STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGE ANALYSIS

OYSTER CREEK NUCLEAR GENERATING STATION

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I. PURPOSE

The purpose of this study was to determine analytically if the o.:.ite power system and the onsite distribution system for Oyster Creek Nuclear Generating Station is of sufficient capacity and capability to automatically start as well as operate all required safety loads within their required voltage ratings in the event of: 1) an anticipated transient (such as a unit trip); or 2) an accident (such as a LOCA). This must be assured regardless of other actions the electric power system is designed to automatically initiate and without the need for manual shedding of any electric loads. The impetus for this study was the Arkansas Nuclear One event of September 16, 1978, which was described in NRC IE Information Notice No. 79-04, and the NRC letter of August 8, 1979, to all Power Reactor Licensees which contained specific actions required to be taken as a result of the Arkansas event.

II. EXISTING CONDITIONS AT OYSTER CREEK

Undervoltage relays are presently provided for the 4160V buses 1A, 1B, 1C, and 1D, and for the Start-up Transformers SA and SB, and are fed from 4200-120V potential transformers. These relays are all General Electric type IAV53K, under/overvoltage induction relays. The undervoltage trip point for these relays is presently set at 88% of the 93V overvoltage trip set point or 2864V on the 4160V buses. With this set point, they will trip in 3 seconds on total loss of voltage.

In addition to these undervoltage relays, some 460V loads are provided with undervoltage trip devices which are integrally mounted in individual circuit breakers. These undervoltage devices trip their individual loads after 5 seconds of less than 50% voltage

The grid voltage is limited to voltages between 212.75 KV and 238 KV per Attachment #1. The Auxiliary Transformer is set on tap number 5; and, the Start-up Transformers are set on tap number 4. Unit Substation Transformers 1A1, 1B1, 1A3, and 1B3 are set on tap number 1; and Unit Substation Transformers 1A2 and 1B2 are set on tap number 3.

III. ANALYTICAL RESULTS

A. General

The voltage drop study for all safety-related buses and pumps was done using an approved Burns and Roe, Inc. computer program, EL0110E. This program has been used for a number of other plant studies, including Three Mile Island, Unit No. 2. In addition, per an NRC request, this program was field verified on Three Mile Island Unit No. 2 to assure its accuracy. The results of the program were within 2% of the field measured values as shown on Attachment #2. This testing provides confidence that the analysis performed accurately predicts the performance of the Oyster Creek systems since testing at Three Mile Island Unit No. 2 verified the capabilities of the program.

The voltage drop calculations for all safety-related valve feeder cables were performed using an iterative approach based on the formula:

$$V_D = \sqrt{3}\ \frac{KVA}{V_A\ \sqrt{3}}\ (R \cos \emptyset + X \sin \emptyset)$$

where V_D=Line to Line Voltage Drop; V_A=Assumed Motor Terminal Voltage; KVA=Load KVA; Ø=Load Power Factor Angle; R=cable resistance; and X=cable reactance.

The assumptions made for the purposes of this program are listed on Attachment #1. Although these are assumptions, they are all firmly based on experience, testing, specification requirements, industry standards, or manufacturer's guarantees. In addition, all assumptions were made in line with the intent of making this a worst case analysis.

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B. Undervoltage

The results of the analysis for Oyster Creek are shown on Tables I, II, III, and IV. As shown on Attachment #1, the minimum allowable voltages for 440 V motors are: 347 V running, and 330 V starting. For 4000 V motors the minimum voltages are: 3400 V running, and 3000 V starting.

Thus, with the grid at its minimum of 212.75 KV as stated in Attachment #1, all safety-related motors will have sufficient voltage at their terminals to start and operate within their ratings. Also, since the minimum Motor Control Center voltage at which all starters can be guaranteed to pick up is 403V, as shown on Attachment #1, all safety-related starters can be shown to pick up under worst case loading and minimum grid voltage.

As stated in Attachment #1, the drop out voltage for the starters at Oyster Creek is 276 V at the Motor Control Center, allowing for voltage drop in the control wiring. This study shows that the lowest voltage a safety-related Motor Control Center will momentarily drop to, when starting the largest non-safety related load, is 326 V. Therefore, at minimum grid voltage, full load, and starting the largest non-safety related load, the starters will not drop out.

C. Overvoltage

As mentioned above, the transformer taps for U.S.S. 1A2 and 1B2 are set on tap #3. The study indicates that with the grid voltage of 238 KV, a minimum load of 2.5 MW randomly distributed among the buses on each Start-up Transformer, and the U.S.S.'s on tap #3 the maximum MCC voltage is 498 V. Per Attachment #1, the maximum voltage for which the 440V motors at Oyster Creek are rated is 484V. Thus, even taking credit for voltage drop in the motor feeders will not guarantee that the motors' maximum voltage limit is not exceeded.

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However, exceeding the motors' maximum voltage limit, is only a potential problem when the plant is not in operation, with a minimal auxiliary load and a grid voltage higher than approximately 233 KV.

In addition, this value of overvoltage is not deemed to be a problem in that there will be less current draw at these higher voltages. This means that the motor winding temperature will be decreased; the amount of wear will be decreased; and the amount of insulation breakdown will be decreased. Therefore, operation of the motors at these higher levels of voltage will not have an adverse effect on the life of the motors.

In conclusion, the possibility of this overvoltage is deemed to be fairly remote. The value of 498 volts (+ 13.2%) is insignificantly above the specified value of 484 volts (+10%) and does not take into account the voltage drop in the feeder cables. Also, during a LOCA, as more loads are started, the voltage level drops such that this "worst case" overvoltage condition will be maintained for no more than three (3) minutes.

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TABLE I - COMPUTER RESULTS 4160V LEVEL

4160V LEVEL:

GRID VOLTAGE & LOAD	START-UP XFMR'S TAP # 4 USS XFMRS' TAP #: 1	2	3	AUX. XFMR TAP # 5 USS XFMRS' TAP #: 1	2	3
230 KV:						
NO LOAD	4266	4266	4266	4379	4379	4379
238 KV:						
MIN. LOAD		4378	4376			
LOCA	4083	4081	4079			
POST LOCA	4139	4137	4136			
LMS					3394	3392
POST LMS					4138	4136
230 KV:						
MIN. LOAD		4228	4226			
LOCA	3929	3926	3925			
POST LOCA	3983	3981	3979			
LMS				3263	3261	3259
POST LMS				3975	3972	3970
218.5 KV:						
LOCA	3707	3704	3703			
POST LOCA	3757	3755	3753			
LMS				3070	3068	3066
POST LMS				3734	3731	3729
216 KV:						
LOCA		3656				
POST LOCA		3706				
LMS					3025	
POST LMS					3678	
212.75 KV:						
LOCA	3595	3593	3591			
POST LOCA	3644	3642	3640			
LMS				2972	2970	2968
POST LMS				3612	3609	3606

Notes:

Min Load is 2.5MW on each Start-Up transformer.

LOCA - values shown are for last pumps to start during a LOCA, which are the second Emergency Service Water Pumps on each bus.

LMS - Largest Motor Starting: the Reactor Feed Pumps were used for this study.

TABLE II - COMPUTER RESULTS 480V LEVEL

480V LEVEL:

GRID VOLTAGE & LOAD	START-UP XFMR'S TAP # 4 — USS XFMRS' TAP #: 1	2	3	AUX. XFMR TAP # 5 — USS XFMRS' TAP #: 1	2	3
230 KV:						
NO LOAD	470	481	492	482	493	505
238 KV:						
MIN. LOAD		487	498			
LOCA	433	443	452			
POST LOCA	439	449	459			
LMS					384	393
POST LMS					455	466
230 KV:						
MIN. LOAD		460	481			
LOCA	417	426	435			
POST LOCA	423	432	441			
LMS				359	368	377
POST LMS				428	437	447
218.5 KV:						
LOCA	393	402	411			
POST LOCA	399	407	416			
LMS				338	347	355
POST LMS				402	410	420
216 KV:						
LOCA		397				
POST LOCA		402				
LMS					342	
POST LMS					405	
212.75 KV:						
LOCA	382	390	398			
POST LOCA	387	395	404			
LMS				326	334	343
POST LMS				389	397	406

Notes:

Min Load is 2.5MW on each Start-Up transformer.

LOCA - values shown are for last pumps to start during a LOCA, which are the second Emergency Service Water Pumps on each bus.

LMS - Largest Motor Starting: the Reactor Feed Pumps were used for this study.

TABLE III

Grid Voltage = 212.75 KV

BUS & LOAD	START-UP XFMRS. (TAP #4) RUNNING V	START-UP XFMRS. (TAP #4) STARTING V	AUXILIARY XFMR. (TAP #5) RUNNING V	AUXILIARY XFMR. (TAP #5) STARTING V
SWGR. 1C	3735	3661 *	3757	3675 *
Core Spray 1A	3731	3644	-	-
Core Spray 1C	3726	3626	-	-
Emerg. S.W.1-1	3730	3655	3652	3654
Emerg. S.W.1-2	3730	3655	3652	3654
SWGR. 1D	3673	3600 *	3663	3582 *
Core Spray 1B	3665	3566	-	-
Core Spray 1D	3669	3584	-	-
Emerg. S.W.1-3	3668	3594	3658	3561
Emerg. S.W.1-4	3668	3594	3658	3561
U.S.S.1A2(TAP-3)	411	382 *	419	390 *
Cont.Spray 1-1	408	361	-	-
Cont.Spray 1-2	408	361	-	-
CRD Feed 8A	410	378	417	382
C.S. BSTR. 3A	408	358	-	-
C.S. BSTR. 3C	408	358	-	-
R.B.CLSD.CLG.1-1	410	380	417	384
U.S.S. 1B2(TAP-3)	403	375 *	407	379 *
Cont.Spray 1-3	396	336	-	-
Cont.Spray 1-4	396	336	-	-
CRD Feed 8B	401	370	405	370
C.S. BSTR. 3B	398	346	-	-
C.S. BSTR. 3D	398	346	-	-
R.B.CLSD.CLG.1-2	400	366	404	367
U.S.S. 1A3(TAP-1)	406	357 *	406	354
Service Wtr. 1-1	405	353	405	350
U.S.S. 1B3(TAP-1)	398	350 *	395	344 *
Service Wtr. 1-2	397	345	394	340

*LOWEST BUS VOLTAGE DUE TO ANY MOTOR STARTING WHEN BUS IS AT FULL LOAD

TABLE IV

Grid Voltage = 212.75 KV

BUS & LOAD	START-UP XFMRS. (TAP #4) RUNNING V	START-UP XFMRS. (TAP #4) STARTING V	AUXILIARY XFMR. (TAP #5) RUNNING V	AUXILIARY XFMR. (TAP #5) STARTING V
MCC 1A21				
Liq.Pois.PP.	402	379	410	385
Fuel Pool Fltr.	407	388	414	393
V-20-21	408	404	415	411
V-20-3	411	410	418	418
V-20-33	411	410	418	418
V-20-12	408	404	415	411
V-21-7	411	410	418	417
V-21-9	411	410	418	417
V-21-11	411	410	418	418
V-21-17	411	411	418	418
V-21-18	411	411	418	418
V-3-88	411	410	418	418
V-20-27	410	409	417	416
MCC 1B21				
Liq.Pois.PP.	394	371	398	374
Fuel Pool Fltr.	398	379	402	382
V-5-106	403	403	406	406
V-20-4	402	402	406	406
V-20-18 & 40	399	395	403	399
V-20-26	402	401	405	404
V-5-147 & 148	403	402	406	406
V-20-32	402	402	406	405
CoreSprayFillPP.	401	397	404	400
V-21-1	402	401	405	404
V-21-3	402	401	405	404
V-21-5	402	402	406	406
V-21-13	402	402	406	406
V-21-15	403	403	406	406
V-3-87	402	402	406	405
V-5-166 & 167	403	402	406	406
MCC 1AB2				
V-20-41	399	395	403	399
V-14-30	397	391	401	395
V-14-32	397	391	401	395
V-14-36	396	389	400	393
V-14-37	396	389	400	393

Attachment #1 - Assumptions

1. According to General Electric technical publication No. GET-3101C, which was in effect at the time of MCC fabrication, the following starter voltage criteria apply:

Normal Voltage	460 VAC
Drop Out Voltage	60% of normal (276 V)
Pick Up Voltage	85% of normal (391 V)

   Testing of safety related starters at Oyster Creek showed that Size 1 and Size 2 starters will pick up below this value, but 85% was used for this study since this is the value guaranteed by General Electric.

2. The maximum voltage drop in control wiring for any safety-related starter circuit is 3 V. Since the motor starters' control transformers have a 4:1 ratio, 12 V on the primary of these transformers is required to account for this control wiring voltage drop. Thus the minimum voltage on the primary side of the control transformers which will guarantee all starters pick up is 403 V (391 V (from #1 above) +12 V).

3. Per random specifications which were checked, safety-related motors furnished for Oyster Creek were required to be capable of starting satisfactorily at a minimum voltage of 75% nominal. In addition, they were required to be capable of continuous operation at any voltage between +10% and -15% of nominal. Thus the guaranteed running voltage for motors rated at 440 V is from 374 V to 484 V with a minimum of 330 V required for starting. For motors rated at 4000 V, the operating range is from 3400 V to 4400 V with 3000 V required for starting.

4. The longest time required for any large motor at Oyster Creek to accelerate to running speed with rated voltage at its terminals is 7 seconds.

5. Per General Electric, the starting inrush for their starters at rated voltage is as follows:

Size 1	145 VA
Size 2	528 VA

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6. The minimum load on the Start-Up Transformers is 2.5 MW each. The basis for this valve is plant operating experience.

7. Where vendor information for motors was not available, the following values were used:

Efficiency	.9
Running pf	.85
Starting pf	.2
Lock Rotor/Full Load Current	6.5
Brake HP	Nameplate HP

8. ES signals trip the Reactor Recirculation Pumps.

9. The grid voltage range is from 212.75 KV to 238 KV. These valves were predicted by grid stability analysis.

10. Control relays are rated at 120 V and can withstand +10% overvoltage. This is equivalent to 528 V @ the 480 V level.

ATTACHMENT #2

PREDICTED VOLTAGE VS. MEASURED VOLTAGE

Bus	Predicted Value	Measured Value	Percent Deviation
2-1	6.991 KV	7.002 KV	-0.2%
2-3	4.209 KV	4.134 KV	+1.8%
2-5	4.207 KV	4.159 KV	+1.2%
2-1E	4.209 KV	4.151 KV	+1.4%
2-3E	4.207 KV	4.153 KV	+1.3%
USS2-11E	0.487 KV	0.478 KV	+1.9%
USS2-12E	0.492 KV	0.482 KV	+2.1%
USS2-31E	0.497 KV	0.492 KV	+1.0%
2-2	7.056 KV	7.092 KV	-0.5%
2-4	4.244 KV	4.198 KV	+1.1%
2-6	4.241 KV	4.213 KV	+0.7%
2-4E	4.243 KV	4.219 KV	+0.6%
USS2-21E	0.491 KV	0.484 KV	+1.4%
USS2-22E	0.497 KV	0.490 KV	+1.4%
USS2-41E	0.501 KV	0.497 KV	+0.8%
2-2E	4.244 KV	4.218 KV	+0.6%