Attachment 3

Engineered Safeguards

Busses Voltage Calculations

Purpose: To compare Engineered Safeguards Bus Voltages with those measured by Florida Power Corporation.

Sources of Information: These are identifed at the appropriate part of the calculations.

Computer Calculation: Not applicable

Assumptions: These are identified at the appropriate part of the calculations.

Indetification of End Results: The comparison of calculated and measured voltages is shown in the Table at the end of the calculations.

The actual one line diagram used (except for impedance values) is given on page 37 of Calculations 11/20/79 in "Adequacy of Station Electric Distribution Voltages - Crystal River 3".

4.16 KV LOADS

Rated KVA taken from "Crystal River Unit 3 - Auxiliary Loading pages 3 and 4.

Number of motors running taken from those in "Adequacy of Station Electric Distribution voltages" pages 4, 5 of Calculations 10/21/80. KVA calculated from latest current information shown on the motor data sheets.

Power factors were also taken from motor data sheets; the power factor of the Auxiliary Building Exhaust Fans, since they were running at just over 50% load was estimated from the full load power factor.

As the impedance of an induction motor will vary as the voltage applied to the terminals, the terminal voltage was estimated at .99 of 4.16 KV (base voltage) from preliminary calcuations.

The impedance of an induction motor when running is given by

$$Z_{base} = Z_{rated} \times \frac{(\text{Actual Terminal Voltage})^2}{\text{Base Voltage}}$$

In calculating the impedance from rated KVA, in terms of the base MVA, motor KVA has been multiplied by $\left(\frac{\text{Base Voltage}}{\text{Actual Terminal Voltage}}\right)^2$, since impendance is proportioned to the inverse of the KVA.

Motor impedance is then $\frac{\text{Base MVA}}{\text{Motor MVA}}$

Base MVA has been taken throughout as 100.

	KVA						Converted to 4.16KV Base		
Unit Bus 3A	Rated	Running	pf	KW	KVAR	Motor Volts	MW	MVAR	MVA
1. CW Pump 3A	1700	1700	.822	1397	968	.99			
2. CW Pump 3C	1700	1700	.822	1397	968	.99			
3. Sec. Service Closed Cycle Pp. 3A	317	317	.875	277	153	.99			
4. Feedwater Boster Pp.	2110	2110	.91	1920	875	.99			
5. Condensate Pp. 3A	1750	1750	.9	1575	763	.99			
6. Normal Nuc. Serv. Sea Water Pp. 3	328	328	.843	277	176	.99			
7. Aux. Bldg. Exh.	180	100	.85	85	53	.99			
8.				6928	3956		7.069	4.036	8.14
Unit Bus 3B									
9. CW Pump 3B	1700	1700	.822	1397	968	.99			
10. CW Pump 3D	1700	1700	.822	1397	968	.99			
11. Sec Service Closed Cycle Pp. 3B	317	317	.875	277	153	.99			

Unit Bus 3B	KVA Rated	KVA Running	pf	KW	KVAR	Motor Volts	Converted to 4.16KV Base MW	MVAR	MVA
12. Feedwater Booster	2110	2100	.91	1920	875	.99			
13. Condensate Pp. 3B	1750	1750	. 9	1575	763	.99			
14. Norm. Nuc. Serv. CCC Pp. 3	227	227	.843	277	176	.99			
15. Aux. Bldg. Exh.	180	100	.85	85	53	.99			
16. Fan 3B				6851	3888		6.99	3.967	8.0372

	Z	Ø	R + jX
Unit Bus 3A	12.285	29.72°	10.669 + j 6.0904
Unit Bus 3B	12.442	29.58°	10.82 + j 6.142

ES Bus 3A	KVA Rated	KVA Running	pf	KW	KVAR	Motor Volts	Converted to 4.16KV Base MW	MVAR	MVA
Make UP Pump 3A	588	588	.926	545	222	.99			
Reactor Bldg. Spray Pump 3A	215	215	.925	199	82	.99			
Decay Heat Pump	339	339	.921	312	132	.99			
Emerg. N. S. Sea Water Pump 3A	643	643	.87	559	317	.99			
Emerg. N. S. CCC Pump 3A	620	620	.89	552	283	.99			
Decay Heat Serv. Sea Water Pp.	285	285	.827	236	160	.99			
				2403	1196		2.452	1.22	2.7387

	Z	Ø	R + jX
ES Bus 3A	36.513	26.45	32.691 + j 16.264
ES Bus 3B	36.513	26.45	32.691 + j 16.264

6.9 KV LOADS

Only the Reactor Coolant Pumps.

Volts = 6.6 KV FLC = 685 amp. 1250 rmp. synchronous

KVA Input = ✓ 3 x 6.6 x 685 = 7830

hp = 9000

kW Output = 9000 x .746 = 6714

pf x efficiency = $\frac{6714}{7830}$ = .8575

Efficiency must be less than unity, so that pf must be greater than .8575.

Examine 4 KV Motors

hp	rpm	efficency	pf	
2000	1200	.946	. 9	
1750	257	.934	.822	low speed, not fair comparison
400	1800	.938	.921	
800	1800	.936	. 89	
2500	1800	.948	. 91	
700	1800	.951	.926	
700	900	.933	. 87	
700	1200	.933	. 89	

Lowest efficiency = .933 If we use this, pf would be $\frac{.8575}{.933}$ = .919 Highest pf in above table = .926, but his is at 1800 rpm.

Suggest use .9 pf for reactor coolant pump motor.

Running Load = 4 x 7020 KVA = 28.08 MVA at 6.6KV.

Impedance at rated volts on 100 MVA base = $\frac{100}{28.08}$ = 3.56125 pu.

Preliminary calculations showed that volts at motor terminals was approximately 1.033 pu of base voltage, 6.9 KV

Impedance at 6.9 KV = $3.56125 \times 1.033^2 = 3.8007 \angle j25.84$

$= 3.42021 + j\ 1.65634$

480 V LOADS

Loads directly connected to the 480 V Switchgear Buses are taken from "Adequacy of Station Electric Distribution Voltages" - Calculations 10/21/80 pp. 5 thru 7. Pf taken from motor data sheets. Motor KVA Loads are based on 460 volts. See "Crystal River 3 - Auxiliary Loading."

Loads on Motor Control Centers are taken from "Adequacy of Station Electric Distribution Voltage" - Calculations 11/20/79. For the ES Buses the case is Load at End of Block Loading Sequence Including Manually Applied Loads. The loads have been calculated on 480 volts so the motor loads must first be expressed in terms of the 460 volt rating - See "Crystal River 3 - Auxiliary Loading". From examination of motor data sheets it was apparent that an average pf of 0.85 would be a suitable value.

Non motor loads were expressed at 480 volts, so as these are constant impedance loads there is no need to convert to a rated 460 volts.

In order to simulate cable impedances to loads, the load impedances were increased by 2%.

Motor Terminal voltages on the Unit Buses were estimated to be 94% of base voltage and 93% of base voltage on ES Buses. These figures were obtained from preliminary calculations.

480 V LOADS CONNECTED DIRECTLY TO SWITCHGEAR BUSES

	KVA 460. V			Running		KVA 480 V
	Connected	Running	pf	KW	KVAR	
Condr. Vac. Pump 3A	137	137	. 92	126	54	
Station Service Air Compressor 3A	91	50	.905	45	21	
React Bldg. Ind. Cooler Pump 3A	73	50	.835	42	28	
Cond. Injection Pump 3A	134	50	.915	46	20	
				259	123	
Resistive						315
480V React Aux Bus 3A						
Inst. Air Compressor 3A		50	.905	45	21	
Resistive						345
480V Intake Bus 3A						
Screen Wash Pump		70	. 85	60	37	
480V Heating Bus 3						
Heaters						827
480V Turbine Bus 3B						
Motors - As Bus 3A				259	123	
Heaters						195
480V Reactor Aux. Bus 3B						
Motors - As Bus 3A		50	.905	45	21	
Heaters						20

	KVA 460. V Connected	Running pf	Running kW	Running KVAR	KVA 480 V
480V Intake Bus 3B					
Screen Wash Pump 3B		70 . 85	60	37	
Screen Wash Pump 3C		70 . 85	60	37	
			120	74	
480V ES Bus 3A					
Decay Heat CCC Pump 3A		96 . 86	83	49	
Cont. Comp. Wat. Chiller 3A		213 . 9	192	93	
			275	142	
480V ES Bus 3B					
As Bus 3A			275	142	
480V Plant Aux. Bus 3					
Resistive					733

4.16KV UNIT BUS 3A 480V LOAD IMPEDANCES

	KVA 480V	KW 460V	KVAR 460V	Motor Volts	Converted to 480V KW	Converted to Base KVAR	MVA	Z	Ø	1.02Z	R + j x
Heating Transformer											
Resistive	827						.827	120.92	0	123.34	123.34+j0
Machine Shop MCC											
Motors	102.3	83.4	51.75	.94	94.39	58.57					
Heaters	177				177	58.57					
					271.39	58.57	.27764	360.18	12.18	367.38	359.11+j77.5
Turbine Aux xfr. 3A											
Turbine Bus 3A											
Motors		259	123	.94	293	139					
Heaters	315				315						
					608	139	.62369	160.34	12.88	163.54	159.43+j36.45
Turbine MCC 3A											
Motors	288	235	146	.94	266	165					
Heaters	219				219						
					485	165	.5123	195.2	18.79	199.1	188.49+j64.13
Water Treat MCC 3A											
Motors	205.4	167	104	.94	189	118					
Heaters	50				50						
					239	118	.26654	375.17	26.28	382.68	343.13+j169.43

4.16KV UNIT BUS 3A 480V LOAD IMPEDANCES (Cont'd)

	KVA 480V	KW 460V	KVAR 460V	Motor Volts	Converted to 480V KW	Converted to Base KVAR	MVA	Z	ø	1.02Z	R + j x
Vent MCC 3A											
Motors	284	231	143	.94	261	162					
Heaters	125				12.5						
					273.5	162	.31788	314.59	30.64	320.88	276.08+j163.53
Reactor Aux. xfr 3A											
Reator Bus 3A											
Motors		45	21	.94	51	24					
Heaters	345				345						
					396	24	.39673	252.06	3.47	257.1	256.63+j15.56
Reactor MCC 3A1											
Motors	52.2	43	26	.94	49	29					
Heaters	124.3				124.3						
					173.3	29	.17571	569.12	9.5	500.5	493.64+j82.61
Press. Heater MCC 3A	726				726		.726	137.74	0	140.5	140.5+j0

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4.16KV UNIT BUS 3A 480V LOAD IMPEDANCES (Cont'd)

	KVA 480V	KW 460V	KVAR 460V	Motor Volts	Converted to 480V KW	Converted to Base KVAR	MVA	Z	∅	1.02Z	R +
Reactor MCC 3A2											
Motors	92.6	75	47	.94	85	53					
Heaters	114.4				114.4						
					199.4	53	.20632	484.68	14.8[illegible]	494.37	477.79+j126.95
Intake xfr. 3A											
Intake Bus 3A											
Motors		60	37	.94	68	42	.07992	1251.17	31.7	1276.2	1085.81+j670.61
Heaters											
Intake MCC 3A											
Motors	54.2	44	28	.94	50	32					
Heaters	60				60						
					110	32	.11456	872.9	16.22	890.36	854.92+j248.7

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4.16KV UNIT BUS 3B 480V LOAD IMPEDANCES

	KVA 480V	KW 460V	KVAR	Motor Volts	Converted to 480V KW	Base KVAR	MVA	Z	ø	1.02Z	R + j x
Turbine Aux xfr. 3B											
Turbine Bus 3B											
Motors		259	123	.94	293	139					
Resistive	195				195						
					488	139	.50741	197.08	15.9	201.02	193.33+j55.07
Turbine MCC 3B											
Motors	206.9	169	104	.94	191	118					
Resistive	132				132						
					323	118	.34388	290.8	20.07	296.62	278.61+j101.79
WT MCC 3B											
Motors	150.5	123	76	.94	139	86					
Resistive	96				96						
					235	86	.25024	399.61	20.1	407.61	382.78+j140.08

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4.16KV UNIT BUS 3B 480V LOAD IMPEDANCES (Cont'd)

	KVA 480V	KW 460V	KVAR 460V	Motor Volts	Converted to 480V KW	Converted to Base KVAR	MVA	Z	ø	1.02Z	R + j x
Vent MCC 3B											
Motors	299	243	151	.94	275	171					
Resistive	21				21						
					296	171	.34184	292.53	30.02	298.39	258.36+j149.29
Reactor Aux. xfr 3B											
Reactor Bus 3B											
Motors		45	21	.94	51	24					
Resistive	20				20						
					71	24	.07495	1334.28	18.68	1360.97	1289.28+j435.89
Reactor MCC 3B1											
Motors	42.3	35	21	.94	40	24					
Resistive	57				57						
					97	24	.09992	1000.75	13.9	1020.77	990.88+j245.22

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4.16KV UNIT BUS 3B 480V LOAD IMPEDANCES (Cont'd)

	KVA 480V	KW 460V	KVAR	Motor Volts	Converted to 480V KW	Base KVAR	MVA	Z	∅	1.02Z	R + j x
Reactor MCC 3B2											
Motors	83.5	68	42	.94	77	48					
Resistive	147				147						
					224	48	.22909	436.52	12.09	445.25	435.37+j93.26
Press Heater 3B	847				847		847	118.06	0	120.43	120.63+j0
Intake xfr 3B											
Intake Bus 3B											
Motors		120	74	.94	136	84	.15985	625.59	317	638.1	542.9+j335.3
WTMCC 3C											
Motors	134	109	68	.94	123	77	.14511	689.11	32.05	702.9	595.77+j373

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4.16KV UNIT BUS 3A 480V LOAD IMPEDANCES

	KVA 480V	KW 460V	KVAR	Motor Volts	Converted to 480V KW	Base KVAR	MVA	Z	Ø	1.02Z	R + j x
ES Aux xfr 3A											
ES Bus 3A											
Motors		275	142	.93	318	164	.3578	279.49	27.28	285.08	253.37+j130.66
ES MCC 3A1											
Motors	97.1	80	49	.93	92	57					
Resistive	213				213						
					305	57	.31028	322.29	10.59	328.73	323.13+j60.41
ES MCC 3A2											
Motors	240.1	196	122	.93	227	141					
Resistive	88				88						
					315	141	.34512	289.76	24.11	295.55	269.77+j120.73
ES MCC 3AB											
Motors	119.4	98	60	.93	113	69					
Resistive	39				39						
					152	69	.16693	599.06	24.42	611.04	556.38+j252.62

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4.16KV UNIT BUS 3B 480V LOAD IMPEDANCES

	KVA 480V	KW 460V	KVAR 460V	Motor Volts	Converted to 480V KW	Converted to Base KVAR	MVA	Z	Ø	1.02Z	R + j x
ES Aux xfr 3B											
Motors		275	142	.93	318	163	.3578	279.49	27.28	285.08	253.37+j130.66
ES MCC 3B1											
Motors	260.9	213	132	.93	246	153					
Reristive	96				96						
					342	153	.37466	266.91	24.1	272.25	248.52+j111.16
ES MCC 3B2											
Motors	70.95	58	35	.93	67	40					
Resistive	236				236						
					303	40	.30563	327.19	7.52	333.74	330.87+j43.68
ES MCC 3AB		98	60	.93	113	69					
	39				39						
					152	69	.16693	599.06	24.42	611.04	556.38+j252.62
Plant Aux xfr 3	733						.733	136.43	0	139.15	139.15+j0

NOTE: As ES MCC 3AB can be supplied from either ES Bus 3A or ES Bus 3B, for the purpose of the calculation it was assumed to be supplied from ES Bus 3A.

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CABLE IMPEDANCES

4.16 and 6.9 KV cable impedances were ignored. Previous experience has shown that for voltage drop calculations, these impedances are so small as to be justifiably disregarded.

Although cable impedances from 480 volt switchgear to Motor Control Centers are of little significance, they were taken into account by using actual lengths; the resistance and reactance for 1000 yards were taken from typical 600 V cable information.

REACTORS

The per unit values of reactance were taken from "Adequacy of Station Electric Distribution Voltages - Crystal River 3" - Calculations dated 11/20/79.

Reactor Aux xfr 3A	Reactor MCC 3A1	500	2	.0294	.0257	538	.00791	.00691	3.433	2.999	-	2.999
	Press. Htr. MCC 3A	750	3	. 021	. 025	313	.00219	.00261	.9505	1.1328	2.1701	3.3029
	Reactor MCC 3A2	350	2	.0406	.0264	309	.00627	.00408	2.721	1.771	1.997	3.768
Intake Aux xfr 3A	Intake MCC 3A	350	1	.0406	.0264	60	.00122	.00158	.53	.686	-	.686
Turbine Aux xfr 3B	Turbine MCC 3B	500	2	.0294	.0257	356	.00524	.00457	2.274	1.984	1.997	3.981
	WT MCC 3B	500	2	.0294	.0257	416	.00612	.00535	2.656	2.322	1.997	4.319
	Vent MCC 3B	500	2	.0294	.0257	318	.00468	.00409	2.118	1.755	1.997	3.752
Reactor Aux xfr 3B	Reactor MCC 3B1	500	2	.0294	.0257	530	.00779	.00681	3.381	2.956	-	2.956
	Press. Htr. MCC 3B	750	3	. 021	.025	326	.00228	.00272	.9896	1.181	2.1701	3.3511
	Reactor MCC 3B2	500	2	.0294	.0257	347	.0051	.00446	2.214	1.936	-	1.936
Intake Aux xfr 3B	WT MCC 3C	500	2	.0294	.0257	630	.00926	.0081	4.019	3.516	-	3.516
ES Aux xfr 3A	ES MCC 3A1	350	2	.0406	.0264	120	.00244	.00158	1.059	.686	-	.686
	ES MCC 3A2	350	2	.0406	.0264	157	.00319	.00207	1.385	.898	-	.898
	ES MCC 3AB	500	1	.0294	.0257	265	.00779	.00681	3.381	2.956	-	2.956
ES Aux xfr 3B	ES MCC 3B1	500	2	.0294	.0257	198	.00291	.00254	1.263	1.102	-	1.102
	ES MCC 3B2	500	2	.0294	.0257	226	.00332	.0029	1.441	1.259	-	1.259
	ES MCC 3AB	500	1	.0294	.0257	295	.00867	.00758	3.763	3.29	-	3.29

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CABLE IMPEDANCES

4.16 and 6.9 KV cable impedances for voltage drop calculations, t disregarded.

Although cable impedances from 4 little significance, they were t resistance and reactance for 100 information.

REACTORS

The per unit values of reactance Distribution Voltages - Crystal

TRANSFORMER IMPEDANCES

The Start Up Transformer equivalent circuit impedance was developed from test data supplied by telephone 6/15/82 from Florida Power Corporation.

The 4160/480 volt transformer impedances were obtained from Test Reports in Correspondence File EE (letter dated 7/8/1971.) As it was not known which serial number applied to individual transformers an average value was taken for each KVA rating. Individual values were so close that any variation would be insignificant.

The tap setting for the Start Up Transformer was 224 250 volts which was the setting when voltage measurements were taken.

As FPC did not know the taps on which the 4160/480 volt transformer were set, calculations were performed with those transformers on nominal taps. (Telephone conversation with FPC 6/17/82).

START-UP TRANSFORMER IMPEDANCES

Resistance

Load Loss H-X = 31.9 KW at 18 MVA

Load Loss H-Y = 62.5 KW at 15 MVA

Load Loss X-Y = 77.65 KW at 15 MVA

Rpu H-X = $\frac{31.9}{18000}$ = .001772 at 18 MVA = .009844 at 100 MVA

H-Y = $\frac{62.5}{15000}$ = .004167 at 15 MVA = .02778 at 100 MVA

X-Y = $\frac{77.65}{15000}$ = .005177 at 15 MVA = .034513 at 100 MVA

$$HO = \frac{HX+HY-XY}{2} = \frac{.009844+.02778-.034513}{2} = .001556 \text{ pu}$$

$$OX = \frac{HX+XY-HY}{2} = \frac{.009844+.034513-.02778}{2} = .008289 \text{ pu}$$

$$OY = \frac{XY+HY-HX}{2} = \frac{.034513+.02778-.009844}{2} = .026225 \text{ pu}$$

Zpu H-X = .0585 pu at 18 MVA = .325 pu at 100 MVA
H-Y = .086 pu at 15 MVA = .57333 pu at 100 MVA
X-Y = .1158 pu at 15 MVA = .772 pu at 100 MVA

$$HO = \frac{.325+.57333-.772}{2} = .063165$$

$$OX = \frac{.325+.772-.57333}{2} = .261835$$

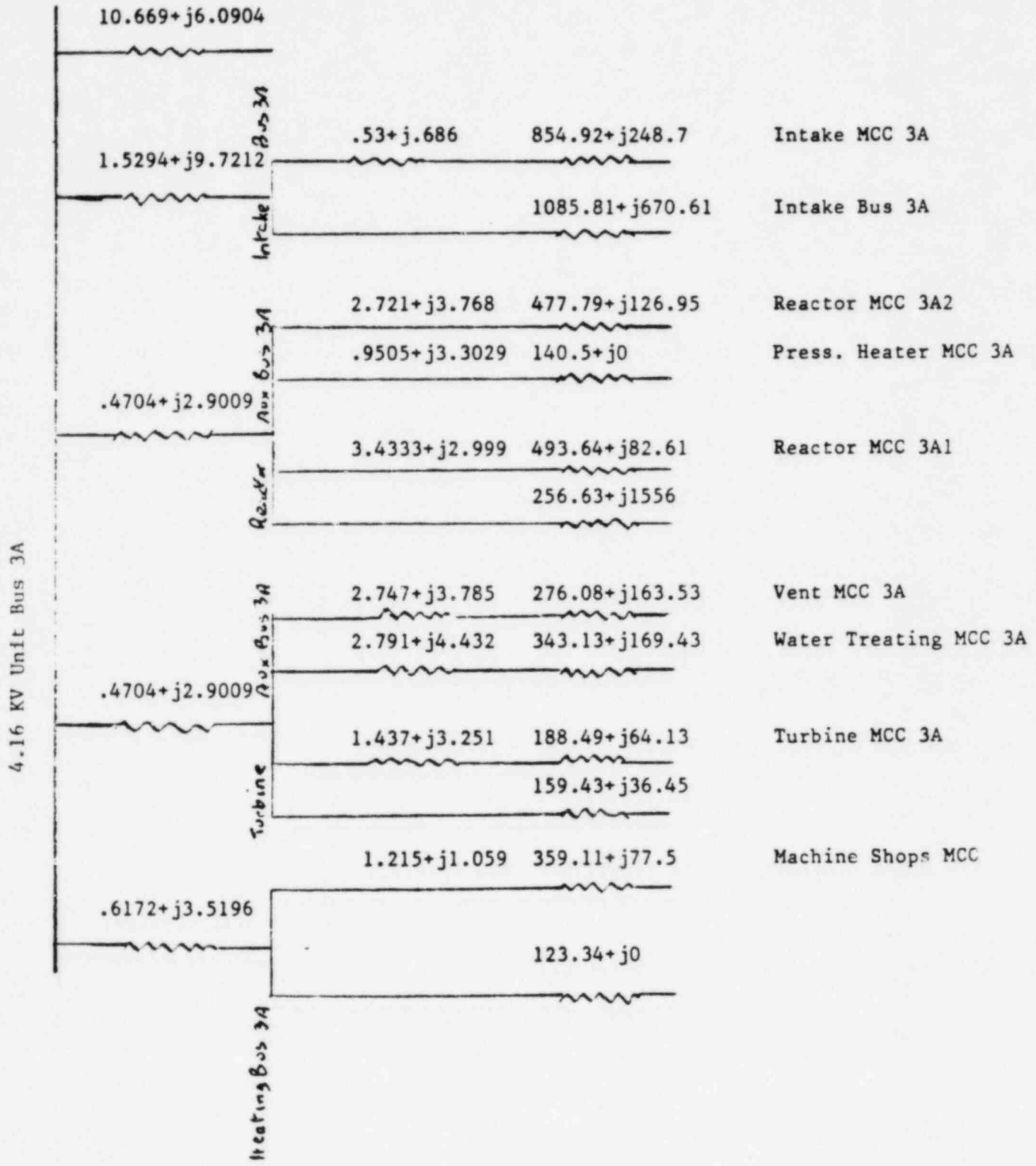
$$OY = \frac{.772+.57333-.325}{2} = .510165$$

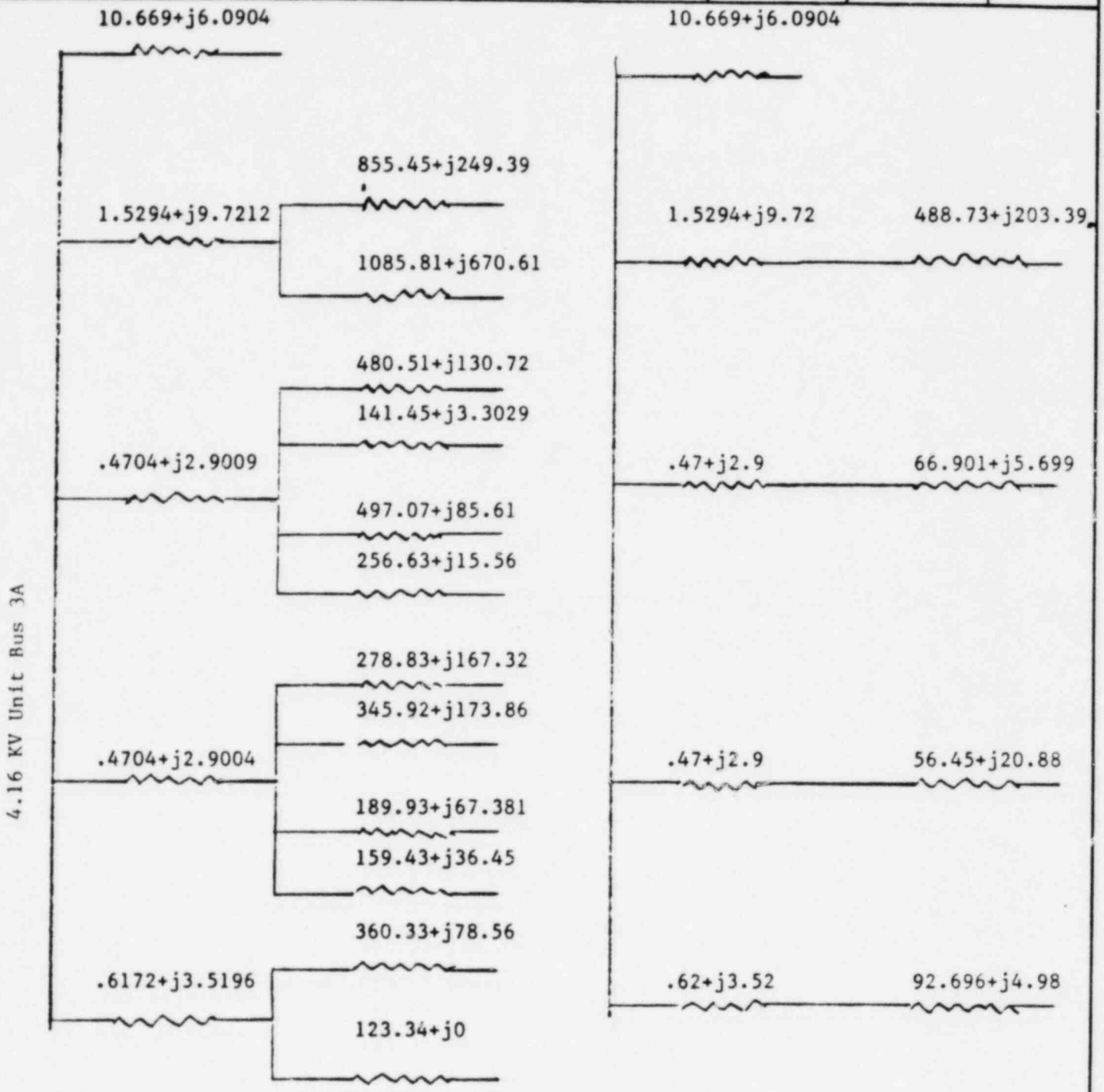
$$Xpu = Zpu^2 - R^2pu^{1/2}$$

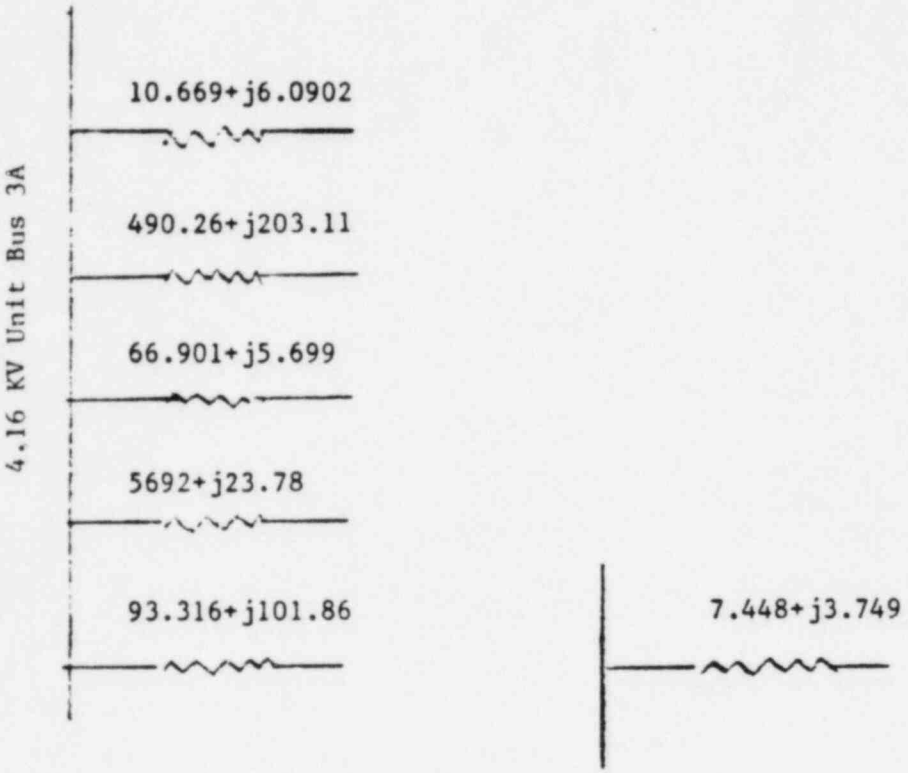
$$HO = .063165^2 - .0015562^{1/2} = .063146$$
$$OX = .261835^2 - .008289^2{}^{1/2} = .261704$$
$$OY = .510165^2 - .026225^2{}^{1/2} = .509491$$

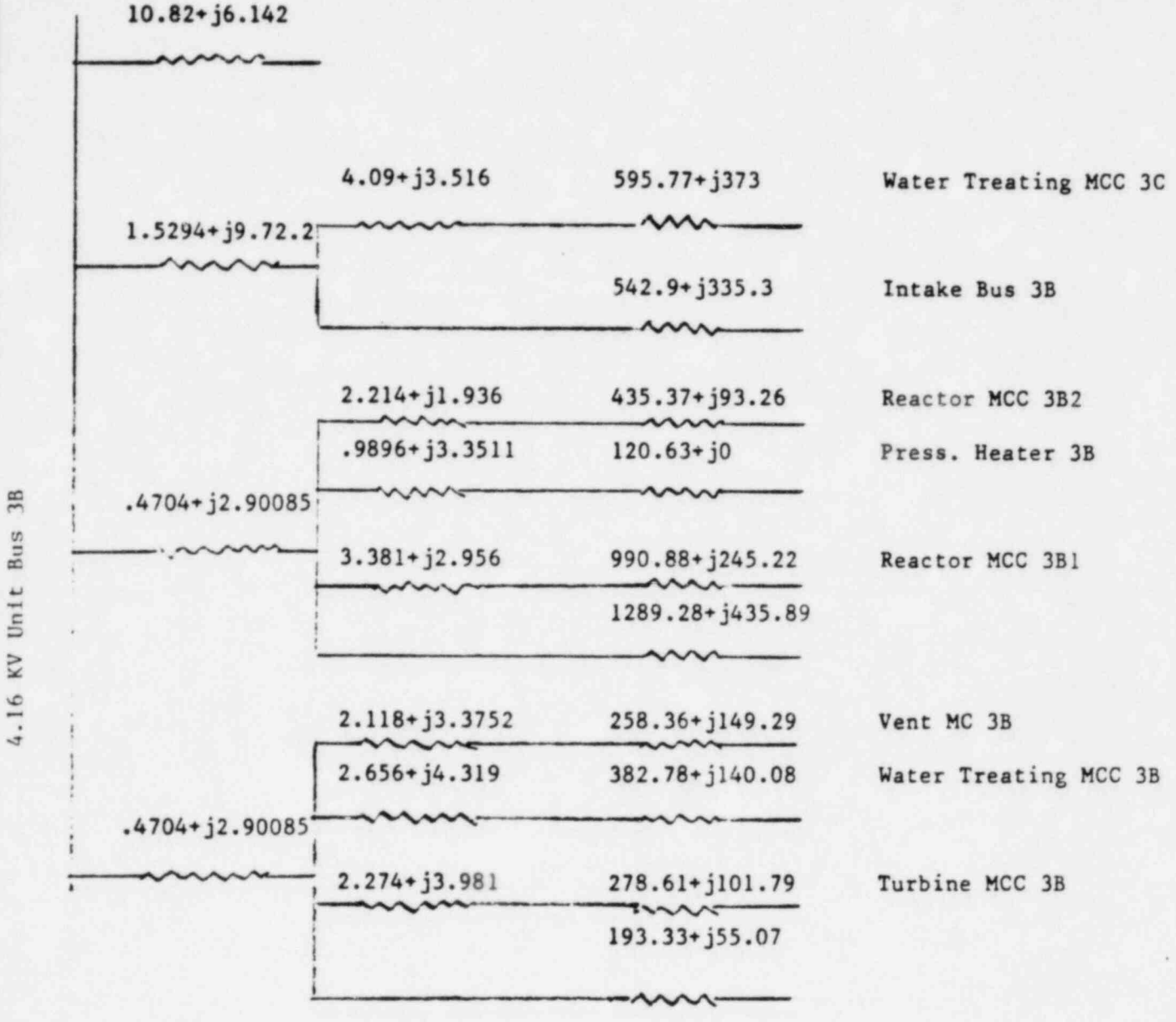
4160/480 VOLT TRANSFORMER IMPEDANCES

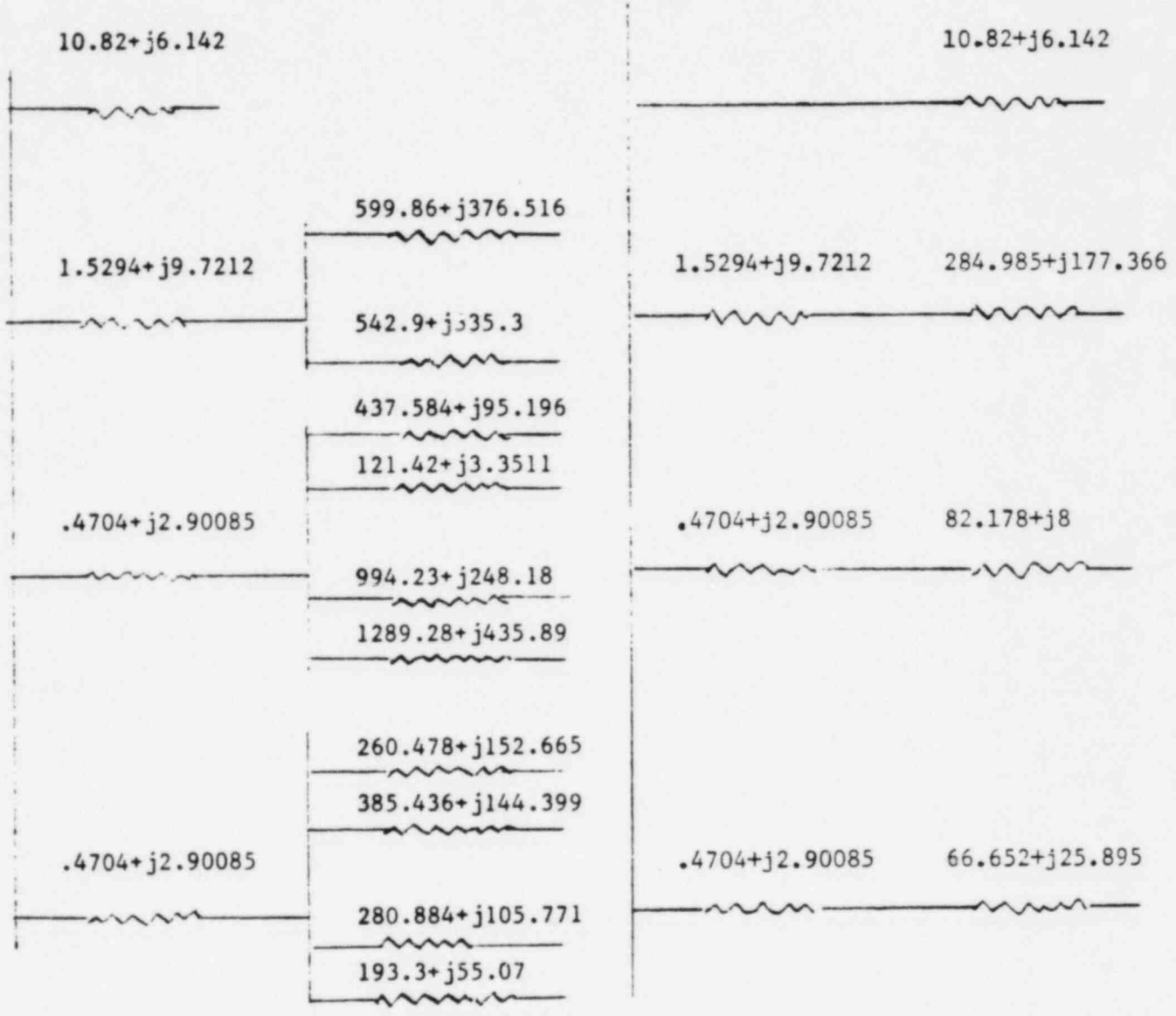
KVA	LOAD LOSS KW	R%	Z%	X%	DARE	SERIAL NO.	PER UNIT IMPEDANCE ON 100 MVA BASE R	X
500	3.816	.7632	4.85	4.7896	1.29.71	48-20329-C1		
500	3.831	.7662	4.99	4.9315	1.29.71	48-20329-D1		
Average		.7647		4.8606			1.5294	9.7212
1000	11.973	1.1973	5.35	5.2143	1.26.71	20329-B1		
	11.871	1.1871	5.32	5.1859		20329-B2		
	11.858	1.1858	5.28	5.1451		20329-B3		
Average	11.9007	1.1907		5.1818			1.1907	5.1818
1500	13.887	.9258	5.36	5.2794	2.10.71	20329-A3	.6172	3.5196
2000	18.705	.9533	5.97	5.8934	5.14.71	48-20329-E01		
	18.775	.93875	5.96	5.8856	5.14.71	48-20329-E02		
	19.034	.9517	5.95	5.8734	5.15.71	48-20329-E03		
	18.39	.9195	5.63	5.5544	5.15.71	48-20329-E04		
Average		.9408		5.8017			.4704	2.90085

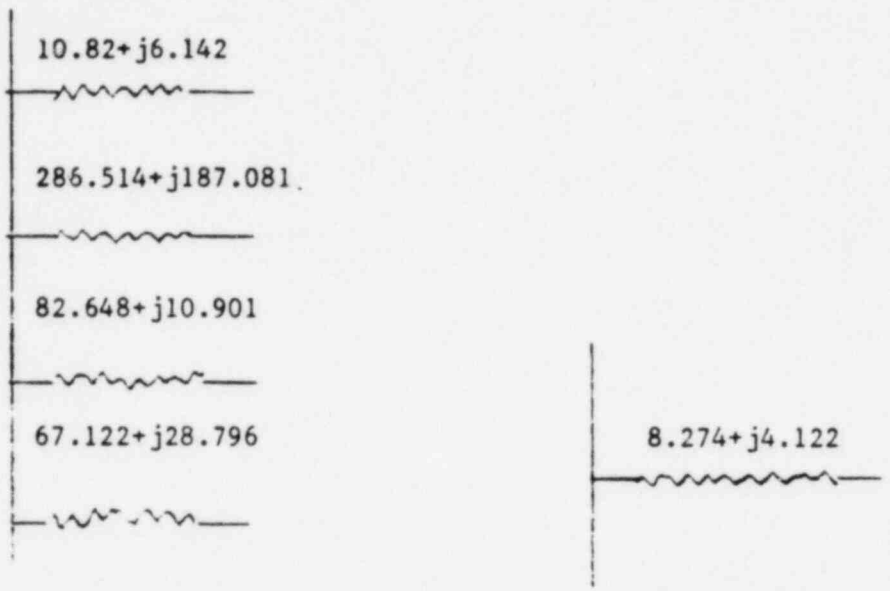

4.16 KV Unit Bus 3A
10.669+j6.0904
1.5294+j9.7212
Bus 3A
.53+j.686
854.92+j248.7
Intake MCC 3A
Intake
1085.81+j670.61
Intake Bus 3A
.4704+j2.9009
Aux Bus 3A
2.721+j3.768
477.79+j126.95
Reactor MCC 3A2
.9505+j3.3029
140.5+j0
Press. Heater MCC 3A
Reactor
3.4333+j2.999
493.64+j82.61
Reactor MCC 3A1
256.63+j1556
.4704+j2.9009
Aux Bus 3A
2.747+j3.785
276.08+j163.53
Vent MCC 3A
2.791+j4.432
343.13+j169.43
Water Treating MCC 3A
Turbine
1.437+j3.251
188.49+j64.13
Turbine MCC 3A
159.43+j36.45
1.215+j1.059
359.11+j77.5
Machine Shops MCC
.6172+j3.5196
123.34+j0
Heating Bus 3A

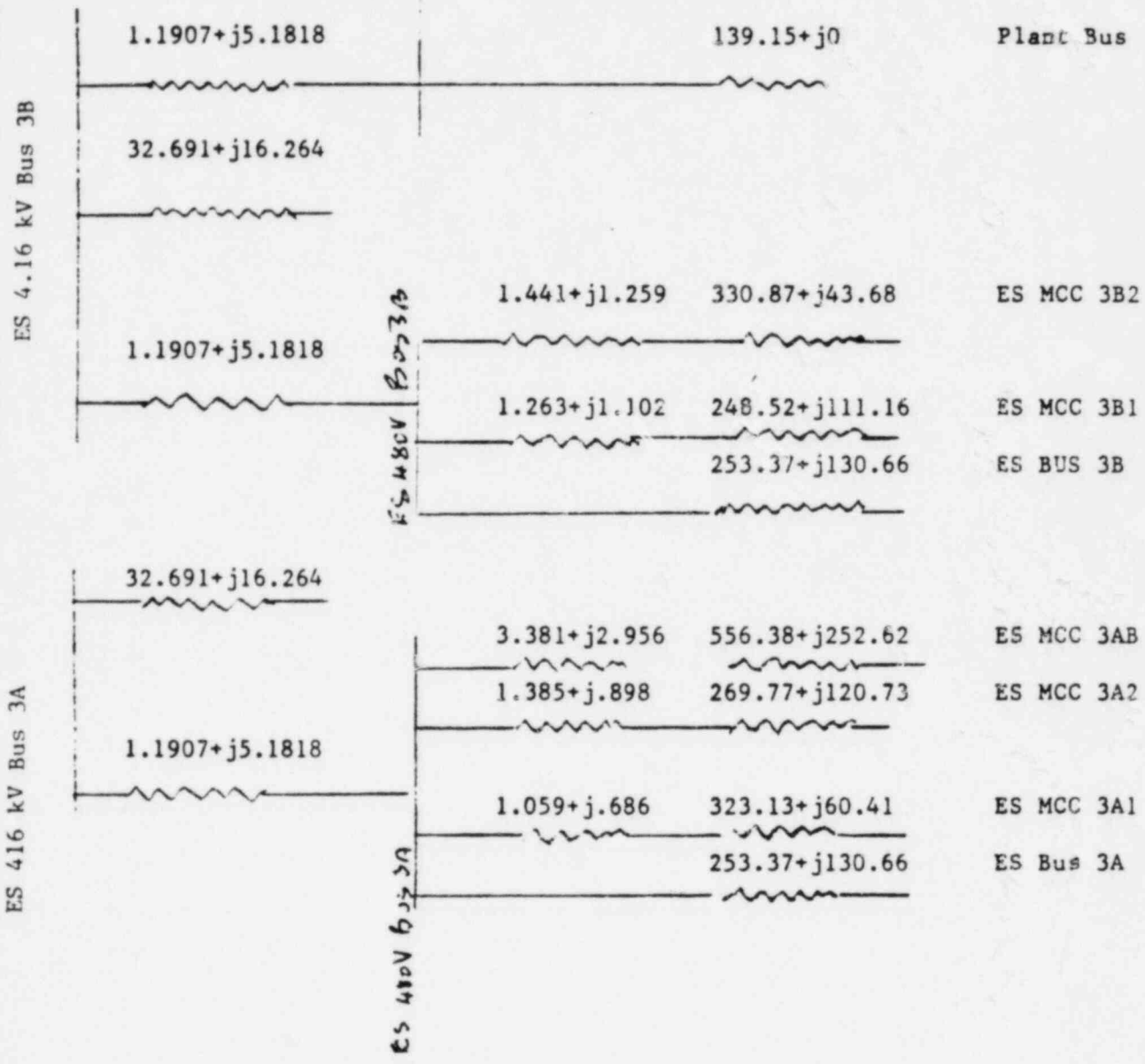

4.16 KV Unit Bus 3A
10.669+j6.0904
1.5294+j9.7212
855.45+j249.39
1085.81+j670.61
.4704+j2.9009
480.51+j130.72
141.45+j3.3029
497.07+j85.61
256.63+j15.56
.4704+j2.9004
278.83+j167.32
345.92+j173.86
189.93+j67.381
159.43+j36.45
.6172+j3.5196
360.33+j78.56
123.34+j0
10.669+j6.0904
1.5294+j9.72
488.73+j203.39
.47+j2.9
66.901+j5.699
.47+j2.9
56.45+j20.88
.62+j3.52
92.696+j4.98

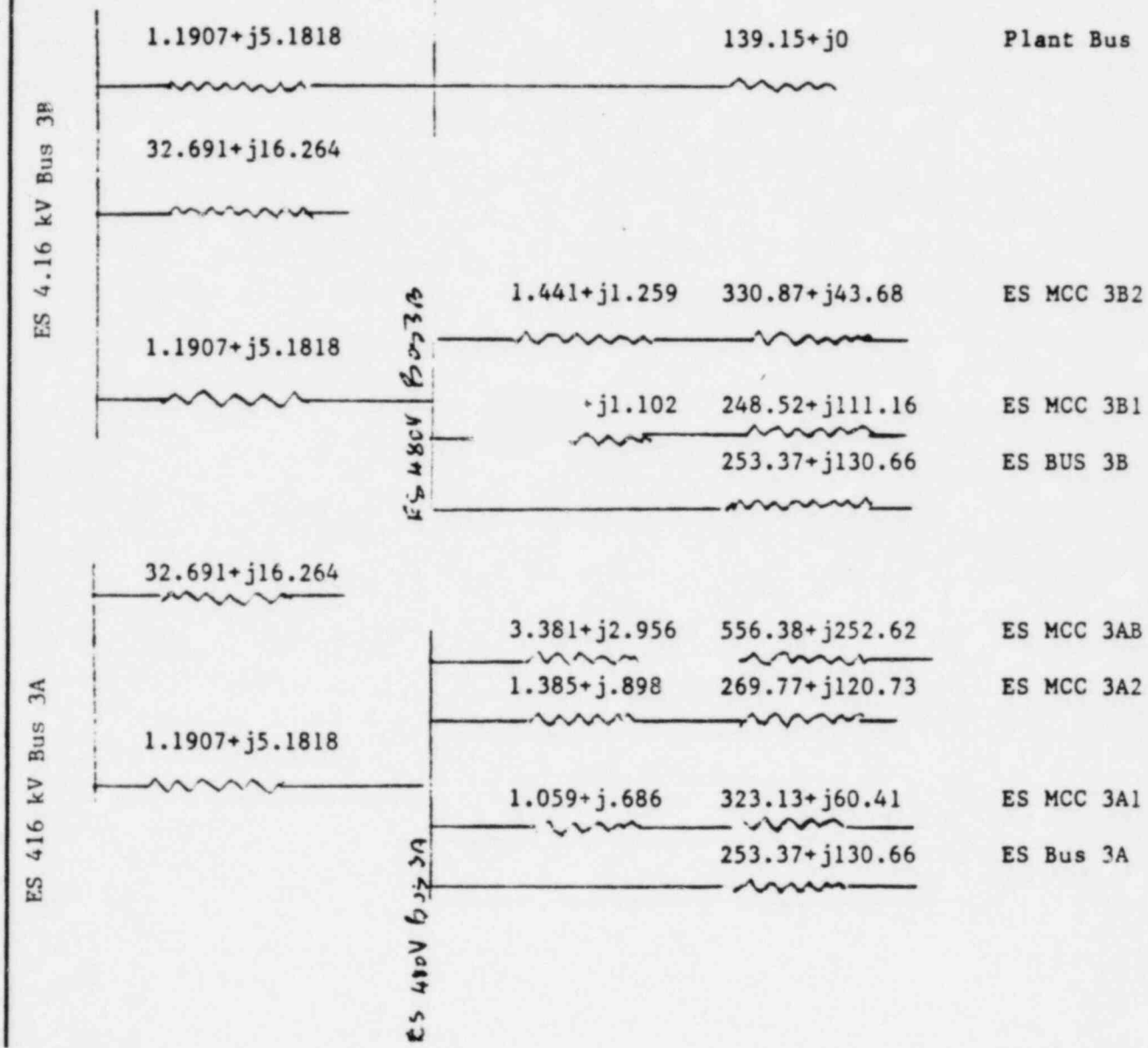

4.16 KV Unit Bus 3A
10.669+j6.0902
490.26+j203.11
66.901+j5.699
5692+j23.78
93.316+j101.86
7.448+j3.749

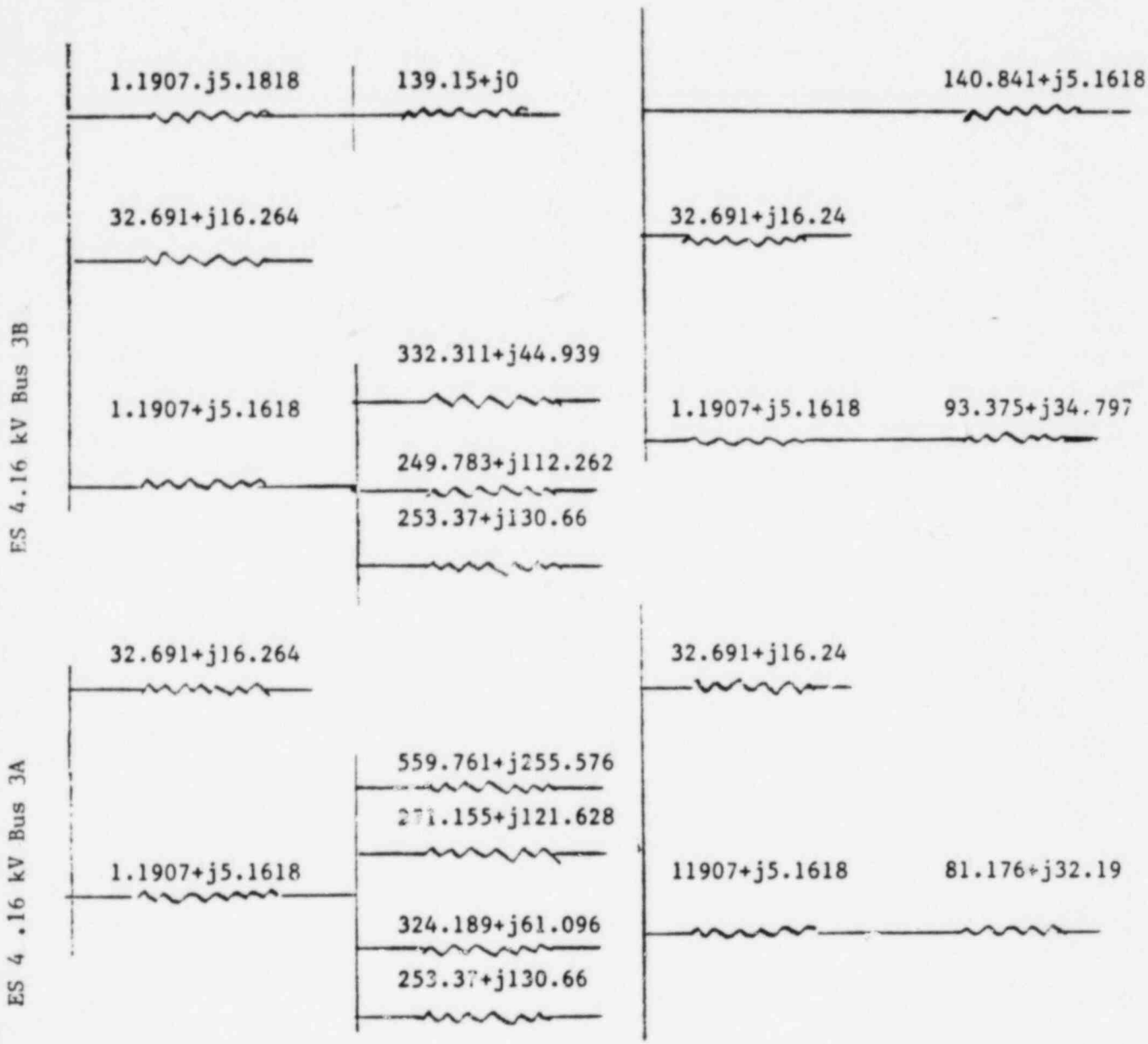

4.16 KV Unit Bus 3B
10.82+j6.142
4.09+j3.516
595.77+j373
Water Treating MCC 3C
1.5294+j9.72.2
542.9+j335.3
Intake Bus 3B
2.214+j1.936
435.37+j93.26
Reactor MCC 3B2
.9896+j3.3511
120.63+j0
Press. Heater 3B
.4704+j2.90085
3.381+j2.956
990.88+j245.22
Reactor MCC 3B1
1289.28+j435.89
2.118+j3.3752
258.36+j149.29
Vent MC 3B
2.656+j4.319
382.78+j140.08
Water Treating MCC 3B
.4704+j2.90085
2.274+j3.981
278.61+j101.79
Turbine MCC 3B
193.33+j55.07

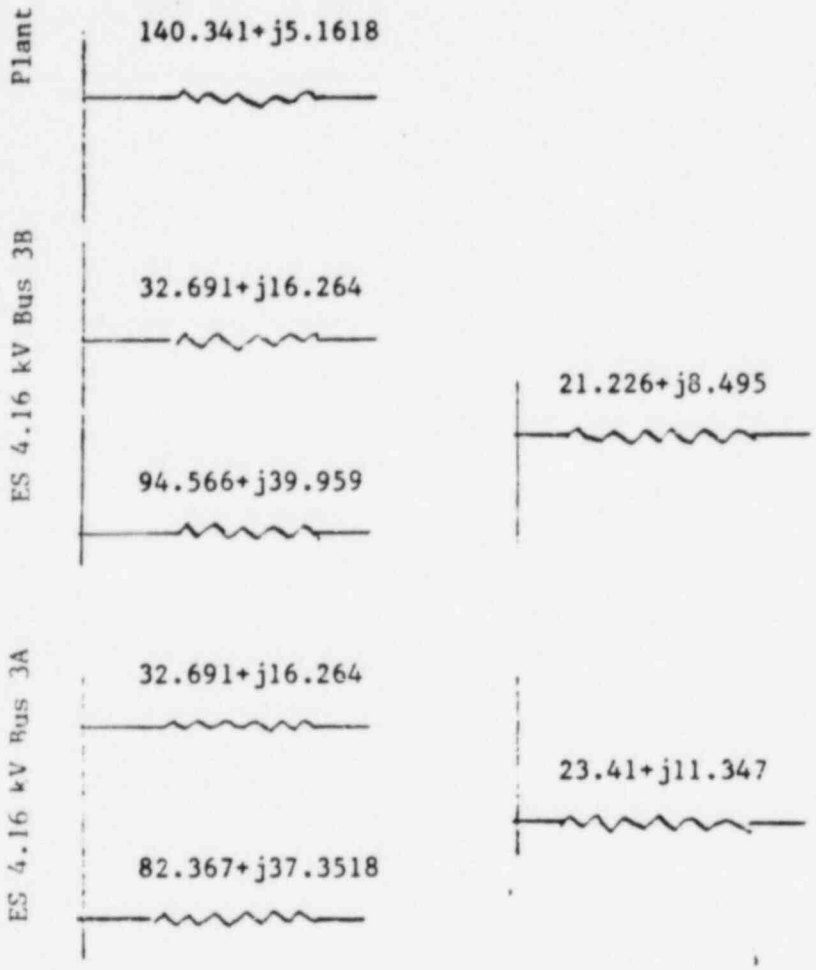

4.16 KV Unit Bus 3B
10.82+j6.142
599.86+j376.516
1.5294+j9.7212
542.9+j35.3
437.584+j95.196
121.42+j3.3511
.4704+j2.90085
994.23+j248.18
1289.28+j435.89
260.478+j152.665
385.436+j144.399
.4704+j2.90085
280.884+j105.771
193.3+j55.07
10.82+j6.142
1.5294+j9.7212
284.985+j177.366
.4704+j2.90085
82.178+j8
.4704+j2.90085
66.652+j25.895

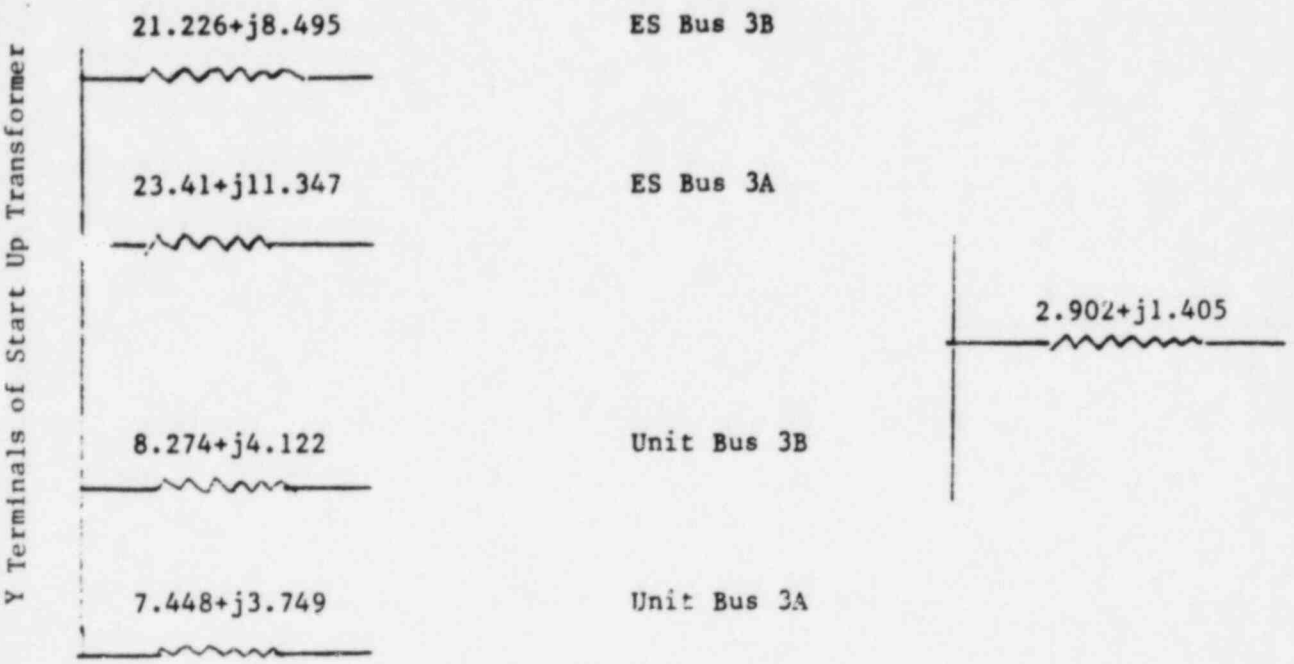

4.16 KV Unit Bus 3B
10.82+j6.142
286.514+j187.081
82.648+j10.901
67.122+j28.796
8.274+j4.122


ES 4.16 kV Bus 3B
1.1907+j5.1818
139.15+j0
Plant Bus
32.691+j16.264
1.441+j1.259
330.87+j43.68
ES MCC 3B2
1.1907+j5.1818
1.263+j1.102
248.52+j111.16
ES MCC 3B1
253.37+j130.66
ES BUS 3B
ES 4.16 kV Bus 3A
32.691+j16.264
3.381+j2.956
556.38+j252.62
ES MCC 3AB
1.385+j.898
269.77+j120.73
ES MCC 3A2
1.1907+j5.1818
1.059+j.686
323.13+j60.41
ES MCC 3A1
253.37+j130.66
ES Bus 3A

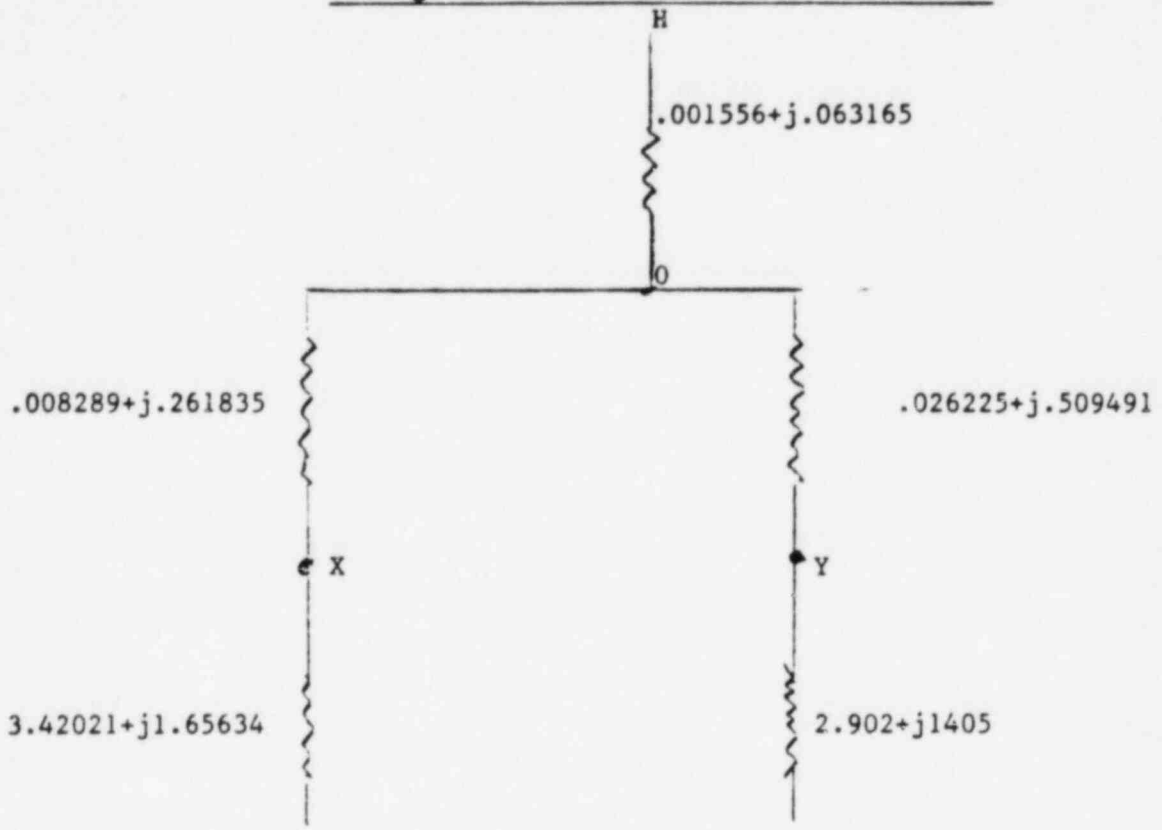

ES 4.16 kV Bus 3B
1.1907+j5.1818
139.15+j0
Plant Bus
32.691+j16.264
1.441+j1.259
330.87+j43.68
ES MCC 3B2
1.1907+j5.1818
+j1.102
248.52+j111.16
ES MCC 3B1
253.37+j130.66
ES BUS 3B
ES 480V Bus 3B
ES 416 kV Bus 3A
32.691+j16.264
3.381+j2.956
556.38+j252.62
ES MCC 3AB
1.385+j.898
269.77+j120.73
ES MCC 3A2
1.1907+j5.1818
1.059+j.686
323.13+j60.41
ES MCC 3A1
253.37+j130.66
ES Bus 3A
ES 480V Bus 3A


ES 4.16 kV Bus 3B
1.1907.j5.1818
139.15+j0
140.841+j5.1618
32.691+j16.264
32.691+j16.24
332.311+j44.939
1.1907+j5.1618
1.1907+j5.1618
93.375+j34.797
249.783+j112.262
253.37+j130.66
ES 4 .16 kV Bus 3A
32.691+j16.264
32.691+j16.24
559.761+j255.576
271.155+j121.628
1.1907+j5.1618
11907+j5.1618
81.176+j32.19
324.189+j61.096
253.37+j130.66


Plant
140.341+j5.1618
ES 4.16 kV Bus 3B
32.691+j16.264
94.566+j39.959
21.226+j8.495
ES 4.16 kV Bus 3A
32.691+j16.264
82.367+j37.3518
23.41+j11.347

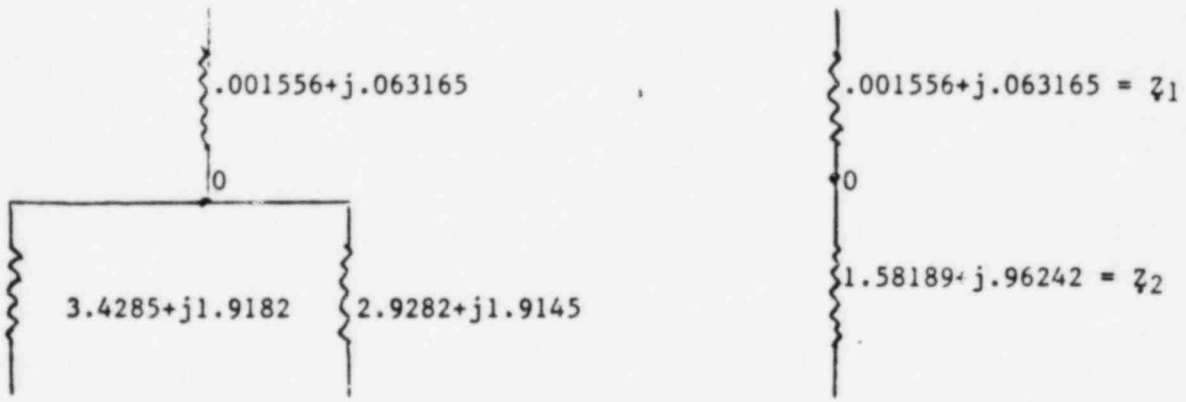

Y Terminals of Start Up Transformer
21.226+j8.495
ES Bus 3B
23.41+j11.347
ES Bus 3A
2.902+j1.405
8.274+j4.122
Unit Bus 3B
7.448+j3.749
Unit Bus 3A

Voltage At 4.16 kv Buses and 6.9 kv Buses



6.9 Motor Load

4.16kv Winding Load



Volts at 0 = $\frac{Z_2}{Z_1+Z_2}$ = .9815 of Volts at H

Measured voltage at H = 244.8 kv
Tap = 224.25 kv
Equivalent No load volts at H = 244.8/224.25 = 1.091639 p.u.

Voltage at 0 = .9815 x 1.091639 = 1.07144 p.u.

Voltage at Y = $\frac{2.902+j1.405}{.026225+j.50949+2.902+j1.405}$ x 1.07144 p.u.

= .92159 x 1.07144 = .98743 p.m. = .98743 x 4.16 = 4.108 kv

This is voltage at 4.16 kv bus.
We used .99% base voltage at 4 kv motor terminals to determine the motor inpedance, which is very close to .98743 so that no readjustment of motor impedance is necessary

Voltage at X = $\frac{3.42021+j1.65634}{.008289+j.261835+3.4202+j1.65634}$ x 1.07144 p.u.

= .967305x1.07144 = 1.0364 p.u. which is sufficiently close to the value of 1.033 p.u. assumed for motor voltage so that no readjustment of motor inpedance is necessary.

VOLTAGE AT ES 480V BUS 3A

From page 30

E.S. 4.16kv Bus 3A Volts .98743 p.u.

480V Transformer 1.1907+j5.1618

ES480VBus3A

480V Load 81.176+j32.19

$$\text{Voltage at 480V Bus} = \frac{81.176+j32.19}{1.1907+j5.1618+81.176+j32.19} \times .98743 \text{ p.u.}$$

$$= .96556 \times .98743 = .95342 \text{ p.u.}$$

$$= .95342480 = 457.6$$

VOLTAGE AT ES 480V BUS 3B

From page 30

ES4.16kv Bus 3B Volts = .98743 p.u.

1.1907+j5.1618

ES480V Bus 3B

93.375+j34.797

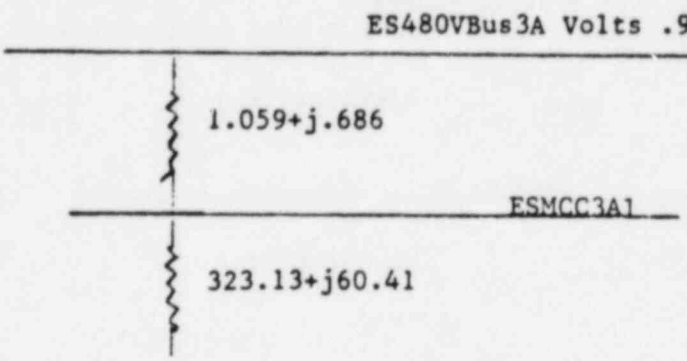
$$\text{Voltage at 480V Bus} = \frac{93.375+j34.797}{1.1907+j5.1618+93.375+j34.797} \times .98743$$

= .97065 x .98743 .95845 p.u.

= .95845 x 480 = 460V

VOLTAGE AT ESMCC3A1

From page 29



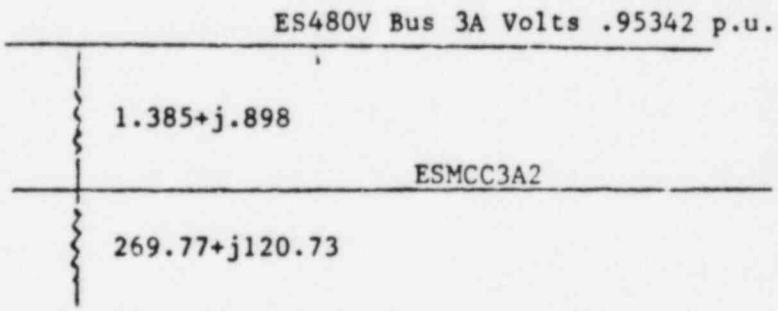
$$\text{Voltage at MCC 3A1} = \frac{323.13+j60.41}{1.059+j.686+323.13+j60.41} \times .95342$$

$$= .99646 \times .95342 = .95004 \text{ p.u.}$$

$$= .95004 \times 480 = 456 \text{ volts}$$

VOLTAGE AT ES MCC 3A2

From page 29



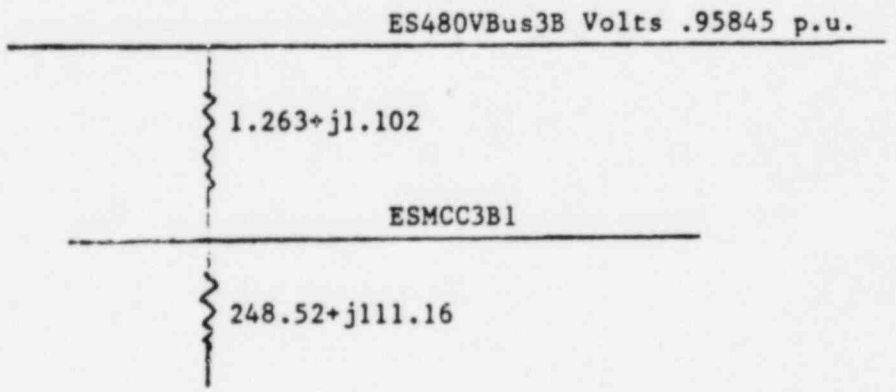
$$\text{Voltage at MCC 3A2} = \frac{269.77+j120.73}{1.385+j.898+269.77+j120.73} \times .95342 \text{ p.u.}$$

$$= .99451 \times .95342 = .94819 \text{ p.u.}$$

$$= .94819 \times 480 = 455.1 \text{ volts}$$

VOLTAGE AT ESMCC 3B1

From page 29



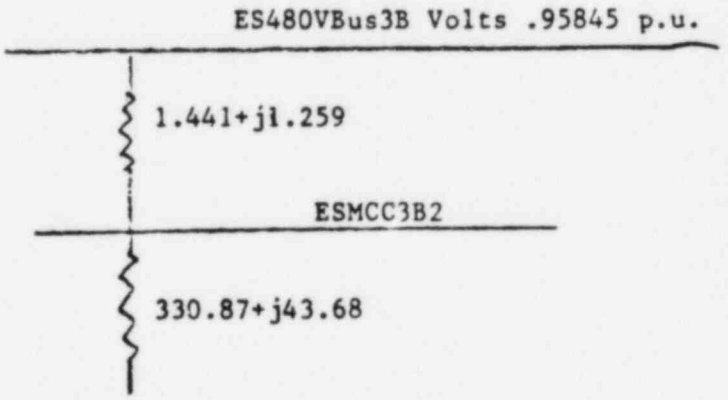
$$\text{Voltage at MCC 3B1} = \frac{248.52+j111.16}{1.263+j1.102+248.52+j111.16} \times .95845 \text{ p.u.}$$

$$= .99415 \times .95845 = .9528 \text{ p.u.}$$

$$= .9528 \times 480 = 457.3 \text{ volts}$$

VOLTAGE AT ES MCC 3B2

From page 29



$$\text{Voltage at MCC 3B2} = \frac{330.87+j43.68}{1.441+j1.259+330.87+j43.68} \times .95845 \text{ p.u.}$$

$$= .99524 \times .95845 = .95389 \text{ p.u.}$$

$$= .95389 \times 480 = 457.9 \text{ volts}$$

VOLTAGE AT ESMCC3AB

from page 29

ES480VBus3A Volts .95342 p.u.

3.381+j2.956

ESMCC3AB

556.38+j282.62

$$\text{Voltage at ESMCC3AB} = \frac{556.38+j252.62}{3.381+j2.956+j556.38+j252.62} \times .95342$$

$$= .99301 \times .95342 = .94676 \text{ p.u.}$$

$$= .94676 \times 480 = 454.4 \text{ volts}$$

Bus	Calculated Value	Measured Values Plant At Full Load Steady State Condition
230kv Grid	244.8kv	244.8kv
4160V Switchgear		
ES Bus 3A	4108V	4183V
ES Bus 3B	4108V	4179V
480V Switchgear		
ES Bus 3A	458V	472V
ES Bus 3B	460V	475V
MCC480V		
ES 3A1	456V	469V
ES 3A2	455V	468V
ES 3AB	454V	468V
ES 3B1	457V	472V
ES 3B2	458V	471V

The calculations were made on the basis of the 4160/480 volt transformers being on the nominal tap. If, however the tap was such as to give a 2-1/2% voltage boost then the 480V switchgear and MCC voltages would be increased by approximately 2-1/2%.

If the voltage on the high voltage side of the startup transformer were $240 - 1\frac{1}{2} =$ 236.4kv, the calculated voltages would be obtained as a very close approximation by multiplying the calculated voltages in the above table by .965686.

Impedance of Load on Y winding of Start Up Transformers = 2.902+j1.405 = 3.224 pu which corresponds to a load of $\frac{100}{3.224}$ = 31.015 MVA at .9 pf.

FOA 65C rating of Y winding = 28 MVA.

Impedance of load on ES Aux Transformers 3A = 81.176+j32.19 = 87.325 pu. which corresponds to a load of $\frac{100}{87.325}$ = 1.145 MVA

OA rating of transformers = 1 MVA

Impedance of load on ES Aux Transformer 3B = 93.375+j34.797= 99.648 pu which corresponds to a load of $\frac{100}{99.648}$= 1.004 MVA

OA rating of Transformer = 1 MVA

No load
volts of Start Up Transformer Y winding = $\frac{244.8}{224.25}$ X 4160 = 4541 volts

Measured volts on ES 4.16 KV Bus 3A = 4183 volts
Drop through Y winding = 4541-4183 = 358 volts

Calculated volts on ES 4.16 KV Bus 3A = 4108
Calculated drop through Y winding = 4541-4108 = 433

i.e. calculated drop is $(\frac{433}{358} - 1) \times 100$ = 20.95% greater than meesured volt drop.

Measured no load volts on ES Aux Transformer 3A
= 4179 x $\frac{480}{4160}$ = 482 assuming on nominal tap.

Measured volts on ES 480 V Bus 3A = 472

Measured Volt drop through ES Aux Transformer 3A = 482-472 = 10

Calculated no load volts on ES Aux. Transformer 3A

$= 4108 \times \frac{480}{4160} = 474$

Calculated voltage on 480 V swgr. bus = 458

Calculated volt drop through ES Aux. Transformer 3A = 474-458 = 16

The discrepancy between calculated and measured voltages is most probably due to loads as measured being appreciably lower than loads used in the calculation.

The calculated load on the 4.16 KV winding of the Start Up Transformer was approximately 31 MVA; the FOA 65 C rating of this winding is 28 MVA. It is improbable that the measurements would be made with a load as great as 28 MVA.

The calculated load on ES Auxiliary Transformer 3A was approximately 1.15 MVA, the OA rating of the transformer being 1 MVA.

Calculated loads in many cases were taken as rated loads of equipment also the condition used in the calculations was that of Maximum Plant Loading including Maximum Engineered Safeguard Loads.

Previous calculations were approximate and are superseded by the present calculations from which the comparative voltage table is compiled, so that relay settings should be based on the above table.

ATTACHMENT 4

LICENSING PLAN FOR DEGRADED GRID VOLTAGE UNDERVOLTAGE RELAYING

PROJECT SCHEDULE

PROJECT MANAGEMENT ITEM NO.	DESCRIPTION	SCHEDULED COMPLETION DATE
282901007	This activity is the completion of the as-builts of relay cabinets to correct constructibility problem for an installation of the second level undervoltage relays.	9/2/82
282901042	This activity is the preparation of a scope letter to Gilbert Associates for their preparation of an estimate to perform a Field Change Notice for the second level undervoltage relaying design package to resolve constructibility problem.	12/3/82
282901049	This represents the activity of Gilbert Associates preparing the scope letter to prepare FCN for MAR 81-1-2.	12/17/82
282901065	This activity is FPC preparing the work authorization and approval for Gilbert Associates to prepare the FCN to correct the constructibility problem with the undervoltage relaying MAR.	1/12/83
282901069	This activity is the actual preparation of the FCN by Gilbert Associates.	2/24/83
282901084	This activity is the FPC review and approval of the FCN.	3/10/83
282901090	This is a milestone activity. This represents the FPC issuing of the FCN to MAR 81-1-2.	3/10/83
282900100	This activity represents the October transmittal to the NRC of the latest distribution voltage calculations.	11/12/82
282900103	This is the NRC review of the calculations submitted in October 1982.	1/14/83
282900121	This activity is the development of the licensing plan and schedule.	11/22/82
282900123	This activity is the NRC review of the Tech Spec licensing plan.	12/14/82

PROJECT MANAGEMENT ITEM NO.	DESCRIPTION	SCHEDULED COMPLETION DATE
282900125	This activity represents a possible meeting between FPC and the NRC to review the content of the licensing plan.	12/16/82
282900127	This is the milestone activity of the NRC approving the proposed licensing plan.	1/4/83
282900130	This represents the NRC approving the temporary relay settings submitted in the October 1982 submittal.	1/4/83
282900105	This represents the installation of MAR 81-1-2, the second level undervoltage relaying system.	5/13/83
282900110	This represents the FPC monitor and review of the performance of the second level undervoltage system and temporary relaying setting.	5/13/83
282900120	This represents the quarterly (or semiannually) calibration checks on the relay settings.	5/13/83
282900131	This is FPC's preparation of scope letter to Gilbert Associates for their preparation of additional calculations.	11/15/82
282900133	This activity represents Gilbert preparing the scope letter for revised calculations for changing taps on the 4160 volt transformer.	1/18/83
282900135	This represents the FPC preparation of the work authorization and approval for Gilbert Associates to proceed with performing the calculations for revised tap settings.	2/16/83
282900137	This activity is the actual Gilbert performance of the revised calculations.	12/15/83
282900139	This activity is the FPC review of the results of the Gilbert calculations.	1/17/84
282900150	This is a possible activity based upon positive results from the calculations and is a milestone activity.	1/17/84

PROJECT MANAGEMENT ITEM NO.	DESCRIPTION	SCHEDULED COMPLETION DATE
282900140	This is the other possible milestone activity based upon results of the calculations being negative.	1/17/84
282900160	Ths activity is transmitting the revised calculations to the NRC.	1/17/84
282900161	This activity represents the NRC review of the calculations.	3/15/84
282900163	This activity is the FPC preparation of revised Tech Specs based on revised tap settings and new relay settings.	4/13/84
282900165	This activity is the changing of the transformer taps at the plant.	5/14/84
282900167	This activity is rework of the voltage test measurements based on new tap settings.	8/9/84
282900169	This activity represents FPC review of test measurements.	9/7/84
282900171	This activity represents transmittal of the test measurements and revised calculations to the NRC.	9/14/84
282900173	This activity represents the NRC review of test measurements.	11/13/84
282900175	This activity represents preparation of the final Tech Specs.	1/10/85
282900179	This activity represents internal FPC review of the revised Tech Specs by the NGRC Committee.	2/8/85
282900181	This activity is the NRC review and approval of Tech Specs.	4/9/85
282900183	This activity is FPC preparing final relay settings to the plant.	5/8/85
282900190	This activity is the issuance of final relay settings to the plant.	5/8/85