Onsite AC Power System Calculation

Non Proprietary Version

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Abstract

This study provides assessment of the onsite ac power system in the US-APWR to verify that plant electrical equipment will start and operate as designed under an array of electrical power configurations and operational modes. Electrical parameters included in this study are steady state load flow, motor starting, short circuit, transfer of medium voltage switchgear and harmonic analysis. Operational modes encompassed in this study are normal operation and startup/shutdown. In the normal operation mode, the main generator is operating, the Generator Load Breaker Switch is closed, and each onsite power bus is powered from Unit Auxiliary Transformer or Reserve Auxiliary Transformer. In the startup/shutdown mode, the main generator is not operating and Generator Load Breaker Switch is open. For each operational mode, three conditions for supplying power to the Medium Voltage buses are considered. These conditions are the normal condition when Class 1E buses are powered from Reserve Auxiliary Transformer and Non-Class 1E buses are powered from the Unit Auxiliary Transformer, the condition where the Unit Auxiliary Transformer is unavailable so all buses are powered from the Reserve Auxiliary Transformer and the condition where the Reserve Auxiliary Transformer is unavailable so all buses are powered from the Unit Auxiliary Transformer. Section 7 of this study provides the acceptance criteria for each of the electrical parameters described above. All electrical equipment considered in this study met the acceptance criteria for the applicable parameters.

This document supports US-APWR Design Control Document, Chapter 8.

Table of Contents

List of Tables

List of Figures

List of Acronyms

ac	alternating current
AAC	alternate alternating current
ANSI	American National Standards Institute
BTP	Branch Technical Position
CFR	Code of Federal Regulations
dc	Direct current
DCD	Design Control Document
ETAP	electrical transient analyzer program
FWP	feed water pump
GDC	General Design Criteria
GLBS	generator load break switch
GTG	gas turbine generator
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronics Engineers
IPB	isolated phase bus duct
LC	Load center
LOOP	loss of off-site power
LV	low voltage
MCC	motor control center
MCR	main control room
MG	main generator
MOV	motor operated valve
MT	main transformer
MV	medium voltage
NEMA	National Electrical Manufacturer's Association
NFPA	National Fire Protection Association
NPGS	nuclear power generating station
NRC	U.S. Nuclear Regulatory Commission
OLTC	on-load tap changer
PPS	preferred power supply
PS/B	power source building
RAT	reserve auxiliary transformer
RCP	reactor coolant pump
RG	Regulatory Guide
SRP	Standard Review Plan
SST	station service transformer
THD	total harmonic distortion
UAT	unit auxiliary transformer

1.0 INTRODUCTION

This technical report provides an evaluation of the onsite alternating current (ac) power system capability in the US-APWR. The purpose of this document is to provide the result of the calculation as referenced by US-APWR Design Control Document (DCD) (Reference 3.4), Subsection 8.3.1. Steady state load flow, motor starting analysis, short circuit, transfer of medium voltage (MV) switchgear and harmonic analysis are utilized to examine major electrical equipment specifications based on the design criteria. These studies are calculated using the electrical transient analyzer program (ETAP). ETAP complies with 10 Code of Federal Regulations (CFR) Part 50 Appendix B (Reference 3.1.2) and Part 21 (Reference 3.1.3), and ASME NQA-1 (Reference 3.3.33).

2.0 SCOPE

The onsite power system consists of medium voltage (MV) switchgears, low voltage (LV) switchgears, motor control centers (MCC), station service transformers (SST), standby power sources, cables, and their accessories. This technical report includes calculations for the onsite power system and some portion of the offsite power system such as unit auxiliary transformers (UAT), reserve auxiliary transformers (RAT) etc.

The following studies are addressed in this technical report.

- Steady State Load Flow
- Motor Starting Analysis
- Short Circuit
- Transfer of MV switchgear
- Harmonic Analysis

3.0 APPLICABLE CODES, STANDARDS, AND REGULATORY GUIDES

3.1 U.S. Regulations

3.1.1 10 CFR 50, Appendix A, “General Design Criteria for Nuclear Power Plants”
General Design Criteria (GDC) 17, “Electric Power Systems”

3.1.2 10 CFR 50, Appendix A, “General Design Criteria for Nuclear Power Plants”
GDC 18, “Inspection and testing of electric power systems”

3.1.3 10 CFR 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants”

3.2 U.S. Nuclear Regulatory Guidance

3.2.1 RG 1.32, Revision 3, March 2004 Criteria for Power Systems for Nuclear Power Plants

3.2.2 RG 1.53, Rev. 2, November 2003 Application of the Single-Failure Criterion to Safety Systems

3.2.3 RG 1.75, Rev. 3, February 2005 Criteria for Independence of Electrical Safety Systems

3.2.4 RG 1.93, Rev. 0, December 1974 Availability of Electric Power Sources

3.2.5 RG 1.155, Rev. 0, August 1988 Station Blackout

3.2.6 NUREG-0800, Standard Review Plan (SRP)

3.2.7 BTP 8-6 Adequacy of Station Electric Distribution System Voltages

3.3 U.S. Industry Guidance

3.3.1 IEEE 141-1993 IEEE Recommended Practice for Electric Power Distribution for Industrial Plants

3.3.2 IEEE 308-2001 IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations

3.3.3 IEEE 379-2000 IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems

3.3.4 IEEE 384-1992 IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits

3.3.5 IEEE 387-1995 IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations (as applicable to GTGs)

3.3.6 IEEE 399-1997 IEEE Recommended Practice for Industrial and Commercial Power System Analysis

3.3.7 IEEE 422-1986 Guide for the Design and Installation of Cable Systems in Power Generating Stations

3.3.8 IEEE 446-1995 IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

3.3.9 IEEE 493-1997 IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems

3.3.10 IEEE 666-1991 IEEE Design Guide for Electric Power Service Systems for Generating Stations

3.3.11 IEEE 765-2006 IEEE Standard for Preferred Power Supply (PPS) for Nuclear Power Generating Stations (NPGS)

3.3.12 IEEE 835-1994 IEEE Standard Power Cable Ampacity Tables

3.3.13 IEEE 1015-1997 IEEE Recommended Practice for Applying Low Voltage Circuit Breakers in Industrial and Commercial Power Systems

3.3.14 IEEE 1247-2005 IEEE Standard for Interrupter Switches for Alternating Current, Rated Above 1,000 V
3.3.15 IEEE C2-2002 ANSI/IEEE National Electrical Safety Code
3.3.16 IEEE C37.010-1999 IEEE Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
3.3.17 IEEE C37.04-1999 IEEE Standard Rating Structure for AC High Voltage Circuit Breakers
3.3.18 IEEE C37.06-2000 American National Standard AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis-Preferred Ratings and Related Required Capabilities
3.3.19 IEEE C37.13-1990 IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures
3.3.20 IEEE C37.16-2000 American National Standard Low-Voltage Power Circuit Breakers and AC Power Circuit Breakers . Preferred Ratings, Related Requirements and Application Recommendations
3.3.21 IEEE C37.20.1-2002 Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
3.3.22 IEEE C37.20.2-1999 Metal-Clad and Station-Type Cubicle Switchgear
3.3.23 IEEE C37.20.3-2001 Standard for Metal-Enclosed Interrupter Switchgear
3.3.24 IEEE C37.20.4-2001 Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear
3.3.25 IEEE C37.22-1997 Preferred Ratings and Related Required Capabilities for Indoor AC Medium Voltage Switches Used in Metal-Enclosed Switchgear
3.3.26 IEEE C37.23-2003 IEEE Standard for Metal-Enclosed Bus
3.3.27 IEEE C57.12.00-2000 IEEE Standard General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers
3.3.28 NEMA MG-1-2006 Motors and Generators
3.3.29 ANSI C50.41-2000 American National Standard for Polyphase Induction Motors for Power Generating Stations
3.3.30 NEMA WC-51-2003 Ampacities for Cables Installed in Cable Trays
3.3.31 NEMA WC-70-1999 ICEA S-95-658, Standard for Nonshielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy
3.3.32 NFPA 70 - 2005 National Electrical Code ANSI/ISA-S67.04.01-2006, “Setpoints for Nuclear Safety-Related Instrumentation” published by the Instrumentation, Systems, and Automation Society, May 2006.
3.3.33 ASME NQA-1-1994 Quality Assurance Requirements for Nuclear Facility Applications

3.4 Other References

3.4.1 Design Control Document for the US-APWR, Rev. 2, October 2009.

4.0 AC POWER SYSTEM DESCRIPTIONS

4.1 Offsite Power System

The offsite power system is a non safety-related, non-Class 1E system. The plant switchyard is connected to the transmission grid by at least two electrically independent and physically isolated power circuits. As a minimum, there are two electrically isolated and physically independent power circuits connecting the plant to the switchyard. There are at least two electrically isolated and physically independent power circuits as normal and alternate preferred power sources.

Offsite electric power is provided to the onsite power system from the grid and other generating stations by at least two physically independent transmission lines. During plant startup, shutdown, maintenance, and during all postulated accident conditions, offsite electric power can be supplied to the plant site from the plant high voltage switchyard through two physically independent transmission tie lines. One of these two transmission tie lines connects to the high voltage side of the main transformer (MT), and the other connects to the high voltage side of the RATs. The main generator (MG) is connected to the low voltage side of the MT and the high voltage side of the UATs. There is a generator load break switch (GLBS) between the MG and the MT. When the MG is on-line, it provides power to the onsite non safety-related electric power system through the UATs. When the GLBS is open, offsite power to the onsite non safety-related electric power system is provided through the MT and the UATs. With GLBS either open or closed, offsite power to the onsite safety-related electric power system is provided through the RATs. If power is not available through the UATs, offsite power is provided to both safety-related and non safety-related onsite electric power systems through the RATs. Similarly, if power is not available through the RATs, offsite power is provided to both safety-related and non safety-related onsite electric power system through the UATs. Both normal and alternate preferred power sources have the capability to serve the total plant auxiliary and service loads during all modes of plant operation including postulated accident conditions.

4.2 Onsite AC Power System

The onsite power system provides power to the plant auxiliary and service loads during all modes of plant operation. The onsite power system consists of both ac power system and direct current (dc) power system. Both ac and dc systems include Class 1E and non-Class 1E systems. The onsite ac power system and its connections to the offsite power system are shown in Figure 4.2-1.

The onsite ac power system is supplied offsite power from the transmission system by two independent connections to the transmission system. Each offsite power connection has enough capacity and capability to power the loads required during all modes of plant operation, including the plant startup, shutdown, maintenance and postulated accident conditions. One connection to the transmission system is provided through the MT and UATs. The UATs are also connected to the MG through a GLBS. During power operation mode, GLBS is closed and the MG is connected to the transmission system through the MT and also supplies power to the UATs. The second connection to the transmission system is provided through the RAT. The onsite ac power systems are normally fed from either the UATs or RATs. The MV Class 1E buses are normally fed from the RATs. MV non-Class 1E buses are normally fed from the UATs.

Four two-winding UATs and four three-winding RATs are provided for each unit. Delta connected tertiary winding is provided for the star-star connected RATs. The tertiary winding is not loaded. The UATs are connected on the high voltage side to the isolated phase bus duct (IPB) through disconnecting links. The disconnecting links are always closed except during UAT maintenance. UAT1, UAT2, RAT1 and RAT2 provide power to the 13.8kV onsite ac buses and UAT3, UAT4, RAT3 and RAT4 provide power to the 6.9kV onsite ac buses.

Four emergency Class 1E gas turbine generators (GTG) provide backup power to the Class 1E 6.9kV onsite ac buses. In addition, two non-Class 1E alternate alternating current (AAC) GTGs provide backup power to the non-Class 1E 6.9kV permanent buses.

4.2.1 Non-Class 1E Onsite AC Power System

The 13.8kV ac system includes non-Class 1E buses N1 and N2. Bus N1 is connected to either UAT1 or RAT1 and bus N2 is connected to either UAT2 or RAT2 by non-segregated busduct/cable buses.

The non-Class 1E 6.9kV ac system includes buses N3, N4, N5, N6, P1 and P2. Buses N3, N4 and P1 are connected to either UAT3 or RAT3 and buses N5, N6 and P2 are connected to either UAT4 or RAT4 by non-segregated busduct/cable buses.

The UAT and RAT ratings are adequate to meet the maximum load requirements during normal plant operation, start-up, shutdown and design-basis events, as evaluated in the DCD Section 8.3 (Table 8.3.1-3).

Non-Class 1E 6.9kV permanent buses P1 and P2 are also connected to the non-Class 1E A-AAC GTG and B-AAC GTG, respectively. The loads which are not safety-related but require operation during loss of offsite power (LOOP) are connected to these buses. Any one AAC GTG is adequate to meet the load requirements as evaluated in the DCD Section 8.3 (Table 8.3.1-5 and Table 8.3.1-6).

Normal offsite power to the non-Class 1E 13.8kV buses N1, N2 and non-Class 1E 6.9kV buses N3, N4, N5, N6, P1 and P2 is provided from the UATs and alternate offsite power is provided from the RATs. Automatic bus transfer schemes are provided on all these buses to automatically transfer the loads from the normal offsite power source to the alternate offsite power source in case of loss of normal power to the buses.

The A-AAC GTG and B-AAC GTG can also be connected manually to their respective 6.9kV permanent buses P1 and P2 during periodic online testing of the AAC GTGs. This can be done locally from the panels located in the power source buildings (PS/B) housing the AAC GTGs, or remotely from the main control room (MCR).

13.8kV-480V, two winding SSTs connected to the 13.8kV buses N1 and N2 provide power to the non-Class 1E 480V load center (LC) buses N1 and N2 respectively. 6.9kV-480V, two winding SSTs connected to the 6.9kV buses N3, N4, N5, N6, P1 and P2 provide power to non-Class 1E 480V load center buses N3, N4, N5, N6, P1 and P2 respectively. The non-Class 1E 480V load center buses feed the non-Class 1E MCC buses.

4.2.2 Class 1E Onsite AC Power System

The Class 1E onsite ac power systems provide power to the safety-related loads required during LOOP and postulated accident conditions. The power from the transmission system to the Class 1E distribution is the preferred power source under accident and post-accident conditions. The Class 1E onsite ac power system consists of four independent and redundant trains A, B, C and D. Two independent connections to the offsite power system are provided to each of the Class 1E 6.9kV ac onsite buses A, B, C and D. Class 1E 6.9kV buses A and B have connections to UAT3 and RAT3, and buses C and D have connections to UAT4 and RAT4 through non-segregated busducts/cable buses. Each redundant train is backed-up by a Class 1E GTG. The four trains are physically separated and electrically isolated from each other and also from the non-Class 1E systems.

6.9kV-480V, two winding SSTs connected to the Class 1E 6.9kV buses A, B, C and D provide power to Class 1E 480V load center buses A, B, C and D respectively. The Class 1E 480V load center buses feed the Class 1E MCC buses except for the Class 1E 480V ac motor operated valve (MOV) MCCs, which are supplied from the inverters.

5.0 STUDY

5.1 Steady State Load Flow

Load flow studies determine the voltage, current, active, and reactive power, power factor and losses in the onsite power system. Load flow studies are performed to evaluate that loading meets equipment rating indicated in DCD Chapter 8, Table 8.3.1-1, and that steady state voltages are maintained within acceptable voltage variation for each equipment. The load flow is calculated with the Newton-Raphson method.

5.2 Motor Starting Study

The starting current of most ac motors is several times normal full load current. Motor-starting torque varies directly as the square of the applied voltage. If the terminal voltage drop is excessive, the motor may not have enough starting torque to accelerate up to running speed. Running motors may stall from excessive voltage drops, or undervoltage relays may operate.

Motor starting studies calculate voltage drop on the onsite power system to evaluate motor terminal voltages are maintained within acceptable voltage under the applicable motor starting condition. Motor starting studies include evaluating voltage drop at starting motor and voltage drop at operating motors. The motor starting studies are calculated with the static motor starting method.

5.3 Short Circuit Study

Short circuit studies are done to determine the magnitude of the prospective currents flowing throughout the power system at various time intervals after a fault occurs. The magnitude of the currents flowing through the power system after a fault vary with time until they reach a steady-state condition. This behavior is due to system characteristics and dynamics. During this time, the protective system is called on to detect, interrupt, and isolate these faults. The duty imposed on this equipment is dependent upon the magnitude of the current, which is dependent on the time from fault inception.

Short circuit studies calculate momentary asymmetrical crest and interrupting symmetrical rms short circuit current, and check the protective device rated close and latching and adjusted interrupting capability against the fault current.

5.4 Preliminary MV Bus Transfer

Switching transient due to MV bus transfer has an impact on operating motors with brief moment of voltage variation. Preliminary MV bus transfer study evaluates voltage behavior at motor terminal and buses due to fast transfer of MV buses.

5.5 Harmonic Analysis

The presence of harmonics in the onsite power system may give to a variety of problems including equipment overheating, reduced power factors, deteriorating performance of electrical equipment and incorrect operation of protective relays. This analysis calculates individual and total harmonic distortion (THD) and checks calculation result meets acceptance criteria.

6.0 STUDY CONDITION

6.1 General

6.1.1 Configuration
Configuration of onsite ac power system is indicated in Figure 4.2-1.

6.1.2 Mode of Operation
Normal operation and start-up/shutdown mode are considered in steady state load flow and motor starting studies.

All modes of operation are considered in the studies. Supply power to the MV buses in each mode are shown in Table 6.1-1 to Table 6.1-3.

6.1.3 Parameter of Equipment
Parameters of equipment including MG, UATs, RATs, SSTs, GTGs, switchgears and MCCs are shown in Table 6.1-4 to Table 6.1-7

6.1.4 Allowable Voltage Variation for Motor Loads
Allowable voltage variation for each bus load is indicated below:

Connected Bus	Nominal Voltage	Normal Condition	Motor Starting Condition [1]	Momentary Condition [1]
Non-Class 1E MV	13.8kV	±10%	-20%	-25%
	6.9kV	±10%	-20%	-25%
Class 1E MV	6.9kV	±10%	-20%	-25%
Non-Class LV	480V	±10%	-20%	-25%
Class 1E LV	480V	±10%	-25%	-25%

Note 1: These percent values are based on motor rated voltage.

6.1.5 Maximum Motor Load for Motor Starting Study
Motor starting study is calculated assuming maximum motor starting for each voltage.
Maximum motor at each voltage is follows:
13.8kV: Feed Water Pump (FWP)
6.9kV: Reactor Coolant Pump (RCP)
480V: 300HP motor

6.2 Assumptions

6.2.1 Offsite Grid Voltage
Offsite grid rated voltage is assumed 345kV.

6.2.2 Offsite Grid Voltage Variation
Maximum and minimum offsite grid voltage variations are below:
Maximum: 105% of rated voltage
Minimum: 95% of rated voltage

6.2.3 Offsite Grid Short Circuit MVA

Maximum and minimum short circuit contributions from the offsite grid are below:

Maximum short circuit MVA: 99,999 MVA, X/R: 99999
Minimum short circuit MVA: 18,823 MVA, X/R: 10

6.2.4 Load data

Major loads shown in the DCD Chapter 8 Table 8.3.1-3, Table 8.3.1-4, Table 8.3.1-5 and Table 8.3.1-6 are assumed. Low voltage miscellaneous loads are assumed as lump load. Hypothetical loads are assumed to connect to the buses to nearly reach the transformer ratings for considering future load conservatively.

6.2.5 Cables

Cables are modeled with consideration as below:
Feeder cables are sized based on full load amps. Length of feeder cables is assumed shorter than planned length except maximum motors, because voltage drops of motor terminal are calculated for maximum motor starting. Voltage drop of feeder cables at motor steady operation will be determined as follows:

Medium voltage: 0.5 %
Low voltage: 3 %

Voltage drop for load terminal is assured by including cable voltage drop indicated above into acceptance criteria at bus voltage. Therefore evaluation of voltage drop for individual operating load is not performed in this study.

6.2.6 Rectifier and Uninterruptible Power Supply

Onsite power system has UPS and battery charger to supply constant and uninterruptible power to control and protection equipment etc. These power sources generate harmonic. It is conservatively assumed that these power sources have 6-pulse input converter.

7.0 ACCEPTANCE CRITERIA

7.1 Steady State Bus Voltage

Acceptance criteria for steady state bus voltage are established to satisfy allowable steady state voltage for equipment. The acceptance criteria for bus voltage variation are summarized below:

Bus	Nominal Voltage	Acceptance Criteria [1, 2]	Remarks
13.8 kV	13.8 kV	+5%/-10%	Acceptance criteria percent value is based on bus nominal voltage
6.9kV Non-Class 1E	6.9 kV	+5%/-10%	Acceptance criteria percent value is based on bus nominal voltage
6.9kV Class 1E	6.9 kV	+5%/-10%	Acceptance criteria percent value is based on bus nominal voltage
480V	480 V	+5%/-10%	Acceptance criteria percent value is based on bus nominal voltage

Notes

1. The following maximum allowable motor terminal voltages (110 % of nominal motor voltage) are satisfied by compliance with the above acceptance criteria.
   - 13.8 kV bus: 13.2kV *1.1 = 14.52 kV (=105.2 %)
   - 6.9 kV bus: 6.6 kV *1.1 = 7.26 kV (=105.2 %)
   - 480 V bus: 460*1.1 = 506 V (=105.4%)

2. The minimum allowable motor terminal voltages (90% of nominal motor voltage) are in compliance with above acceptance criteria.
   - 13.8 kV bus: 13.2kV *0.9 + (13.8*0.005) = 11.95 kV (=86.6 %)
   - 6.9 kV bus: 6.6 kV *0.9 + (6.9*0.005) = 5.98 kV (=86.6 %)
   - 480 V bus: 460*0.9 + (480*0.03) = 428.4 V (=89.3 %)

7.2 Motor Starting Study

Acceptance criteria for motor starting study are established to satisfy allowable minimum voltage for starting motor and allowable minimum voltage for running motor. The acceptance criteria for motor starting are summarized in below:

Bus	Starting Motor Acceptance Criteria [1]	Running Motor Acceptance Criteria [1]	Bus Momentary Voltage Acceptance Criteria [2, 3]	Remarks
13.8 kV	80 %	75 %	72.2 %	
6.9kV Non-Class 1E	80 %	75 %	72.1 %	
6.9kV Class 1E	80 %	75 %	72.1 %	
480V Non-Class 1E	80 %	75 %	74.8 %	
480V Class 1E	75 %	75 %	74.8 %	

1. The above acceptance criteria percent values are based on motor rated voltage.
2. The above acceptance criteria percent values are based on bus nominal voltage.
3. The above acceptance criteria of running motors are based on the following:
   - 13.8 kV bus: 13.2kV *0.75 + (13.8*0.005) = 9.969 kV (=72.2 %)
   - 6.9 kV bus: 6.6 kV *0.75 + (6.9*0.005) = 4.98 kV (=72.1 %)
   - 480 V bus: 460*0.75 + (480*0.03) = 359.4 V (=74.8 %)

7.3 Short Circuit Study

Short circuit acceptance criteria are established for available short circuit current to satisfy applicable circuit breaker ratings. The acceptance criteria for short circuit are summarized below:

- 13.8 kV circuit breaker: 50 kA interrupting (rms, sym),
  130 kA closing and latching (asym, peak)
- 6.9 kV circuit breaker: 63 kA interrupting (rms, sym),
  170 kA closing and latching (asym, peak)
- 480 V Load center circuit breaker: 65 kA interrupting (rms, sym)
- 480 V Motor control center circuit breaker: 65 kA interrupting (rms, sym)

7.4 Preliminary MV bus Transfer

Acceptance criteria for preliminary MV bus transfer are established to meet allowable voltage variation for operating motors. The acceptance criterion for preliminary MV bus transfer is that bus and motor terminal voltage is restored to allowable voltage of loads immediately.

7.5 Harmonic Analysis

Acceptance criteria for harmonic analysis are established to meet allowable harmonic distortion of electrical equipment. The acceptance criteria for harmonic analysis are summarized below:

	Individual Voltage Distortion	Total Voltage Distortion THD
Acceptance Criteria	3.0 %	5.0 %

8.0 EVALUATION AND RESULT

8.1 Steady State Load Flow

Load flow studies have been performed to evaluate loading and steady state voltage, for each piece of equipment.

Normal operation (MG on line) mode and start-up/shutdown mode are considered in load flow studies. The normal operation mode is with the main generator operating, GLBS closed, and each onsite power bus powered from UAT or RAT respectively. In start-up/shutdown mode, main generator is not operated and GLBS is open. Operation of on-load tap changer (OLTC) on the UATs and RATs are considered to maintain the voltage at MV buses to around nominal bus voltage in each operation mode. For each operational mode, three variations of power supply to each MV bus are considered. These variations are normal condition when Class 1E buses are powered from RATs and Non-Class 1E buses are powered from UATs, unavailable condition of UATs such that all buses are powered from RATs, and unavailable condition of RATs such that all buses are powered from UATs. Offsite grid voltage is assumed as minimum voltage.

8.1.1 Normal Configuration

This case was calculated with following initial conditions. The main generator is synchronized to the grid and Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses are supplied from UATs and Class 1E buses are supplied from RATs as shown in Table 6.1-1

In this configuration, calculation results for UATs and RATs loading are summarized in Table 8.1-1. Station service transformer loading is summarized in Table 8.1-2. MV buses and load centers loading are summarized in Table 8.1-3 and 8.1-4 respectively. Steady state voltages are summarized in Table 8.1-5 and 8.1-6 respectively for MV buses and load centers. These steady state voltages meet acceptance criteria.

8.1.2 Unavailable Condition of UATs

This case was calculated with following initial conditions. The main generator is synchronized to the grid and Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from RATs as shown in Table 6.1-2.

In this configuration, calculation results for UATs and RATs loading are summarized in Table 8.1-1. Station service transformer loading is summarized in Table 8.1-2. MV buses and load centers loading are summarized in Table 8.1-3 and 8.1-4 respectively. Steady state voltages are summarized in Table 8.1-5 and 8.1-6 respectively for MV buses and load centers. These steady state voltages meet acceptance criteria.

8.1.3 Unavailable Condition of RATs

This case was calculated with following initial conditions. The main generator is synchronized to the grid and Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from UATs as shown in Table 6.1-3.

In this configuration, calculation results for UATs and RATs loading are summarized in Table 8.1-1. Station service transformer loading is summarized in Table 8.1-2. MV buses and load centers loading are summarized in Table 8.1-3 and 8.1-4 respectively. Steady state voltages are summarized in Table 8.1-5 and 8.1-6 respectively for MV buses and load centers. These steady state voltages meet acceptance criteria.

8.1.4 Normal Configuration (Start-up/Shutdown)

This case was calculated with following initial conditions. The main generator is off and GLBS is open. Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses are supplied from UATs and Class 1E buses are supplied from RATs as shown in Table 6.1-1

In this configuration, calculation results for UATs and RATs loading are summarized in Table 8.1-7. Station service transformer loading is summarized in Table 8.1-8. MV buses and load centers loading are summarized in Table 8.1-9 and 8.1-10 respectively. Steady state voltages are summarized in Table 8.1-11 and 8.1-12 respectively for MV buses and load centers. These steady state voltages meet acceptance criteria.

8.1.5 Unavailable Condition of UATs (Start-up/Shutdown)

This case was calculated with following initial conditions. The main generator is off and GLBS is open. Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from RATs as shown in Table 6.1-2

In this configuration, calculation results for UATs and RATs loading are summarized in Table 8.1-7. Station service transformer loading is summarized in Table 8.1-8. MV buses and load centers loading are summarized in Table 8.1-9 and 8.1-10 respectively. Steady state voltages are summarized in Table 8.1-11 and 8.1-12 respectively for MV buses and load centers. These steady state voltages meet acceptance criteria.

8.1.6 Unavailable Condition of RATs (Start-up/Shutdown)

This case was calculated with following initial conditions. The main generator is off and GLBS is open. Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from UATs as shown in Table 6.1-3

In this configuration, calculation results for UATs and RATs loading are summarized in Table 8.1-7. Station service transformer loading is summarized in Table 8.1-8. MV buses and load centers loading are summarized in Table 8.1-9 and 8.1-10 respectively. Steady state voltages are summarized in Table 8.1-11 and 8.1-12 respectively for MV buses and load centers. These steady state voltages meet acceptance criteria.

8.1.7 Maximum Voltage Condition

This case was calculated with following initial conditions for normal configuration, unavailable of UAT and unavailable of RAT. The main generator is off and GLBS is open. Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from UATs as shown in Table 6.1-1, 6.1-2 and 6.1-3, respectively.

In this configuration, calculation results are summarized in Table 8.1-13 and 8.1-14 for medium voltage buses and 480 V load centers respectively. These steady state voltages meet acceptance criteria.

8.2 Motor Starting Study

Motor starting studies have been performed to evaluate voltage drop of motor terminal for proper motor operation.

Normal operation (MG one line) mode and start-up/shutdown mode are considered in motor starting studies. The normal operation mode is with the main generator operating, GLBS closed, and each onsite power bus powered from UAT or RAT respectively. In start-up/shutdown mode, main generator is not operated and GLBS is open. Operation of OLTC on the UATs and RATs are considered to maintain the voltage at MV buses before motor starting to around nominal bus voltage in each operational mode. For each operational mode, three variations of power supply to each MV bus are considered. These are normal condition when Class 1E buses are powered from RATs and Non-Class 1E buses are powered from UATs, unavailable condition of UATs when all buses are powered from RATs, and unavailable condition of RATs when all buses are powered from UATs. Furthermore, since there are a number of UAT and RAT respectively, MV motor starting is considered for each transformer. Offsite grid voltage is assumed as minimum voltage.

8.2.1 Normal Configuration

This case was calculated with following initial conditions. The main generator is synchronized to the grid and Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses are supplied from UATs and Class 1E buses are supplied from RATs as shown in Table 6.1-1

In this configuration, calculation results for motor starting study are summarized in Table 8.2-1. Voltage drop at starting motor and voltage drop at operating motors meet acceptance criteria.

8.2.2 Unavailable Condition of UATs

This case was calculated with following initial conditions. The main generator is synchronized to the grid and Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from RATs as shown in Table 6.1-2.

In this configuration, calculation results for motor starting study are summarized in Table 8.2-2. Voltage drop at starting motor and voltage drop at operating motors meet acceptance criteria.

8.2.3 Unavailable Condition of RATs

This case was calculated with following initial conditions. The main generator is synchronized to the grid and Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from UATs as shown in Table 6.1-3.

In this configuration, calculation results for motor starting study are summarized in Table 8.2-3. Voltage drop at starting motor and voltage drop at operating motors meet acceptance criteria.

8.2.4 Normal Configuration (Start-up/Shutdown)

This case was calculated with following initial conditions. The main generator is off and GLBS is open. Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses are supplied from UATs and Class 1E buses are supplied from RATs as shown in Table 6.1-1

In this configuration, calculation results for motor starting study are summarized in Table 8.2-4. Voltage drop at starting motor and voltage drop at operating motors meet acceptance criteria.

8.2.5 Unavailable Condition of UATs (Start-up/Shutdown)

This case was calculated with following conditions. The main generator is off and GLBS is open. Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from RATs as shown in Table 6.1-2.

In this configuration, calculation results for motor starting study are summarized in Table 8.2-5. Voltage drop at starting motor and voltage drop at operating motors meet acceptance criteria.

8.2.6 Unavailable Condition of RATs (Start-up/Shutdown)

This case was calculated with following initial conditions. The main generator is off and GLBS is open. Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from UATs as shown in Table 6.1-3.

In this configuration, calculation results for motor starting study are summarized in Table 8.2-6. Voltage drop at starting motor and voltage drop at operating motors meet acceptance criteria.

8.3 Short Circuit Study

Short circuit studies have been performed to evaluate required circuit breaker interrupting ratings.

Normal operation mode is considered for short circuit studies. The normal operational mode is with the main generator operating, GLBS closed, and each onsite power bus powered from UAT or RAT respectively. Furthermore, loading test of a Class 1E GTG synchronized to offsite power is assumed. In normal operational mode, three variations of power supply to each MV bus are considered. These are normal condition when Class 1E buses are powered from RATs and Non-Class 1E buses are powered from UATs, unavailable condition of UATs when all buses are powered from RATs, and unavailable condition of RATs when all buses are powered from UATs. All short circuit cases are conservatively calculated with a pre-fault voltage of 105 % of nominal bus voltage at the faulted bus. Offsite grid voltage is assumed as maximum voltage.

8.3.1 Normal Configuration

This case was calculated with following initial conditions. The main generator and a Class 1E GTG are synchronized to the grid and remaining Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses are supplied from UATs and Class 1E buses are supplied from RATs as shown in Table 6.1-1.

In this configuration, calculation results for short circuit study are summarized in Table 8.3-1, 8.3-4 and 8.3-5 for MV switchgears, LV load centers and LV MCCs, respectively. Short circuit currents at each distribution system meet acceptance criteria.

8.3.2 Unavailable Condition of UATs

This case was calculated with following initial conditions. The main generator and a Class 1E GTG are synchronized to the grid and remaining Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from RATs as shown in Table 6.1-2.

In this configuration, calculation results for short circuit study are summarized in Table 8.3-2, 8.3-4 and 8.3-5 for MV switchgears, LV load centers and LV MCCs, respectively. Short circuit currents at each distribution system meet acceptance criteria.

8.3.3 Unavailable Condition of RATs

This case was calculated with following initial conditions. The main generator and a Class 1E GTG are synchronized to the grid and remaining Class 1E GTGs and AAC GTGs are off. Non-Class 1E buses and Class 1E buses are supplied from UATs as shown in Table 6.1-3

In this configuration, calculation results for short circuit study are summarized in Table 8.3-3, 8.3-4 and 8.3-5 for MV switchgears, LV load centers and LV MCCs, respectively. Short circuit currents at each distribution system meet acceptance criteria.

8.4 Preliminary MV Bus Transfer

This study was calculated with two conditions. One is transfer from RAT to UAT. The other is transfer from UAT to RAT. Fast transfer scheme is considered in this study. Fast transfer is modeled such that normal power breakers are opened at 1.000 second and alternate breakers are closed at 1.1000 second.

Evaluation results of preliminary MV bus transfer are shown in Figure 8.4-1 to 8.4-8. Figure 8.4-1 to 8.4-4 show voltage profile at buses and terminals of main feed water pumps and reactor coolant pumps when fast transfer is performed on the Class 1E buses. Figure 8.4-5 to 8.4-8 show voltage profile at buses and terminals of main feed water pumps and reactor coolant pumps when fast transfer is performed on Non-Class 1E buses. Each voltage at motor terminals and buses meets acceptance criterion.

8.5 Harmonic Analysis

Onsite power system has UPS and battery charger to supply constant and uninterruptible power to control and protection equipment etc. These power sources generate harmonics. Total harmonic distortion generated from the power sources at each distribution system was calculated.

Calculation results of harmonic analysis are summarized in Table 8.5-1 and 8.5-2. Individual harmonic distortion and THD at each distribution system meets acceptable criteria.

Table 6.1-1
Offsite Power Sources to MV Buses
(Normal Configuration)

Bus	Normal Power	Alternate Power
13.8kV Non-Class 1E Bus N1	UAT1	RAT1
13.8kV Non-Class 1E Bus N2	UAT2	RAT2
6.9kV Non-Class 1E Bus N3	UAT3	RAT3
6.9kV Non-Class 1E Bus N4	UAT3	RAT3
6.9kV Non-Class 1E Bus N5	UAT4	RAT4
6.9kV Non-Class 1E Bus N6	UAT4	RAT4
6.9kV Non-Class 1E Bus P1	UAT3	RAT3
6.9kV Non-Class 1E Bus P2	UAT4	RAT4
6.9kV Class 1E Bus A	RAT3	UAT3
6.9kV Class 1E Bus B	RAT3	UAT3
6.9kV Class 1E Bus C	RAT4	UAT4
6.9kV Class 1E Bus D	RAT4	UAT4

Table 6.1-2
Offsite Power Source to MV Buses
(Unavailable Condition of UATs)

Bus	Offsite Source
13.8kV Non-Class 1E Bus N1	RAT1
13.8kV Non-Class 1E Bus N2	RAT2
6.9kV Non-Class 1E Bus N3	RAT3
6.9kV Non-Class 1E Bus N4	RAT3
6.9kV Non-Class 1E Bus N5	RAT4
6.9kV Non-Class 1E Bus N6	RAT4
6.9kV Non-Class 1E Bus P1	RAT3
6.9kV Non-Class 1E Bus P2	RAT4
6.9kV Class 1E Bus A	RAT3
6.9kV Class 1E Bus B	RAT3
6.9kV Class 1E Bus C	RAT4
6.9kV Class 1E Bus D	RAT4

Table 6.1-3
Offsite Power Source to MV Buses
(Unavailable Condition of RATs)

Bus	Offsite Source
13.8kV Non-Class 1E Bus N1	UAT1
13.8kV Non-Class 1E Bus N2	UAT2
6.9kV Non-Class 1E Bus N3	UAT3
6.9kV Non-Class 1E Bus N4	UAT3
6.9kV Non-Class 1E Bus N5	UAT4
6.9kV Non-Class 1E Bus N6	UAT4
6.9kV Non-Class 1E Bus P1	UAT3
6.9kV Non-Class 1E Bus P2	UAT4
6.9kV Class 1E Bus A	UAT3
6.9kV Class 1E Bus B	UAT3
6.9kV Class 1E Bus C	UAT4
6.9kV Class 1E Bus D	UAT4

Table 6.1-4
Generator Data

Table 6.1-5
Transformer Ratings (MT, UAT and RAT)

Parameter	MT	UAT1 & UAT2	UAT3 & UAT4	RAT1 & RAT2	RAT3 & RAT4
MVA	1830	72	53	72	53
Frequency (Hz)	60	60	60	60	60
HV Winding Voltage (kV)	345	26	26	345	345
LV Winding Voltage (kV)	26	13.8	6.9	13.8	6.9
HV Winding Connection	Wye-Gnd	Delta	Delta	Wye-Gnd	Wye-Gnd
XV Winding Connection	Delta	Wye-ResGnd	Wye-ResGnd	Wye-ResGnd	Wye-ResGnd
OLTC and Range	NA	+10/-15%, 26 taps	+10/-15%, 26 taps	+10/-15%, 26 taps	+10/-15%, 26 taps
Modeled Tap Setting	Nominal	Various	Various	Various	Various
Impedance base (MVA)	1830	72	53	72	53
Impedance	15	13.5	14.5	13.5	14.5
Impedance Tolerance (%)	10	10	10	10	10
Approx. X/R Ratio	50	34.1	34.1	34.1	34.1

Table 6.1-6
Transformer Ratings (SST)

Parameter	SST N1 and N2	SST A, B, C, D, N3, N4, N5, N6, P1 and P2
kVA	2500	2500
HV Winding Voltage (kV)	13.8	6.9
LV Winding Voltage (kV)	0.48	0.48
Off-Load Taps and Range	+/- 5%, 2.5% steps	+/- 5%, 2.5% steps
Impedance base (kVA)	2500	2500
Impedance	8	8
Impedance Tolerance (%)	10	10
X/R	10.67	10.67
Modeled Tap Setting	- 2.5%	- 2.5%

Table 6.1-7
Switchgear and MCC Data

Parameter	**MC- N1 & N2**	**MC- P1 & P2**	**MC- N3,N4,N5,N6**	**MC- A,B,C,D**
Bus Continuous Current (A)	3000	2000	3000	1200
Breaker Rated SC Current (kA, rms sym)	50	63	63	63
Breaker Withstand (C&L) (kA, peak)	130	170	170	170
Parameter	**LC- N1 & N2**	**LC - P1 & P2**	**LC- N3,N4,N5,N6**	**LC- A,B,C,D**
Bus Continuous Current (A)	4000	4000	4000	4000
Breaker Rated SC Current (kA, rms, sym)	65	65	65	65
Parameter	**MCCs N11, N21**	**MCCs P11, P21**	**MCCs P12, P22**	**MCCs N31, 32, 41, 42 51, 52, 61, 62**
Breaker Rated SC Current (kA, rms, sym)	65	65	65	65

Table 8.1-1
UATs and RATs Loading Summary
(Normal Operation)

Table 8.1-2
Station Service Transformers Loading Summary
(Normal Operation)

Table 8.1-3 Medium Voltage Buses Loading Summary
(Normal Operation)

Table 8.1-4 480V Load Centers Loading Summary
(Normal Operation)

Table 8.1-5 Medium Voltage Buses Steady State Minimum Voltage Summary
(Normal Operation)

Table 8.1-6 480V Load Centers Steady State Minimum Voltage Summary
(Normal Operation)

Table 8.1-7 UATs and RATs Loading Summary
(Start-up/Shutdown)

Table 8.1-8 Station Service Transformers Loading Summary
(Start-up/Shutdown)

Table 8.1-9 Medium Voltage Buses Loading Summary
(Start-up/Shutdown)

Table 8.1-10 480V Load Centers Loading Summary
(Start-up/Shutdown)

Table 8.1-11 Medium Voltage Buses Steady State Minimum Voltage Summary (Start-up/Shutdown)

Table 8.1-12 480V Load Centers Steady State Minimum Voltage Summary (Start-up/Shutdown)

Table 8.1-13 Medium Voltage Buses Steady State Maximum Voltage Summary

Table 8.1-14 480V Load Centers Steady State Maximum Voltage Summary

Table 8.2-1 (Sheet 1 of 2) Motor Starting Study Summary
(Normal Operation, Normal Configuration)

Table 8.2-1 (Sheet 2 of 2) Motor Starting Study Summary
(Normal Operation, Normal Configuration)

Table 8.2-2 (Sheet 1 of 2) Motor Starting Study Summary
(Normal Operation, From RAT)

Table 8.2-2 (Sheet 2 of 2) Motor Starting Study Summary
(Normal Operation, From RAT)

Table 8.2-3 (Sheet 1 of 2) Motor Starting Study Summary
(Normal Operation, From UAT)

Table 8.2-3 (Sheet 2 of 2) Motor Starting Study Summary
(Normal Operation, From UAT)

Table 8.2-4 (Sheet 1 of 2) Motor Starting Study Summary
(Start-up/Shutdown, Normal Configuration)

Table 8.2-4 (Sheet 2 of 2) Motor Starting Study Summary
(Start-up/Shutdown, Normal Configuration)

Table 8.2-5 (Sheet 1 of 2) Motor Starting Study Summary
(Start-up/Shutdown, From RAT)

Table 8.2-5 (Sheet 2 of 2) Motor Starting Study Summary
(Start-up/Shutdown, From RAT)

Table 8.2-6 (Sheet 1 of 2) Motor Starting Study Summary
(Start-up/Shutdown, From UAT)

Table 8.2-6 (Sheet 2 of 2) Motor Starting Study Summary
(Start-up/Shutdown, From UAT)

Table 8.3-1 Short Circuit Study Summary (MV)
(Normal Configuration)

Table 8.3-2 Short Circuit Study Summary (MV)
(From RAT)

Table 8.3-3 Short Circuit Study Summary (MV)
(From UAT)

Table 8.3-4 Short Circuit Study Summary (480V Load Center)

Table 8.3-5 Short Circuit Study Summary (480V MCC)

Table 8.5-1 Harmonic Analysis Summary
(Normal Configuration)

Table 8.5-2 Harmonic Analysis Summary
(From RAT)

Table 8.5-3 Harmonic Analysis Summary
(From UAT)

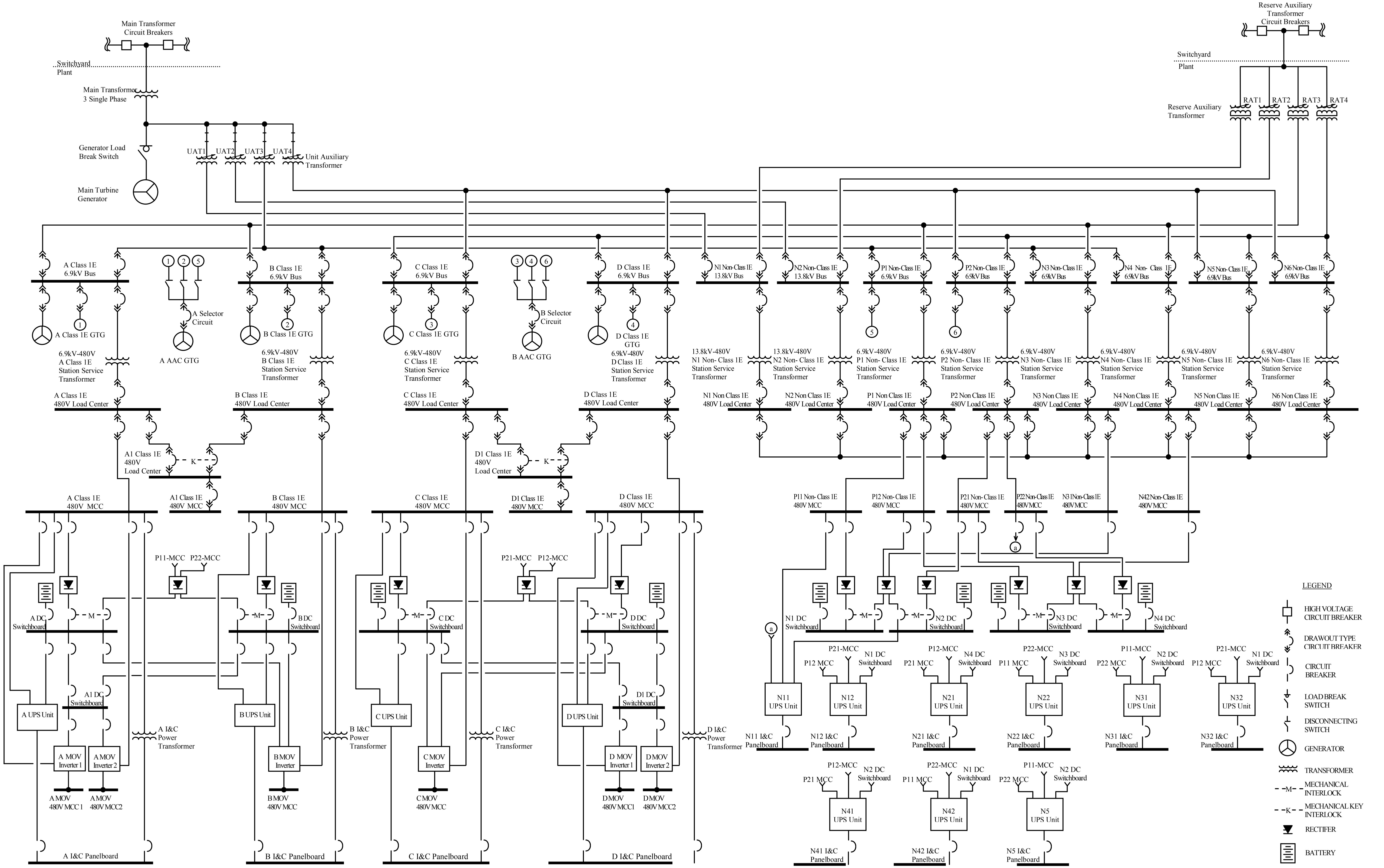

Figure 4.2-1 Simplified One Line Diagram

Figure 8.4-1 6.9kV Class 1E Buses Voltage Profile (Transfer from RAT to UAT)

Figure 8.4-2 13.8 kV Non-Class 1E Buses Voltage Profile (Transfer from RAT to UAT)

Figure 8.4-3 (Sheet 1 of 2) 6.9 kV Non-Class 1E Buses Voltage Profile (Transfer from RAT to UAT)

Figure 8.4-3 (Sheet 2 of 2) 6.9 kV Non-Class 1E Buses Voltage Profile (Transfer from RAT to UAT)

Figure 8.4-4 (Sheet 1 of 2) Motor Terminal Voltage Profile (Transfer from RAT to UAT)

Figure 8.4-4 (Sheet 2 of 2) Motor Terminal Voltage Profile (Transfer from RAT to UAT)

Figure 8.4-5 6.9kV Class 1E Buses Voltage Profile (Transfer from UAT to RAT)

Figure 8.4-6 13.8 kV Non-Class 1E Buses Voltage Profile (Transfer from UAT to RAT)

Figure 8.4-7 (Sheet 1 of 2) 6.9 kV Non-Class 1E Buses Voltage Profile (Transfer from UAT to RAT)

Figure 8.4-7 (Sheet 2 of 2) 6.9 kV Non-Class 1E Buses Voltage Profile (Transfer from UAT to RAT)

Figure 8.4-8 (Sheet 1 of 2) Motor Terminal Voltage Profile (Transfer from UAT to RAT)

Figure 8.4-8 (Sheet 2 of 2) Motor Terminal Voltage Profile (Transfer from UAT to RAT)