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SUBJECT: Forwards results of analysis required by Items 6 & 9 of NRC 790808 ltr on degraded grid voltage.Undervoltage trip setpoint will be changed for startup transformers & administrative controls will be established by 800701.

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NOTES: M. Cunningham - all amendments to FSAR + changes to tech specs

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June 4, 1980

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. R. W. Reid, Chief
Operating Reactors Branch No. 4

Subject: Oconee Nuclear Station
Docket Nos. 50-269, -270, -287

Dear Sir:

My letter of March 13, 1980 addressed delays involved in completing analytical work required by Items 6 and 9 of your August 8, 1979 generic letter on degraded grid voltage. Please find attached the results of the required analysis. The conclusions drawn include a commitment to change the undervoltage trip setpoint for the startup transformers and to establish administrative controls requiring correction of the undervoltage condition and manual load shed of non-essential loads in the normally tripped unit in a timely fashion. These actions will be completed by July 1, 1980.

Very truly yours,

William O. Parker, Jr

KRW:scs

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OCONEE NUCLEAR STATION

NRC Request for Information
Degraded Grid Voltage

I. INTRODUCTION

In the January 11, 1980 telecon between Duke and NRC, the NRC asked that Duke respond to Item 2 of the Guidelines for Voltage Drop Calculations. This item of the guidelines which were enclosed with the NRC letter of August 8, 1979 stated:

> "For multi-unit stations a separate analysis should be performed for each unit assuming (1) an accident in the unit being analyzed and simultaneous shutdown of all other units at that station; or (2) an anticipated transient in the unit being analyzed (e.g., unit trip) and simultaneous shutdown of all other units at that station, whichever presents the largest load demand situation."

Specifically, the NRC requested that the Item 2 conditions be analyzed assuming the outage of one startup transformer as allowed by the Oconee Technical Specifications. This Technical Specification permits the connection of one unit's auxiliary power system to the startup transformer of another unit.

Analyses have been performed using the Item 2 criteria and the following conditions:

1. Startup transformer CT2 is out of service. Any load which would have been carried by startup transformer CT2 is connected to startup transformer CT3.

2. Unit 3 is assumed to be at full power (≈40 MW auxiliary load) when an accident in the unit results in a ESG signal and unit trip. The pre-accident auxiliary load which was connected to normal auxiliary transformer 3T is transferred to startup transformer CT3.

2. Concurrent with Condition 2 (above), Unit 2 is assumed to trip from full power. The pre-trip auxiliary load which was connected to normal auxiliary transformer 2T is transferred to startup transformer CT3.

4. The 230 kV switchyard voltage is at its historical low of 217kV.

II. ANALYSIS

With the conditions postulated above, the normal auxiliary loads of Units 2 and 3 will transfer from their respective normal auxiliary transformers to startup transformer CT3. Figure 1 provides the voltage profiles existing after the transfer of normal auxiliary loads to transformer CT3, but before the ESG signal initiates the starting of the required safety loads of Unit 3. The ESG signal generated in Unit 3 actuates the starting of the following required safety-related loads:

Starting Loads	HP
High Pressure Injection (2)	600
Low Pressure Injection (2)	400
Reactor Building Spray (2)	250
Low Pressure Service Water (1)	600
Reactor Building Cooling Fan (1)	75
Penetration Room Vent Fan (2)	5
MOVs (Misc)	92.3 (Total HP)
Emergency Feedwater (2)	600
Total Starting Horsepower	4477.3 HP

All of the above motor loads on Unit 3 are started simultaneously with the normal auxiliary loads of Units 2 and 3 already running and connected to startup transformer CT3. The voltage profiles for this case are shown in Figure 2 and represent the voltages on the respective buses at the instant the initial locked rotor current inrush of the accident loads is supplied by the power system. As indicated in Figure 2, upon starting the required safety-related loads, the voltages at the motor terminals dip below the rated starting voltages for the loads. Therefore, a detailed dynamic analysis of these conditions was performed. The results of this analysis show that the motors will start and accelerate their loads as required.

Dynamic Motor Analysis

A dynamic simulation was performed using the speed-torque curve of each of the required motors and the motor's respective load curve. The analysis indicates that each motor will start and accelerate its load in a timely manner. The approximate time for each motor to accelerate its load to operating speed is as follows:

Motor	Approx. Time To Accelerate	Approx. Operating RPM
RB Cooling Fan	7.5 sec	585
HP Injection	5.6 sec	3560
EFWP	1.6 sec	3550
LP Injection	1.6 sec	1773
RB Spray	3.9 sec	3565
LP Service Water	1.5 sec	888

Figure 3 reflects the system voltages with the valve operators drawing their running current during valve travel time. As the required accident loads accelerate, the current drawn by the motors decreases and the system voltages ultimately recover to the values shown in Figure 4. Hence, Figure 4 summarizes the final steady-state voltages with startup transformer CT3 carrying the normal auxiliary loads of two units and the ESG loads of the accident unit. Note that valves have completed their travel and are not a part of the Figure 4 conditions.

III. EVALUATION OF POSTULATED CONDITIONS ON AUXILIARY SYSTEM EQUIPMENT

With the outage of one startup transformer (as allowed by the Technical Specifications), the Item 2 postulated events in conjunction with the degraded grid voltage result in the auxiliary system operating continuously at a level below the preferred 90% rated voltage. However, the impact of the degraded voltage levels required further investigation of the equipment in the auxiliary power system.

1. Startup Transformer

First, the startup transformer is required to operate in an overload condition during the postulated events or until operator action can shed some of the non-essential loading. Under the assumed loading conditions, the transformer will carry approximately 109 MVA after starting the ESG loads and the steady-state conditions have been re-established. The nameplate rating of the startup transformer is 67.2 MVA. Thus, the conditions under study require the transformer to operate at a maximum overload of 167% of its nameplate rating.

To determine the reduction of life expectancy of the transformer under these conditions, the guide for transformer loading (ANSI C57.92) was used. Conservatively assuming an ambient temperature of 30°C(86°F) and an equivalent loading of 33.6 MVA before the overload condition, the following estimates the loss of life versus the time of overloading (Reference Table 92-02.2001 in C57.92):

Peak Load In Hours	Life Loss (%) Not More Than
0.5	<0.25%
1.0	<0.50%
2.0	≈2.00%

4. Other Equipment

The postulated voltage levels of the assumed conditions will not degrade the proper operation of motor contactors, fuses, and control transformers. Manufacturer's testing of the motor contactors of the type used in safety-related applications at Oconee has shown that the contactors will pickup and hold-in at the voltage conditions of this study.

IV. STARTING AND RUNNING OF A NON-SAFETY LOAD

In further consideration of the NRC's request for this analysis, a study was performed assuming the starting of a large non safety-related motor. Figures 7 and 8 show the voltage profiles for starting and running a condensate booster pump motor (2000 hp) after the auxiliary systems of two units and the accident loads of one unit have reached the steady-state conditions presented in Figure 4. The analysis indicates that the condensate booster pump would start and accelerate its load.

V. CONCLUSIONS

In response to the NRC's request, the above analysis considers the case of two units being supplied from one startup transformer assuming a degraded grid voltage, an accident in one of the units sharing the startup transformer, and a simultaneous trip of the other unit sharing the startup transformer.

The undervoltage relays that are provided to separate the auxiliary power system from an unacceptable voltage source are presently set to operate at 88% of rated bus voltage (i.e. setpoint corresponds to 3660 volts). This setting was based on a previous analysis which assumed only one unit being supplied from its associated startup transformer under degraded grid voltage conditions. Based on the results of the above analysis, the present 88% setpoint for the undervoltage relays will not permit continued operation of two units' auxiliary systems and their loads from the degraded but still acceptable source under the assumed conditions. This detailed analysis does show, however, that the auxiliary systems are capable of continuous operation (including the starting of the required ESG loads of one unit) at a system voltage level of 80% of rated voltage (3328 volts). Therefore, since the loads connected to the auxiliary power system are appropriately protected on an individual basis and since the function of the undervoltage relays is to separate the auxiliary system from an unacceptable voltage source, the setpoint of the undervoltage relays will be changed to 77% (80%-3% relay tolerance) of rated system voltage. The reset of the undervoltage relay setpoint will be completed on a timely schedule. Administrative procedures will be provided that will require the selective manual shedding of non-safety-related loads and the restoration of an acceptable grid voltage within a few hours of this postulated event.

It should be noted that a lower ambient and/or lower initial loading will result in reducing the expected loss of life. The standard C57.92 (section 92-02.130) states as a guide that "an average loss of life of 4% per year or 5% in any one emergency operation is considered reasonable." Thus, the transformer can be operated in the stated conditions until loading can be reduced with a minimal loss of life.

2. Motors

To determine the impact of the lower voltages upon the various motors and their loads, a dynamic analysis was performed for various motors (both safety and non-safety) at incremental voltage levels. The simulation for each motor used the speed-torque curves for both the motor and its load to calculate its operating current. In addition, the studies revealed the starting characteristics and approximate operating speeds. Figure 5 indicates the currents required for the ESG motors at various voltage levels. In turn, Figure 6 summarizes from the results shown in Figure 5, the minimum allowable voltage for continuous operation on the basis of current carrying capabilities (thermal) of each motor.

As seen in Figure 6 some of the ESG motors have minimum allowable voltages (based on thermal ratings) falling between 80% and 90% of their rated voltage. However, the analysis indicates that all of the ESG motors continue to operate properly since none of them drop to a speed below their respective breakdown speed.

An additional investigation into the temperature rises caused by the operation of the motors at 80% of their rated voltages has been completed. The results of the analysis indicates that the ESG motors can operate at the 80% voltage level for a limited time (at least 4 hours) with minimal degradation in the expected life to the motors.

3. Motor Operated Valves (MOVs)

Motors applied to operate valves have a number of degrees of conservatism included in their design. The conservatisms are based on the variables of application such as valve friction, stem packing friction, pressure variance, flow variance, and voltage variance. These variables result in the motor operators being oversized by design. Therefore, based on design conservatisms and our own operating experience, we feel that the valve operators will perform their intended function at 80% of rated voltage. However, at this time, sufficient data is not available to analytically confirm the effects of low voltage on the operation of motor operated valves. Duke Power Company will test valves/valve operators under degraded voltage conditions to verify proper operation.

VI. VERIFICATION OF ANALYSIS METHOD

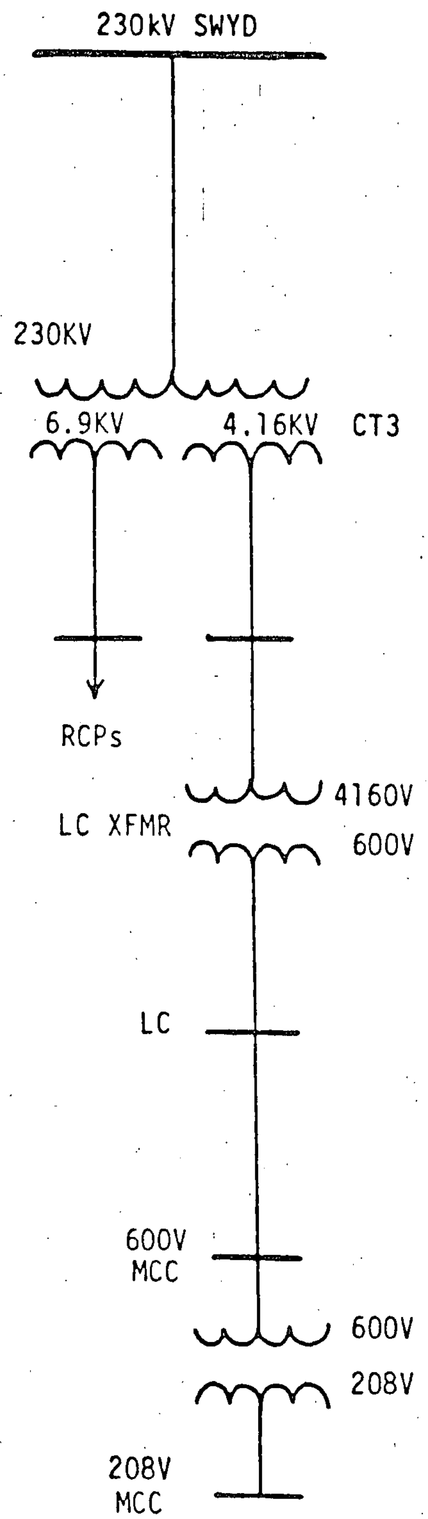
In the last several years, the Oconee Nuclear Station auxiliary electrical power system has been evaluated for the effects of a degraded grid voltage. The necessary analyses have been performed analytically using a computer program developed by Duke Power Company.

To verify the computer model of the Oconee auxiliary system, test measurements were taken in May, 1980 at existing test blocks and other measurement points on the Oconee Unit 3 power system. These measurements were recorded during a normal power operation with the generator on-line and the unit auxiliary transformer (3T) supplying the distribution system. The recorded data is summarized in Table 1.

From the measured power loadings at the various locations, the analytical model of the test system was derived. This model was then used to calculate the respective voltage profiles of the system with its appropriate loading distribution. The calculated results are given in Table 2 and are compared to the measured values.

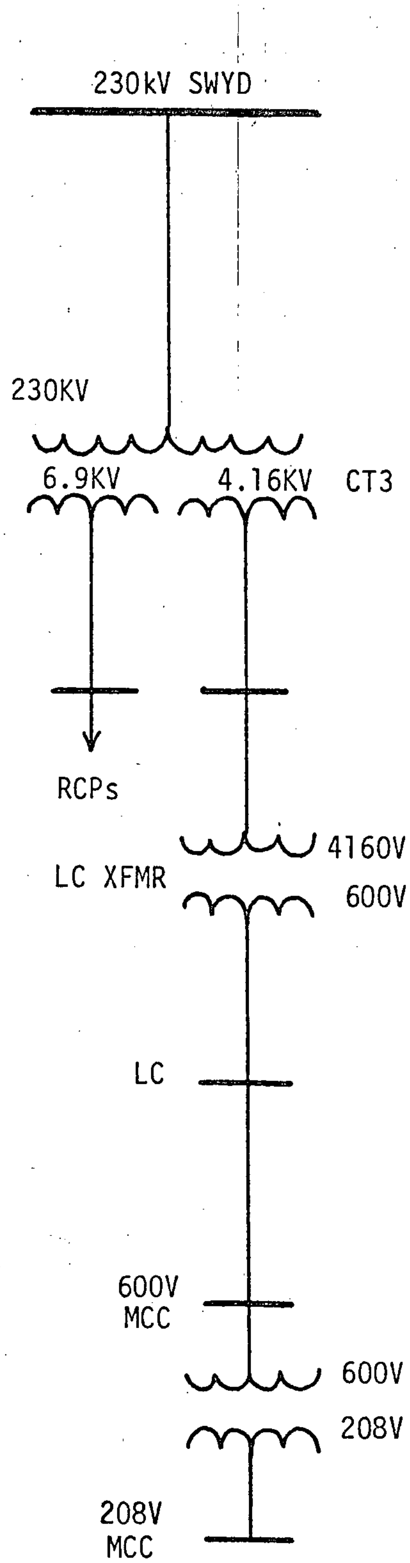
As seen in Table 2, there is an excellent correlation between the measured quantities (both voltages and currents) and the calculated results. The small differences between the measured and calculated results are well within accepted measurement accuracies. The main source of the slight differences is the accuracy capability of both the current and potential transformers at the measurement points.

The comparison between measured voltage conditions at the station and calculated results of the test conditions shows that the analytical methods are valid. In addition to the above comparison to the test measurements, the computer program has been verified by other approved methods. These include the comparison to (1) approved methods of hand calculations, (2) solutions obtained by other computer programs of known validity, and(3) solved examples in standard textbooks.



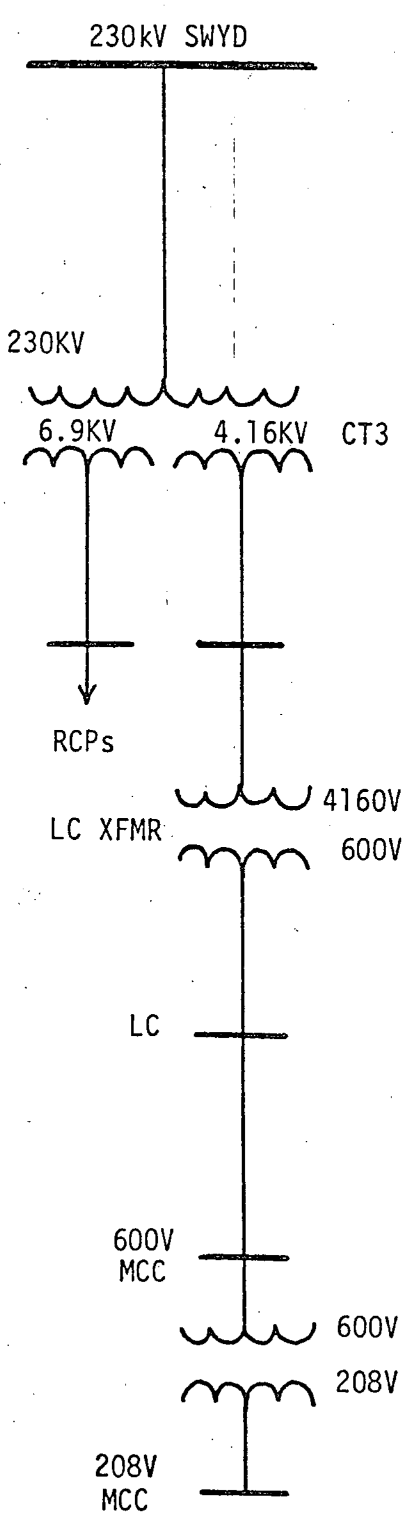
LOCATION	BUS NAME	PER UNIT VOLTAGE NOMINAL BASE	VOLTAGE	PER UNIT VOLTAGE MOTOR BASE
SWYD	230KV SWYD	0.9435	217 KV	NA
6.9KV SWGR	3TA	0.8702	6.00 KV	0.910
	3TB	0.8701	6.00 KV	0.910
4.16KV SWGR	3TC	0.8249	3432 V	0.858
	3TD	0.8247	3431 V	0.858
	3TE	0.8246	3430 V	0.858
600V LC	3X8	0.8188	491 V	0.854
	3X9	0.8174	490 V	0.853
	3X10	0.8224	493 V	0.858
600V MCC	3XS1	0.8186	491 V	0.854
	3XS2	0.8170	490 V	0.853
	3XS3	0.8217	493 V	0.858
208V MCC	3XS1	0.8186	170 V	0.851
	3XS2	0.8170	170 V	0.850
	3XS3	0.8217	171 V	0.855

FIGURE 1
VOLTAGES EXISTING BEFORE ESG SIGNAL WITH
NORMAL LOAD OF TWO UNITS



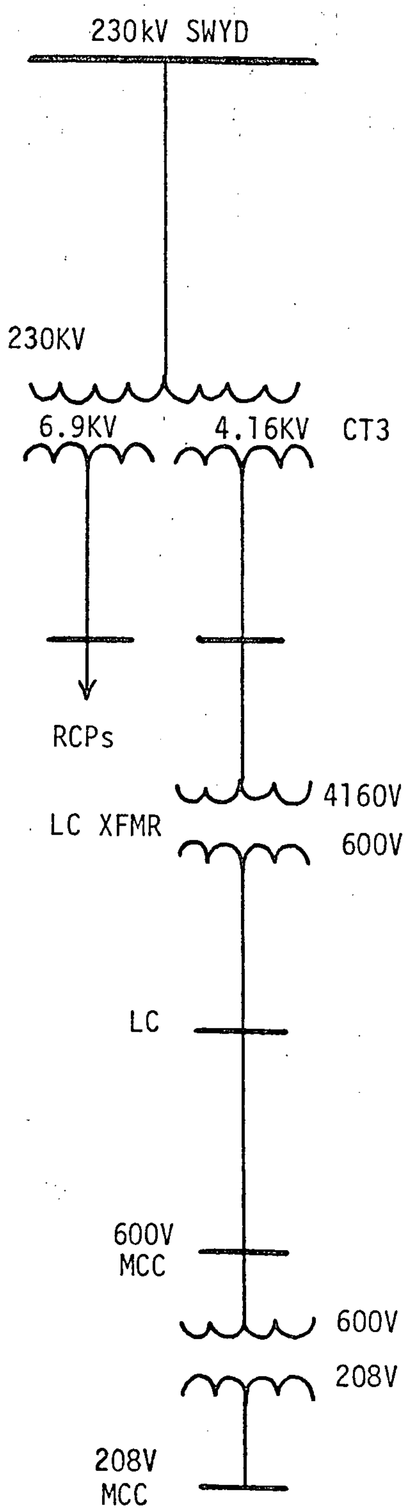
LOCATION	BUS NAME	PER UNIT VOLTAGE NOMINAL BASE	VOLTAGE	PER UNIT VOLTAGE MOTOR-BASE
SWYD	230KV SWYD	0.9435	217KV	NA
6.9KV SWGR	3TA	0.8420	5810V	0.880
	3TB	0.8419	5809V	0.880
4.16KV SWGR	3TC	0.7118	2961V	0.740
	3TD	0.7113	2959V	0.740
	3TE	0.7110	2958V	0.739
600V LC	3X8	0.6912	415V	0.721
	3X9	0.6895	414V	0.720
	3X10	0.6409	385V	0.669
600V MCC	3XS1	0.6906	414V	0.721
	3XS2	0.6885	413V	0.718
	3XS3	0.6327	380V	0.660
208V MCC	3XS1	0.6438	134V	0.670
	3XS2	0.6515	136V	0.678
	3XS3	0.6199	129V	0.645

FIGURE 2
STARTING ESG LOADS WITH CT3
CARRYING THE NORMAL LOAD OF TWO UNITS



LOCATION	BUS NAME	PER UNIT VOLTAGE NOMINAL BASE	VOLTAGE	PER UNIT VOLTAGE MOTOR BASE
SWYD	230KV SWYD	0.9435	217KV	NA
6.9KV SWGR	3TA	0.8653	5971V	0.905
	3TB	0.8652	5970V	0.904
4.16KV SWGR	3TC	0.8076	3360V	0.840
	3TD	0.8074	3359V	0.840
	3TE	0.8072	3358V	0.840
600V LC	3X8	0.7985	479V	0.833
	3X9	0.7970	478V	0.832
	3X10	0.7822	469V	0.816
600V MCC	3XS1	0.7981	479V	0.833
	3XS2	0.7964	478V	0.831
	3XS3	0.7785	467V	0.812
208V MCC	3XS1	0.7893	164V	0.821
	3XS2	0.7895	164V	0.821
	3XS3	0.7753	161V	0.806

FIGURE 3
VOLTAGES WITH NORMAL LOAD OF TWO UNITS + ESG LOADS + ALL VALVES RUNNING



LOCATION	BUS NAME	PER UNIT VOLTAGE NOMINAL BASE	VOLTAGE	PER UNIT VOLTAGE MOTOR BASE
SWYD	230KV SWYD	0.9435	217KV	NA
6.9KV SWGR	3TA	0.8654	5971V	0.905
	3TB	0.8654	5971V	0.905
4.16KV SWGR	3TC	0.8082	3362V	0.841
	3TD	0.8079	3361V	0.840
	3TE	0.8078	3360V	0.8401
600V LC	3X8	0.8019	481V	0.837
	3X9	0.8005	480V	0.835
	3X10	0.7832	470V	0.817
600V MCC	3XS1	0.8018	481V	0.837
	3XS2	0.8001	480V	0.835
	3XS3	0.7796	468V	0.814
208V MCC	3XS1	0.8018	167V	0.834
	3XS2	0.8001	166V	0.832
	3XS3	0.7796	162V	0.811

FIGURE 4
VOLTAGES WITH NORMAL LOAD OF TWO UNITS
+ ESG LOADS - ALL VALVES OFF

MOTOR	100% RATED VOLTAGE					90% VOLTAGE		85% VOLTAGE		80% VOLTAGE	
	HP	SF	ACTUAL		RATED						
			FLA	RPM	SF X FLA	FLA	RPM	FLA	RPM	FLA	RPM
HP Injection	600	1.15	69.8	3582	85.10	81.2	3575	88.3	3570	95.6	3565
LP Injection	400	1.15	49.2	1781	60.03	54.3	1777	57.3	1774	60.6	1771
LP Service	600	1.15	55.3	891	86.83	61.1	889	64.5	888	69.8	886
RB Spray	250	1.15	31.3	3570	36.80	34.9	3562	37.0	3558	39.3	3552
RB Cooling Fan	150/75	1.0	120.0	590	124.0	132.1	588	139.0	587	146.6	585
Emergency Feedwater	500	1.25	61.5	3580	78.50	70.4	3574	75.5	3570	81.1	3565
Emergency Feedwater	600	1.25	58.1	3571	93.75	64.2	3565	69.2	3559	75.8	3550
Pent Rm Vent Fan	5	1.15	5.28	3458	6.21	5.91	3420	6.23	3395	6.58	3367

FIGURE 5

OPERATING CURRENTS AT VARIOUS VOLTAGE LEVELS

MOTOR	HP	MAXIMUM CURRENT ALLOWED (See Note 1)	MINIMUM PERCENT VOLTAGE (See Note 2)
HP Injection	600	85.1A	87%
LP Injection	400	60.0A	81%
LP Service	600	86.8A	< 80%
RB Spray	250	36.8A	85.5%
RB Cooling Fan	150/75	124.0A	90%
Emergency Feedwater	500	78.5A	82%
Emergency Feedwater	600	93.8A	< 80%
Pent Rm Vent Fan	5	6.21	85%

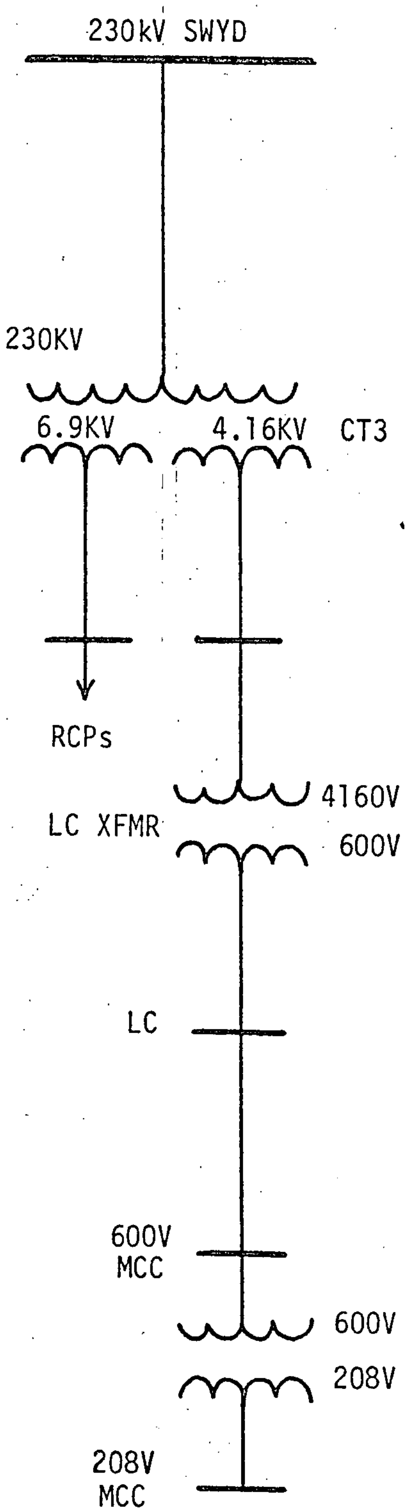
NOTES:

1. The maximum current is based upon the product of the service factor and the rated full load current at rated voltage.

2. The minimum continuous voltage is based on the motor voltage. It is based first upon the maximum current allowed (SF X FLA). However, in some cases the standard 10% deviation from rated voltage is the lowest voltage.

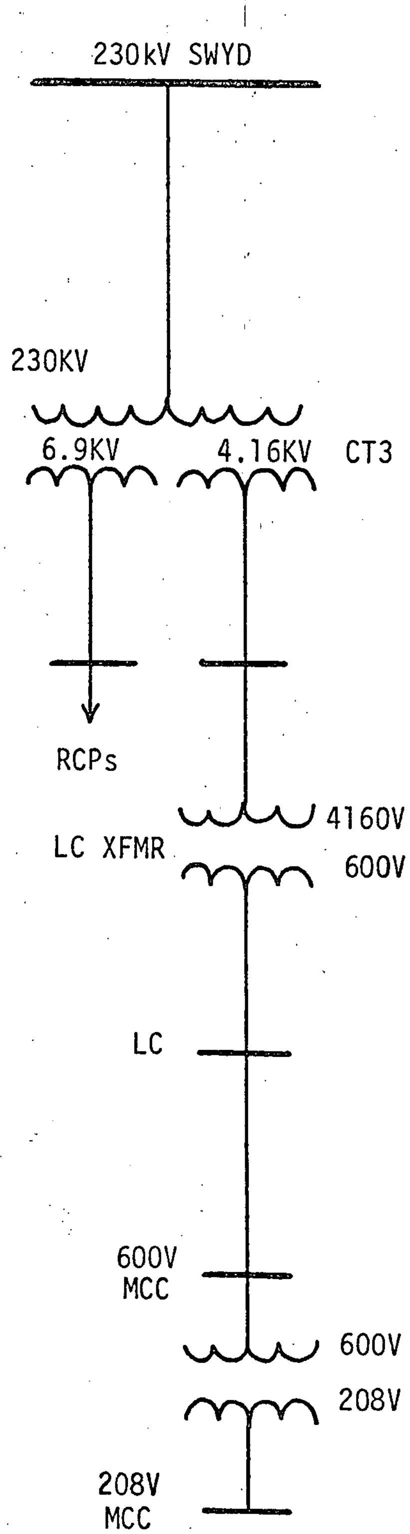
FIGURE 6

CALCULATED MINIMUM CONTINUOUS VOLTAGES



LOCATION	BUS NAME	PER UNIT VOLTAGE NOMINAL BASE	VOLTAGE	PER UNIT VOLTAGE MOTOR BASE
SWYD	230KV SWYD	0.9435	217KV	NA
6.9KV SWGR	3TA	0.8531	5887V	0.892
	3TB	0.8530	5886V	0.892
4.16KV SWGR	3TC	0.7584	3155V	0.789
	3TD	0.7579	3153V	0.788
	3TE	0.7576	3152V	0.788
600V LC	3X8	0.7517	451V	0.784
	3X9	0.7499	450V	0.783
	3X10	0.7312	439V	0.763
600V MCC	3XS1	0.7515	451V	0.784
	3XS2	0.7496	450V	0.782
	3XS3	0.7274	436V	0.759
208V MCC	3XS1	0.7515	156V	0.782
	3XS2	0.7496	156V	0.780
	3XS3	0.7274	151V	0.756

FIGURE 7
STARTING COND BOOSTER AFTER STEADY-STATE VOLTAGES RE-ESTABLISHED



LOCATION	BUS NAME	PER UNIT VOLTAGE NOMINAL BASE	VOLTAGE	PER UNIT VOLTAGE MOTOR-BASE
SWYD	230KV SWYD	0.9435	217KV	NA
6.9KV SWGR	3TA	0.8633	5957V	0.903
	3TB	0.8632	5956V	0.902
4.16KV SWGR	3TC	0.8005	3330V	0.833
	3TD	0.8002	3329V	0.832
	3TE	0.8001	3328V	0.832
600V LC	3X8	0.7942	477V	0.829
	3X9	0.7927	476V	0.827
	3X10	0.7753	465V	0.809
600V MCC	3XS1	0.7940	476V	0.829
	3XS2	0.7924	475V	0.827
	3XS3	0.7716	463V	0.805
208V MCC	3XS1	0.7940	165V	0.826
	3XS2	0.7924	165V	0.824
	3XS3	0.7716	160V	0.802

FIGURE 8
FINAL STEADY-STATE VOLTAGES WITH COND BOOSTER RUNNING

LOCATION	VOLTAGE	CURRENT	REAL POWER	REACTIVE POWER
525 KV SWYD	513.6 KV	-	-	-
GENERATOR	18.85 KV	27.6 KA	883.6 MW	174.6 MVAR
XFMR 3T - HI	18.81 KV	1.33 KA	36.98 MW	22.58 MVAR
- 7KV	-	1.99 KA	-	-
- 4KV	-	2.34 KA	-	-
7 KV SWGR 3TA	7218 V	1003 A	11.48 MW	5.04 MVAR
7 KV SWGR 3TB	7220 V	995 A	11.40 MW	5.00 MVAR
MAIN FEEDER BUS #1	4271 V	1258 A	7.53 MW	5.44 MVAR
BUS #2	4269 V	1039 A	6.21 MW	4.53 MVAR
4KV SWGR - 3TC	4261 V	1005 A	5.50 MW	4.98 MVAR
- 3TD	4263 V	351 A	2.30 MW	1.20 MVAR
- 3TE	4263 V	902 A	5.45 MW	3.84 MVAR
4 KV FEEDER TO - LC 3X8	4261 V	20.2 A	115.2 KW	94.7 KVAR
- LC 3X9	4263 V	15.8 A	81.8 KW	83.1 KVAR
- LC 3X10	4263 V	16.65 A	62.7 KW*	105.7 KVAR
600V LC 3X8	609.6 V	-	-	-
600V LC 3X9	610 V	-	-	-
208V MCC 3XS1	209.8 V	-	-	-
3XS2	208.8 V	-	-	-
3XS3	213.3 V	-	-	-

* An error suspected in test block connection. Test reading of power factor was 26%. Since power level approximately equal to RBCU fan in low speed, the running power factor of this motor was assumed (51%)

TABLE 1

TEST MEASUREMENT DATA

TABLE 2

COMPARISON OF CALCULATED AND MEASURED VALUES

LOCATION	VOLTAGE			CURRENT		
	MEASURED	CALCULATED	Δ%	MEASURED	CALCULATED	Δ%
525 KV SWYD	513.6 KV	512.6 KV	0.19	*		
GENERATOR	18.85 KV	18.85 KV	Note 1	27.58 KA	27.58 KA	0.0
XFMR 3T - HI	18.81 KV	18.83 KV	0.11	1.33 KA	1.30 KA	2.26
- 7KV	*			1.99 KA	2.00 KA	0.50
- 4KV	*			2.34 KA	2.25 KA	3.84
7 KV SWGR - 3TA	7218 V	7221 V	0.04	1003 A	1002 A	0.10
- 3TB	7220 V	7222 V	0.03	995 A	994 A	0.10
MAIN FEEDER BUS #1	4271 V	4283 V	0.28	1258 A	Note 2	
BUS #2	4269 V		0.33	1039 A		
4 KV SWGR - 3TC	4261 V	4273 V	0.28	1005 A	997 A	0.80
- 3TD	4263 V	4272 V	0.21	351 A	346 A	1.42
- 3TE	4263 V	4272 V	0.21	902 A	904 A	0.22
4 KV FEEDER TO - LC 3X8	4261 V	4273 V	0.28	20.2 A	20 A	0.99
- LC 3X9	4263 V	4272 V	0.21	15.8 A	16 A	1.27
- LC 3X10	4263 V	4272 V	0.21	16.7 A	17 A	1.80
600 V LC 3X8	609.6 V	611.6 V	0.33	*		
3X9	610 V	612.1 V	0.34	*		
208 V MCC 3XS1	209.8 V	212.0 V	1.05	*		
3XS2	208.8 V	212.2 V	1.63	*		
3XS3	213.3 V	209.6 V	1.73	*		

* Not measured

(1) Reference voltage for swing bus

(2) Swgr 3B1T and 3B2T were modeled electrically the same and the model did not distinguish the two incoming feeders