PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

SEABROOK STATION

VOLTAGE REGULATION STUDY

TABLES OF CONTENTS

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
SEABROOK STATION
VOLTAGE REGULATION STUDY

I. PURPOSE

The purpose of this calculation is to determine voltages present at various buses and motors throughout the plant during the following conditions:

A. Unit at full load (maximum anticipated unit steady state load) with the utility grid at the minimum anticipated voltage.

B. Unit at full load with the utility grid at the minimum anticipated voltage and simultaneous start of all accident loads or start of other large motor loads.

C. Unit at Cold Shutdown or Refueling (minimum anticipated load) with the utility grid at the maximum anticipated voltage.

II. SYSTEM MODEL

This section contains all assumed and actual data to establish the system being studied.

A. Utility Grid

The utility grid is assumed to be an infinite bus with a resultant zero impedance. The 345 kV bus voltage is assumed to vary between 105% and 97.5%.

There are two available connections to the offsite power supply (utility grid); one through the Unit Auxiliary Transformer (UAT) and the other through the Reserve Auxiliary Transformer (RAT).

B. Main Generator and Isolated Phase Bus Duct

It is assumed that during running and starting conditions the utility grid voltage dip will be limited to 97.5% of rated. To compensate for the Generator Step-Up Transformer (GSU) regulation

the generator output voltage must exceed the voltage of 97.5% of rated on the GSU high voltage terminals. Due to this higher generator (and hence, Unit Auxiliary Transformer primary) voltage, the lowest source voltage can not be obtained with the generator connected. Therefore, it is assumed that the main generator is disconnected and that the auxiliary system is being back fed from the utility grid through the GSU. Light load condition is assumed to occur during shutdown with the main generator disconnected and the grid voltage at 105%. The isolated phase bus duct connecting the GSU and Unit Auxiliary Transformer has such a small impedance that it is neglected during voltage drop considerations.

C. Generator Step-Up Transformer

The generator step-up transformer (GSU) has an impedance of 10% on a 1230 MVA base. This impedance is insignificant compared to other transformer impedances (UAT and unit substation transformers) so that the actual resultant voltage drop is a very small percentage of the total voltage drop. In addition, the computer program used to solve for the voltages in this calculation has convergence difficulties when impedances which differ by several orders of magnitude are incorporated into the impedance digram. For these reasons, the GSU impedance has been neglected in this study.

D. Unit Auxiliary Transformer (UAT)

The UAT has the following ratings:

1) Voltages: 24.5-13.8-4.3 kV

2) MVA Ratings of windings (in OA/FA/(Future) FOA)

   a) Primary: 27/36/45 MVA

   b) 13.8 kV: 18/24/30 MVA

   c) 4.3 kV : 12/16/20 MVA

3) Leakage reactances between windings

   a) Primary to 13.8 kV (H-X): 7.5% on 27 MVA base

   b) Primary to 4.3 kV (H-Y): 12% on 27 MVA base

   c) 13.8 kV to 4.3 kV (X-Y): 18.53% on 27 MVA base

The above leakage reactances are subject to a ± 10% manufacturing tolerance.

E. Reserve Auxiliary Transformer (RAT)

The RAT has the following ratings:

1) Voltages: 345-13.8-4.3 kV

2) MVA ratings of the windings (in OA/FA/(Future)FOA)

   a) Primary: 27/36/45 MVA

   b) 13.8 kV: 18/24/30 MVA

   c) 4.3 kV: 12/16/20 MVA

3) Leakage reactances between windings:

   a) Primary to 13.8 kV (H-X): 8.265% on 27 MVA base

   b) Primary to 4.3 kV (H-Y): 10.395% on 27 MVA base

   c) 13.8 kV to 4.3 kV (X-Y): 20.12% on 27 MVA base

The above leakage reactances are tested values.

F. Secondary Unit Substation Transformers

1. All transformers, except that for unit substation (US) #64, have the following ratings:

   a) Voltages: 13.8 kV (or 4.16 kV) - 480V

   b) KVA rating: 1000/1333 KVA, AA/FA

   c) Impedance: 8% on 1000 KVA base) Tested values of all unit substations are approximately equal to 8%.

   d) $\frac{X}{R} = 8$

2. Transformer connected to unit substation (US) #64 has the following rating:

   a) Voltages: 4.16 kV - 480V

   b) KVA rating: 1000 KVA, AA

   c) Impedance: 5.75% on 1000 KVA base) Subject to ± 7.5% tolerance.

   d) $\frac{X}{R} = 6$

G. Non-Segregated Phase Bus Duct

For the purpose of this calculation, there are two types of non-segregated phase bus duct:

1) Type 1 has the following rating:

   a) Voltage: 13.8 kV

   b) Impedance: $(11.4 + j56.5)x10^{-6}$ ohms/foot

2) Type 2 has the following ratings:

   a) Voltage: 4.16 kV

   b) Impedances: $(6.1 + j43.1)x10^{-6}$ ohms/foot

H. Cables

Cables are copper conductor throughout and have lengths and sizes as indicated on Figures 1, 2, 3 and 4.

Lengths of all cables have been selected on a worst case basis. That is, the longest cable run within reason has been used in order to yield conservative results.

I. Transformer Tap, Settings

All transformer taps are on the primary winding. Therefore, a tap set on the UAT or RAT has an effect on both low voltage windings. A tap set in the minus direction has the effect of raising the secondary voltage. For the assumed utility system voltage variation of 97.5% to 105% of 345 kV, transformer taps are assumed to be set as follows:

1) GSU: + 2½%

2) RAT: + 5%

3) UAT: Normal tap

4) All US transformers, except for US #64: -5%

5) US #64 transformer: -2½%

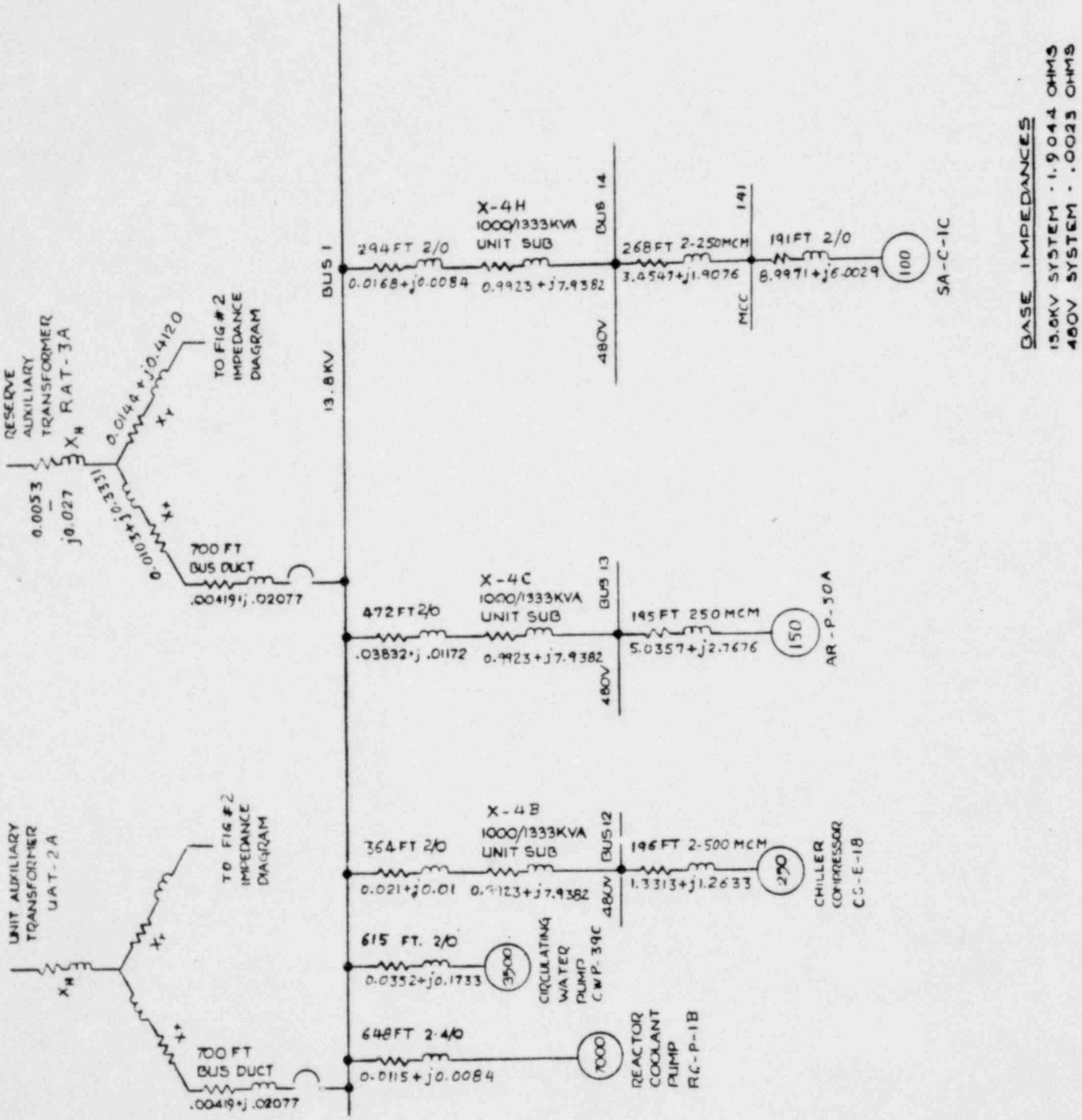
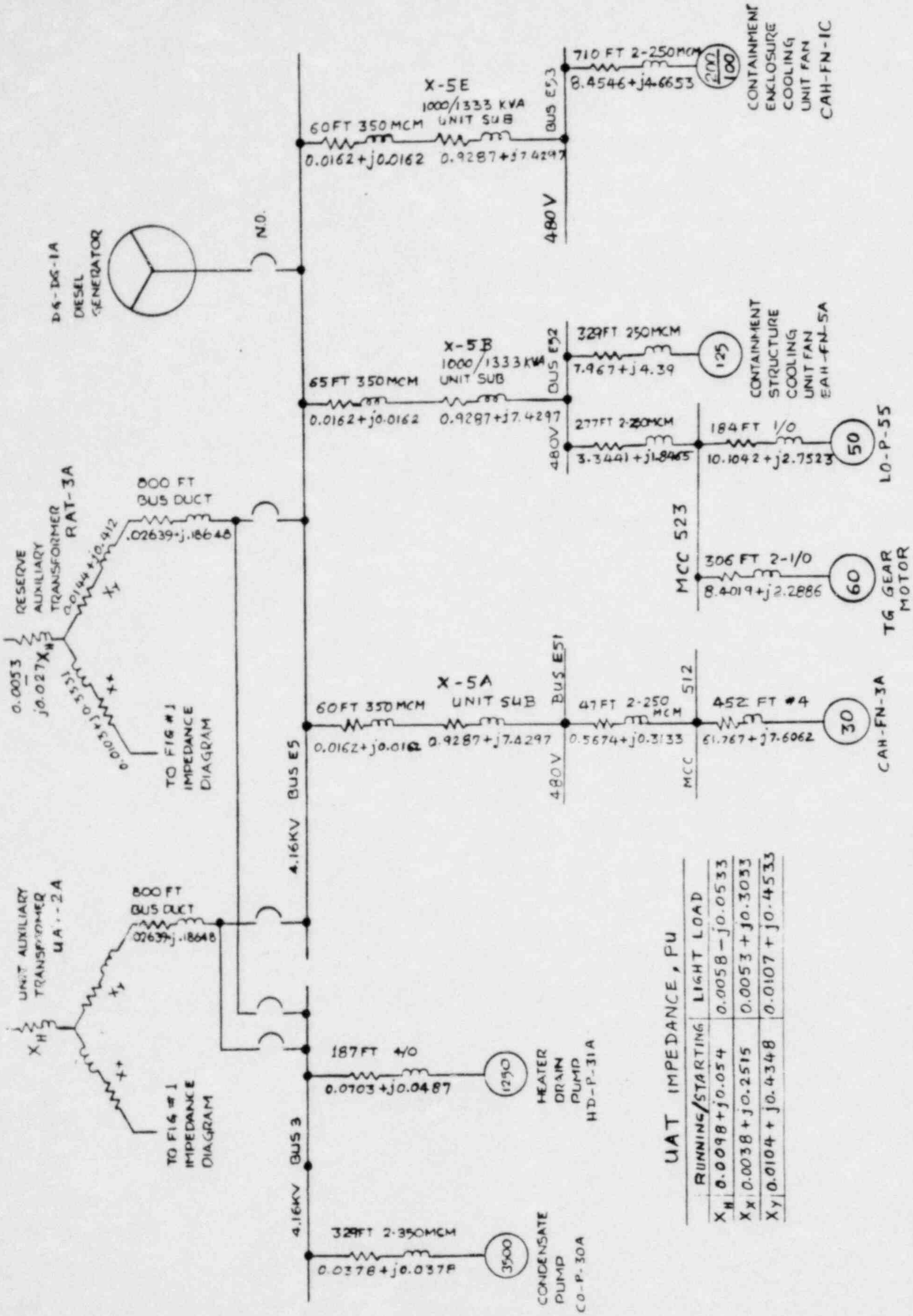


FIGURE 1

BUS 1 IMPEDANCE DIAGRAM



UAT IMPEDANCE, PU

	RUNNING/STARTING	LIGHT LOAD
X_H	0.0098+j0.054	0.0058−j0.0533
X_X	0.0038+j0.2515	0.0053+j0.3033
X_Y	0.0104+j0.4348	0.0107+j0.4533

BASE IMPEDANCES

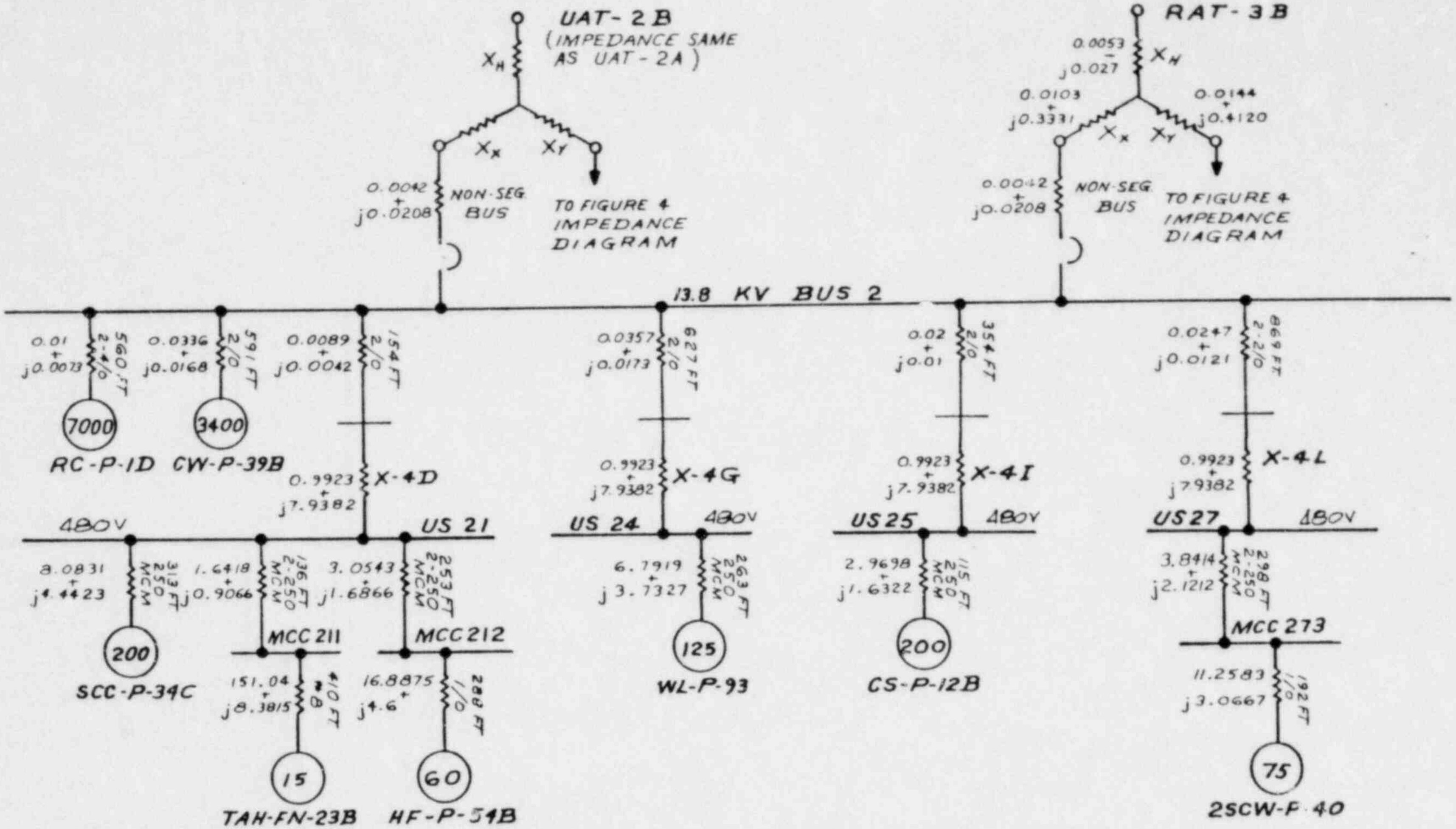
4.16KV SYSTEM - .1849 OHMS
480V SYSTEM - .00246 OHMS

FIGURE 2

BUS 3 & E5 IMPEDANCE DIAGRAM

FIGURE 3

BUS 2 IMPEDANCE DIAGRAM



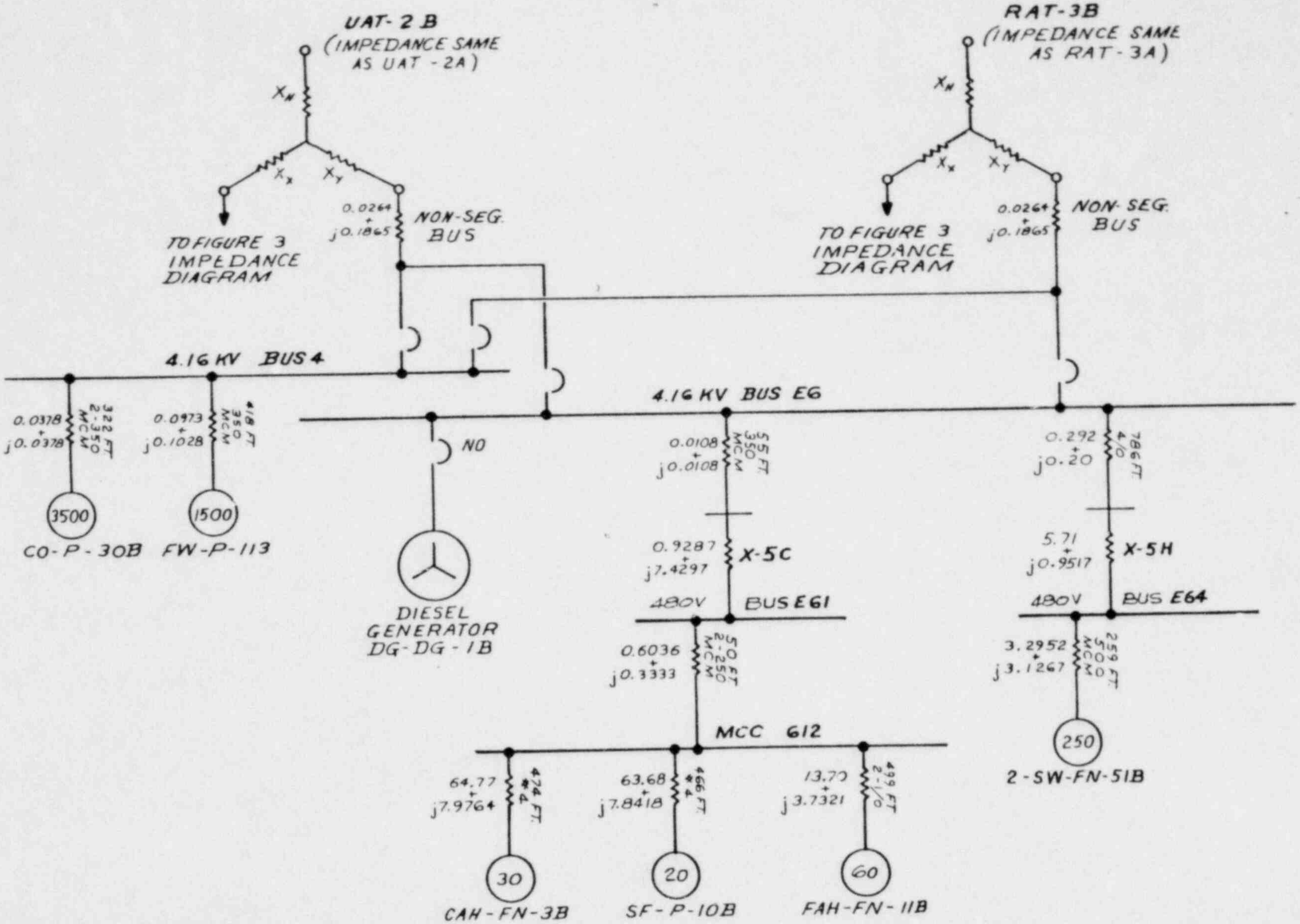


FIGURE 4

BUS 4 & E6 IMPEDANCE DIAGRAM

III. LOAD MODEL

This section contains all assumed and actual data for the loads being studied.

A. Starting Motors

The motors shown on figures 1, 2, 3 and 4 were chosen because of their large size and/or long feeder length All motors were specified to start successfully with 80% of their voltage at their terminals.

B. Running Loads - UAT or RAT Power Supply

For the purpose of this calculation, the total running loads on the medium voltage buses are assumed to be as follows:

1) Bus #1: (20.66) + j (11.21) MVA

2) Bus #2: (18.01) + j (9.37) MVA

3) Bus #3 & E5: (11.662)+ j (5.521) MVA

4) Bus #4 & E6: (10.473)+ j (5.126) MVA

The above bus loading represents worst case loads on these buses during normal and accident conditions.

Running load for the equipment shown on Figures 1, 2, 3 & 4 is derived in the following manner:

a) Motors - Manufacturer's data (when available) or catalog information is used to determine running MVA and power factor.

b) Unit Substations - All 1000/1333 KVA unit substations except US #64 are assumed loaded to 1000 KVA at .85 power factor and 0.8 diversity factor in lieu of detailing all their connected loads. US #64 is assumed loaded to 600 KVA at 0.85 power factor.

c) Motor Control Centers - The total running loads on the MCC were estimated to be as follows:

MCC #	MW	MVAR
523	0.338	0.210
612	0.313	0.164

C. Light Loads (Unit at Cold Shutdown)

The following loads are assumed to be running simultaneously:

1) R.H. Removal pumps 8A/B (400 hp), service water pumps 41A/B (600 hp) and PCC water pumps 11A/B (700 hp) are running at full load.

2) Each unit substation, except US #64, is loaded to 400 kVA at 0.8 pf.

3) Unit substation No. 64 is loaded to 100 kVA at 0.8 pf.

IV METHODS

Computer assisted calculations were made to evaluate the voltage regulation performance of the electrical power system. The computer program employed was the VOLTS Program; a United Engineers and Constructors Inc. computer program. The VOLTS Program is a 25 bus load flow and voltage regulation computer program which utilizes a Gauss-Seidel iterative method to obtain the load flow solution.

This calculation is done on a worst case basis. For equipment whose parameters are known, the actual values are used, plus a margin where applicable. For equipment whose parameters are unknown, values were assumed which represent the worst reasonable case. Consequently, resultant voltages should be the lowest voltages to be expected during the lifetime of the plant.

V. TABULATION OF RESULTS

The results of the computer calculated voltages are tabulated as follows:

TABLE 1 --- Bus and Motor Terminal Voltages when running at full load and utility grid at the minimum anticipated voltage.

TABLE 2 --- Bus and Motor Terminal Voltages when starting individual motors and the utility grid at the minimum anticipated voltage.

TABLE 3 --- Bus and Motor Terminal Voltages when starting all accident loads simultaneously and the utility grid at the minimum anticipated voltage.

TABLE 4 --- Bus Voltages when running at light load and the utility grid at the maximum anticipated voltage.

TABLE 5 --- 120 V ac System Voltages.

TABLE 1

BUS AND MOTOR TERMINAL VOLTAGES
WHEN RUNNING AT FULL LOAD
UTILITY GRID AT MINIMUM ANTICIPATED VOLTAGE

(ALL VOLTAGES ARE ON MOTOR VOLTAGE BASE)

BUS OR MOTOR TAG #	HP	NOMINAL VOLTAGE, V	SOURCE: FROM UAT, pu	FROM RAT, pu
4.16 kV Bus E5	--	4160	0.9500	0.9458
4.16 kV Bus E6	--	4160	0.9595	0.9545
* CO-P-30A	3500	4000	0.9482	0.9440
480V Bus E52	--	480	0.9586	0.9537
480V Bus E53	--	480	0.9551	0.9504
480V Bus E61	--	480	0.9656	0.9601
480V Bus E64	--	480	0.9557	0.9504
MCC 523	--	460	0.9407	0.9357
MCC 612	--	460	0.9627	0.9571
** CAH-FN-1C	200	460	0.9345	0.9297
EAH-FN-5A	125	460	0.9446	0.9396
FAH-FN-11B	60	460	0.9530	0.9474
2SW-FN-51B	250	460	0.9434	0.9380
SF-P-10B	20	460	0.9481	0.9425

NOTES: * CO-P-30A -- CONDENSATE PUMP IS A 3500 HP NON SAFETY LOAD. THIS REPRESENTS THE WORST VOLTAGE DROP ON THE 4160 VOLT SYSTEM.

** NON SAFETY RELATED.

TABLE 2

BUS AND MOTOR TERMINAL VOLTAGES WHEN STARTING INDIVIDUAL MOTORS UTILITY GRID AT MINIMUM ANTICIPATED VOLTAGE

(ALL VOLTAGES ARE ON MOTOR VOLTAGE BASE)

BUS OR MOTOR TAG #	HP	NOMINAL VOLTAGE, V	SOURCE: FROM UAT, pu	SOURCE: FROM RAT, pu
4.16 kV Bus E5	--	4160	.8412	.8517
4.16 kV Bus E6	--	4160	.8537	.8607
* CO-P-30A	3500	4000	.8339	.8445
480V Bus E52	--	480	.8318	.8433
480V Bus E53	--	480	.8325	.8445
480V Bus E61	--	480	.8431	.8547
480 Bus E64	--	480	.8391	.8500
MCC 523	--	460	.8097	.8217
MCC 612	--	460	.8398	.8515
** CAH-FN-1C	200	460	.7622	.7628
EAH-FN-5A	125	460	.8660	.8663
EAH-FN-11B	60	460	.8430	.8392
2SW-FN-51B	250	460	.8282	.8247
SF-P-10B	20	460	.9229	.9177

NOTES:

1) FOR BUS VOLTAGES, THIS TABLE REPRESENTS MINIMUM VOLTAGE AT THE BUS WHEN STARTING ANY ONE MOTOR FED FROM ANY BUS IN THE PLANT.

2) THIS TABLE SUMMARIZES THE RESULTS OF MANY COMPUTER RUNS. THE BUS VOLTAGES LISTED REPRESENT THE LOWEST VOLTAGES EXPERIENCED AT THAT BUS WHEN STARTING ANY INDIVIDUAL MOTOR, CLASS 1E OR NON-CLASS 1E, IN THE PLANT. THE MOTOR VOLTAGES LISTED ARE THE LOWEST REPRESENTATIVE MOTOR TERMINAL VOLTAGES UPON MOTOR START.

* CO-P-30A, A NON SAFETY LOAD, REPRESENTS THE WORST VOLTAGE DROP ON THE 4160 VOLT SYSTEM, INCLUDING THE SAFETY BUSES.

** THIS IS A NON SAFETY RELATED MOTOR. HOWEVER, ITS CAPABILITY TO SUCCESSFULLY START AND ACCELERATE AT THE AVAILABLE VOLTAGE HAS BEEN VERIFIED BY CALCULATION.

TABLE 3

BUS AND MOTOR TERMINAL VOLTAGES WHEN STARTING ALL ACCIDENT LOADS SIMULTANEOUSLY UTILITY GRID AT MINIMUM ANTICIPATED VOLTAGE

(ALL VOLTAGES ARE ON MOTOR VOLTAGE BASE)

BUS OR MOTOR TAG #	HP	NOMINAL VOLTAGE, V	SOURCE: FROM UAT, pu	SOURCE: FROM RAT, pu
4.16 kV Bus E5	--	4160	.8856	.8944
4.16 kV Bus E6	--	4160	.8661	.8749
* SI-P-6B	450	4000	.8640	.8727
* RH-P-8B	400	4000	.8646	.8733
* CS-P-2B	600	4000	.8626	.8713
* FW-P-37B	900	4000	.8592	.8679
480V Bus E51	--	480	.8811	.8911
480V Bus E52	--	480	.8797	.8897
480V Bus E53	--	480	.8832	.8932
480V Bus E61	--	480	.8597	.8696
480V Bus E64	--	480	.8631	.8724
MCC 512	--	460	.8786	.8886
MCC 612	--	460	.8564	.8663
CAH-FN-3B	30	460	.8313	.8416
CBA-FN-32	40	460	.8499	.8599
2-SW-FN-51B	250	460	.8494	.8589

NOTES: * STARTING LOAD

1) OTHER SAFETY LOADS SUCH AS SERVICE WATER PUMPS, ETC., ARE RUNNING.

2) TABLE LISTS TRAIN B ACCIDENT LOADS, WHICH IS WORST CASE.

TABLE 4

BUS TERMINAL VOLTAGES
WHEN RUNNING AT LIGHT LOAD
UTILITY GRID AT MAXIMUM ANTICIPATED VOLTAGE

(ALL VOLTAGES ARE ON MOTOR VOLTAGE BASE)

BUS OR MOTOR TAG #	HP	NOMINAL VOLTAGE, V	SOURCE: FROM UAT, pu	FROM RAT, pu
4.16 kV Bus E5	--	4160	1.0920	1.0639
4.16 kV Bus E6	--	4160	1.0910	1.0627
480V Bus E52	--	480	1.1293	1.1009
480V Bus E53	--	480	1.1294	1.1010
480V Bus E61	--	480	1.1293	1.0988
480V Bus E64	--	480	1.1176	1.0884
MCC 523	--	460	1.1241	1.0956
MCC 612	--	460	1.1283	1.0978

TABLE 5

120 V ac System Voltages

1. Most of the control and instrumentation circuits for safety related systems at Seabrook Station are power from Vital AC Distribution panels supplied by 118 V ac regulated Uninterruptible Power supply units.

   For the remaining safety related circuits which are powered from non regulated Class 1E 120 V ac power distribution panels (powered from motor control centers), our analysis is as follows:

(LATER)

VI. CONCLUSIONS

A. Full and Light Load Conditions

All motors will receive more than the minimum 90% of their rated voltage during normal plant operating conditions.

During light load conditions, all buses and motors will receive less than 110% of their rated voltage except that some 480 V buses, when fed via the UAT, may exceed the allowable maximum motor voltage by up to 2.9%. However, assuming a nominal motor feeder drop of 2 to 3%, 480 V motor terminal voltage should not exceed the allowable maximum voltage when supplied by the UAT. There is no overvoltage problem when the system is fed via the RAT.

B. Motor Starting Conditions

All safety-related motor receive more than 80% of their rated voltage and will accelerate without any problems.

C. Transformer Tap Settings

The assumed transformer tap settings are acceptable for the assumed utility system voltage variation of 97.5 to 105 percent of 345 kV.

REVISED RESPONSE TO RAI 430.5

RAI 430.5

The voltage levels at the safety-related buses should be optimized for the full load and minimum load conditions that are expected throughout the anticipated range of voltage variations of the offsite power source by appropriate adjustment of the voltage tap settings of the intervening transformers. Submit the planned range of normal operating voltages for each safety-related bus.

RESPONSE (Revised 4/30/82)

Enclosed is the Voltage Regulation Study for the Seabrook Station. This study provides the voltage analysis required by BTP PSB-1 (See RAI 430.14). Additional data for 120 volt ac level will be submitted to the NRC by 6/1/82.