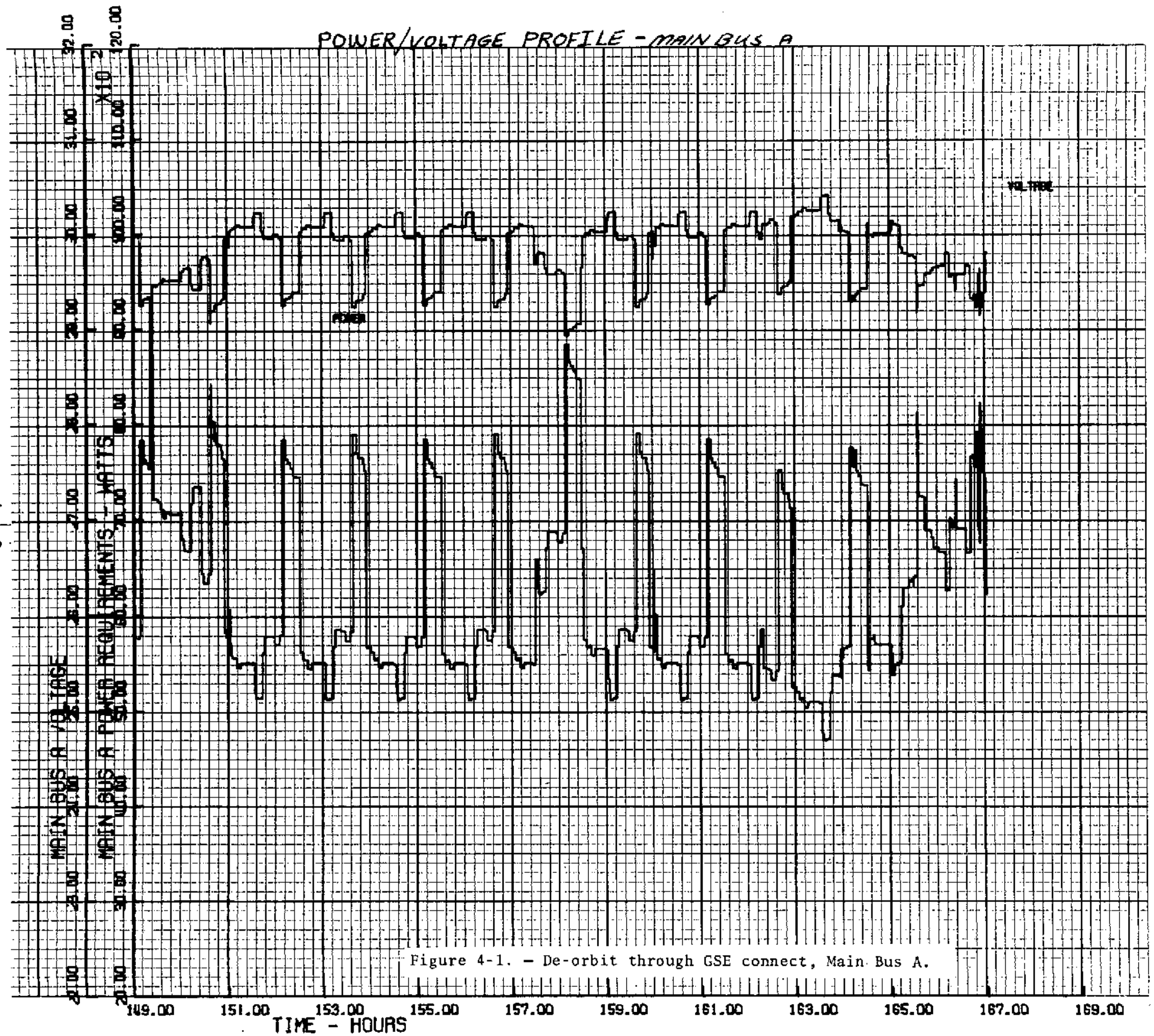


Figure 4-1. — De-orbit through GSE connect, Main Bus A.

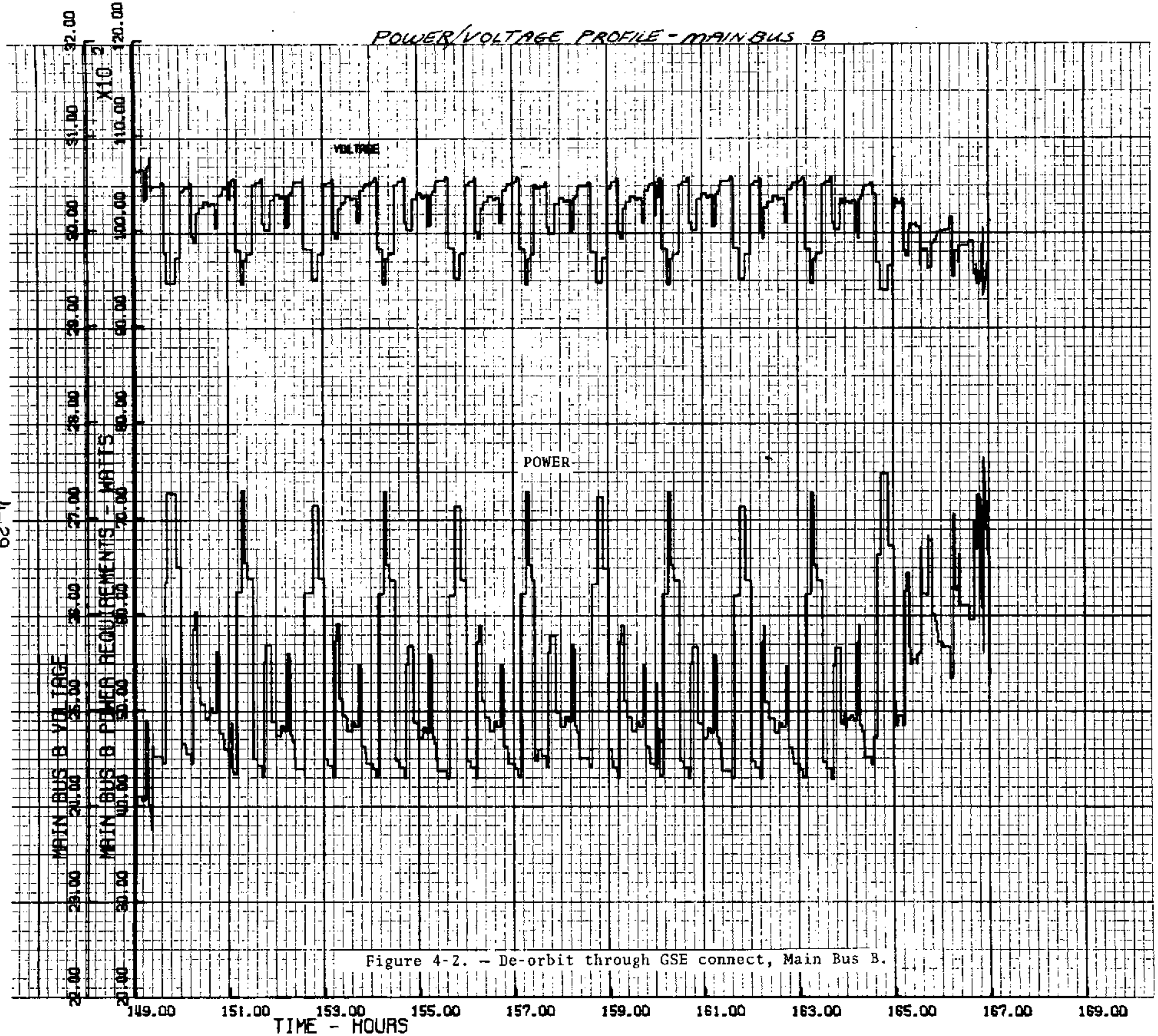


Figure 4-2. — De-orbit through GSE connect, Main Bus B.

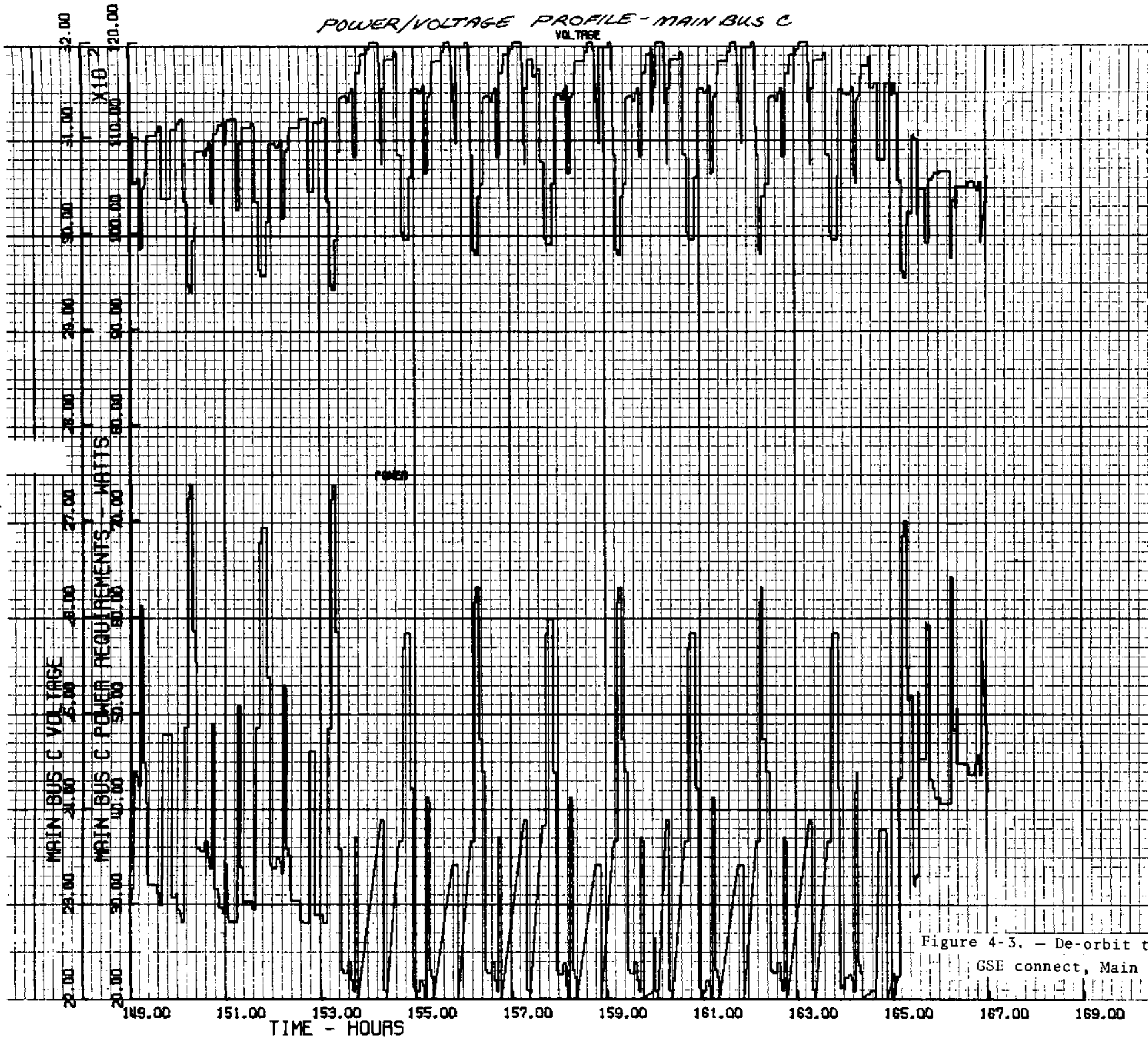


Figure 4-3. — De-orbit through GSE connect, Main Bus C.

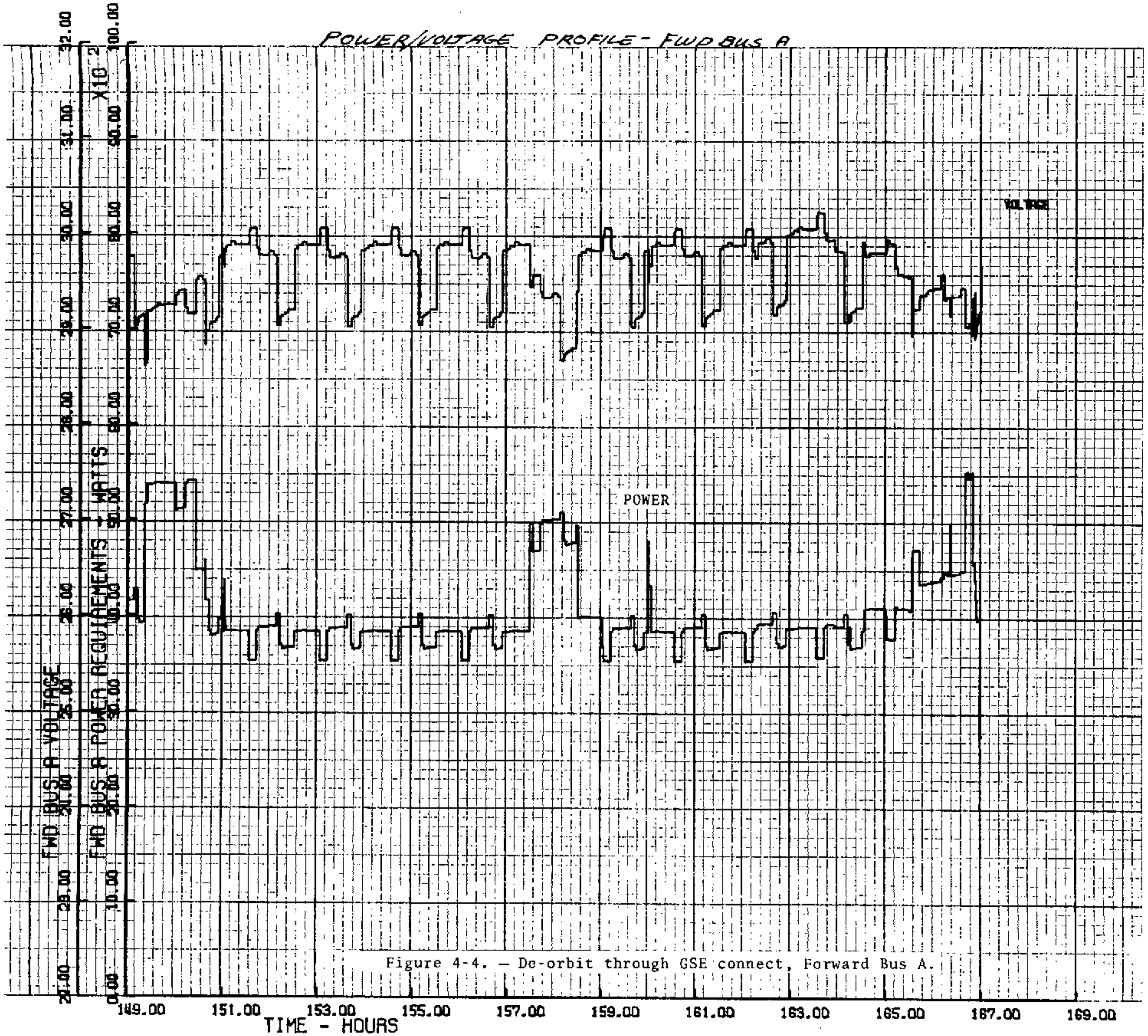


Figure 4-4. — De-orbit through GSE connect, Forward Bus A.

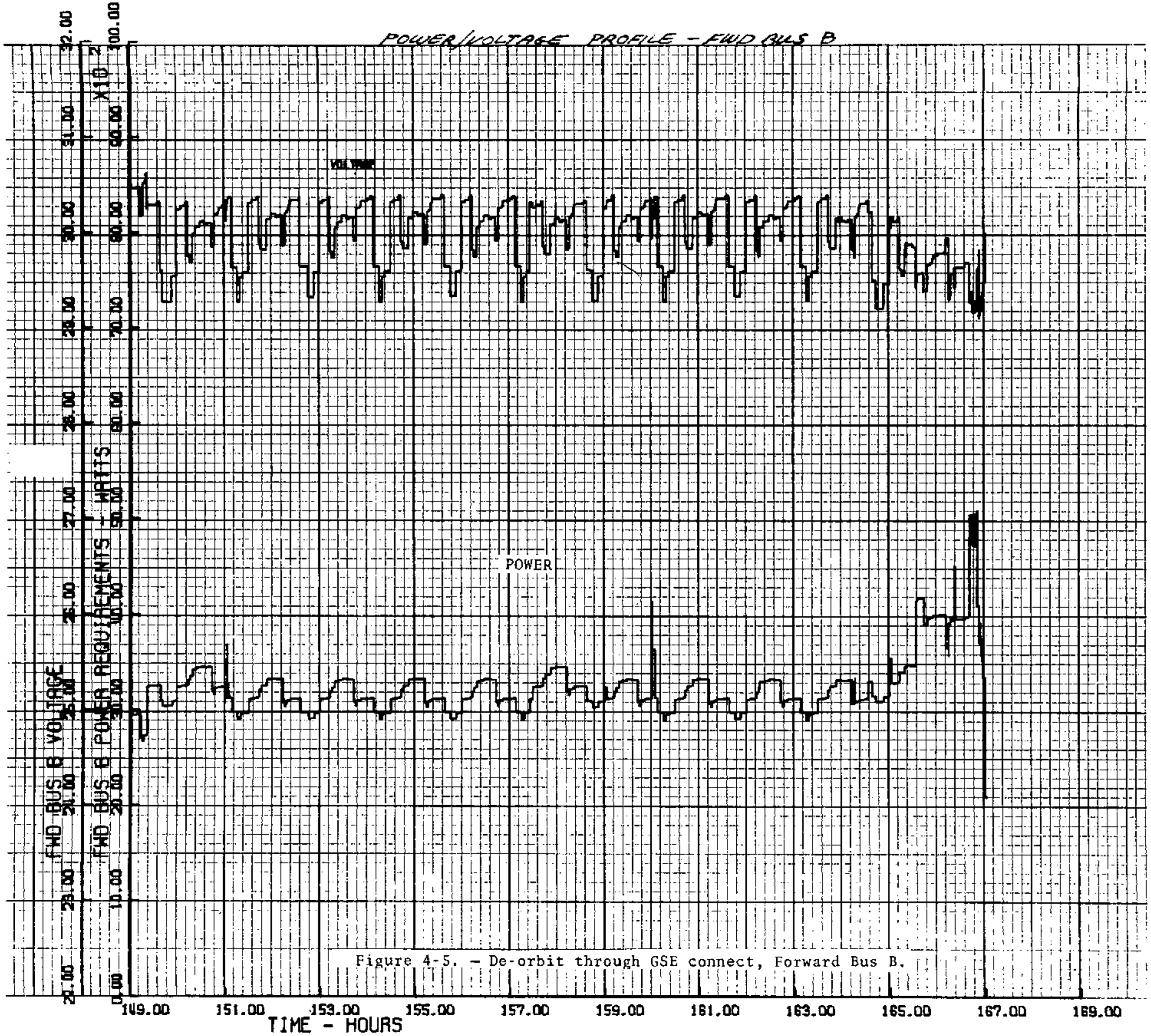


Figure 4-5. - De-orbit through GSE connect, Forward Bus B.

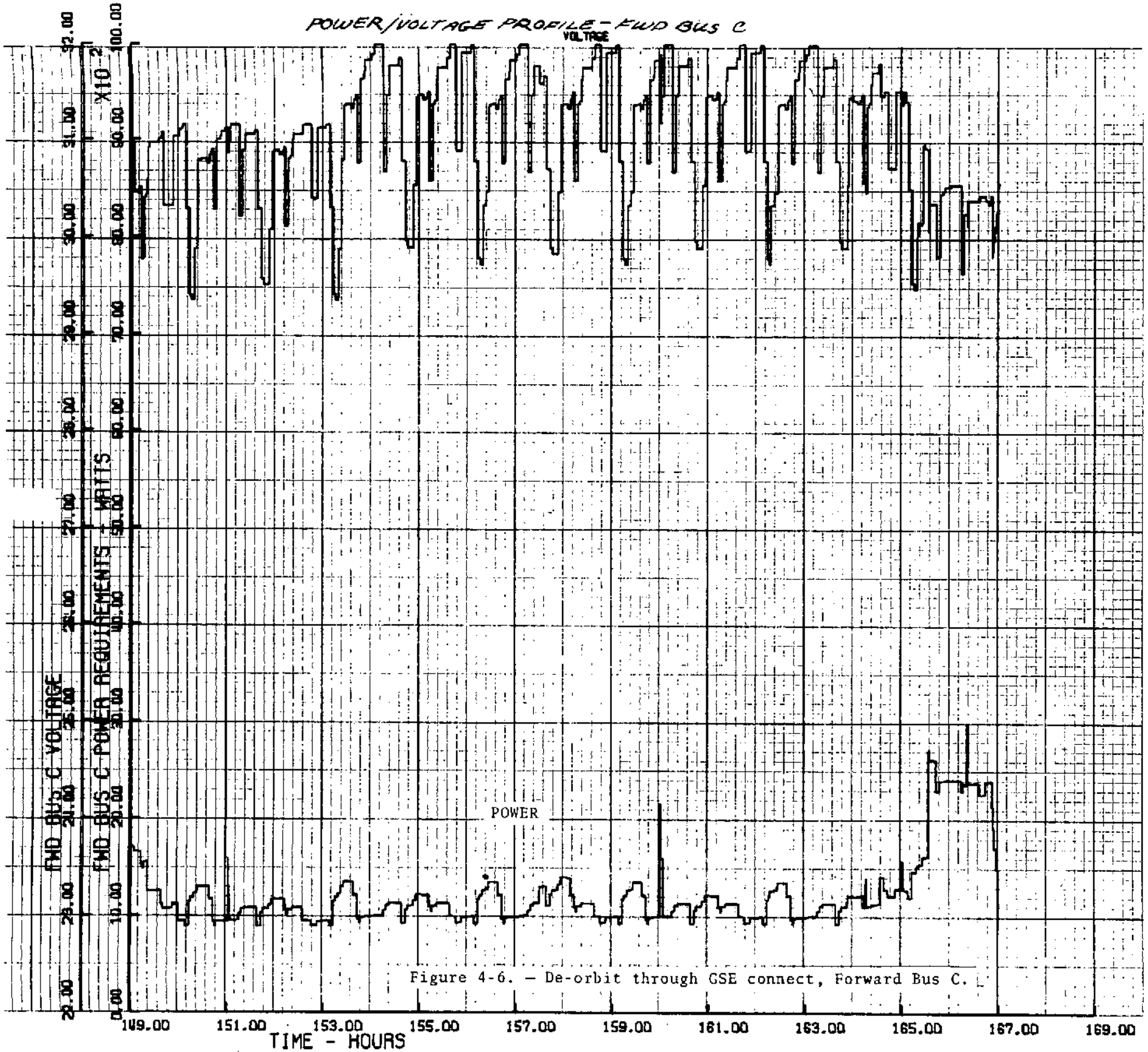


Figure 4-6. — De-orbit through GSE connect, Forward Bus C.

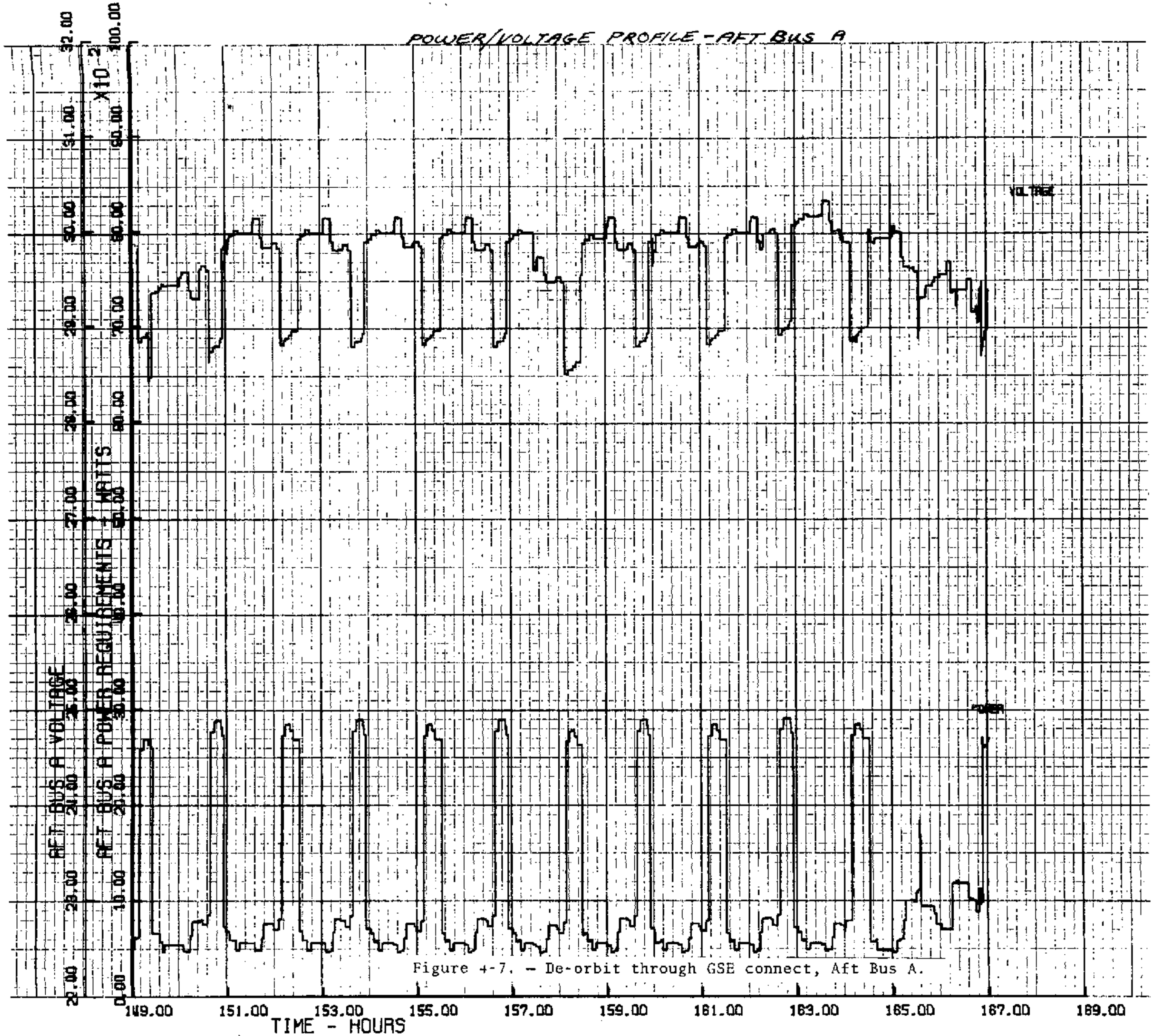


Figure 4-7. – De-orbit through GSE connect, Aft Bus A.

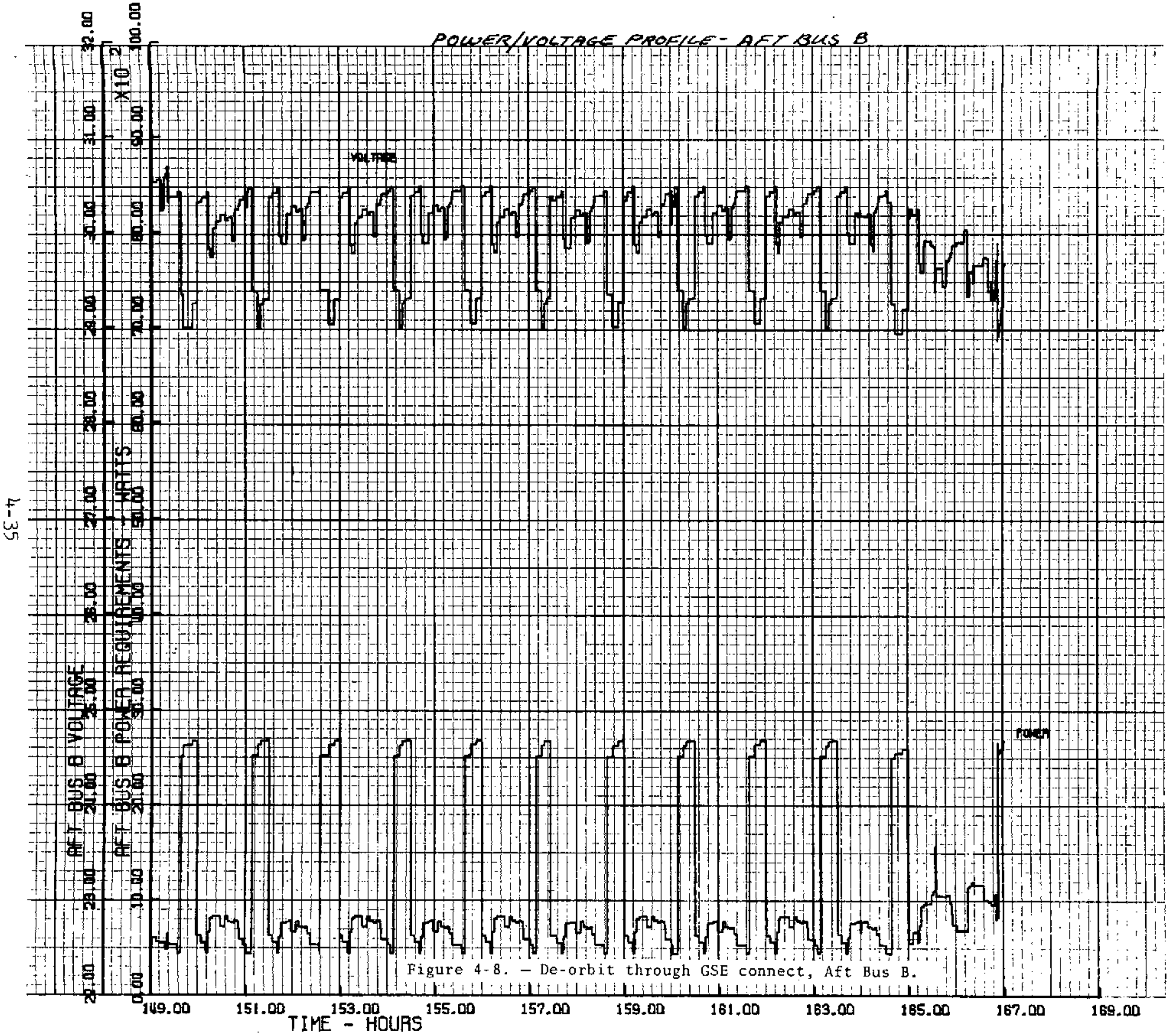


Figure 4-8. — De-orbit through GSE connect, Aft Bus B.

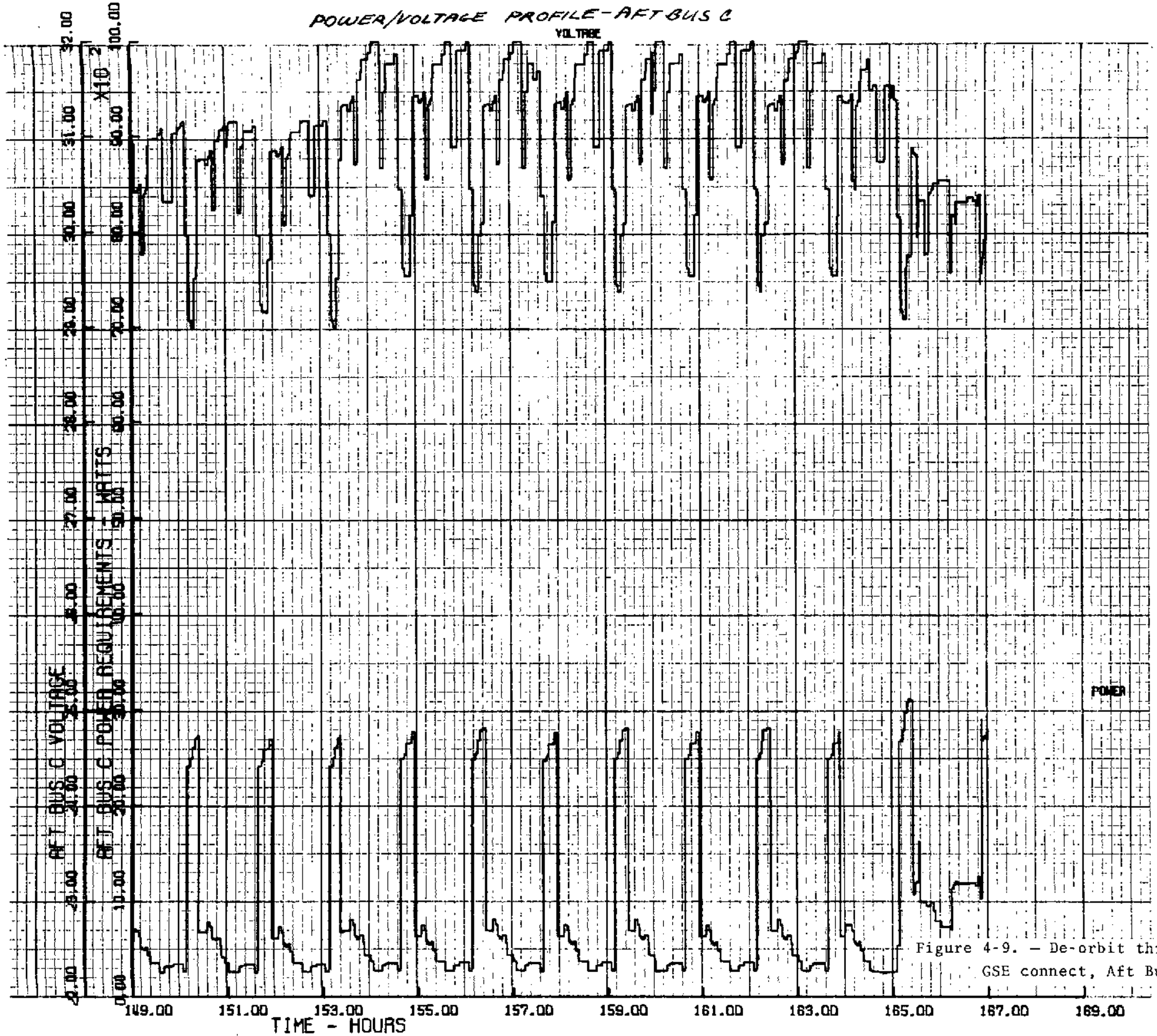


Figure 4-9. — De-orbit through GSE connect, Aft Bus C.

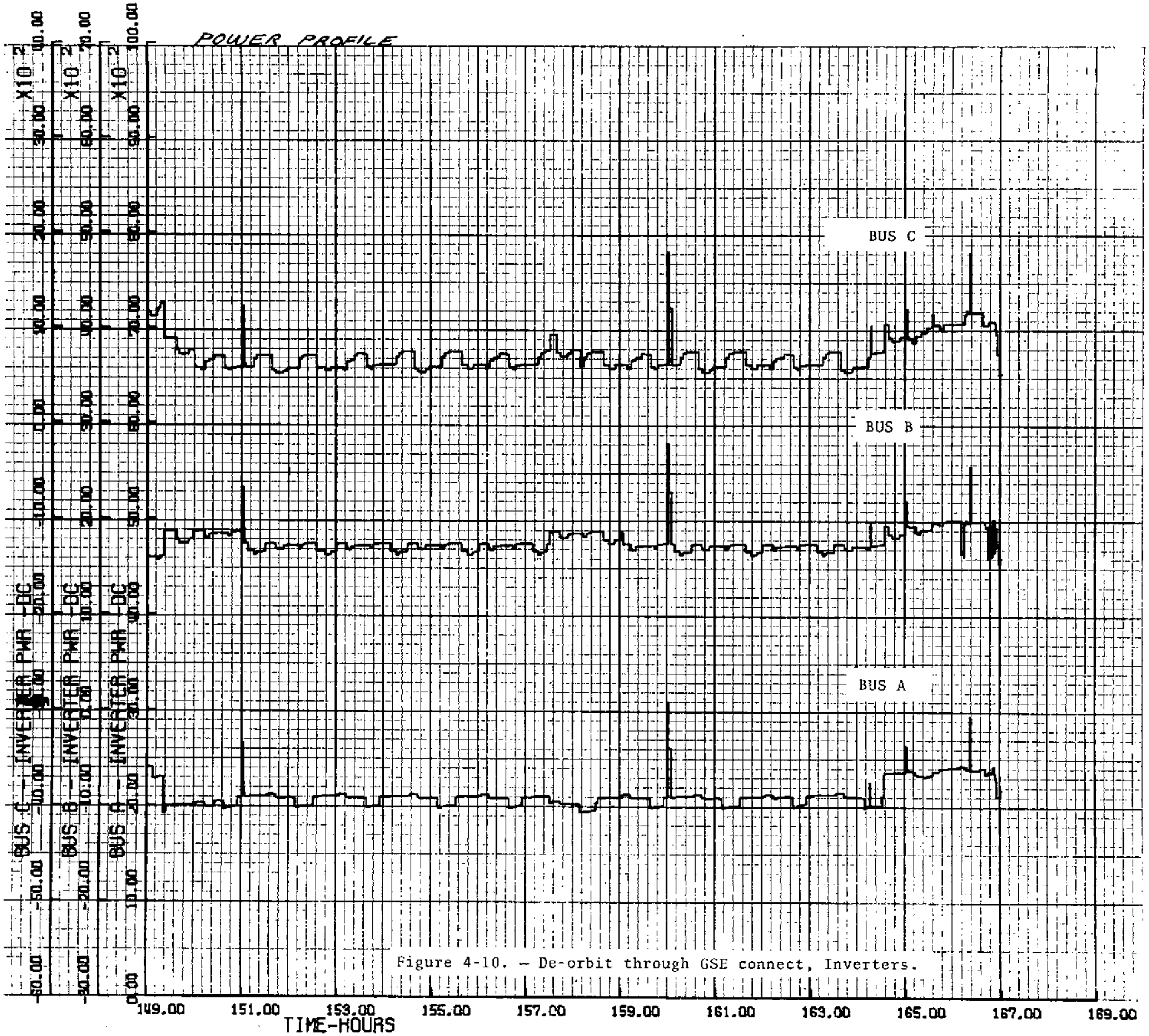


Figure 4-10. – De-orbit through GSE connect, Inverters.