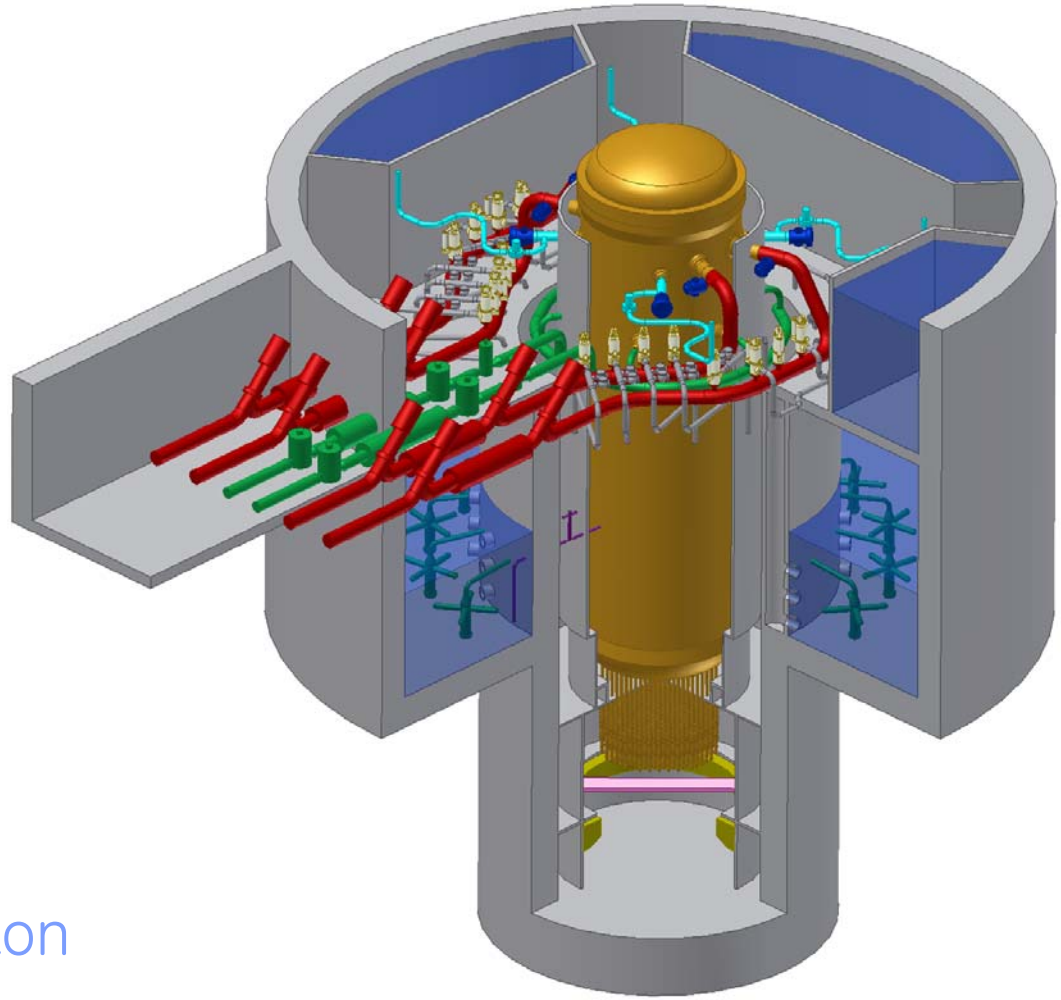
ESBWR Electrical Power System

Overview



Presented by Hugh Upton
September 27, 2005

ESBWR Electrical Power System Overview

- Off-site AC Power System
- On-site AC Power System (R10)
- Medium Voltage AC Power System (R11)
- Low Voltage AC Power System (R12)
- Uninterruptible AC Power Supply (R13)
  - Class 1E
  - Non-Class 1E
- DC Power System (R16)
  - Class 1E
  - Non-Class 1E
- Standby On-site AC Power Supply (R21)
- Load Shedding and Sequencing on PIP Buses
  - Loss of Preferred Power (LOPP)
  - Loss of Coolant Accident (LOCA)
  - LOPP following LOCA

Off-site AC Power System

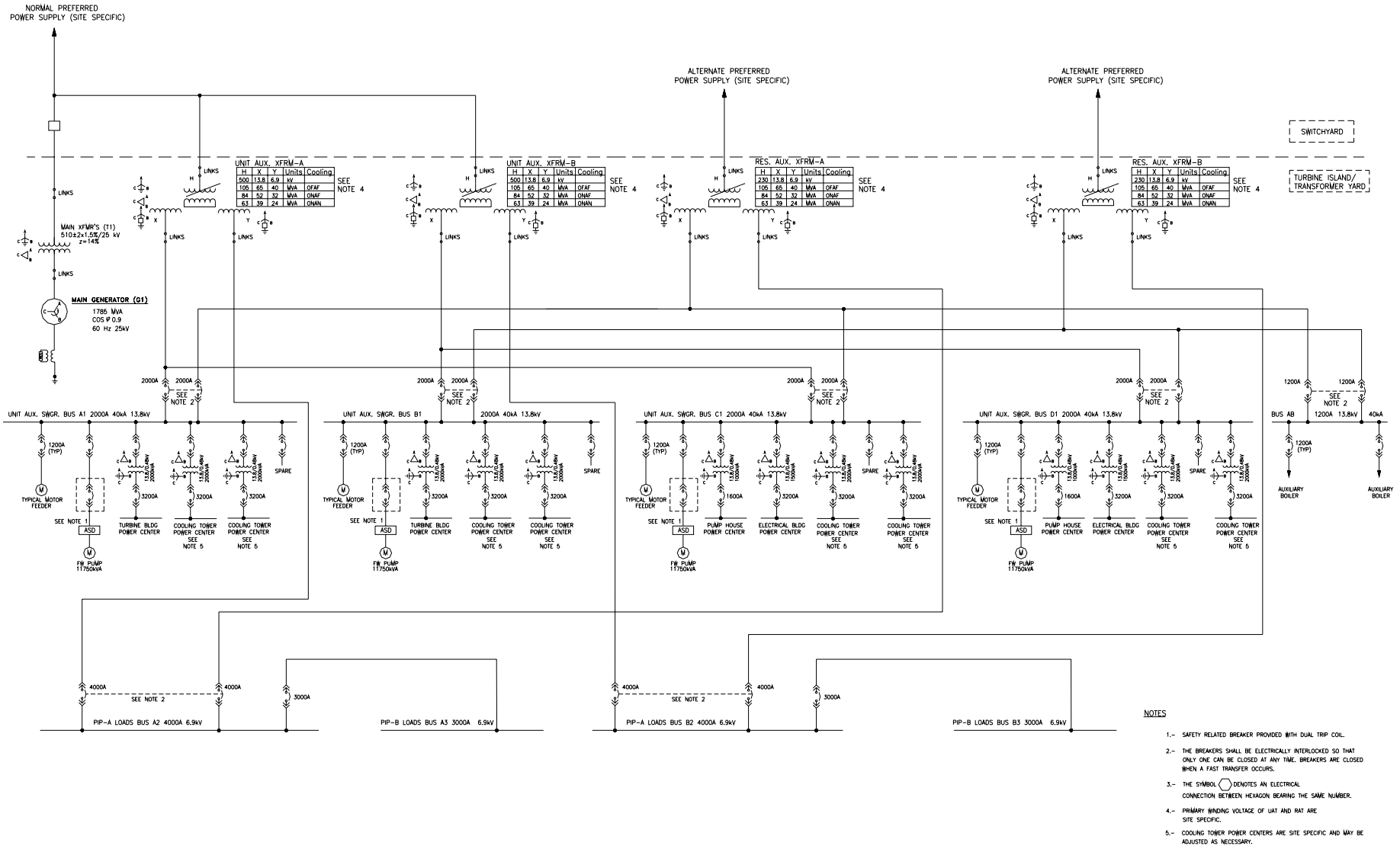
- Provides normal AC power for the operation of plant systems under all plant operating modes, including design basis accidents, when such power is available from the off-site transmission system or the plant main generator.
- The reserve off-site power system provides AC power for plant systems when the normal off-site AC power system is unavailable.
- The off-site AC power system consists of the set of electrical circuits and associated equipment used to interconnect the off-site AC transmission system, the plant main generator, and the on-site AC power system.
- Power is supplied to the plant from two electrically independent and physically separate off-site power sources:
  - Normal Preferred source through Unit Auxiliary Transformers (UATs)
  - Alternate Preferred source through Reserve Auxiliary Transformers (RATs)

On-site AC Power System Description

- System provides the distribution system of normal AC power to on-site Power Generation (PG) loads and Plant Investment Protection (PIP) loads
- Provides power under all plant operating modes, including design basis accidents, as long as normal power is available from the off-site power system or the plant main generator.
- The on-site AC power system consists of medium voltage, low voltage, and standby AC power systems.
- On-site AC power system consists of both non-safety related and safety related components

Medium Voltage AC Power System

- Distributes medium voltage AC power to plant medium voltage PG, PIP, auxiliary, and service loads.
- PG loads are those loads required for reliable unit operation during startup, normal operation, and normal shutdown.
- PIP loads are those loads required for defense-in-depth and those loads required to remain operational independent of the unit operating conditions.
- Auxiliary and service loads are fed from PG or PIP busses depending upon their requirements for unit operating modes.
- The system includes medium voltage power distribution equipment and circuits with operating voltages of 13.8 kV and 6.9 kV (both nominal).
- This equipment and circuits supply power to medium voltage loads. The medium voltage AC power system equipment and circuits include switchgear busses and circuit breakers, as well as their associated local instrumentation, metering, controls, and protective relaying, and circuits connecting the switchgear to their loads.



NOTES

1.– SAFETY RELATED BREAKER PROVIDED WITH DUAL TRIP COIL.

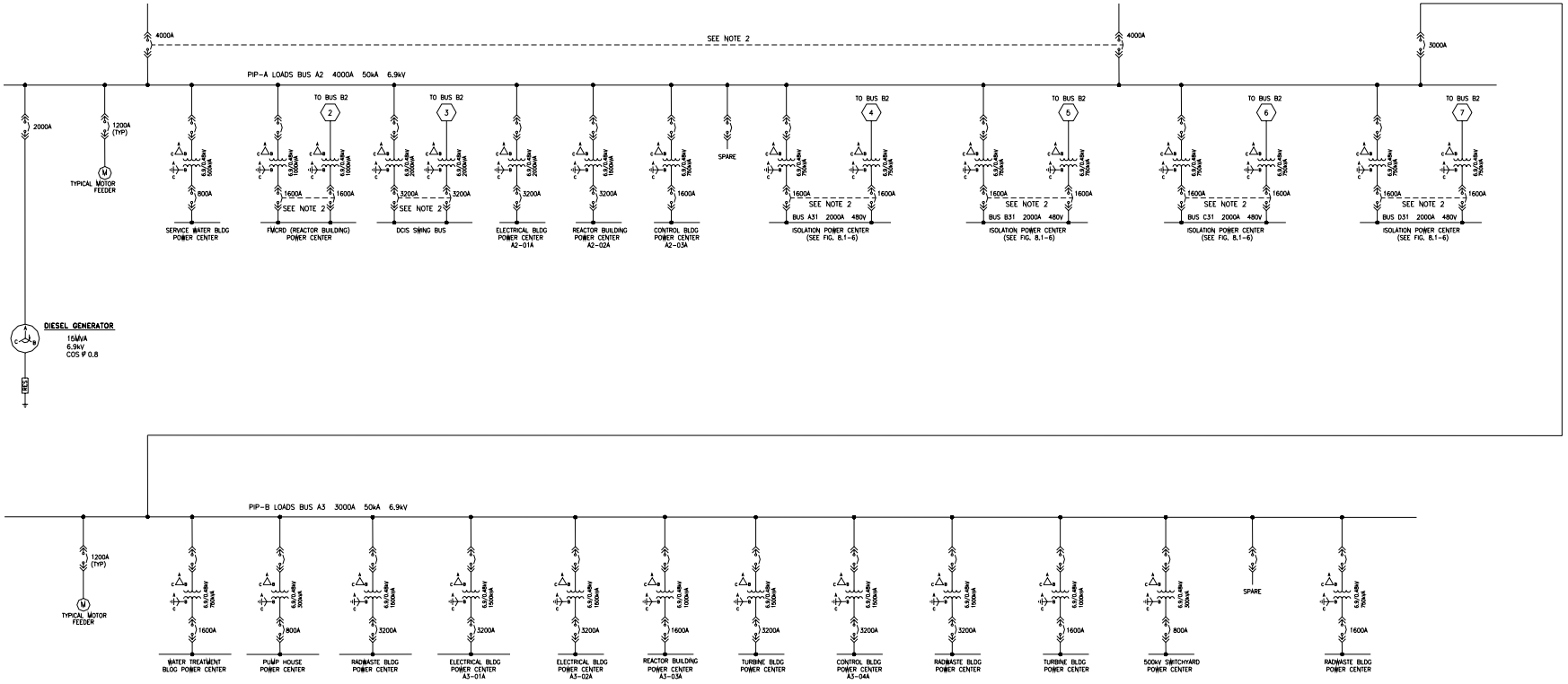
2.– THE BREAKERS SHALL BE ELECTRICALLY INTERLOCKED SO THAT ONLY ONE CAN BE CLOSED AT ANY TIME. BREAKERS ARE CLOSED WHEN A FAST TRANSFER OCCURS.

3.– THE SYMBOL ⬡ DENOTES AN ELECTRICAL CONNECTION BETWEEN HEXAGON BEARING THE SAME NUMBER.

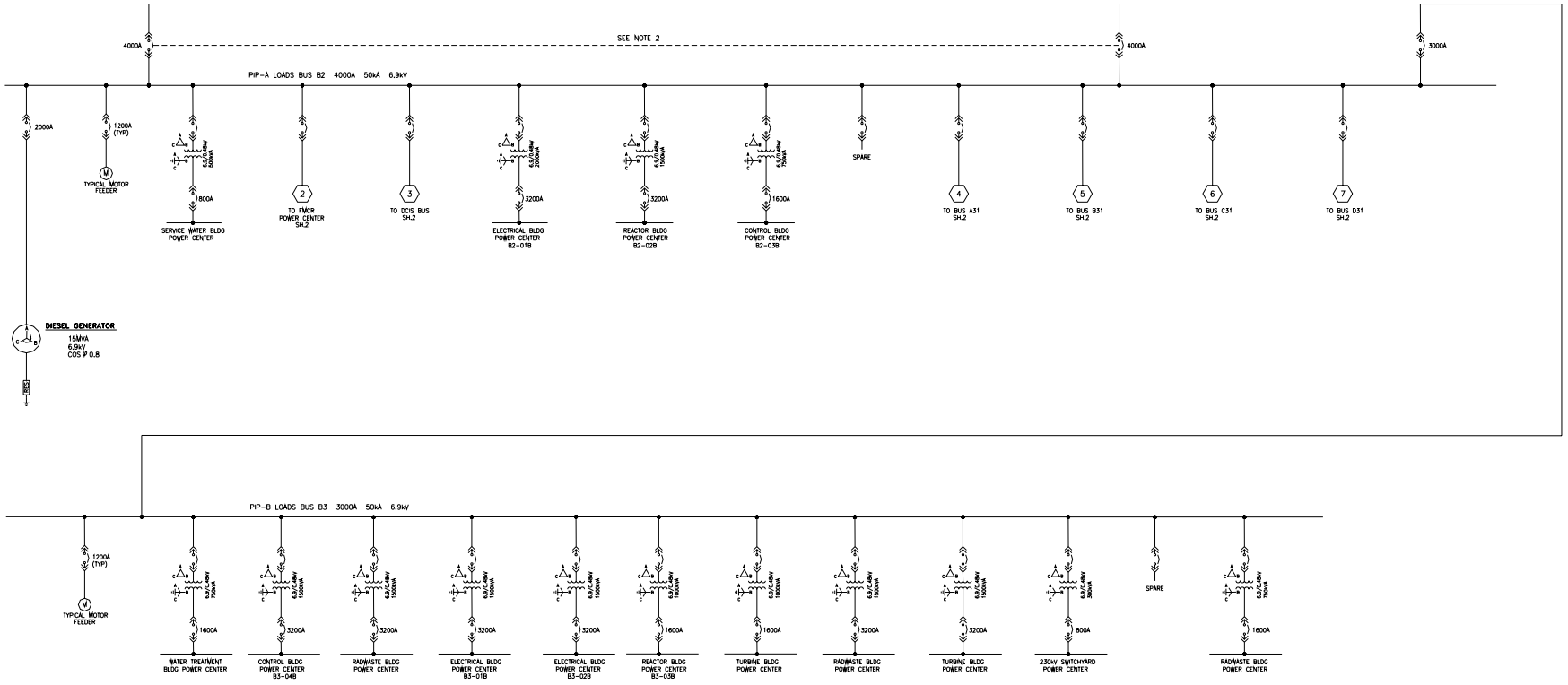
4.– PRIMARY WINDING VOLTAGE OF UAT AND RAT ARE SITE SPECIFIC.

5.– COOLING TOWER POWER CENTERS ARE SITE SPECIFIC AND MAY BE ADJUSTED AS NECESSARY.

EPDS One Line Diagram



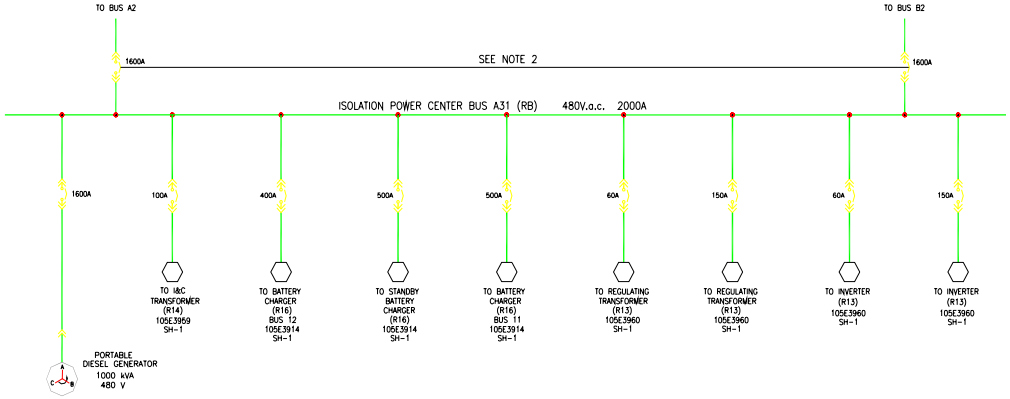
EPDS One Line Diagram – Sheet 2

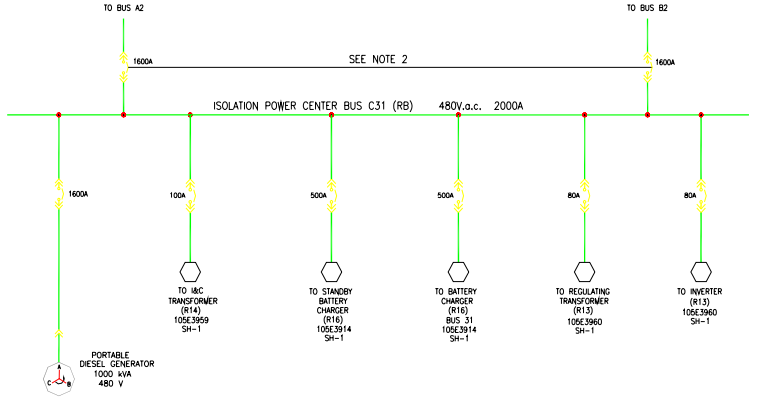


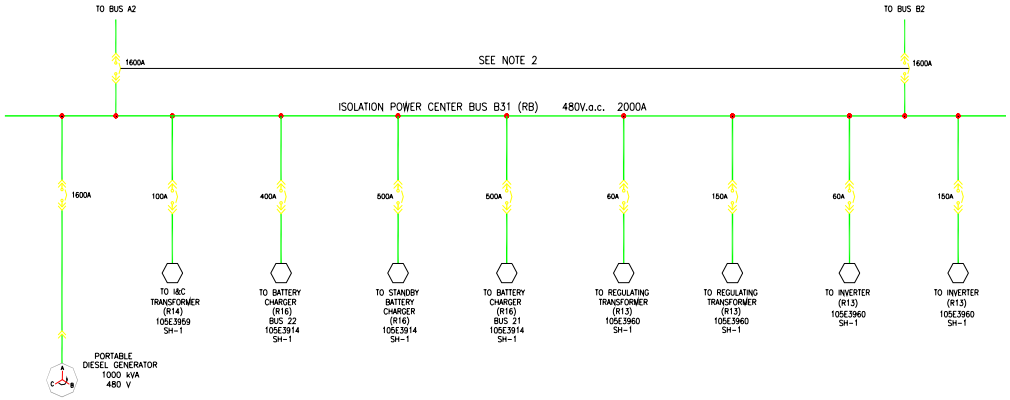
EPDS One Line Diagram – Sheet 3

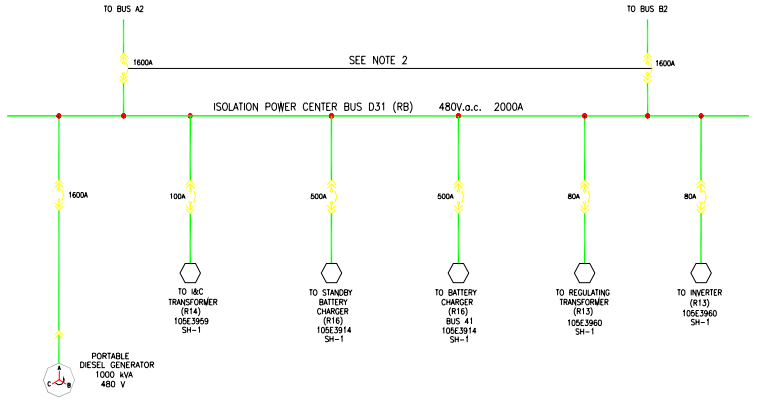
Low Voltage AC Power System

- Distributes low voltage AC power to plant low voltage PG, PIP, auxiliary, and service loads.
- A limited portion of the low voltage AC power system contains safety-related power centers to provide low voltage AC power to safety related battery chargers and regulating transformers.
- Includes low voltage power distribution equipment and circuits with an operating voltage of 480 V (nominal).
- System includes power center transformers, switchgear busses and circuit breakers; motor control centers (MCCs), distribution transformers, and distribution panelboards, as well as associated local instrumentation, metering, controls, and protective relaying, and connecting circuits.
- Selected equipment within the low voltage AC power system is provided with plug-in connections. These plug-in points provide a convenient and secure means of connecting portable AC power sources to restore AC power to selected plant loads in the event all other sources of AC power are lost.









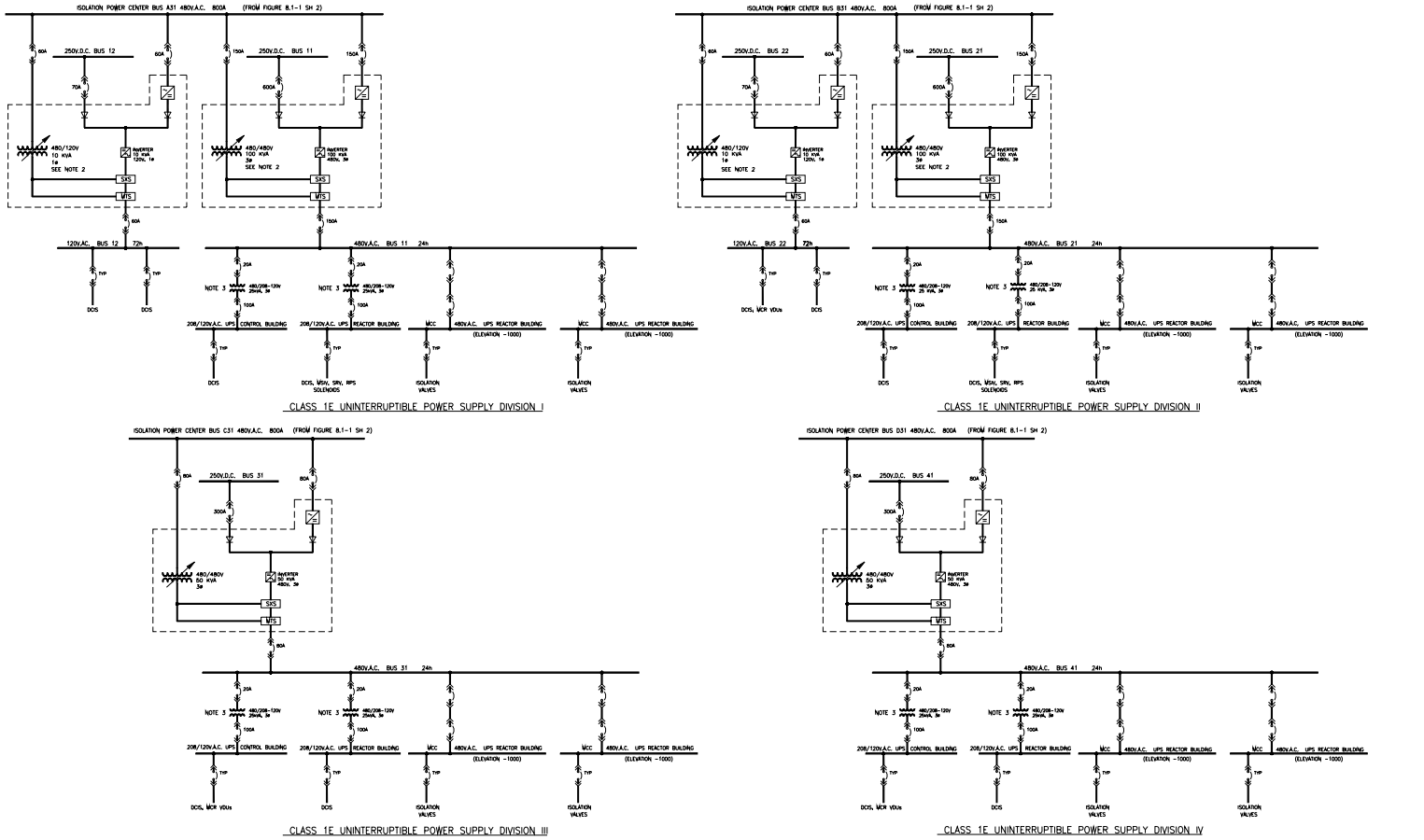
NOTES

2.- THE BREAKERS SHALL BE ELECTRICALLY INTERLOCKED SO THAT ONLY ONE CAN BE CLOSED AT ANY TIME NEVERTHELESS THE TWO BOTH INCOMING CIRCUIT. BREAKERS COULD BE CLOSED WHEN A FAST TRANSFER OCCURS.

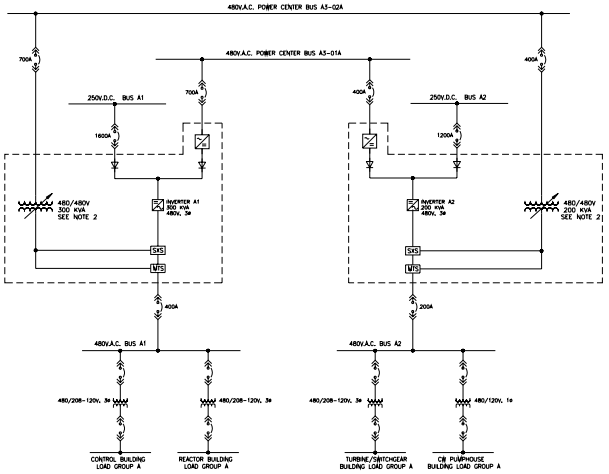
480 Volt Power Centers - One Line Diagram – Sheet 1 of 4 (Example)

Uninterruptible AC Power Supply (R13)

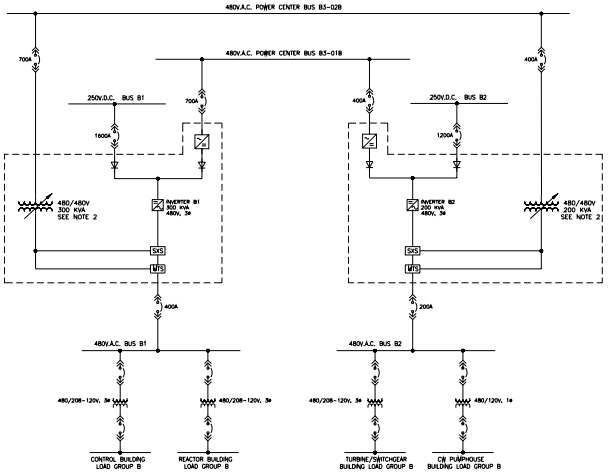
- Four Divisions of Class-1E UPS supplies reliable power to safety-related MOVs and other 480 VAC safety-related loads (See Class 1E UPS One Line).
  - > Supports safety-related logic & control functions during normal, upset & accident conditions
  - > Powered through separate & independent Class 1E inverters connected to Class 1E DC bus and from it's own 480 VAC Isolation Power Center
  - > Each DC bus backed by separate Class 1E batteries
  - > On loss of AC power UPS is powered by Class 1E batteries – transferring from AC to DC power is transparent to loads
- Five Divisions of Non-Class 1E UPS supplies reliable 480 VAC power to the load groups in the CB, RB/FB, TB, EB, CW Pump house and the TSC (See Non-Class 1E UPS One Line).
  - > Powered from independent Non-Class 1E inverters connected to non-class 1E DC bus and from respective 480 VAC Power Center
  - > Each DC bus backed by separate non-Class 1E Batteries
  - > On loss of AC power UPS is powered by Non-Class 1E battery – transferring from AC to DC power is transparent to loads
  - > 480 VAC Power Centers that provides normal and alternate AC sources are backed by on-site standby DG
- UPS designed for bumpless transfer to alternate bypass power supply on failure of the inverter power supply



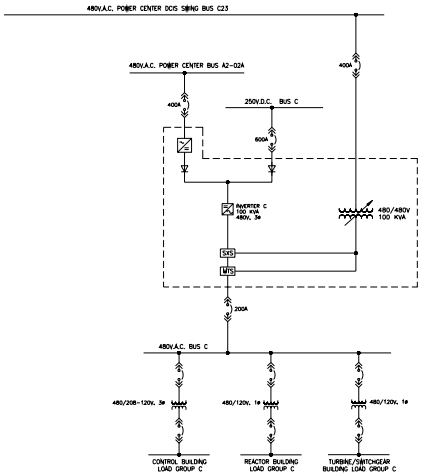
Class 1E UPS One Line Diagram



NON CLASS 1E UNINTERRUPTIBLE POWER SUPPLY



NON CLASS 1E UNINTERRUPTIBLE POWER SUPPLY



NON CLASS 1E UNINTERRUPTIBLE POWER SUPPLY

Non-Class 1E UPS One Line Diagram

DC Power System

Non-Class 1E DC Power System

- Non-Class 1E 125 VDC system provides power to non-safety-related loads, communications, lighting and other DC loads.
- Non-Class 1E 250 VDC system provides power to non-essential DCIS and non-Class 1E DC motors
- Supplied power through non-Class 1E battery chargers from non-Class 1E PIP busses. If power to PIP buses is lost, power is supplied from non-Class 1E batteries.
- Non-Class 1E batteries are rated to supply power to their loads for 2-hours

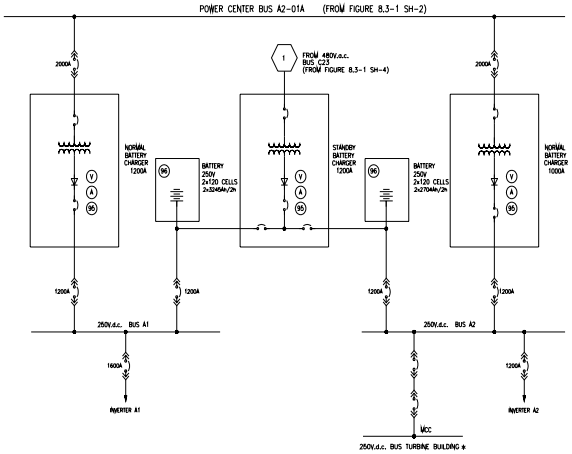
Class 1E DC Power System

- Class 1E 250 VDC system has four divisions that are physically and electrically separated in the RB.
- System provides power to safety-related loads and Essential DCIS.
- Normal power supplied thru Class 1E battery chargers and Isolation Power Center and powered from non-Class 1E PIP busses. If power to PIP buses is lost, power is supplied from Class 1E batteries.

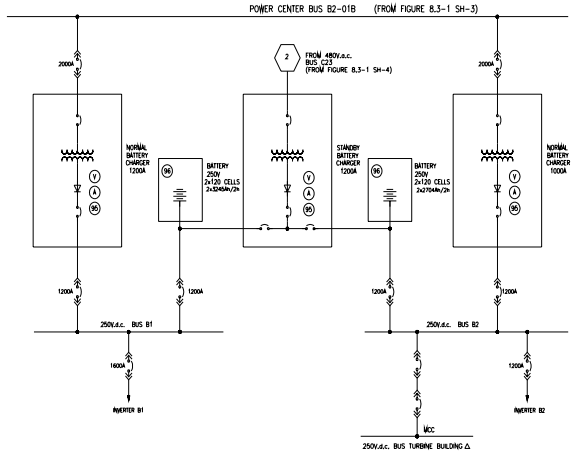
DC Power System Cont'd

Class 1E VDC System cont'd

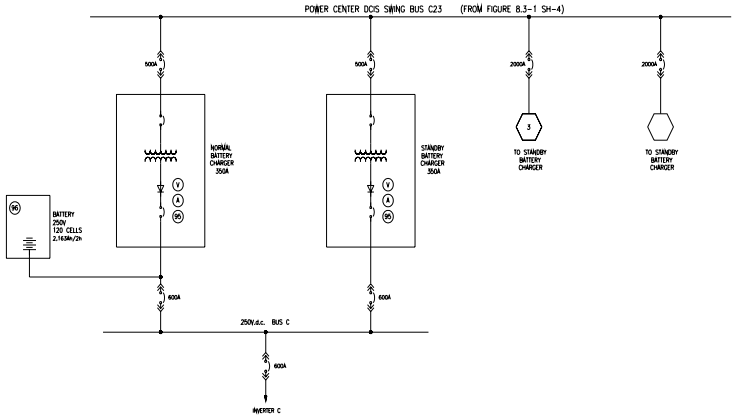
- Division 1 and 2 has two separate 250 VDC Class 1E batteries rated to supply power to safety rated loads for 72-hours and 24-hours following SBO conditions
- Division 3 and 4 only has batteries rated to supply power to the loads for 24-hour following SBO conditions.
- 24hr 250Vdc batteries supply the necessary power for reactor safe shutdown and monitoring.
- 72hr 250Vdc batteries supply 120Vac safety-related power for post accident monitoring.
- Class 1E DC system is designed such that no single active failure in any division would result in conditions that prevent safe plant shutdown
- Each battery room is ventilated to remove the H2 produced during battery charging. The battery room HVAC system precludes possibility of H2 accumulation.



NON-CLASS 1E 250V.d.c. POWER SYSTEM



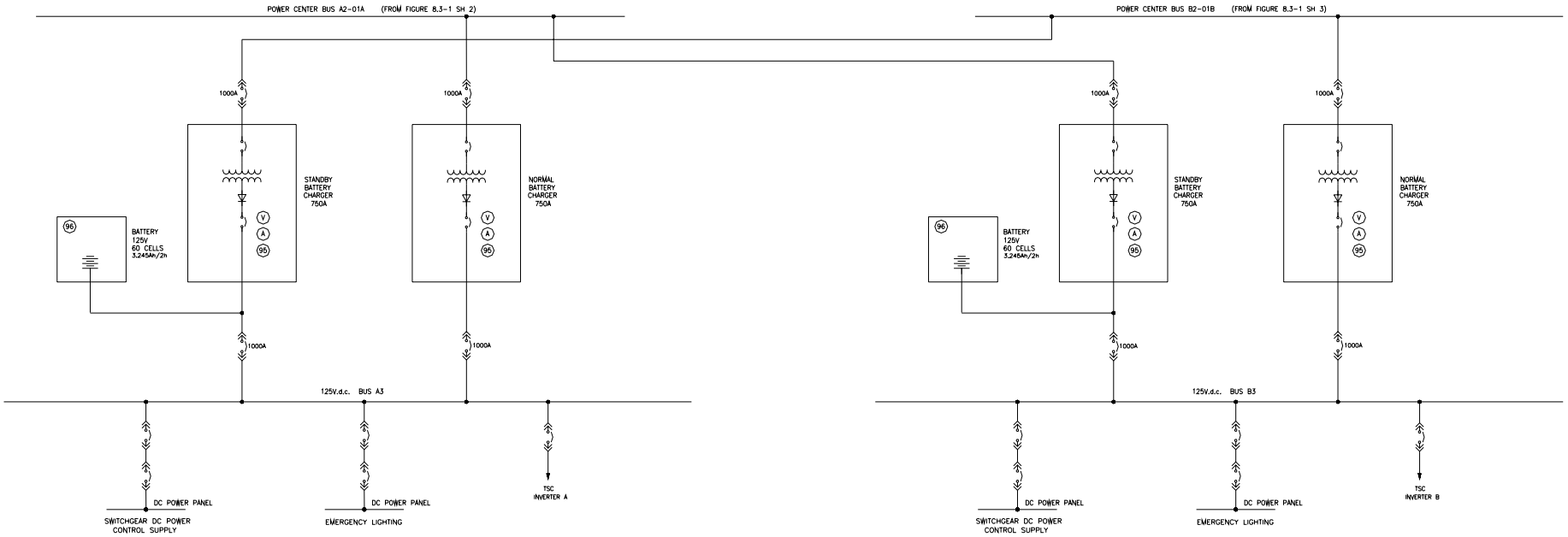
NON-CLASS 1E 250V.d.c. POWER SYSTEM



NON-CLASS 1E 250V.d.c. POWER SYSTEM

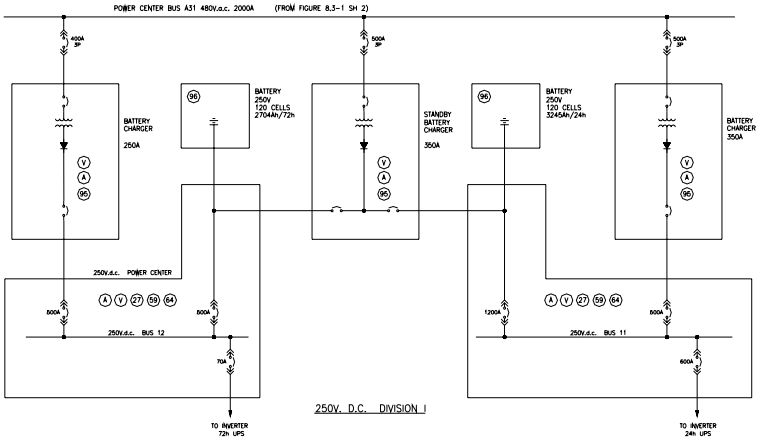
* -A FW MOTOR EMERGENCY OIL PUMP.
-C FW MOTOR EMERGENCY OIL PUMP.
Δ -B FW MOTOR EMERGENCY OIL PUMP.
-D FW MOTOR EMERGENCY OIL PUMP.

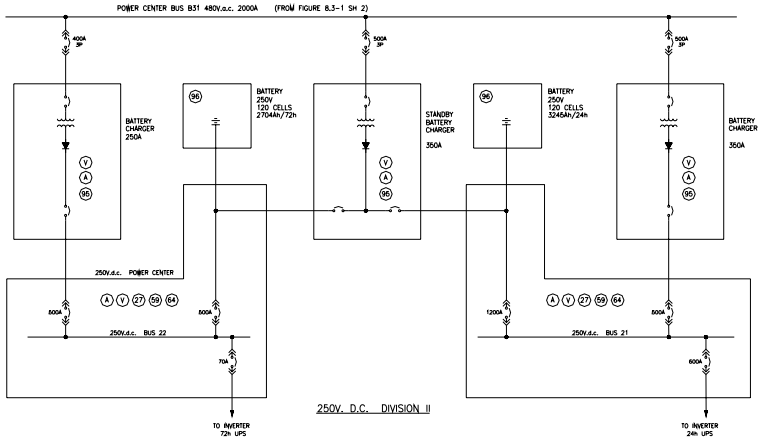
250 VDC Power Supply (non- Class 1E) One Line Diagram

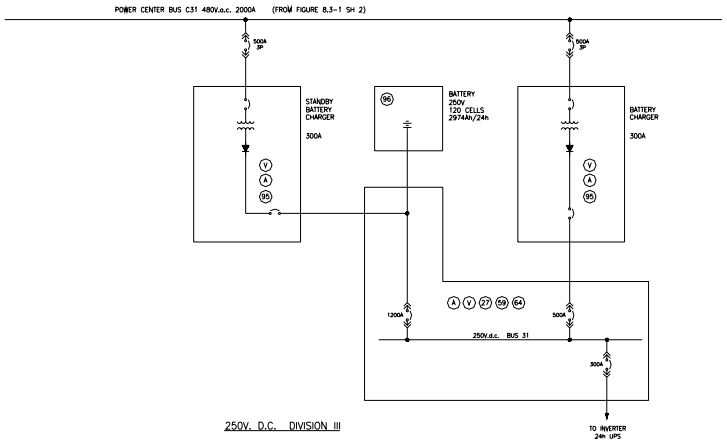


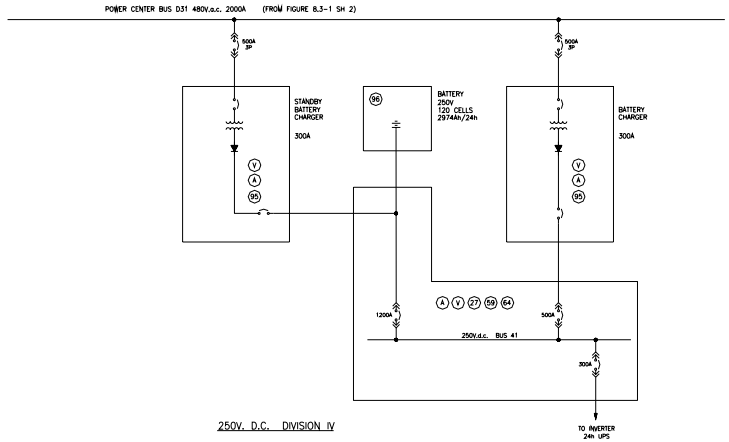
NON-CLASS 1E 125V.d.c. SYSTEM

125 VDC Power Supply (non- Class 1E) One Line Diagram









250 VDC Power Supply (Class 1E) One Line Diagram

Standby On-site AC Power Supply

- Consists of two 15 MVA independent diesels coupled to 6.9 kV AC generators, the DG auxiliary systems, fuel storage and transfer systems and associated local instruments and controls.
- Each DG supplies non-safety AC power to it's associated PIP busses on loss of voltage for plant investment protection.
- On PIP bus undervoltage the DG starts, accelerates with in 1 minute.
- Major loads are tripped from the 6.9 kV PIP busses.
- DG will connect to the PIP busses when incoming preferred and alternate preferred source breakers have been tripped.
- Large motor loads are then reapplied sequentially and automatically after DG power source breaker closes.
- The DG is capable of being fully loaded within 600 seconds.
- DG operation is not required to ensure nuclear safety – only investment protection

Load Shedding and Sequencing on PIP Buses

- **Loss of Preferred Power (LOPP)**
  - > 6.9kV busses normally energized from normal preferred power supply
  - > Normal power lost, initiate fast transfer to alternate preferred power supply
  - > If bus voltage decays to 70% of nominal rated value plus a time delay, dead bus transfer is initiated to standby on-site AC power source (standby DG's).
  - > Signal trips the supply breakers, starts the DG's,
  - > As bus voltage decays large pump motor breakers are tripped and low voltage motor starters are opened on undervoltage
  - > The standby power supply breaker closes when a ready to load signal is received.
  - > Once bus voltage has been reestablished, large motors are sequence started as required
  - > Transfer to the preferred source is done manually

Load Shedding and Sequencing on PIP Buses Cont'd

- **Loss of Coolant Accident (LOCA)**
  - > Load sequence timers are started if 6.9kV PIP bus voltage is greater that 70% - loads are applied to the bus at the end of preset times
  - > Each load has an individual load sequence timer that is initiate on a LOCA signal plus PIP bus voltage > 70% regardless of the source of the PIP bus voltage.
  - > Timers are part of the circuit logic for each LOCA load – A common mode failure is not possible.
  - > If a timer fails, the LOCA load can be manually loaded by the operator if PIP bus voltage is > 70% of normal

- **LOPP Following LOCA**
  - > If bus voltage is lost following a LOCA transfer to an alternate power sources is as described in LOPP above