Florida
Power
CORPORATION

October 19, 1982
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File: 3-0-3-a-3
3-E-3

Mr. John F. Stolz, Chief
Operating Reactors Branch #4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Crystal River Unit 3
Docket No. 50-302
Operating License No. DPR-72
Adequacy of Station Electric Distribution System Voltage

Dear Mr. Stolz:

By letter dated February 19, 1982, Florida Power Corporation submitted calculated and measured bus voltages to demonstrate the adequacy of the Crystal River Unit 3 Electrical Distribution System. The calculated voltages used several assumptions that did not adequately model the measured conditions. During subsequent telephone conversations, Florida Power Corporation agreed to revise our calculations to more accurately model our system. The following attachments are included:

1. Comparative Voltage Table,
2. Explanation of Difference Between Original Calculation and Present Calculations, and
3. Engineered Safeguards Buses Voltage Calculations

The first calculations were made on the basis of the 4160/480 volt (V) transformers being on the nominal tap. The revised calculations were made for a tap setting to give a 2½% voltage boost; this results in the 480V switches and motor control center voltages being increased by approximately 2½%. This assumption should satisfy the NRC concern that the measured voltages were too high and provide assurance that we will not exceed the voltage limits. The starting voltage for the calculations was the same as that for measured voltages, i.e., 244.8 kV.

If the starting voltage were 240kV-1½% = 236.4kV (lowest 240kV system voltage), then the calculated voltages would be obtained to a very close approximation by multiplying the calculated voltages in the attached table by .965686.

A015

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

The calculated load on the 4160V winding of the Startup Transformer was approximately 31 Mega volt amps (MVA); the forced-oil-and-air-at-65°C rating of this winding is 28 MVA. It is improbable that the measurements were made with a load as great as 28 MVA. The calculated load on Engineered Safeguards Auxiliary Transformer 3A was approximately 1.15 MVA, the oil-air 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 bus 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; therefore, relay settings should be based on the present calculations.

The review of these calculations and the assessment of effects on the system that could be caused by changes in the relay settings has involved considerable engineering effort. Fitting this work into the schedule of preparing for our next outage has caused considerable delay in submitting the results of these revised calculations.

Florida Power Corporation will install the protection relays during the Spring 1983 Refueling Outage. The proposed trip setpoint is 3780V with a maximum value of 3866V and minimum value of 3763V. This will allow a 4.2% drop between the 4160V buses and 480V motor control center.

Florida Power Corporation plans to perform additional calculations at raised tap settings to improve the voltage drop to 2%. We plan to monitor the performance of these relays and to make additional voltage calculations before finalizing the Technical Specification Change Request. Florida Power Corporation will submit the schedule for final calculations, voltage measurement checks, and technical specification submittal upon development and approval of that schedule.

Very truly yours,

Patsy Y. Baynard

Dr. Patsy Y. Baynard
Assistant to Vice President
Nuclear Operations

WRK/myf

Attachment 1

COMPARATIVE VOLTAGE TABLE

CR-3 START-UP TRANSFORMER

BUS	CALCULATED VOLTAGES		MEASURED VALUES PLANT AT FULL LOAD-STEADY STATE CONDITIONS
	Original Value (2/19/82)	Present Value (10/6/82)	Numerical Value
230 kV GRID	243.6 kV	244.8 kV	244.8 kV
4160 V SWGR			
ES BUS 3A	4276 V	4108 V	4183 V
ES BUS 3B	4276 V	4108 V	4179 V
480 V SWGR			
ES BUS 3A	489 V	458 V	472 V
ES BUS 3B	489 V	460 V	475 V
MCC 480 V			
ES 3A1	489 V	456 V	469 V
3A2	489 V	455 V	468 V
3AB	489 V	454 V	468 V
ES 3B1	489 V	457 V	472 V
3B2	489 V	458 V	471 V

EXPLANATION OF DIFFERENCE BETWEEN ORIGINAL CALCULATIONS AND PRESENT CALCULATIONS

Errors in Original Calculations

1. The H-Y Impedance of the Startup Transformer was taken as 7.96% from our early nameplate drawing instead of the later value of 8.6%.

2. Cable impedances were neglected.

The above errors would result in the calculated voltage drop being smaller than would actually be the case.

Difference In Methods of Calculation

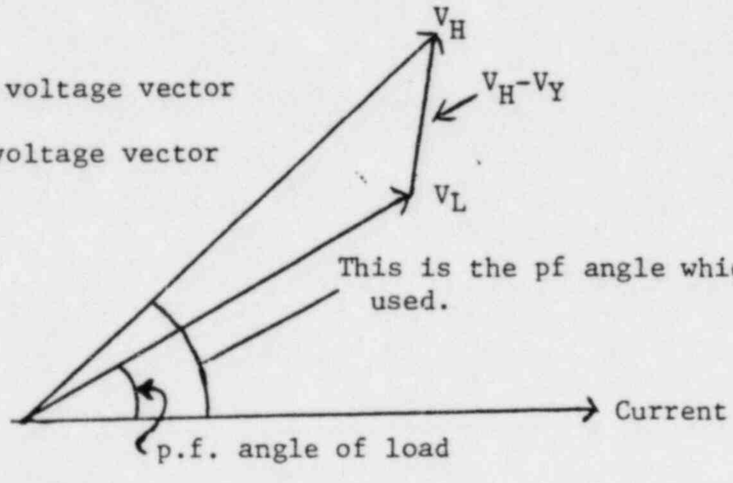
Original Method

Loads were expressed in terms of current rather than impedance. Voltage drops were calculated by multiplying currents by impedances, and then subtracted from the voltage on the high side of the impedance through which the load current passed.

Loads were expressed in terms of the transformer output voltage vector, yet when calculating this voltage, the input voltage vector was taken as the reference vector.

V_H = High side voltage vector

V_L = Low side voltage vector



The correct pf angle being greater than the load pf angle, would result in a greater voltage drop. This occurs in two cases,

a. for the Startup Transformer
b. for the 4160/480V transformers

so that when calculating the voltage drop through the two transformers, a double error is incurred.

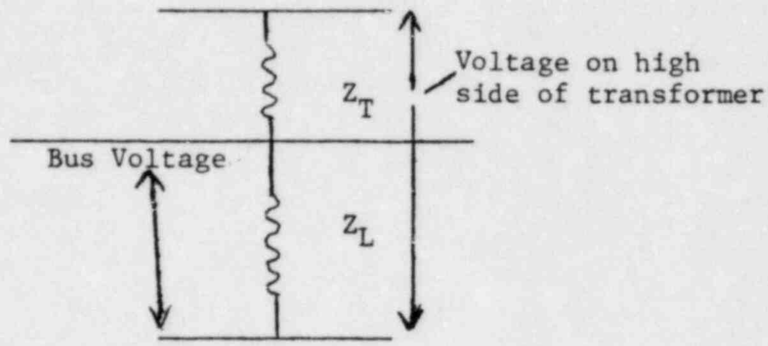
Present Method

This is the voltage divider method and avoids the error caused by using too small a pf. angle. Loads are expressed as impedances. The principle is as follows:

Z_L = Impedance of load

Z_T = Impedance of transformer

Impedances expressed vectorially



$$\text{Bus Voltage} = \frac{Z_L}{Z_L+Z_T} \times \text{Voltage on high side of transformer.}$$

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".

<u>4.16 KV LOADS</u>

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

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

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					Motor	Converted to 4.16KV Base		
Unit Bus 3A	Rated	Running	pf	KW	KVAR	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.	21[illegible]	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 = $\sqrt{3}$ 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 = $3.56125 \times 1.033^2 = 3.8007\varepsilon^{j25.84}$

$= 3.42021 + j\,1.65634$

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 Connected	KVA 460. V Running	pf	Running KW	Running KVAR	KVA 480 V
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

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	Connected	KVA 460. V 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

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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	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 Base KW	Converted to 480V Base KVAR	MVA	Z	Ø	1.02Z	R + j x
Reactor MCC 3A2											
Motors	92.6	75	47	.94	85	53					
Heaters	114.4				114.4						
					199.4	53	.20632	484.68	14.88	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 460V	Motor Volts	Converted to 480V Base KW	Converted to 480V 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 Base KW	Converted to 480V 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 460V	Motor Volts	Converted to 480V Base KW	Converted to 480V Base KVAR	MVA	Z	Ø	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

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
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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Reading, Pennsylvania

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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					
Resistive	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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DATE 7/8/82

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.

480V SYSTEM CABLE IMPEDANCES

From	To	Size MCM	Cables/ Phase	R/ 1000	X/ 1000	Length Feet	R Ω	X Ω	R pu	Xpu	Xpu Reactor	Xpu Total
Heating Aux xfr. 3	Machine Shops MCC	500	2	.0294	.0257	190	.0028	.00244	1.215	1.059	-	1.059
Turb. Aux	Turbine MCC 3A	500	2	.0294	.0257	225	.00331	.00289	1.437	1.254	1.997	3.251
	WT MCC 3A	500	2	.0294	.0257	437	.00643	.00561	2.791	2.435	1.997	4.432
	Vent MCC 3A	350	2	.0406	.0264	312	.00633	.00412	2.747	1.788	1.997	3.785
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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CALCULATION

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REV. 0 | 1 | 2 | 3
MICROFILMED
ORIGINATOR: [signature]
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CISID: 04-5011-113

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

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

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

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

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

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

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

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

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

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

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

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

$$HO = .063165^2 - .001556^2 \quad ^{1/2} = .063146$$

$$OX = .261835^2 - .008289^2 \quad ^{1/2} = .261704$$

$$OY = .510165^2 - .026225^2 \quad ^{1/2} = .509491$$

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

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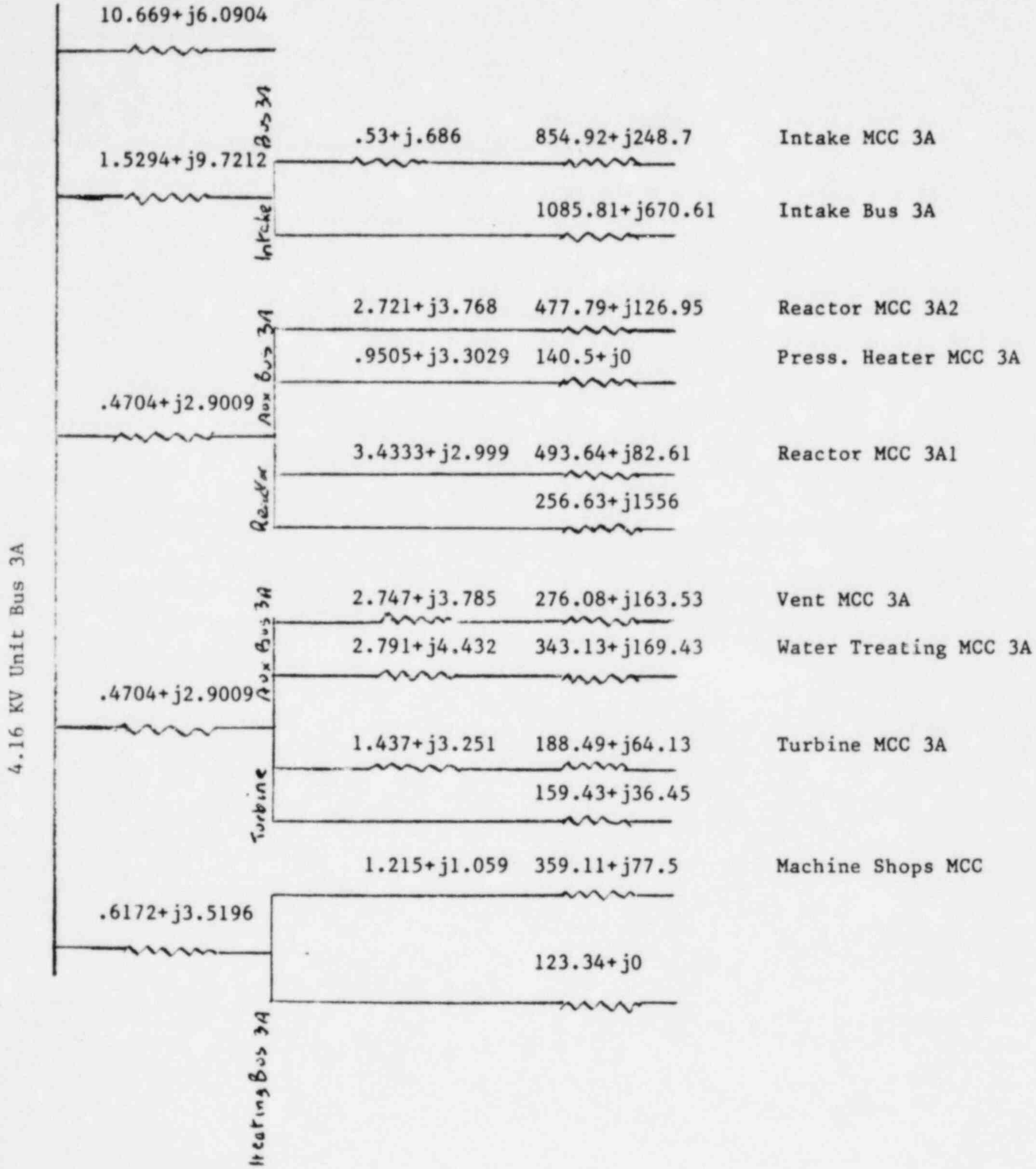
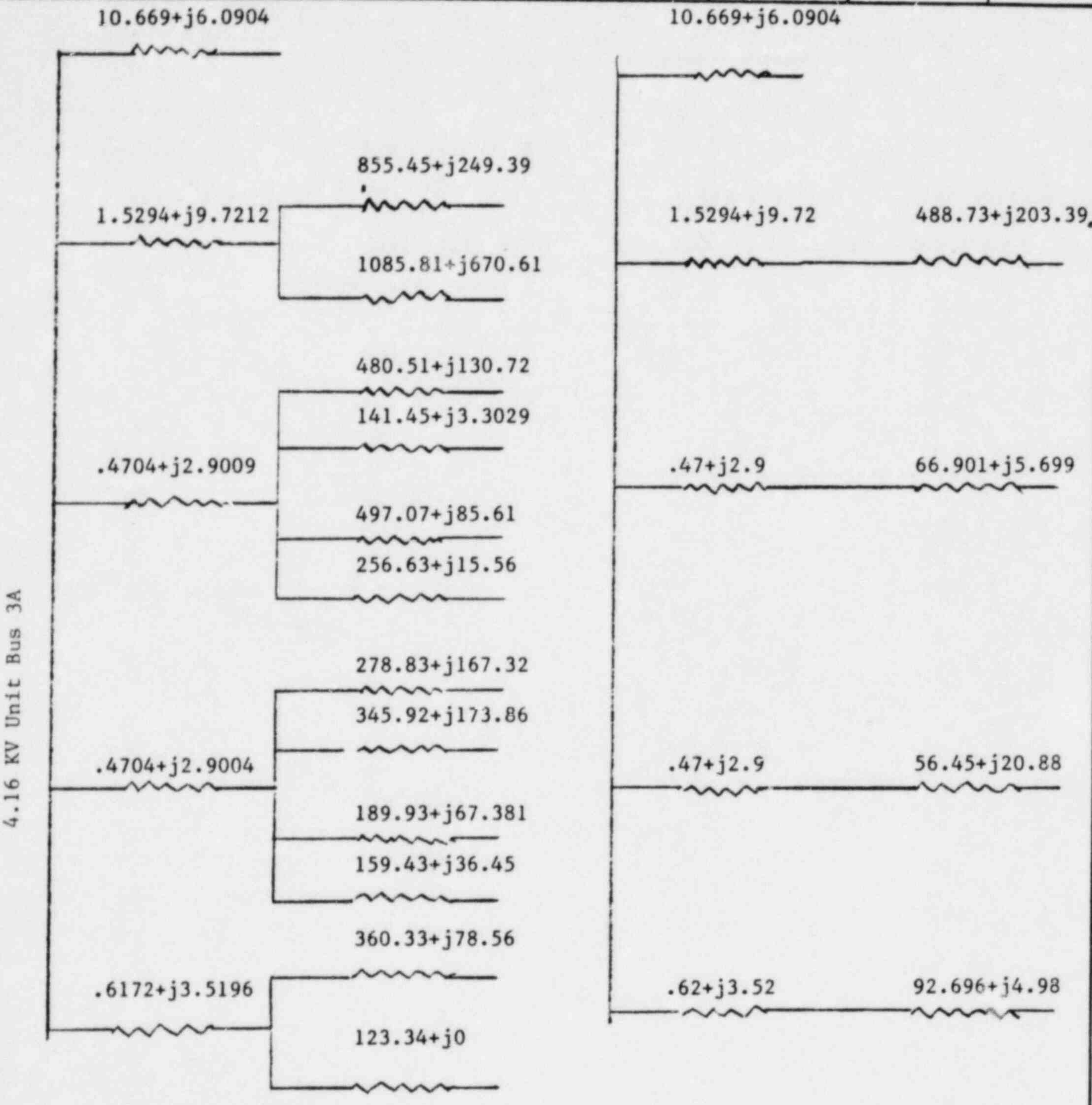
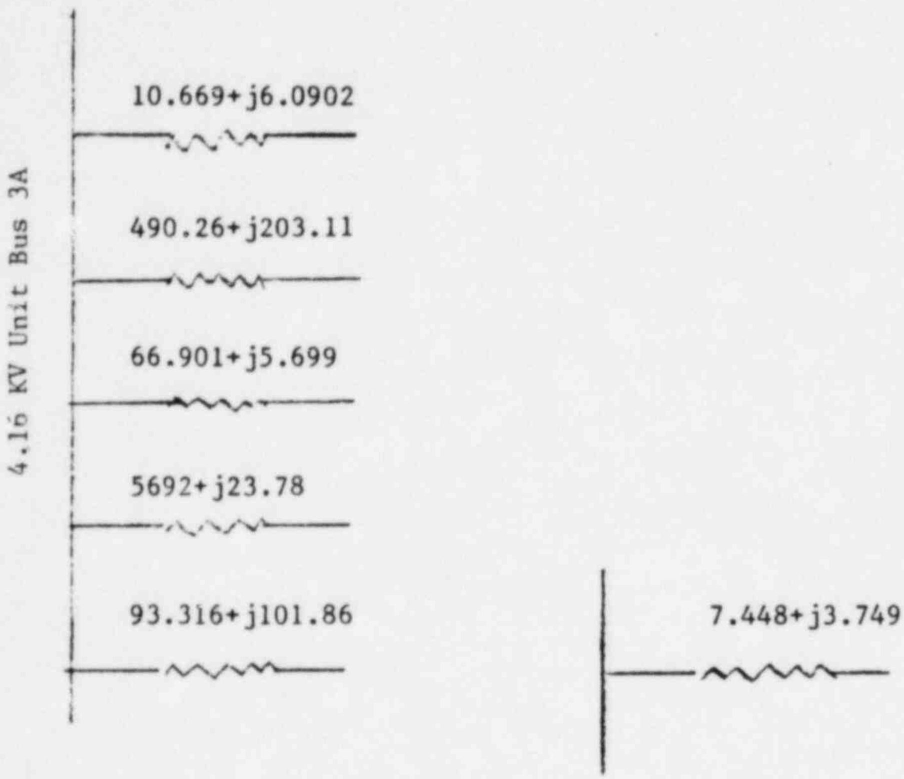
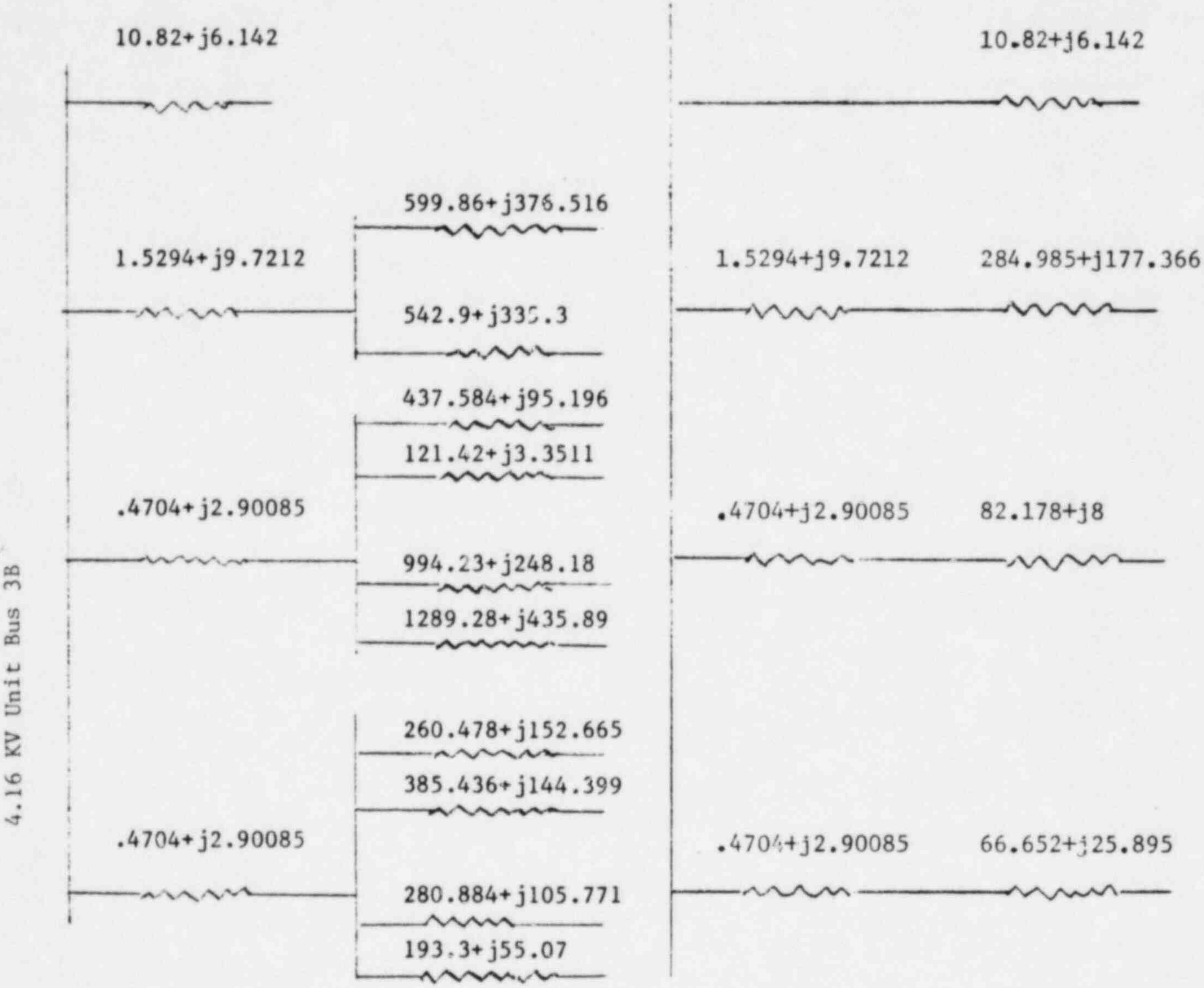
ORIGINATOR	[signature]			
DATE	7/8/82			




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

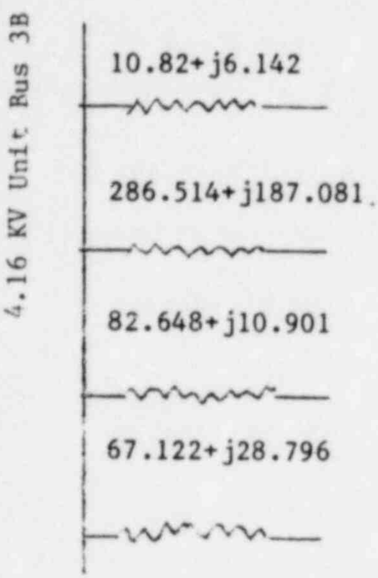


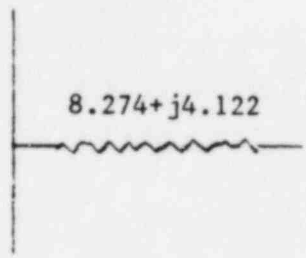
4.16 KV Unit Bus 3A
10.669+j6.0902
490.26+j203.11
66.901+j5.699
5692+j23.78
93.316+j101.86
7.448+j3.749



10.82+j6.142
10.82+j6.142
599.86+j376.516
1.5294+j9.7212
1.5294+j9.7212
284.985+j177.366
542.9+j335.3
437.584+j95.196
121.42+j3.3511
.4704+j2.90085
.4704+j2.90085
82.178+j8
994.23+j248.18
1289.28+j435.89
4.16 KV Unit Bus 3B
260.478+j152.665
385.436+j144.399
.4704+j2.90085
.4704+j2.90085
66.652+j25.895
280.884+j105.771
193.3+j55.07

Gilbert Associates, Inc. Reading, Pennsylvania **CALCULATION**	SUBJECT ENGINEERED SAFEGUARDS BUSES VOLTAGE CALCULATIONS		CISID 04-5011-113		PAGE 27 OF 40 PAGES
	REV. 0	1	2	3	
	MICROFILMED				
	ORIGINATOR R. Wilson				
	DATE 7/8/82				





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	REV. 0	1	2	3	
	MICROFILMED				
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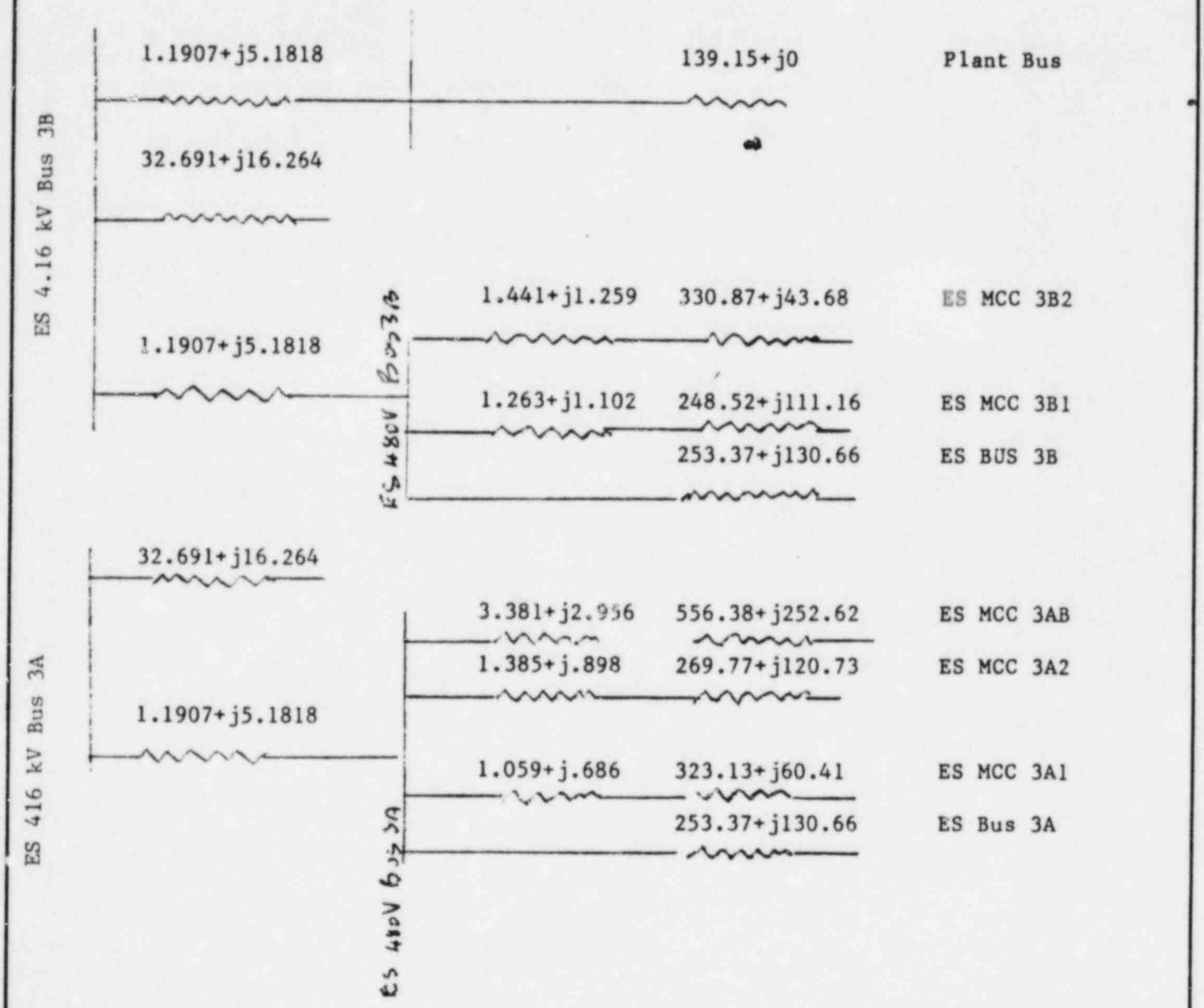

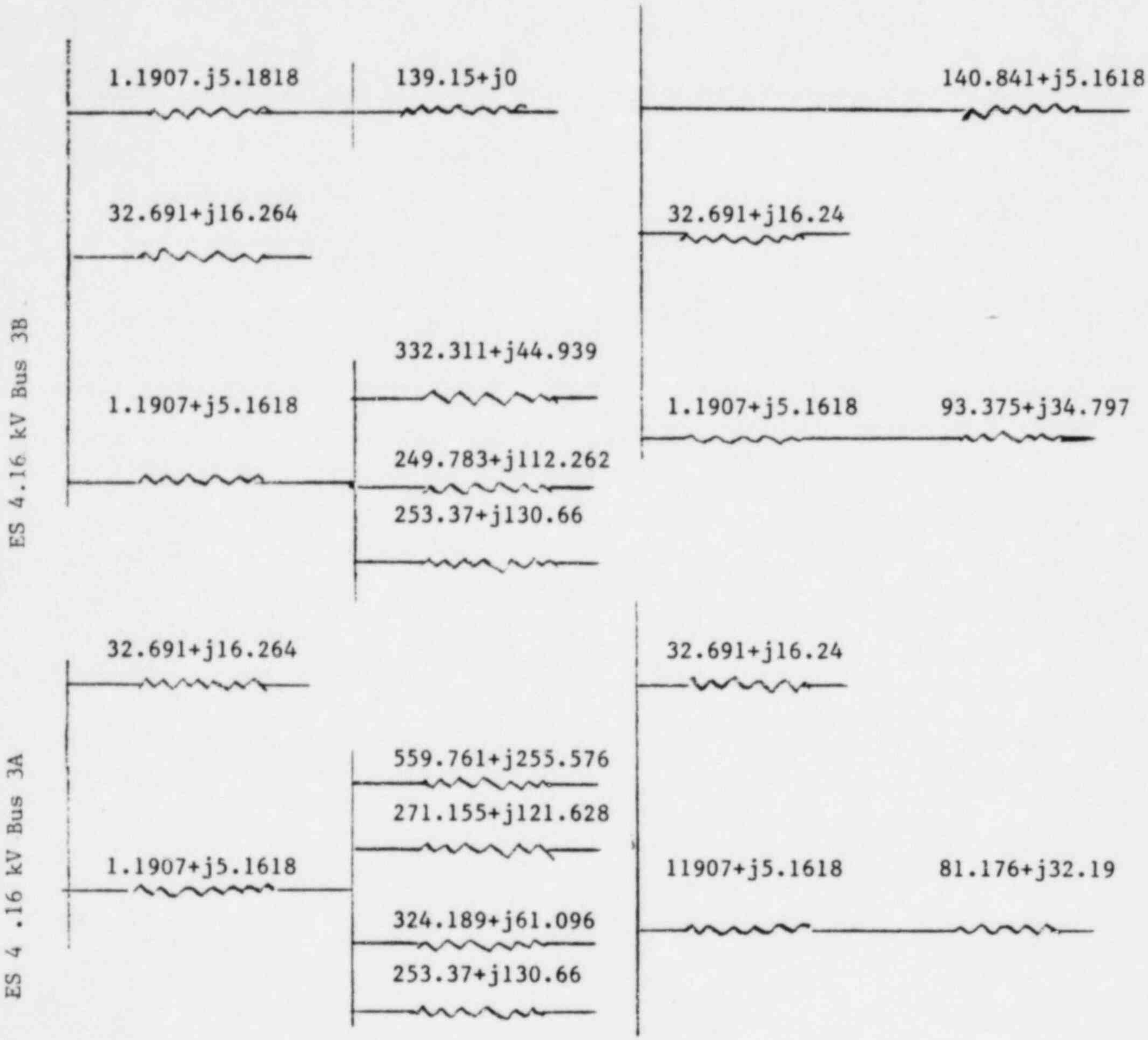
ES 4.16 kV Bus 3B
1.1907.j5.1818
139.15+j0
140.841+j5.1618
32.691+j16.264
32.691+j16.24
332.311+j44.939
1.1907+j5.1618
1.1907+j5.1618
93.375+j34.797
249.783+j112.262
253.37+j130.66
ES 4 .16 kV Bus 3A
32.691+j16.264
32.691+j16.24
559.761+j255.576
271.155+j121.628
1.1907+j5.1618
11907+j5.1618
81.176+j32.19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

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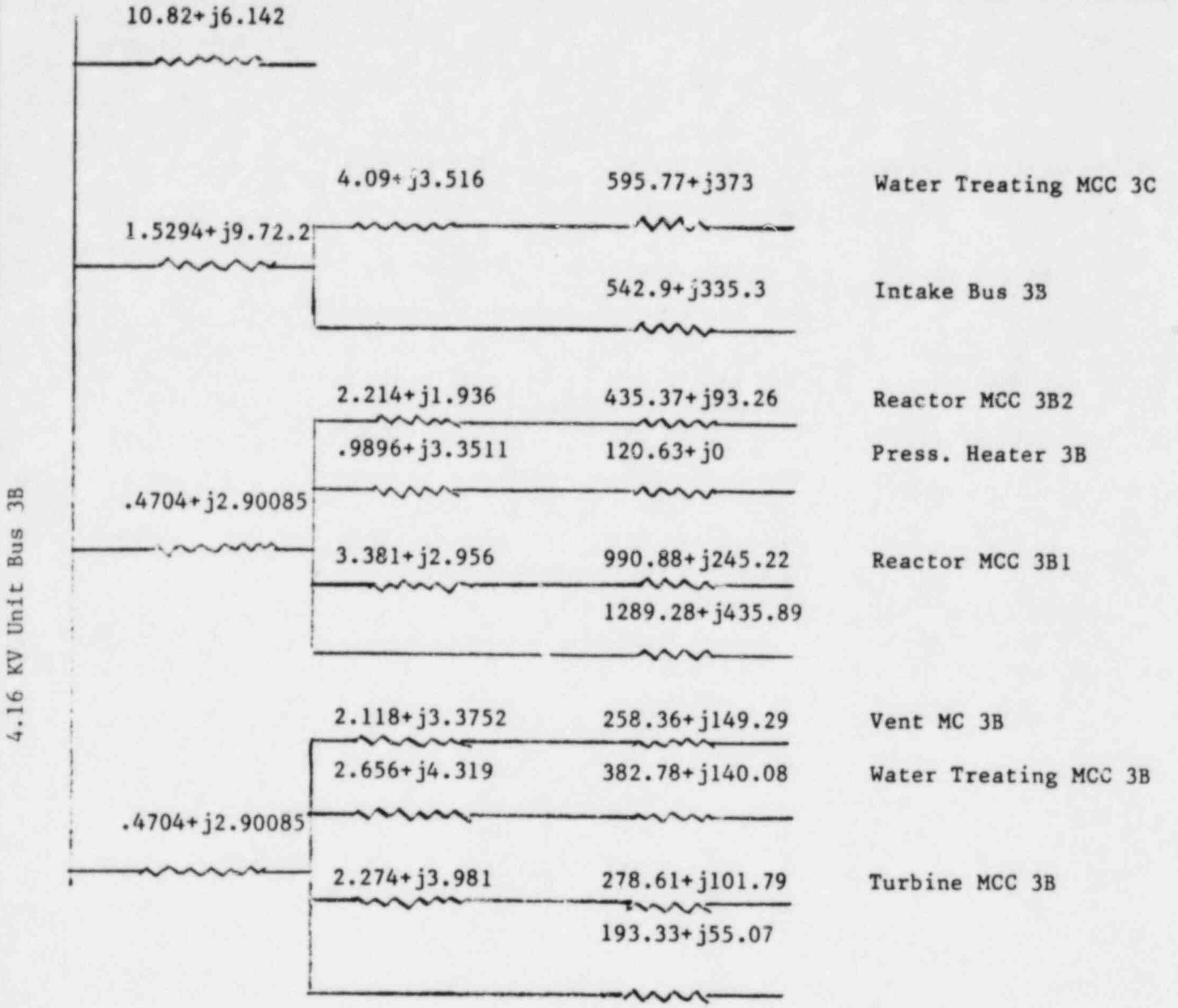
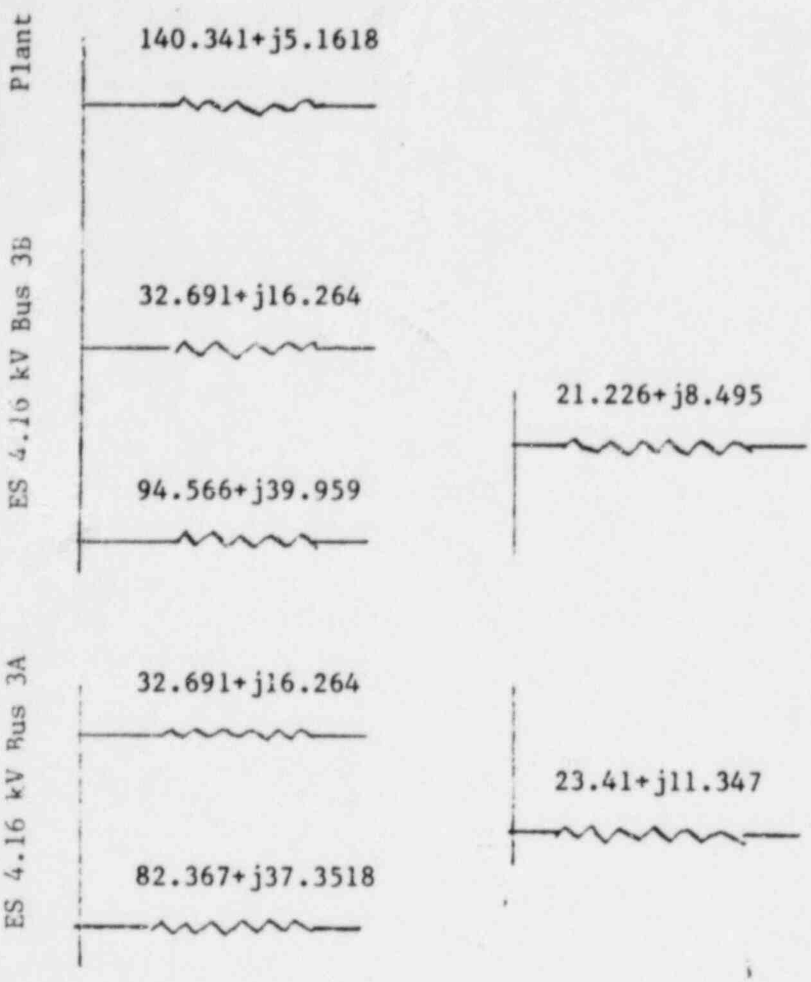
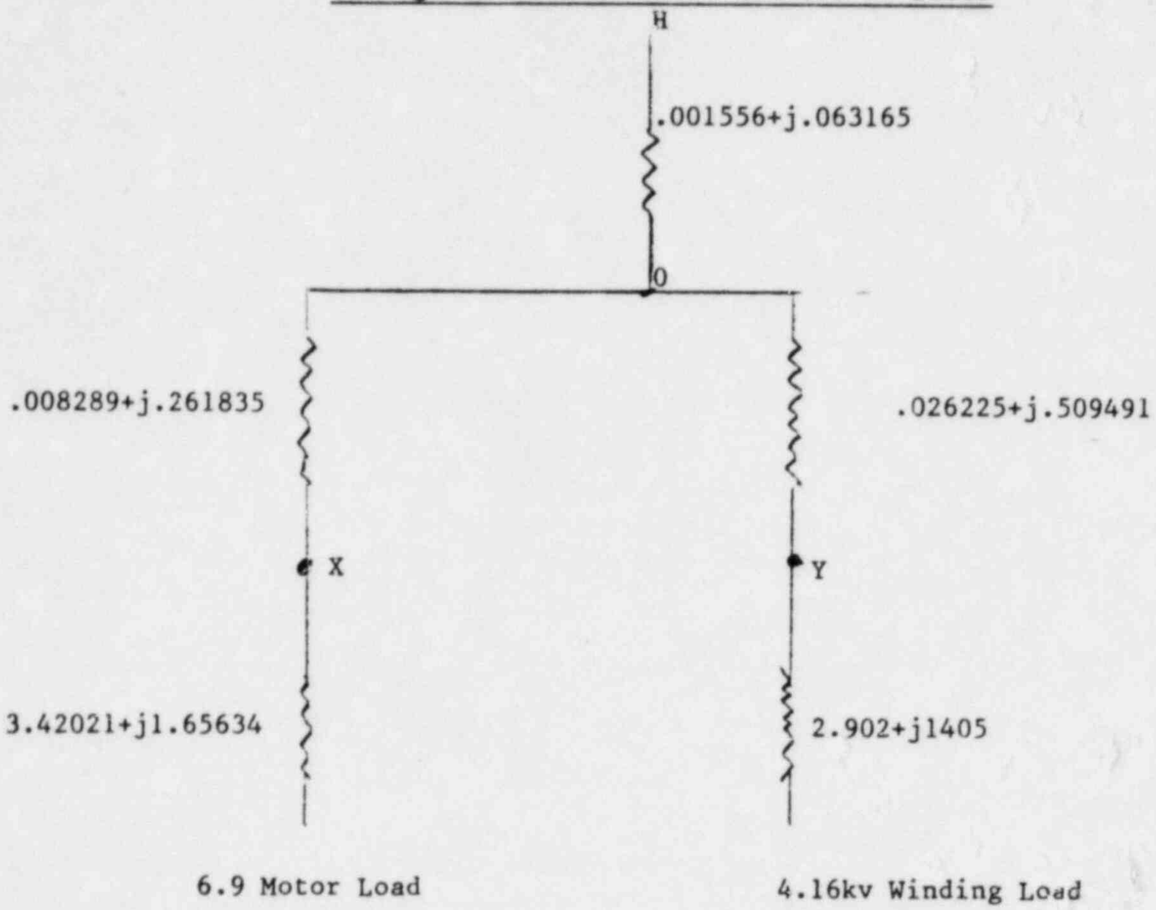
REV. 0	1	2	3	
MICROFILMED				
ORIGINATOR: R. Wilson				
DATE: 7/8/82				

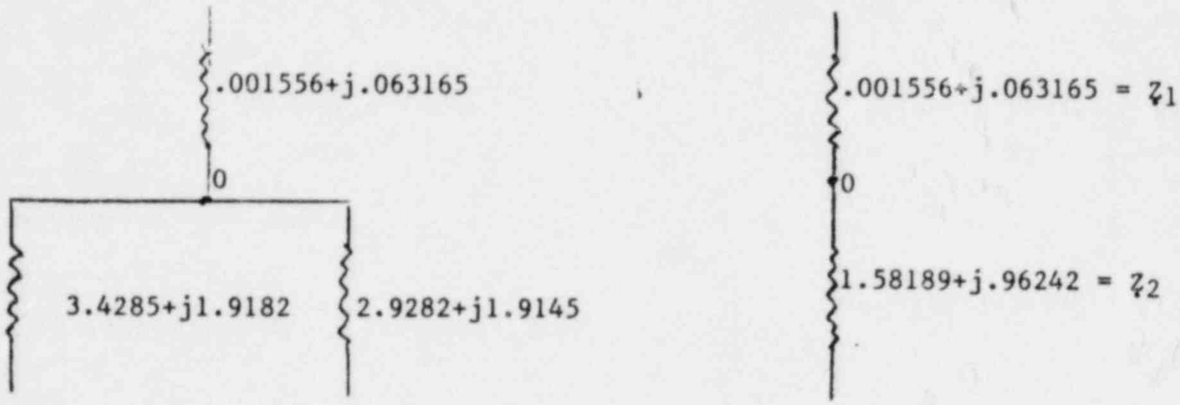




Plant
140.341+j5.1618
ES 4.16 kV Bus 3B
32.691+j16.264
94.566+j39.959
21.226+j8.495
ES 4.16 kV Bus 3A
32.691+j16.264
82.367+j37.3518
23.41+j11.347

Voltage At 4.16 kv Buses and 6.9 kv Buses





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.

$$\text{Voltage at Y} = \frac{2.902+j1.405}{.026225+j.50\text{[illegible]}9+2.902+j1.405} \times 1.07144 \text{ p.u.}$$

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

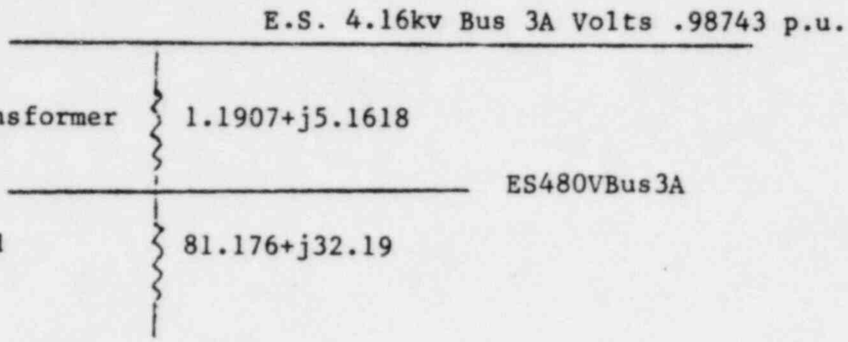
This is voltage at 4.16 kv bus.
We used .99% base voltage at 4 kv motor terminals to determine the motor inpedance, which is very close to .98743 so that no readjustment of motor impedance is necessary

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

= .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



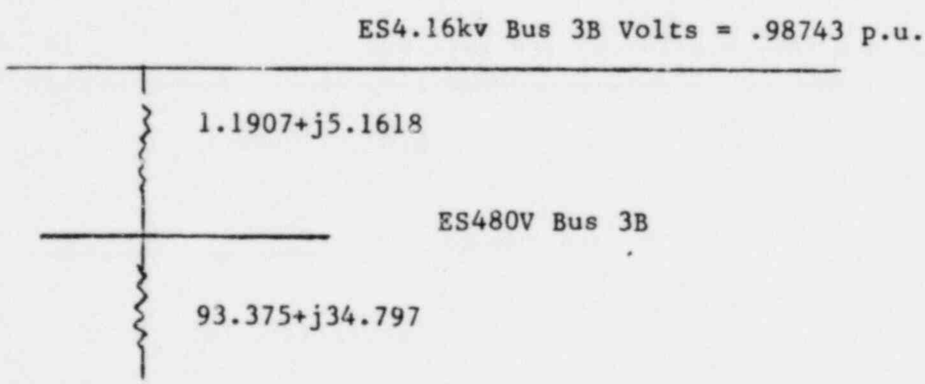
$$\text{Voltage at 480V Bus} = \frac{81.176+j32.19}{1.1907+j5.1618+81.176+j32.19} \times .98743 \text{ p.u.}$$

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

$$= .95342480 = 457.6$$

VOLTAGE AT ES 480V BUS 3B

From page 30



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

$$= .97065 \times .98743 \quad .95845 \text{ p.u.}$$

$$= .95845 \times 480 = 460V$$

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	MICROFILMED				
	ORIGINATOR R Gibson				
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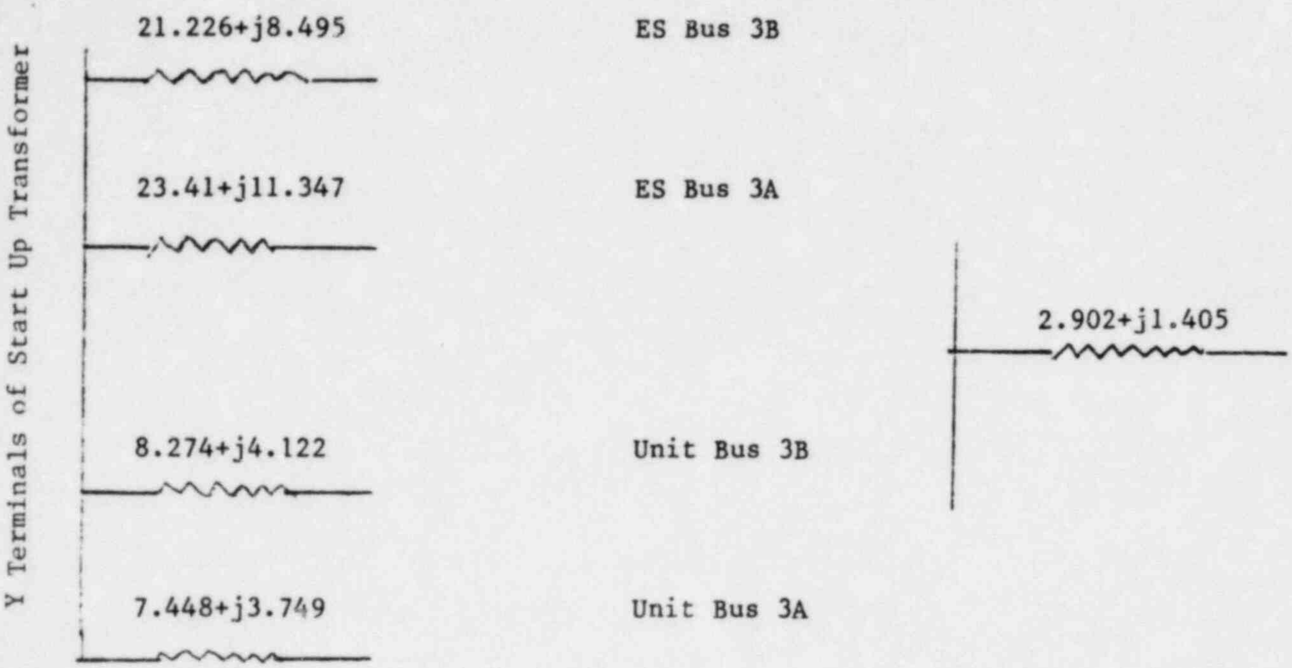
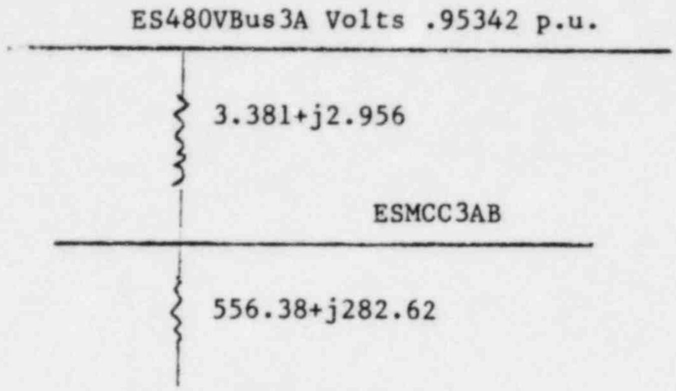


VOLTAGE AT ESMCC3AB

from page 29



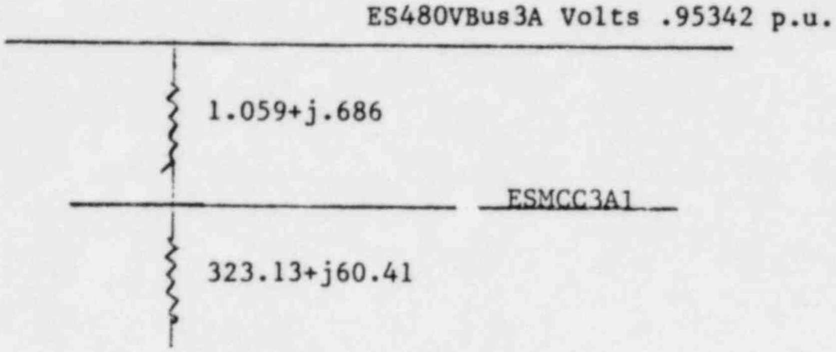
$$\text{Voltage at ESMCC3AB} = \frac{556.38+j252.62}{3.381+j2.956+j556.38+j252.62} \times .95342$$

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

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

VOLTAGE AT ESMCC3A1

From page 29



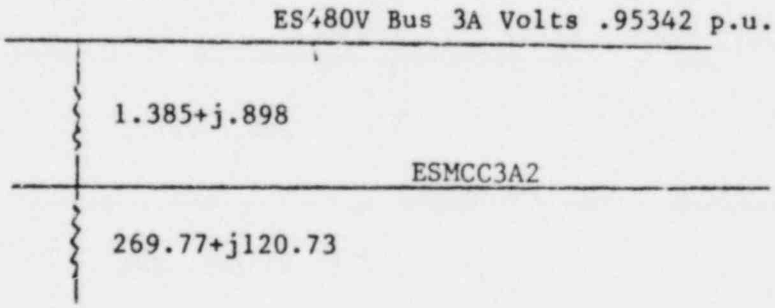
$$\text{Voltage at MCC 3A1} = \frac{323.13+j60.41}{1.059+j.686+323.13+j60.41} \times .95342$$

$= .99646 \times .95342 = .95004$ p.u.

$= .95004 \times 480 = 456$ volts

VOLTAGE AT ES MCC 3A2

From page 29



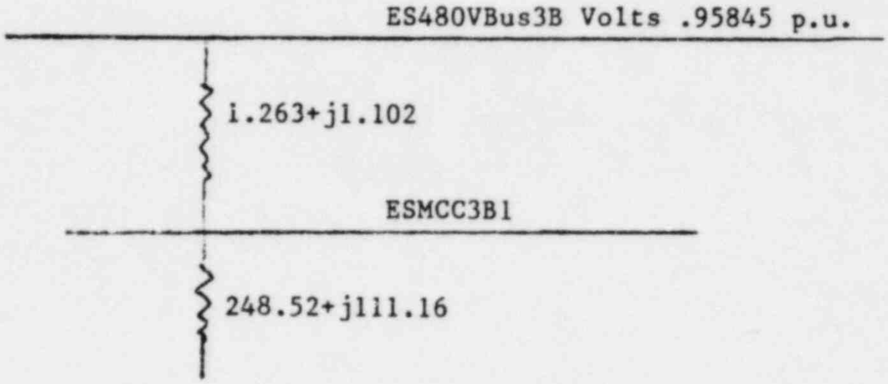
$$\text{Voltage at MCC 3A2} = \frac{269.77+j120.73}{1.385+j.898+269.77+j120.73} \times .95342 \text{ p.u.}$$

$= .99451 \times .95342 = .94819$ p.u.

$= .94819 \times 480 = 455.1$ volts

VOLTAGE AT ESMCC 3B1

From page 29



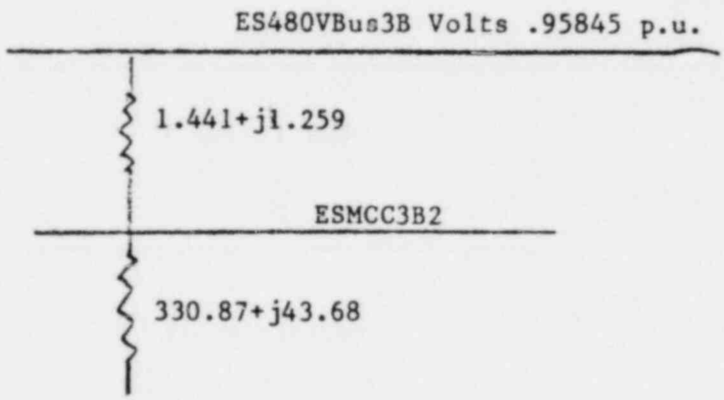
$$\text{Voltage at MCC 3B1} = \frac{248.52+j111.16}{1.263+j1.102+248.52+j111.16} \times .95845 \text{ p.u.}$$

$= .99415 \times .95845 = .9528$ p.u.

$= .9528 \times 480 = 457.3$ volts

VOLTAGE AT ES MCC 3B2

From page 29



$$\text{Vol[illegible] MCC 3B2} = \frac{330.87+j43.68}{1.441+j1.259+330.87+j43.68} \times .95845 \text{ p.u.}$$

$= .99524 \times .95845 = .95389$ p.u.

$= .95389 \times 480 = 457.9$ volts

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 measured volt drop.

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

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 - 1½% = 236.4kv, the calculated voltages would be obtained as a very close approximation by multiplying the calculated voltages in the above table by .965686.

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.