Yankee Atomic Electric Company

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AUXILIARY POWER SYSTEM VOLTAGE STUDY FOR VERMONT YANKEE NUCLEAR POWER STATION

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ABSTRACT

This report presents the results of an exhaustive review of the auxiliary power system at the Vermont Yankee Nuclear Power Station. This review was initiated by a directive from the Nuclear Regulatory Commission. This report demonstrates that the Vermont Yankee Nuclear Power Station auxiliary power system is of sufficient capacity to automatically start and operate all safety loads, assuming that all onsite power systems are not available.

ACKNOWLEDGEMENTS

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We also wish to thank the staff of the Rhode Island, Eastern Massachusetts, and Vermont Energy Control (REMVEC); especially Dave Hayward, Paul Karnett, and Russ Burke for their assistance and the use of their facilities.

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1.0 INTRODUCTION

Criterion 17 of 10CFR50 Appendix A, "General Design Criteria for Nuclear Power Plants" states in part that:

> "an onsite electric power system and an offsite power system shall be provided to permit functioning of structures, systems, and components important to safety. The safety function of each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences and (2) the core is cooled and containment integrity and other vital functions maintained in the event of postulated accidents."

An incident at Arkansas Nuclear One has brought into question the conformance of that station to Criterion 17 regarding the station electric distribution system design. Consequently the NRC has required all power reactors to review their electric power systems to determine if the offsite power system and the onsite distribution system are of sufficient capacity to automatically start and operate all safety loads, assuming that all onsite ac power sources are not available. (This directive to all power reactor licensees is included as Reference (a)).

This report presents the results of our review which demonstrates the adequacy of the station electrical distribution system at Vermont Yankee.

2.0 AUXILIARY POWER SYSTEM

2.1 Description

The Vermont Yankee Auxiliary Power System is shown in Figures 2.1 through 2.5. During plant operation, power is supplied to the station auxiliary power system through both the unit auxiliary transformer (T-2) and through the start-up transformer (T-3B). The unit auxiliary transformer supplies power to 4160 volt bus 1 and 4160 volt bus 2 while the start-up transformer supplies power to 4160 volt buses 5A and 5B. 4160 volt emergency bus 3 is connected to 4160 volt bus 1 by a normally closed tie breaker and likewise, 4160 volt emergency bus 4 is connected to bus 2.

Upon loss of the normal power source the station auxiliary buses are automatically transferred to the start-up transformers. Bus 1 is automatically connected to start-up transformer T-3A and bus 2 is automatically connected to start-up transformer T-3B. Buses 5A and 5B remain connected to start-up transformer T-3B.

There are six 480 volt buses fed from the 4160 volt buses by 4160/480 volt transformers. Buses 8 and 9 are the 480 volt emergency buses. Buses 8 and 9 feed motor control centers which supply smaller 480 volt loads.

2.2 Power System Voltage Requirements

The offsite power system and onsite power distribution system at Vermont Yankee are designed to provide adequate voltage to support the operation of required loads under any mode of operation.

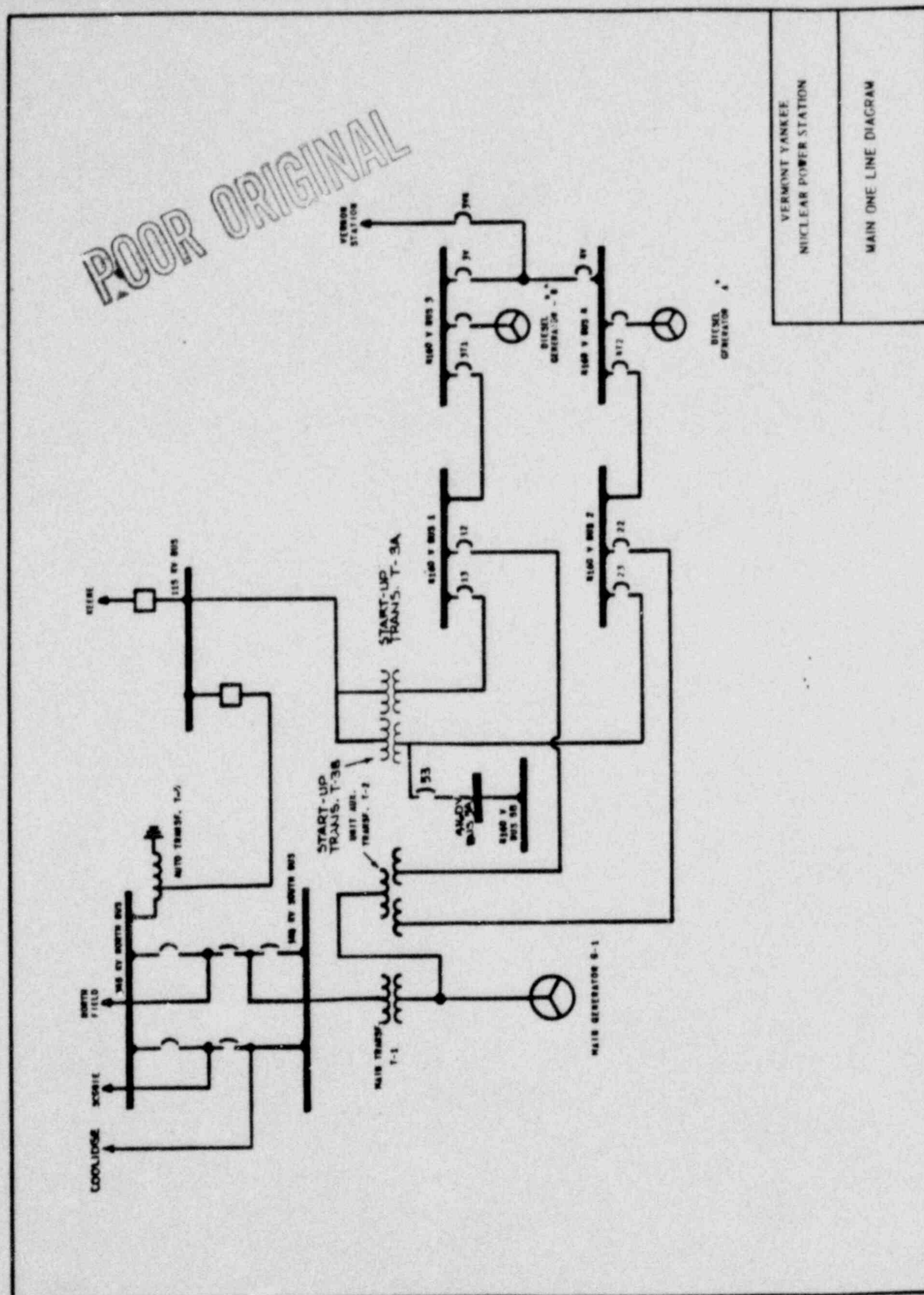

VERMONT YANKEE
NUCLEAR POWER STATION
MAIN ONE LINE DIAGRAM
POOR ORIGINAL
START-UP TRANS. T-3A
START-UP TRANS. T-3B
COOLIDGE

FIGURE 2.1

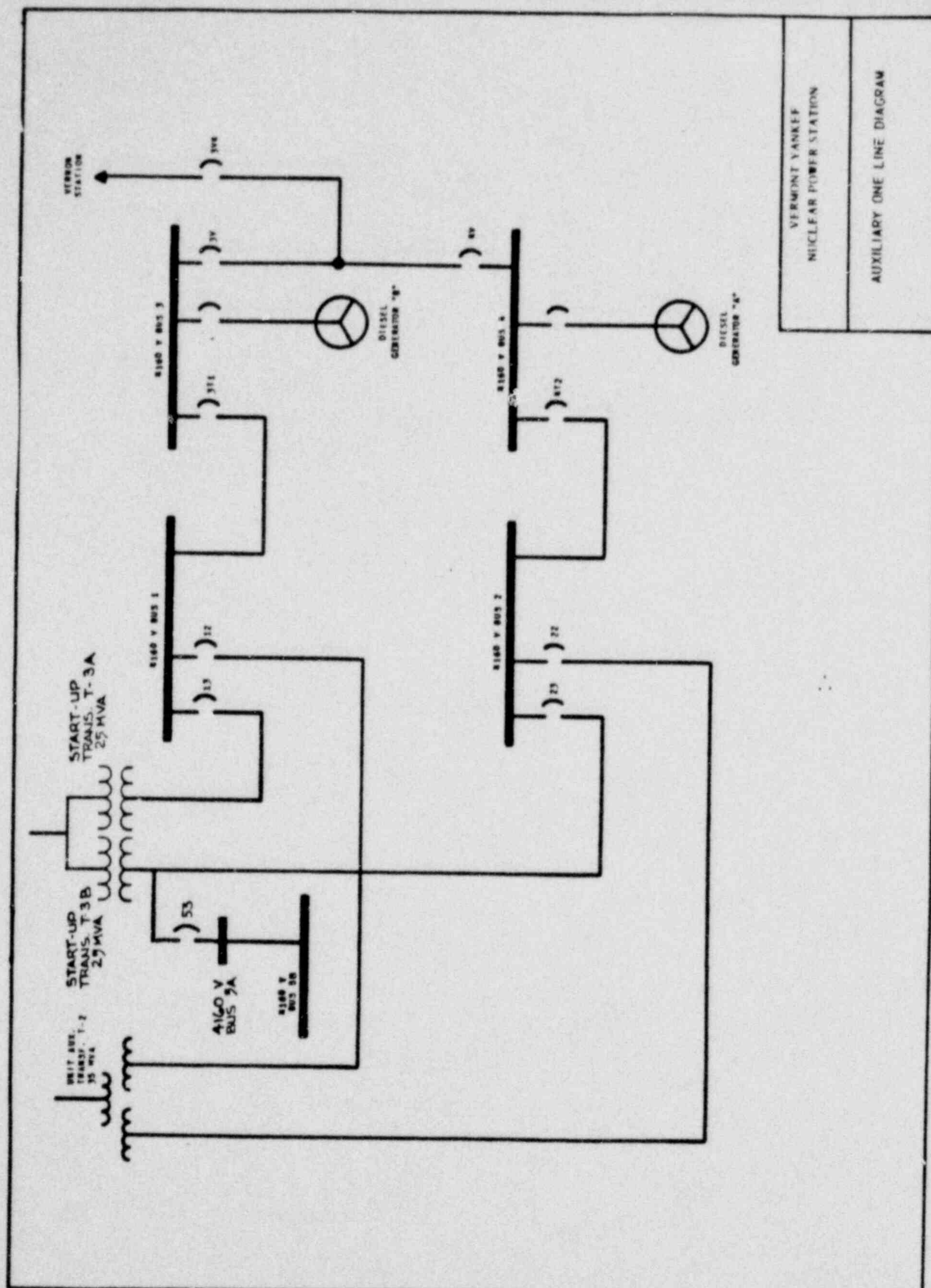

VERMONT YANKEE
NUCLEAR POWER STATION
AUXILIARY ONE LINE DIAGRAM
START-UP
TRANS. T-3A
25 MVA
START-UP
TRANS. T-3B
25 MVA
53
4160 V
BUS 3A
DIESEL
GENERATOR "B"
DIESEL
GENERATOR "A"

FIGURE 2.2

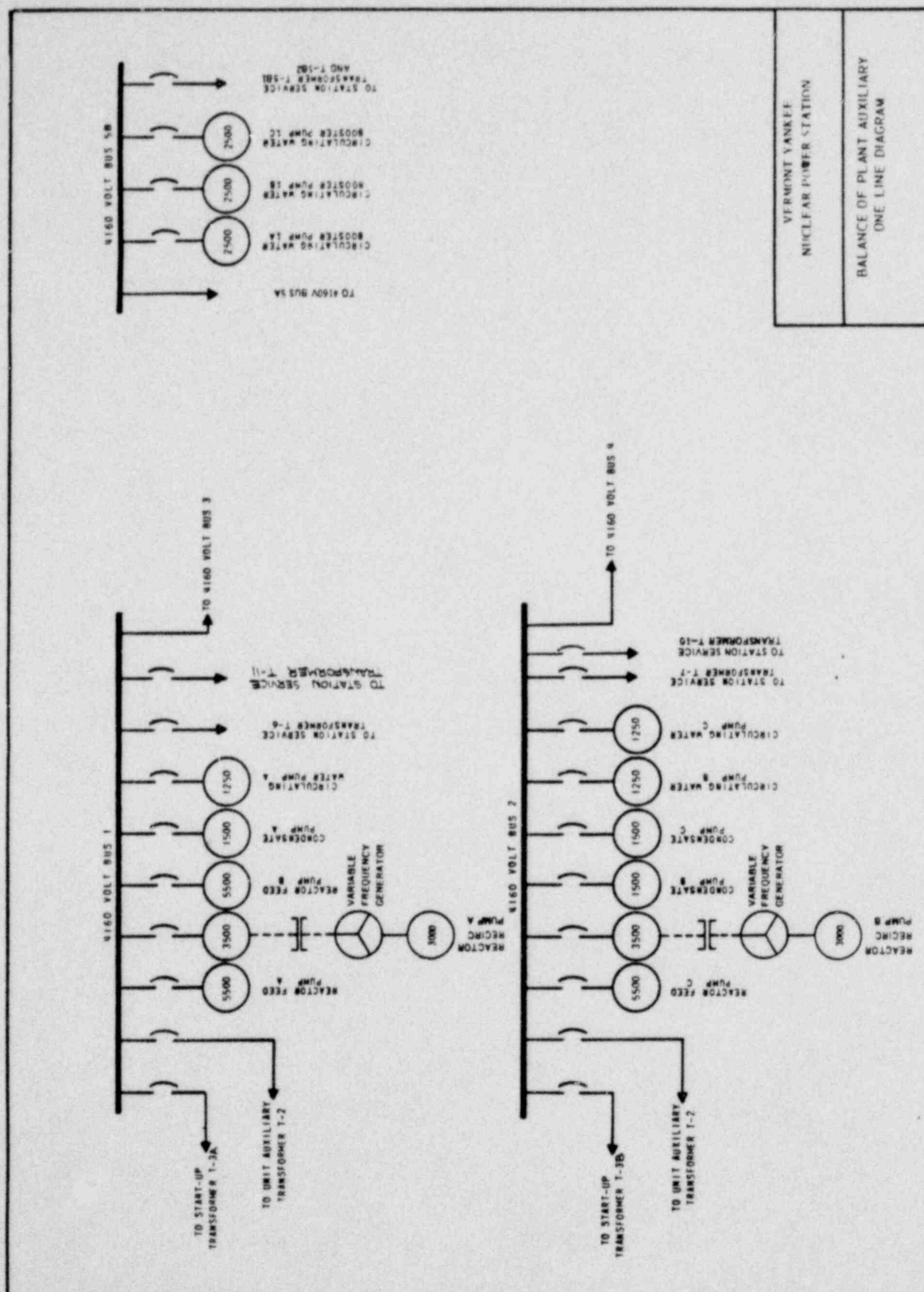

VERMONT YANKEE
NUCLEAR POWER STATION
BALANCE OF PLANT AUXILIARY
ONE LINE DIAGRAM
4160 VOLT BUS 1
4160 VOLT BUS 2
4160 VOLT BUS 5B
TO START-UP TRANSFORMER T-3A
TO UNIT AUXILIARY TRANSFORMER T-2
TO START-UP TRANSFORMER T-3B
TO UNIT AUXILIARY TRANSFORMER T-2
TO 4160 VOLT BUS 3
TO 4160 VOLT BUS 4
TO 4160V BUS 5A
REACTOR FEED PUMP A
REACTOR FEED PUMP B
REACTOR FEED PUMP C
CONDENSATE PUMP A
CONDENSATE PUMP B
CONDENSATE PUMP C
CIRCULATING WATER PUMP A
CIRCULATING WATER PUMP B
CIRCULATING WATER PUMP C
VARIABLE FREQUENCY GENERATOR
REACTOR RECIRC PUMP A
REACTOR RECIRC PUMP B
TO STATION SERVICE TRANSFORMER T-6
TO STATION SERVICE TRANSFORMER T-11
TO STATION SERVICE TRANSFORMER T-7
TO STATION SERVICE TRANSFORMER T-10
CIRCULATING WATER BOOSTER PUMP 1A
CIRCULATING WATER BOOSTER PUMP 1B
CIRCULATING WATER BOOSTER PUMP 1C
TO STATION SERVICE TRANSFORMER T-5B1 AND T-5B2

FIGURE 2.3

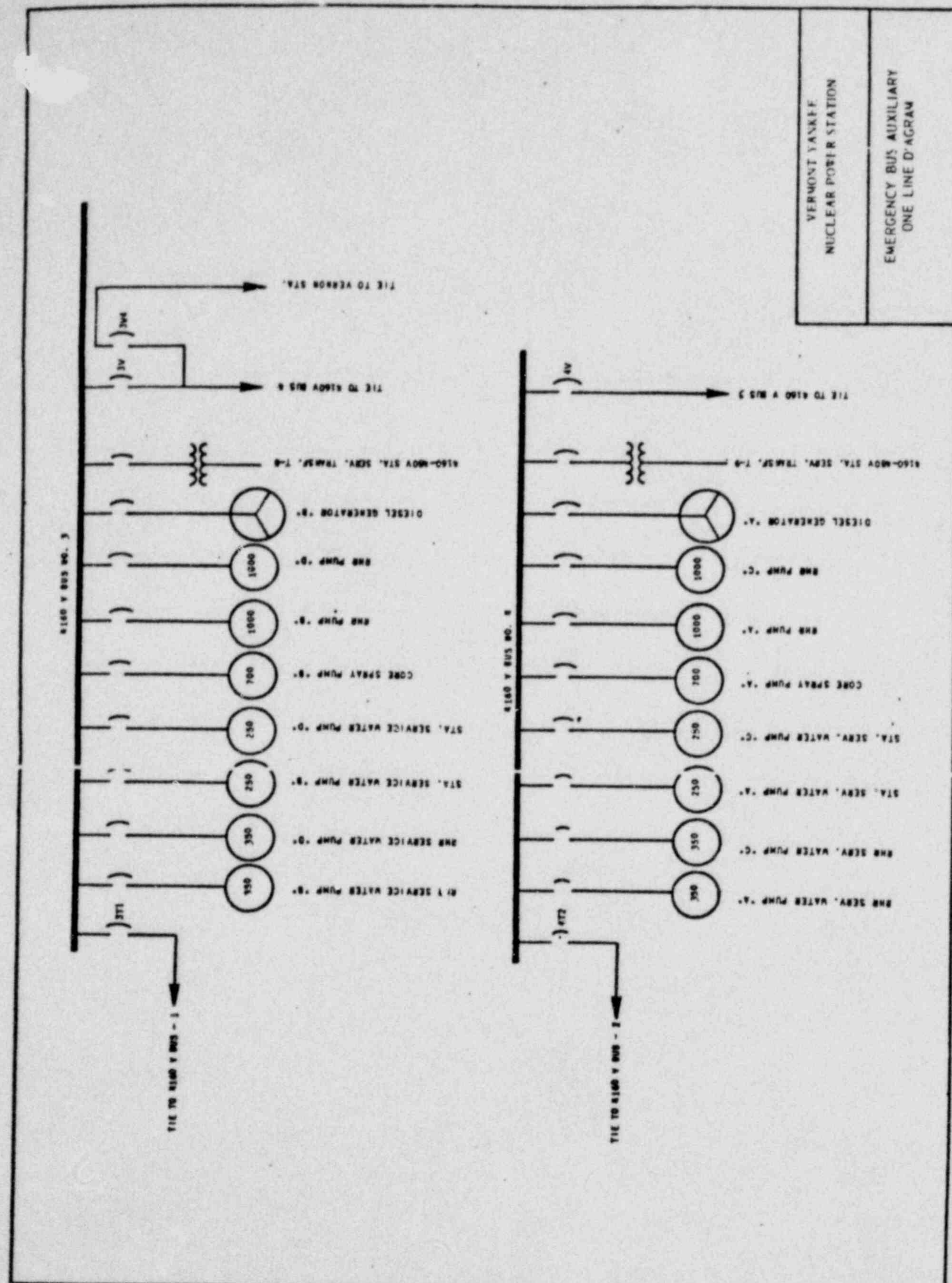
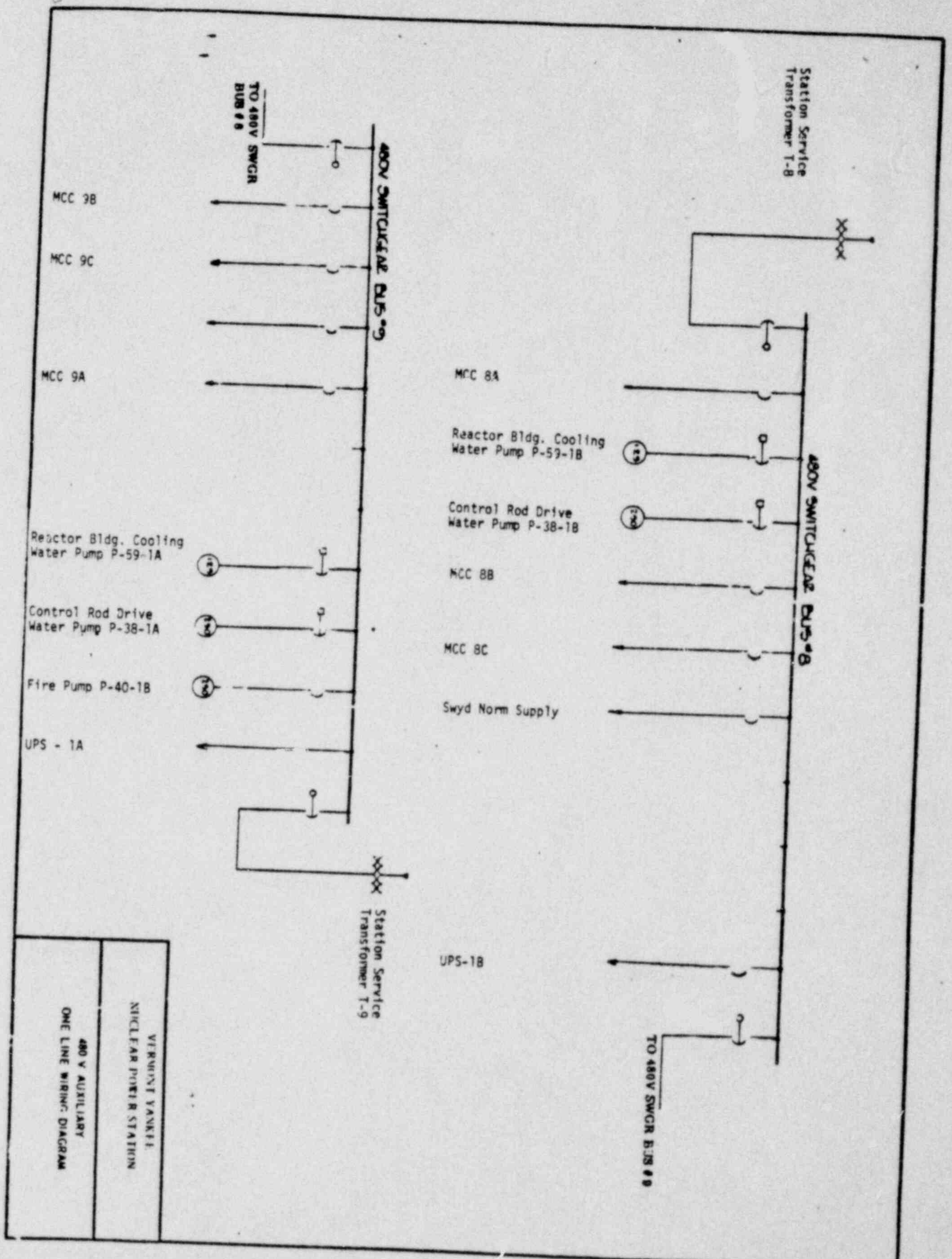

VERMONT YANKEE
NUCLEAR POWER STATION
EMERGENCY BUS AUXILIARY
ONE LINE DIAGRAM
TIE TO VERNON STA.
DIESEL GENERATOR 'B'
RHR PUMP 'D'
RHR PUMP 'B'
CORE SPRAY PUMP 'B'
STA. SERVICE WATER PUMP 'D'
STA. SERVICE WATER PUMP 'B'
RHR SERVICE WATER PUMP 'D'
DIESEL GENERATOR 'A'
RHR PUMP 'C'
RHR PUMP 'A'
CORE SPRAY PUMP 'A'
STA. SERV. WATER PUMP 'C'
STA. SERV. WATER PUMP 'A'
RHR SERV. WATER PUMP 'C'
RHR SERV. WATER PUMP 'A'

FIGURE 2.4

FIGURE 2.5



Station Service Transformer T-8
480V SWITCHGEAR BUS #8
MCC 8A
Reactor Bldg. Cooling Water Pump P-59-1B
Control Rod Drive Water Pump P-38-1B
MCC 8B
MCC 8C
Swyd Norm Supply
UPS-1B
TO 480V SWGR BUS #9
TO 480V SWGR BUS #8
480V SWITCHGEAR BUS #9
MCC 9B
MCC 9C
MCC 9A
Reactor Bldg. Cooling Water Pump P-59-1A
Control Rod Drive Water Pump P-38-1A
Fire Pump P-40-1B
UPS - 1A
Station Service Transformer T-9
VERMONT YANKEE NUCLEAR POWER STATION
480 V AUXILIARY ONE LINE WIRING DIAGRAM

2.2.1 Offsite Power System Operating Voltage Range

Three 345 kV transmission lines are connected to the Vermont Yankee 345 kV switchyard and one 115 kV transmission line is connected to the Vermont Yankee 115 kV switchyard. The 345 kV switchyard and 115 kV switchyards are, in turn, connected through a 345 kV/115 kV autotransformer. The 345 kV transmission lines are extensively interconnected with the 345 kV transmission network in the New England area. The voltage limits of the 345 kV and 115 kV systems at Vermont Yankee are provided in Table 2.1.

Table 2.1

Transmission System Voltages

	Minimum Expected Value	Maximum Expected Value
345 kV System	340 kV	362 kV
115 kV System	110 kV	121 kV

2.2.2 Motors and Contactors

Motors and contactors used in the auxiliary power system at Vermont Yankee require operating voltage between ± 10% of rated nameplate voltage. The basis for the ± 10% operating range are NEMA standards; however, the Core Spray Pumps and RHR Pumps were specified to start at 80% of rated nameplate voltage. The minimum and maximum voltage limits for motors and contactors are provided in Table 2.2.

Table 2.2

Motor and Contactor Voltage Requirements

	Maximum Operating Voltage (volts)	Minimum Operating Voltage (volts)	Minimum Required Starting Voltage (volts)
4160 Volt System			
4000 Volt motors (general)	4400	3600	3600
RHR Pumps	4400	3600	3200
Core Spray Pumps	4400	3600	3200
480 Volt System			
460 volt motors	506	414	
460 volt contactors	506	414 370 (contactor pickup) 322 (contactor dropout)	

2.2.3 Undervoltage Relay Setpoints

Due to the critical nature and the requirements of the loads on the emergency buses 3 and 4, a loss of voltage sensed by undervoltage relays will result in complete isolation of that bus from its normal source of supply and starting of the associated emergency diesel generators. The undervoltage relays are set to operate in 1.25 seconds upon complete loss of power and to operate in 6 seconds with 41% of rated bus voltage. The relays will not operate with voltage above 46% of rated bus voltage.

Additional undervoltage sensors have been installed on emergency buses 3, 4, 8 and 9 to actuate at a voltage above the minimum required operating voltage of equipment to protect the safety loads against undervoltage caused by degraded grid voltage. These sensors will provide an alarm if the bus voltage falls below their setpoints for 8 seconds. The 10 second time delay has been provided to eliminate spurious pickup on short duration voltage transients on the transmission grid or on the auxiliary power system. The operator has been provided with instructions on the action required should the above degraded voltage alarm be received.

3.0 ANALYSIS

3.1 Problem Statement

Reference (a) required that analyses be performed to determine the voltage at each safety load, assuming the need for power is initiated by an anticipated transient (e.g., unit trip) or an accident, whichever presents the largest load demand. The analyses must consider all actions the electric power system is designed to automatically initiate including automatic transfers of bulk loads from one transformer to another. Furthermore, the analyses shall be based on the assumption that the grid voltage is at the "minimum expected value".

In order to comply with these requirements, three cases were developed and evaluated:

Case 1 simulates the voltage drop caused by transfer of auxiliary loads from the unit auxiliary transformer to the start-up transformers with simultaneous start of safeguards loads. At Vermont Yankee, an accident signal initiates a turbine trip which then initiates the transfer and start of safeguards loads. The effect of transient inrush currents caused by transfer are superimposed on the inrush currents caused by starting of safeguards loads.

Case 2 simulates the voltage drop caused by the start of safeguards loads from the start-up transformers with no transfer (plant auxiliary load powered by the start-up transformers).

Case 3 simulates the steady state operation of the safeguards loads and other auxiliary loads powered by the start-up transformer.

Reference (a) also requires that analyses be performed to determine the maximum voltage at the terminals of each safety load. The analyses shall be based on the grid voltage at the maximum expected value and the plant load at the minimum load level. In order to comply with this requirement, Case 4 was developed and evaluated.

Case 4 simulates steady state operating voltages of auxiliary loads powered by the start-up transformers.

3.2 Method

A computer solution of a load flow calculation is needed to determine each bus voltage in a power system because an iterative algorithm is required to solve numerous simultaneous equations. Load flow computer programs require as input such parameters as the load at each bus expressed in watts and vars and the impedance between each bus in the system. A model of the system containing all loads and impedance values must be developed to provide this information.

Yankee Atomic Electric Company has performed the required voltage analysis in cooperation with Rhode Island, Eastern Massachusetts and Vermont Energy Control (REMVEC). REMVEC is responsible for controlling generation and bulk transmission for electric utilities located in the above areas. REMVEC, in order to perform its load dispatch functions, performs daily load flow studies of the New England grid using the Power Systems Simulation Package, PSS/2, of Power Technologies Incorporated (PTI). This program package uses the Newton-Raphson and the Gauss-Seidel techniques which are used extensively for load flow solutions by the electric industry. The

PSS/2 program package can solve both steady state and dynamic power system studies; including standard load flow studies, load flow switching studies, transient stability studies and motor starting calculations. The program software package is the property of PTI and is proprietory information.

3.3 Assumptions

Figure 3.1 is a representation of a model used for the Vermont Yankee load flow studies. This representation shows the plant connected to the start-up transformers. Special node numbers have been assigned for use in the load flow program; these are enclosed by hexagons on Figure 3.1. A group of loads assumed to be connected to a particular bus is represented on Figure 3.1 by the word "load" enclosed in a rectangle.

3.3.1 Impedance Model

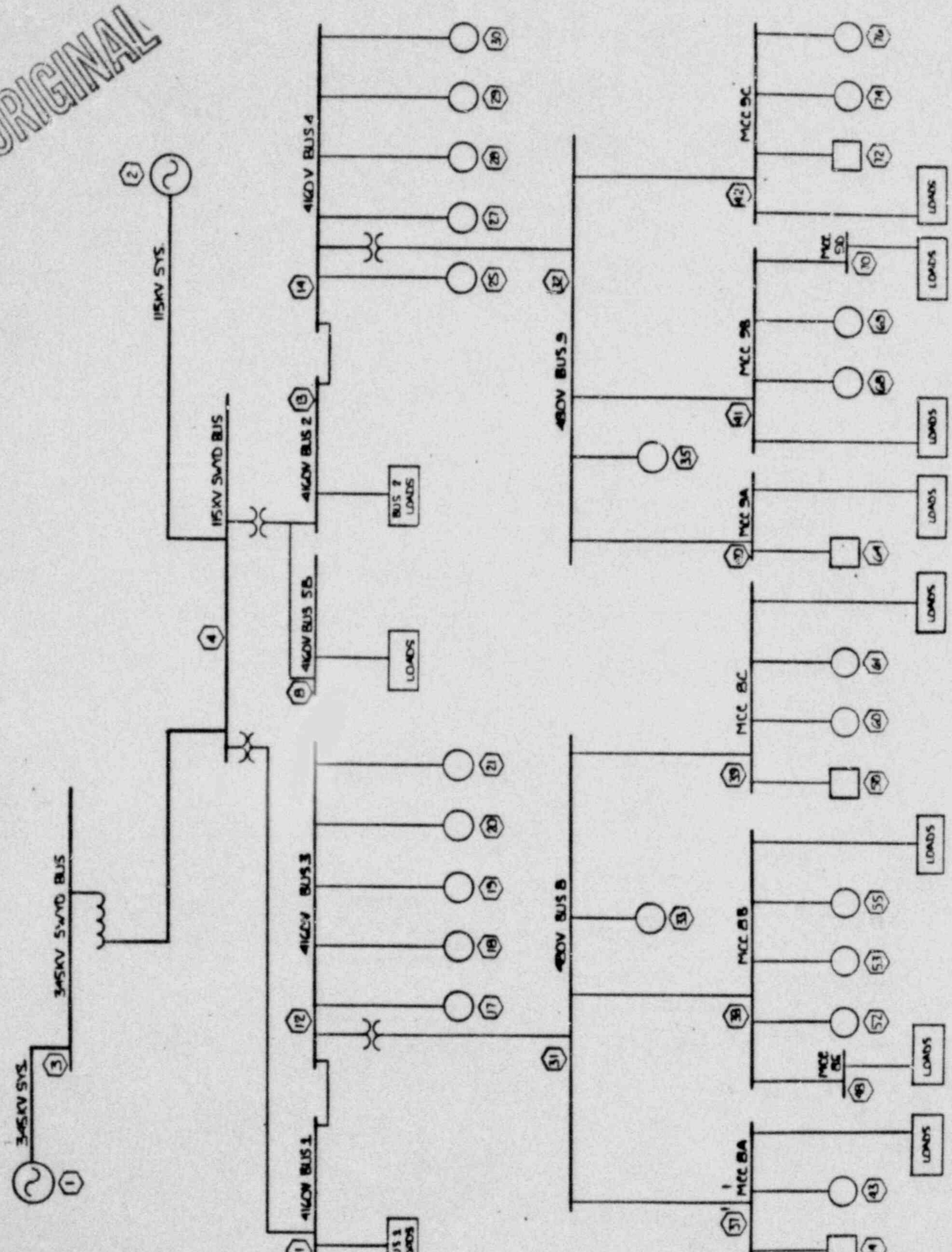
a) The cable impedance (resistance and reactance) to the terminals of each safety load supplied from 4160 V switchgear buses 3 and 4 and 480 V buses 8 and 9 was calculated.

b) The cable impedance of at least one representative load was calculated for each emergency motor control center. The representative load was selected as the load that would experience the worst voltage drop.

c) Cable capacitance was neglected.

d) Transformer impedences were obtained from nameplates.

e) Transformer tap settings were verified by inspection.



LOAD FLOW MODEL
VERMONT YANKEE NUCLEAR POWER STA.
FIGURE 3.1

3.3.2 Maximum Load Model

The loading assumptions for Cases 1, 2 and 3 are presented in Tables 3.1, 3.2 and 3.3 respectively. The following assumptions were used to develop tnese tables:

a) The maximum load was determined to exist when an accident occurs without loss of offsite power.

b) Motor watts and vars were conservatively calculated by using nameplate horsepower instead of the actual horsepower required.

c) The loading for the 4160 V system was determined from discussions with plant personnel, review of plant procedures and review of schematic diagrams.

d) The 480 volt system loading was determined by a review of schematic diagrams and by conservatively assigning load factors to intermittent loads.

e) For motor starting studies, all loads are converted to constant real current and constant imaginary reactance equivalents. This conversion results in conservatively low voltage drops because all resistive loads are treated as motors.

f) No load shedding occurs.

g) The analysis is based on an offsite power system operating voltages of 340 kV for the 345 kV system and of 110 kV for the 115 kV system as provided in Table 2.1.

Table 3.1

Loading Assumptions - Case 1

Conditions: Maximum Load
Transfer to Startup Transformers
Start Safeguards Loads

Node No.*	Description	Steady State Loading Before Transfer	Loads Starting Simultaneously with Transfer
3	345 kV Switchyard		
4	115 kV Switchyard		
8	4.16 kV Bus 5B	9000 kVA	
11	4.16 kV Bus 1	11,125 kVA	
12	4.16 kV Bus 3		
13	4.16 kV Bus 2	13,725 kVA	
14	4.16 kV Bus 4		
17	Station Service Water PP P7-1D	250 hp	
18	Core Spray PP P46-1B		700 hp
19	Residual Heat Removal Pump P10-1D		1000 hp
20	Residual Heat Removal Pump P10-1B		1000 hp
21	Station Service Water PP P7-1B	250 hp	
25	Station Service Water PP P7-1A	250 hp	
27	Station Service Water PP P7-1C	250 hp	
28	Core Spray PP P46-1A		700 hp
29	Residual Heat Removal Pump P10-1A		1000 hp
30	Residual Heat Removal Pump P10-1C		1000 hp
31	480 Volt Bus 8		
32	480 Volt Bus 9		
33	Control Rod Drive Water PP	250 hp	
35	Reactor Building Water PP	125 hp	
37	MCC 8A	20 kVA	
38	MCC 8B	44 kVA	23 hp
39	MCC 8C	10 kVA	
40	MCC 9A	95 kVA	10 hp
41	MCC 9B	155 kVA	21 hp
42	MCC 9C	25 kVA	
43	Standby Gas Treatment Exhaust Fan REF-2B		10 hp
44	Battery Charger BC-1-1A	16 kVA	
48	MCC 8E	25 kVA	
52	Core Spray PP Discharge Valve V14-11B		8 hp
53	Chiller Compressor SCH-1	74 kW	
55	Reactor Recirc Unit RRU-8		5 hp
58	Diesel Generator 1B Auxiliaries	20 kVA	
60	Diesel Generator Room Exhaust Fan TEF-3		20 hp
61	Station and Instrument Air Compressor C1-1A		75 hp
64	Battery Charger BC-1-1B	16 kVA	
68	Core Spray Pump Discharge Valve V14-11A		8 hp
69	Reactor Recirc Unit RRU-7		5 hp
70	MCC 9D	5 kVA	
72	Diesel Generator 1A Auxiliaries	20 kVA	
74	Sta. and Instrument Air Comprressor C1-1B	75 hp	
76	Diesel Generator Room Exhaust Fan TEF-2		20 hp

* See Figure 3.1

Table 3.2

Loading Assumptions - Case 2

Conditions: Maximum Load
Startup Transformers Carrying Auxiliary Load
Startup Safeguards Loads

Node No.*	Description	Steady State Loading Before Transfer	Loads Starting Simultaneously with Transfer
3	345 kV Switchyard		
4	115 kV Switchyard		
8	4.16 kV Bus 5B	9000 kVA	
11	4.16 kV Bus 1	11,125 kVA	
12	4.16 kV Bus 3		
13	4.16 kV Bus 2	13,725 kVA	
14	4.16 kV Bus 4		
17	Station Service Water PP P7-1D	250 hp	
18	Core Spray PP P46-1B		700 hp
19	Residual Heat Removal Pump P10-1D		1000 hp
20	Residual Heat Removal Pump P10-1B		1000 hp
21	Station Service Water PP P7-1B	250 hp	
25	Station Service Water PP P7-1A	250 hp	
27	Station Service Water PP P7-1C	250 hp	
28	Core Spray PP P46-1A		700 hp
29	Residual Heat Removal Pump P10-1A		1000 hp
30	Residual Heat Removal Pump P10-1C		1000 hp
31	480 Volt Bus 8		
32	480 Volt Bus 9		
33	Control Rod Drive Water PP	250 hp	
35	Reactor Building Water PP	125 hp	
37	MCC 8A	20 kVA	
33	MCC 8B	44 kVA	23 hp
39	MCC 8C	10 kVA	
40	MCC 9A	95 kVA	10 hp
41	MCC 9B	155 kVA	21 hp
42	MCC 9C	25 kVA	
43	Standby Gas Treatment Exhaust Fan REF-2B		10 hp
44	Battery Charger BC-1-1A	16 kVA	
48	MCC 8E	25 kVA	
52	Core Spray PP Discharge Valve V14-11B		8 hp
53	Chiller Compressor SCH-1	74 kW	
55	Reactor Recirc Unit RRU-8		5 hp
58	Diesel Generator 1B Auxiliaries	20 kVA	
60	Diesel Generator Room Exhaust Fan TEF-3		20 hp
61	Sta. and Instrument Air Compressor C1-1A		75 hp
64	Battery Charger BC-1-1B	16 kVA	
68	Core Spray Pump Discharge Valve V14-11A		8 hp
69	Reactor Recirc Unit RRU-7		5 hp
70	MCC 9D	5 kVA	
72	Diesel Generator 1A Auxiliaries	20 kVA	
74	Sta. and Instrument Air Compressor C1-1B	75 hp	
76	Diesel Generator Room Exhaust Fan TEF-2		20 hp

* See Figure 3.1

Table 3.3

Loading Assumptions - Case 3

Conditions: Maximum Load
Startup Transformers Carrying Auxiliary Load

Node No.*	Description	Steady State Loading
3	345 kV Switchyard	
4	115 kV Switchyard	
8	4.16 kV Bus 5B	9000 kVA
11	4.16 kV Bus 1	11,125 kVA
12	4.16 kV Bus 3	
13	4.16 kV Bus 2	13,725 kVA
14	4.16 kV Bus 4	
17	Station Service Water PP P7-1D	250 hp
18	Core Spray PP P46-1B	700 hp
19	Residual Heat Removal Pump P10-1D	1000 hp
20	Residual Heat Removal Pump P10-1B	1000 hp
21	Station Service Water PP P7-1B	250 hp
25	Station Service Water PP P7-1A	250 hp
27	Station Service Water PP P7-1C	250 hp
28	Core Spray PP P46-1A	700 hp
29	Residual Heat Removal Pump P10-1A	1000 hp
30	Residual Heat Removal Pump P10-1C	1000 hp
31	480 Volt Bus 8	
32	480 Volt Bus 9	
33	Control Rod Drive Water PP	250 hp
35	Reactor Building Water PP	125 hp
37	MCC 8A	180 kVA
38	MCC 8B	67 kVA
39	MCC 8C	10 kVA
40	MCC 9A	100 kVA
41	MCC 9B	150 kVA
42	MCC 9C	25 kVA
43	Standby Gas Treatment Exhaust Fan REF-2B	10 hp
44	Battery Charger BC-1-1A	16 kVA
48	MCC 8E	25 kVA
52	Core Spray PP Discharge Valve V14-11B	
53	Chiller Compressor SCH-1	74 kW
55	Reactor Recirc Unit RRU-8	5 hp
58	Diesel Generator 1B Auxiliaries	20 kVA
60	Diesel Generator Room Exhaust Fan TEF-3	20 hp
61	Station and Instrument Air Compressor C1-1A	75 hp
64	Battery Charger BC-1-1B	16 kVA
68	Core Spray Pump Discharge Valve V14-11A	
69	Reactor Recirc Unit RRU-7	5 hp
70	MCC 9D	5 kVA
72	Diesel Generator 1A Auxiliaries	20 kVA
74	Station and Instrument Air Compressor C1-1B	75 hp
76	Diesel Generator Room Exhaust Fan TEF-2	20 hp

* See Figure 3.1

3.3.3 Minimum Load Model

The loading assumptions for Case 4 are presented in Table 3.4. The following assumptions were used to develop this table:

a) In developing the minimum load model, the plant was assumed to be at cold shutdown with minimum operating load. This load consists of three station service water pumps, one residual heat removal pump, one RHR service water pump, lighting load, and various other 480 volt system loads.

b) The analysis is based on an offsite power system operating voltage of 362 kV for the 345 kV system and 121 kV for the 115 kV system as provided in Table 2.1.

Table 3.4

Loading Assumptions - Case 4

Conditions: Minimum Load
Startup Transformers Carrying Auxiliary Load

Node No.*	Description	Steady State Loading
3	345 kV Switchyard	
4	115 kV Switchyard	
8	4.16 kV Bus 5B	
11	4.16 kV Bus 1	1333 kVA
12	4.16 kV Bus 3	
13	4.16 kV Bus 2	1333 kVA
14	4.16 kV Bus 4	350 hp
17	Station Service Water PP P7-1D	250 hp
18	Core Spray PP P46-1B	
19	Residual Heat Removal Pump P10-1D	
20	Residual Heat Removal Pump P10-1B	1000 hp
21	Station Service Water PP P7-1B	
25	Station Service Water PP P7-1A	250 hp
[illegible]	Station Service Water PP P7-1C	250 hp
[illegible]	Core Spray PP P46-1A	
29	Residual Heat Removal Pump P10-1A	
30	Residual Heat Removal Pump P10-1C	
31	480 Volt Bus 8	540 kVA
32	480 Volt Bus 9	540 kVA
33	Control Rod Drive Water PP	
35	Reactor Building Water PP	
37	MCC 8A	
38	MCC 8B	
39	MCC 8C	
40	MCC 9A	
41	MCC 9B	
42	MCC 9C	
43	Standby Gas Treatment Exhaust Fan REF-2B	
44	Battery Charger BC-1-1A	
48	MCC 8E	
52	Core Spray PP Discharge Valve V14-11B	
53	Chiller Compressor SCH-1	
55	Reactor Recirc Unit RRU-8	
58	Diesel Generator 1B Auxiliaries	
60	Diesel Generator Room Exhaust Fan TEF-3	
61	Station and Instrument Air Compressor C1-1A	
64	Battery Charger BC-1-1B	
68	Core Spray Pump Discharge Valve V14-11A	
69	Reactor Recirc Unit RRU-7	
70	MCC 9D	
72	Diesel Generator 1A Auxiliaries	
74	Station and Instrument Air Compressor C1-1B	
76	Diesel Generator Room Exhaust Fan TEF-2	

* See Figure 3.1

4.0 CONCLUSIONS

The results of the voltage study for Cases 1, 2, 3 and 4 are presented in Tables 4.1, 4.2, 4.3 and 4.4 respectively. These tables contain operating or motor starting voltages (as applicable) and the allowable voltage range.

The Case 1 and Case 2 results provide the maximum voltage drops when safeguards motors are required to start. These results show that voltages in the 480 volt system drop momentarily to slightly lower than acceptable values.

Case 3 reveals that, under worst case loading, the voltage for some loads fed from 480 V Bus 9 is below the minimum allowable voltage. This low voltage condition exists when the startup transformer which feeds Bus 9 also feeds the closed cooling system loads (Bus 5B). Case 3 also reveals that the voltage for continuous operation of all other loads is within acceptable limits.

Case 4 reveals that under extreme light load conditions in the plant, together with extreme system high voltage, the voltages for the station service water pump motors exceed by 1.4% the allowable high voltage limit for 4000 volt motors.

The low voltages calculated under worst case heavy loading and the high voltages calculated under extreme light loading were reported by Reference (b), LER 80-11/1P. In order to alleviate these potential high and low voltages, a proposed transformer tap change was investigated.

Cases 1, 2, 3 and 4 were repeated with the taps on start-up transformers 3A and 3B changed to the 115 kV tap and the taps on transformers 8 and 9 changed to the 4056 volt tap. These new cases are called 1A, 2A, 3A and 4A. The results of these cases are provided in Tables 4.5, 4.6, 4.7 and 4.8, respectively.

Tables 4.5, 4.6 and 4.7 demonstrate that under worst case loading the voltage is sufficient to start and operate all loads. Table 4.6, Case 2A, results show that voltages in the 480 volt system and voltages for some operating 4160 volt system motors momentarily drop to slightly lower than acceptable values when the large safeguards motors start. This is of no concern because sufficient voltage exists for acceleration of 4000 volt safeguards motors. As the large safeguards motors accelerate (typically one to two seconds) voltage in the 4160 volt and 480 volt systems will recover sufficiently to ensure that all loads will have acceptable voltage. Table 4.8 demonstrates that under extreme light load condition, voltage is within the maximum voltage limit for the operation of all electrical equipment.

Transformer taps for start-up transformers 3A and 3B and the 4160/480 volt station service transformers will be changed before the plant begins closed cycle cooling. Because the potential low voltage exists only when the plant is in the closed cooling mode, this is not of immediate concern.

The study of the auxiliary power system at Vermont Yankee was made using the worst case loading, minimum expected grid voltages and other conservative assumptions. Therefore, we conclude that following the completion of the proposed corrective action to the transformer tap settings the auxiliary power system at Vermont Yankee is of sufficient capacity to automatically start and operate all safety loads, assuming that all onsite power systems are not available.

Table 4.1

Bus and Equipment Terminal Voltages - Case 1

Conditions: Maximum Load
Transfer to Startup Transformers
Start Safeguards Loads

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	340,000	
4	115 kV Switchyard	110,000	
8	4.16 kV Bus 5B	3,744	
11	4.16 kV Bus 1	3,762	
12	4.16 kV Bus 3	3,756	
13	4.16 kV Bus 2	3,738	
14	4.16 kV Bus 4	3,732	
17	Station Service Water PP P7-1D	3,756	4400-3600
18	Core Spray PP P46-1B	3,711	4400-3200
19	Residual Heat Removal Pump P10-1D	3,703	4400-3200
20	Residual Heat Removal Pump P10-1B	3,714	4400-3200
21	Station Service Water PP P7-1B	3,756	4400-3600
25	Station Service Water PP P7-1A	3,732	4400-3600
27	Station Service Water PP P7-1C	3,732	4400-3600
28	Core Spray PP P46-1A	3,718	4400-3200
29	Residual Heat Removal Pump P10-1A	3,713	4400-3200
30	Residual Heat Removal Pump P10-1C	3,705	4400-3200
31	480 Volt Bus 8	411	
32	480 Volt Bus 9	414	
33	Control Rod Drive Water PP	410	506-414
35	Reactor Building Water PP	413	506-414
37	MCC 8A	411	506-414
38	MCC 8B	410	506-414
39	MCC 8C	401	506-414
40	MCC 9A	414	506-414
41	MCC 9B	413	506-414
42	MCC 9C	411	506-414
43	Standby Gas Treat. Exhaust Fan REF-2B	408	506-414
44	Battery Charger BC-1-1A	411	506-414
48	MCC 8E	410	506-414
52	Core Spray PP Disch. Vlv. V14-11B	409	506-414
53	Chiller Compressor SCH-1	409	506-414
55	Reactor Recirc Unit RRU-8	409	506-414
58	Diesel Generator 1B Auxliaries	401	506-414
60	DG Room Exhaust Fan TEF-3	400	506-414
61	Sta. and Instr. Air Compressor C1-1A	398	506-414
64	Battery Charger BC-1-1B	414	506-414
68	Core Spray Pump Disch. Vlv. V14-11A	413	506-414
69	Reactor Recirc Unit RRU-7	412	506-414
70	MCC 9D	413	506-414
72	Diesel Generator 1A Auxiliaries	411	506-414
74	Sta. and Inst. Air Compressor C1-1B	410	506-414
76	DG Room Exhaust Fan TEF-2	410	506-414

* See Figure 3.1

Table 4.2

Bus and Equipment Terminal Voltages - Case 2

Conditions: Maximum Load
Startup Transformers Carrying Auxiliary Load
Start Safeguards Loads

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	340,000	
4	115 kV Switchyard	110,000	
8	4.16 kV Bus 5B	3,665	
11	4.16 kV Bus 1	3,723	
12	4.16 kV Bus 3	3,717	
13	4.16 kV Bus 2	3,651	
14	4.16 kV Bus 4	3,651	
17	Station Service Water PP P7-1D	3,716	4400-3600
18	Core Spray PP P46-1B	3,673	4400-3200
19	Residual Heat Removal Pump P10-1D	3,665	4400-3200
20	Residual Heat Removal Pump P10-1B	3,676	4400-3200
21	Station Service Water PP P7-1B	3,716	4400-3600
25	Station Service Water PP P7-1A	3,650	4400-3600
27	Station Service Water PP P7-1C	3,651	4400-3600
28	Core Spray PP P46-1A	3,638	4400-3200
29	Residual Heat Removal Pump P10-1A	3,633	4400-3200
30	Residual Heat Removal Pump P10-1C	3,624	4400-3200
31	480 Volt Bus 8	404	
32	480 Volt Bus 9	401	
33	Control Rod Drive Water PP	401	506-414
35	Reactor Building Water PP	399	506-414
37	MCC 8A	404	506-414
38	MCC 8B	401	506-414
39	MCC 8C	394	506-414
40	MCC 9A	401	506-414
41	MCC 9B	400	506-414
42	MCC 9C	397	506-414
43	Standby Gas Treat. Exhaust Fan REF-2B	401	506-414
44	Battery Charger BC-1-1A	403	506-414
48	MCC 8E	401	506-414
52	Core Spray PP Discharge Vlv. V14-11B	401	506-414
53	Chiller Compressor SCH-1	399	506-414
55	Reactor Recirc Unit RRU-8	401	506-414
58	Diesel Generator 1B Auxiliaries	393	506-414
60	DG Room Exhaust Fan TEF-3	393	506-414
61	Stat. and Instr. Air Compressor C1-1A	391	506-414
64	Battery Charger BC-1-1B	401	506-414
68	Core Spray Pump Disch. Vlv. V14-11A	399	506-414
69	Reactor Recirc Unit RRU-7	399	506-414
70	MCC 9D	400	506-414
72	Diesel Generator 1A Auxiliaries	396	506-414
74	Sta. and Instr. Air Compressor C1-1B	394	506-414
76	DG Room Exhaust Fan TEF-2	395	506-414

* See Figure 3.1

Table 4.3

Bus and Equipment Terminal Voltages - Case 3

Conditions: Maximum Load
Startup Transformers Carrying Auxiliary Loads

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	340,000	
4	115 kV Switchyard	110,000	
8	4.16 kV Bus 5B	3,781	
11	4.16 kV Bus 1	3,922	
12	4.16 kV Bus 3	3,921	
13	4.16 kV Bus 2	3,776	
14	4.16 kV Bus 4	3,775	
17	Station Service Water PP P7-1D	3,920	4400-3600
18	Core Spray PP P46-1B	3,910	4400-3600
19	Residual Heat Removal Pump P10-1D	3,906	4400-3600
20	Residual Heat Removal Pump P10-1B	3,910	4400-3600
21	Station Service Water PP P7-1B	3,920	4400-3600
25	Station Service Water PP P7-1A	3,773	4400-3600
27	Station Service Water PP P7-1C	3,773	4400-3600
28	Core Spray PP P46-1A	3,769	4400-3600
29	Residual Heat Removal Pump P10-1A	3,767	4400-3600
30	Residual Heat Removal Pump P10-1C	3,764	4400-3600
31	480 Volt Bus 8	427	
32	480 Volt Bus 9	414	
33	Control Rod Drive Water PP	421	506-414
35	Reactor Building Water PP	411	506-414
37	MCC 8A	425	506-414
38	MCC 8B	423	506-414
39	MCC 8C	423	506-414
40	MCC 9A	414	506-414
41	MCC 9B	413	506-414
42	MCC 9C	409	506-414
43	Standby Gas Treat. Exhaust Fan REF-2B	421	506-414
44	Battery Charger BC-1-1A	425	506-414
48	MCC 8E	423	506-414
52	Core Spray PP Disch. Valve V14-11B	423	506-414
53	Chiller Compressor SCH. 1	421	506-414
55	Reactor Recirc Unit RRU-8	420	506-414
58	Diesel Generator 1B Auxiliaries	422	506-414
60	DG Room Exhaust Fan TEF-3	422	506-414
61	Stat. and Instr. Air Compressor C1-1A	419	506-414
64	Battery Charger BC-1-1B	413	506-414
68	Core Spray Pump Disch. Vlv. V14-11A	413	506-414
69	Reactor Recirc Unit RRU-7	408	506-414
70	MCC 9D	413	506-414
72	Diesel Generator 1A Auxiliaries	408	506-414
74	Sta. and Inst. Air Compressor C1-1B	408	506-414
76	DG Room Exhaust Fan TEF-2	408	506-414

* See Figure 3.1

Table 4.4

Bus and Equipment Terminal Voltages - Case 4

Conditions: Minimum Load
Startup Transformers Carrying Auxiliary Loads

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	362,000	
4	115 kV Switchyard	121,000	
8	4.16 kV Bus 5B	4,458	
11	4.16 kV Bus 1	4,462	
12	4.16 kV Bus 3	4,461	
13	4.16 kV Bus 2	4,457	
14	4.16 kV Bus 4	4,456	
17	Station Service Water PP P7-1D	4,460	4400-3600
18	Core Spray PP P46-1A		
19	Residual Heat Removal Pump P10-1D		
20	Residual Heat Removal Pump P10-1B	4,450	4400-3600
21	Station Service Water PP P7-1B		
25	Station Service Water PP P7-1A	4,455	4400-3600
27	Station Service Water PP P7-1C	4,455	4400-3600
28	Core Spray PP P46-1A		
29	Residual Heat Removal Pump P10-1A		
30	Residual Heat Removal Pump P10-1C		
31	480 Volt Bus 8	492	
32	480 Volt Bus 9	492	
33	Control Rod Drive Water PP		
35	Reactor Building Water PP		
37	MCC 8A	492	506-414
38	MCC 8B	492	506-414
39	MCC 8C	492	506-414
40	MCC 9A	492	506-414
41	MCC 9B	492	506-414
42	MCC 9C	492	506-414
43	Standby Gas Treat. Exh. Fan REF-2B		
44	Battery Charger BC-1-1A		
48	MCC 8E	492	506-414
52	Core Spray PP Disch. Vlv. V14-11B		
53	Chiller Compressor SCH-1		
55	Reactor Recirc Unit RRU-8		
58	Diesel Generator 1B Auxiliaries		
60	Diesel Gen. Room Exh. Fan TEF-3		
61	Sta. and Instr. Air Compressor C1-1A		
64	Battery Charger BC-1-1B		
68	Core Spray Pump Disch. Vlv. V14-11A		
69	Reactor Recirc Unit RRU-7		
70	MCC 9D	492	506-414
72	Diesel Generator 1A Auxiliaries		
74	Sta. and Instr. Air Compressor C1-1B		
76	DG Room Exhaust Fan TEF-2		

* See Figure 3.1

Table 4.5

Bus and Equipment Terminal Voltages - Case 1A

Conditions: Maximum Load
Transfer to Startup Transformers
Start Safeguards Loads

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	340,000	
4	115 kV Switchyard	110,000	
8	4.16 kV Bus 5B	3,667	
11	4.16 kV Bus 1	3,690	
12	4.16 kV Bus 3	3,684	
13	4.16 kV Bus 2	3,661	
14	4.16 kV Bus 4	3,656	
17	Station Service Water PP P7-1D	3,684	4400-3600
18	Core Spray PP P46-1B	3,640	4400-3200
19	Residual Heat Removal Pump P10-1D	3,633	4400-3200
20	Residual Heat Removal Pump P10-1B	3,643	4400-3200
21	Station Service Water PP P7-1B	3,684	4400-3600
25	Station Service Water PP P7-1A	3,656	4400-3600
27	Station Service Water PP P7-1C	3,656	4400-3600
28	Core Spray PP P46-1A	3,642	4400-3200
29	Residual Heat Removal Pump P10-1A	3,637	4400-3200
30	Residual Heat Removal Pump P10-1C	3,629	4400-3200
31	480 Volt Bus 8	426	
32	480 Volt Bus 9	429	
33	Control Rod Drive Water PP	426	506-414
35	Reactor Building Water PP	429	506-414
37	MCC 8A	427	506-414
38	MCC 8B	426	506-414
39	MCC 8C	417	506-414
40	MCC 9A	429	506-414
41	MCC 9B	428	506-414
42	MCC 9C	426	506-414
43	Standby Gas Treat. Exh. Fan REF-2B	424	506-414
44	Battery Charger BC-1-1A	427	506-414
48	MCC 8E	426	506-414
52	Core Spray PP Discharge Vlv. V14-11B	425	506-414
53	Chiller Compressor SCH-1	425	506-414
55	Reactor Recirc Unit RRU-8	425	506-414
58	Diesel Generator 1B Auxiliaries	416	506-414
60	Diesel Generator Room Exh. Fan TEF-3	415	506-414
61	Sta. and Instr. Air Compressor C1-1A	413	506-414
64	Battery Charger BC-1-1B	429	506-414
68	Core Spray Pump Disch. Vlv. V14-11A	428	506-414
69	Reactor Recirc Unit RRU-7	428	506-414
70	MCC 9D	428	506-414
72	Diesel Generator 1A Auxiliaries	427	506-414
74	Sta. and Instr. Air Compressor C1-1B	426	506-414
76	DG Room Exhaust Fan TEF-2	425	506-414

* See Figure 3.1

Table 4.6

Bus and Equipment Terminal Voltages - Case 2A

Conditions: Maximum Load
Startup Transformers Carrying Auxiliary Loads
Start Safeguards Loads

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	340,000	
4	115 kV Switchyard	110,000	
8	4.16 kV Bus 5B	3,584	
11	4.16 kV Bus 1	3,626	
12	4.16 kV Bus 3	3,620	
13	4.16 kV Bus 2	3,576	
14	4.16 kV Bus 4	3,570	
17	Station Service Water PP P7-1D	3,620	4400-3600
18	Core Spray PP P46-1B	3,577	4400-3200
19	Residual Heat Removal Pump P10-1D	3,569	4400-3200
20	Residual Heat Removal Pump P10-1B	3,580	4400-3200
21	Station Service Water PP P7-1B	3,618	4400-3600
25	Station Service Water PP P7-1A	3,568	4400-3600
27	Station Service Water PPP7-1C	3,510	4400-3600
28	Core Spray PP P46-1A	3,556	4400-3200
29	Residual Heat Removal Pump P10-1A	3,551	4400-3200
30	Residual Heat Removal Pump P10-1C	3,543	4400-3200
31	480 Volt Bus 8	414	
32	480 Volt Bus 9	416	
33	Control Rod Drive Water PP	411	506-414
35	Reactor Building Water PP	413	506-414
37	MCC 8A	414	506-414
38	MCC 8B	411	506-414
39	MCC 8C	404	506-414
40	MCC 9A	415	506-414
41	MCC 9B	415	506-414
42	MCC 9C	.13	506-414
43	Standby Gas Treat. Exh. Fan REF-2B	411	506-414
44	Battery Charger BC-1-1A	413	506-414
48	MCC 8E	411	506-414
52	Core Spray PP Disch. Valve V14-11B	411	506-414
53	Chiller Compressor SCH-1	409	506-414
55	Reactor Recirc Unit RRU-8	411	506-414
58	Diesel Generator 1B Auxiliaries	403	506-414
60	DG Room Exhaust Fan TEF-3	403	506-414
61	Sta.and Instr. Air Compressor C1-1A	400	506-414
64	Battery Charger BC-1-1B	415	506-414
68	Core Spray Pump Disch. Vlv. V14-11A	413	506-414
69	Reactor Recirc Unit RRU-7	413	506-414
70	MCC 9D	414	506-414
72	Diesel Generator 1A Auxiliaries	413	506-414
74	Sta. and Instr. Air Compressor C1-1B	411	506-414
76	DG Room Exhaust Fan TEF-2	413	506-414

* See Figure 3.1

Table 4.7

Bus and Equipment Terminal Voltages - Case 3A

Conditions: Maximum Load
Startup Transformers Carrying Auxiliary Load

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	340,000	
4	115 kV Switchyard	110,000	
8	4.16 kV Bus 5B	3,668	
11	4.16 kV Bus 1	3,815	
12	4.16 kV Bus 3	3,814	
13	4.16 kV Bus 2	3,662	
14	4.16 kV Bus 4	3,661	
17	Station Service Water PP P7-1D	3,812	4400-3600
18	Core Spray PP P46-1B	3,803	4400-3600
19	Residual Heat Removal Pump P10-1D	3,798	4400-3600
20	Residual Heat Removal Pump P10-1B	3,802	4400-3600
21	Station Service Water PP P7-1B	3,812	4400-3600
25	Station Service Water PP P7-1A	3,659	4400-3600
27	Station Service Water PP P7-1C	3,660	4400-3600
28	Core Spray PP P46-1A	3,655	4400-3600
29	Residual Heat Removal Pump P10-1A	3,653	4400-3600
30	Residual Heat Removal Pump P10-1C	3,650	4400-3600
31	480 Volt Bus 8	437	
32	480 Volt Bus 9	423	
33	Control Rod Drive Water PP	432	506-414
35	Reactor Building Water PP	429	506-414
37	MCC 8A	436	506-414
38	MCC 8B	434	506-414
39	MCC 8C	434	506-414
40	MCC 9A	422	506-414
41	MCC 9B	421	506-414
42	MCC 9C	422	506-414
43	Standby Gas Treat. Exh. Fan REF-2B	431	506-414
44	Battery Charger BC-1-1A	435	506-414
48	MCC 8E	433	506-414
52	Core Spray PP Discharge Vlv. V14-11B	434	506-414
53	Chiller Compressor SCH-1	431	506-414
55	Reactor Recirc Unit RRU-8	431	506-414
58	Diesel Generator 1B Auxiliaries	432	506-414
60	DG Room Exhaust Fan TEF-3	432	506-414
61	Sta. and Instr. Air Compressor C1-1A	430	506-414
64	Battery Charger BC-1-1B	422	506-414
68	Core Spray Pump Disch. Vlv. V14-11A	421	506-414
69	Reactor Recirc Unit RRU-7	417	506-414
70	MCC 9D	421	506-414
72	Diesel Generator 1A Auxiliaries	417	506-414
74	Sta. and Instr. Air Compressor C1-1B	415	506-414
76	DG Room Exhaust Fan TEF-2	417	506-414

* See Figure 3.1

Table 4.8

Bus and Equipment Terminal Voltages - Case 4A

Conditions: Minimum Load
Startup Transformers Carrying Auxiliary Load

Node No.*	Description	Voltage (Volts)	Allowable Voltage Range (Volts) (Sec. 2.2)
3	345 kV Switchyard	362,000	
4	115 kV Switchyard	121,000	
8	4.16 kV Bus 5B	4,346	
11	4.16 kV Bus 1	4,349	
12	4.16 kV Bus 3	4,348	
13	4.16 kV Bus 2	4,345	
14	4.16 kV Bus 4	4,344	
17	Station Service Water PP P7-1D		4400-3600
18	Core Spray PP P46-1B		
19	Residual Heat Removal Pump P10-1D		
20	Residual Heat Removal Pump P10-1B	4,337	
21	Station Service Water PP P7-1B		
25	Station Service Water PP P7-1A	4,342	4400-3600
27	Station Service Water PP P7-1C	4,342	
28	Core Spray PP P46-1A		
29	Residual Heat Removal Pump P10-1A		
30	Residual Heat Removal Pump P10-1C		
31	480 Volt Bus 8	505	
32	480 Volt Bus 9	505	
33	Control Rod Drive Water PP		
35	Reactor Building Water PP		
37	MCC 8A	505	506-414
38	MCC 8B	505	506-414
39	MCC 8C	505	506-414
40	MCC 9A	505	506-414
41	MCC 9B	505	506-414
42	MCC 9C	505	506-[illegible]
43	Standby Gas Treat. Exh. Fan REF-2B		
44	Battery Charger BC-1-1A		
48	MCC 8E	505	506-414
52	Core Spray PP Disch. Valve V14-11B		
53	Chiller Compressor SCH. 1		
55	Reactor Recirc Unit RRU-8		
58	Diesel Generator 1B Auxiliaries		
60	DG Room Exhaust Fan TEF-3		
61	Stat. and Instr. Air Compressor C1-1A		
64	Battery Charger BC-1-1B		
68	Core Spray Pump Discharge Vlv. V14-11A		
69	Reactor Recirc Unit RRU-7		
70	MCC 9D	505	506-414
72	Diesel Generator 1A Auxiliaries		
74	Sta. and Instr. Air Compressor C1-1B		-
76	Diesel Generator Room Exhaust Fan TEF-2		

* See Figure 3.1

5.0 VERIFICATION

Reference (a) required that the adequacy of the onsite and offsite power distribution systems be verified by test to assure that the analysis results are valid. In lieu of actual tests, the computer load flow program and model of the auxiliary power system was used to predict bus voltages for actual plant conditions. Two verifications were made. The results of the verification studies are provided in Table 5.1. Comparison of bus voltages predicted by the computer program to actual bus voltages demonstrates that the computer model is valid.

Table 5.1

Predicted Voltage Vs. Measured Voltage

Verification #1 - December 8, 1979 - 0745 hours

Bus	Predicted Voltage (Volts)	Measured Voltage (Volts)	Percent Deviation (Percent)
4160 volt bus 1	4170	4100	+1.71
4160 volt bus 2	4143	4140	+0.7
4160 volt bus 3	4170	4120	+1.21
4160 volt bus 4	4143	4180	-.89
480 volt bus 8	461	458	+.66
480 volt bus 9	462	457	+1.09

Verification #2 - December 14, 1979 - 1540 Hours

Bus	Predicted Voltage (Volts)	Measured Volgage (Volts)	Percent Deviation (Percent)
4160 volt bus 1	4170	4080	+2.21
4160 volt bus 2	4144	4050	+2.32
4160 volt bus 3	4170	4200	-.71
4160 volt bus 4	4144	4270	-2.95
480 volt bus 8	459	462	-.65
480 volt bus 9	454	462	-1.73

REFERENCES

(a) Letter from United States Nuclear Regulatory Commission to All Power Reactor Licensees, Adequacy of Station Electric Distribution System Voltages, (August 8, 1979).

(b) VYNPC Letter to USNRC, Licensee Event Report 80-11/1P (March 13, 1980).