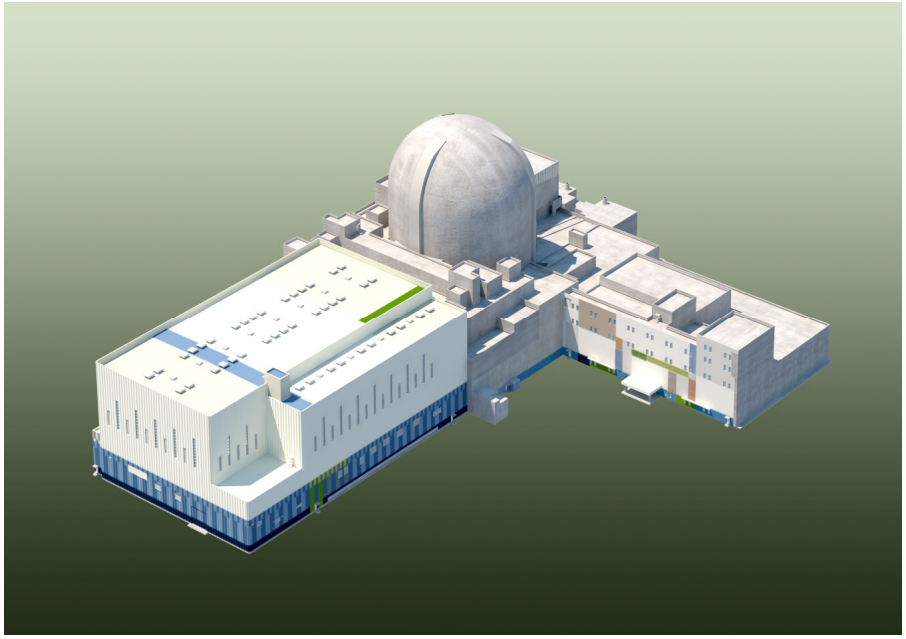
NON-PROPRIETARY

APR 1400 Electrical System Design



KEPCO/KHNP

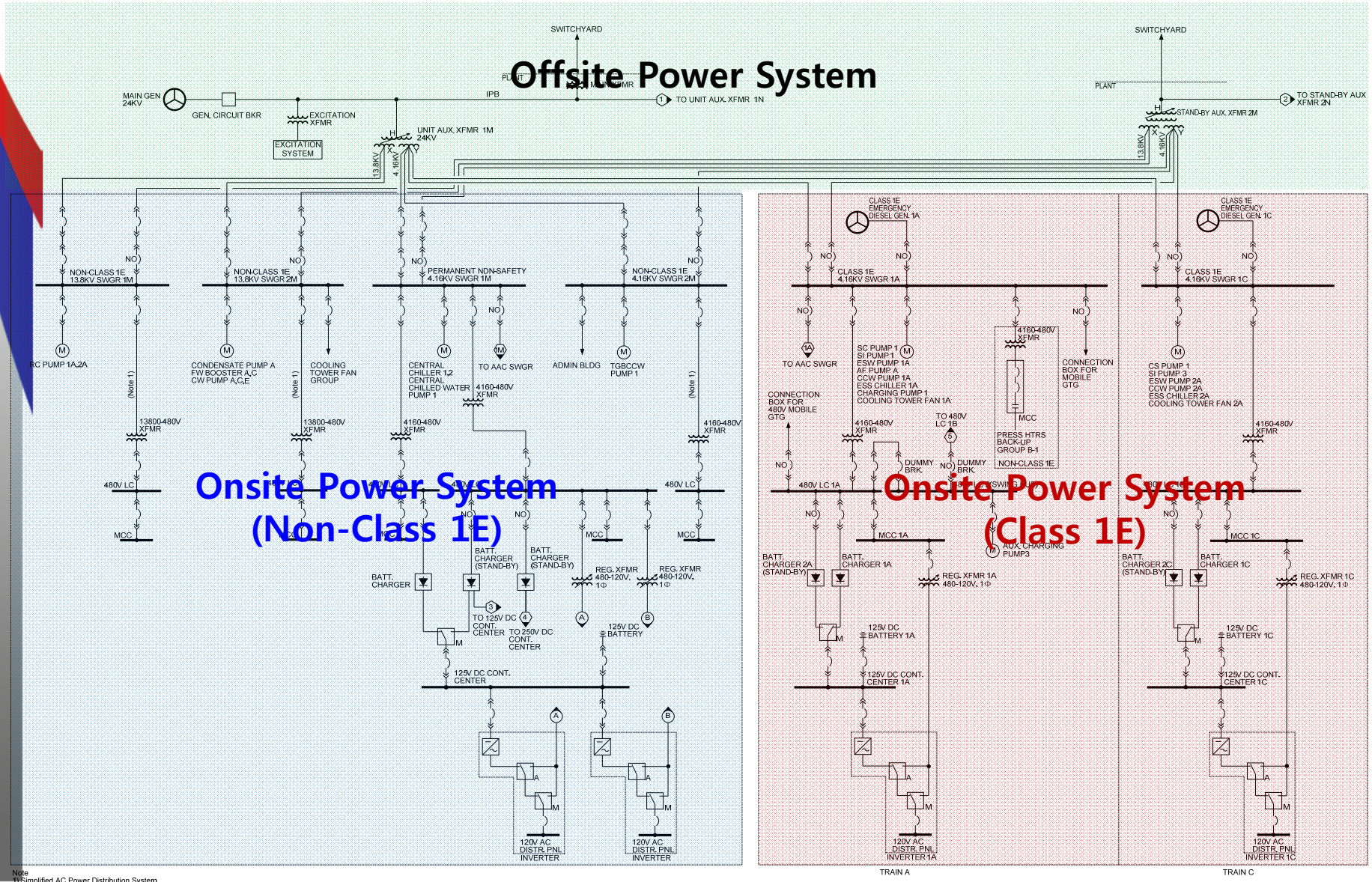
Apr. 20~21. 2016

ACRS Meeting (Apr.20-21. 2016)

Contents

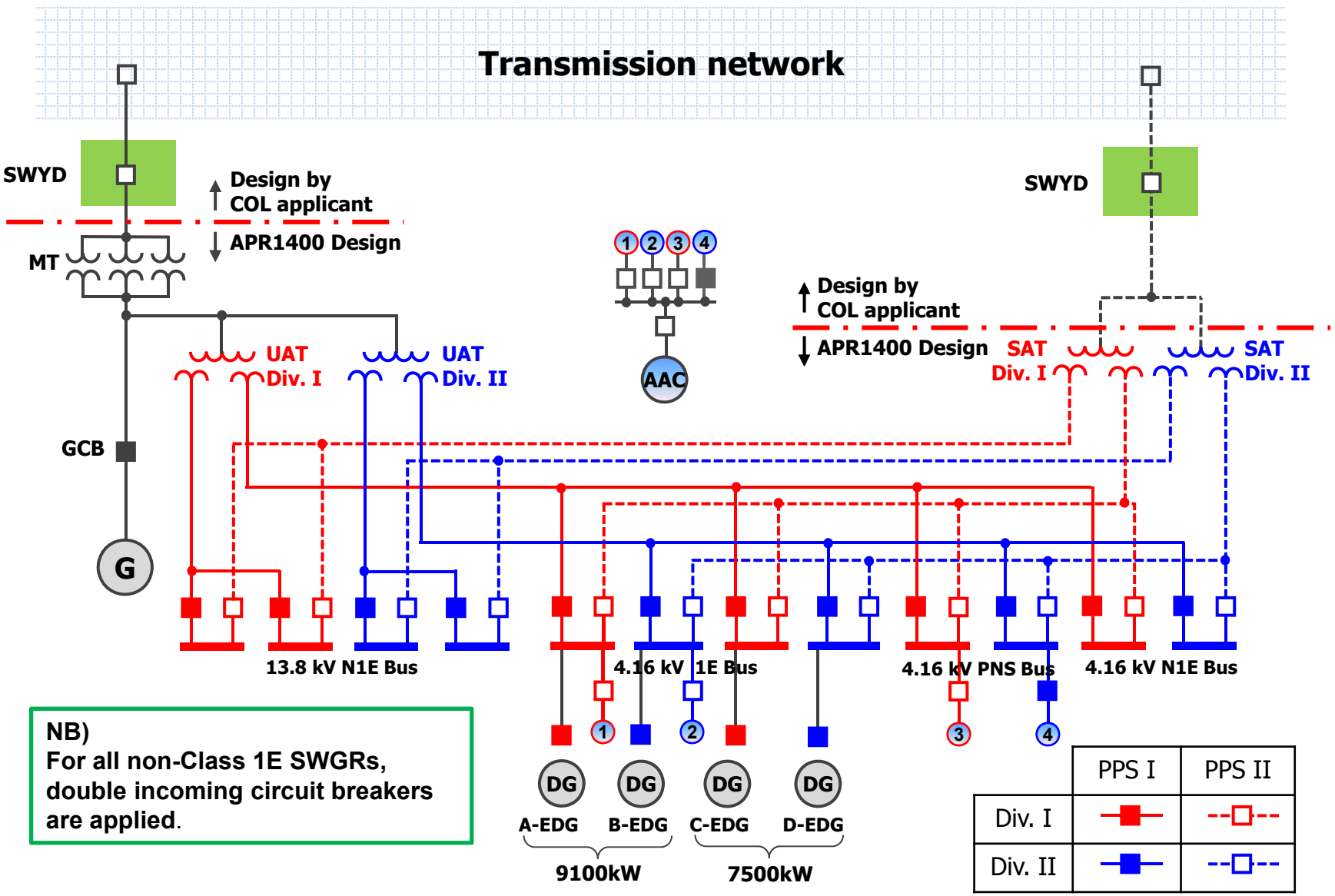
- Introduction
- Design Features
  - Offsite Power System
  - Onsite Power System (AP, EDGs, AAC, DC and IP systems)
- Major differences with System 80+ Electrical System
- Pending Issue
- Conclusion
- Q&A

Introduction



Note
1) Simplified AC Power Distribution System.
Detailed drawing is provided in Figure 8.3.1-1.

Design Features – Offsite Power System



NB)
For all non-Class 1E SWGRs, double incoming circuit breakers are applied.

Design Features – Offsite Power System

❖ **Design Requirements – 10CFR50, Appendix A (GDC) 17**

- Sufficient capacity and capability for all safety functions
- Two physically independent circuits
- Available in sufficient time following loss of all other ac power. One circuit shall be available within a few seconds following a loss-of-coolant accident (LOCA).

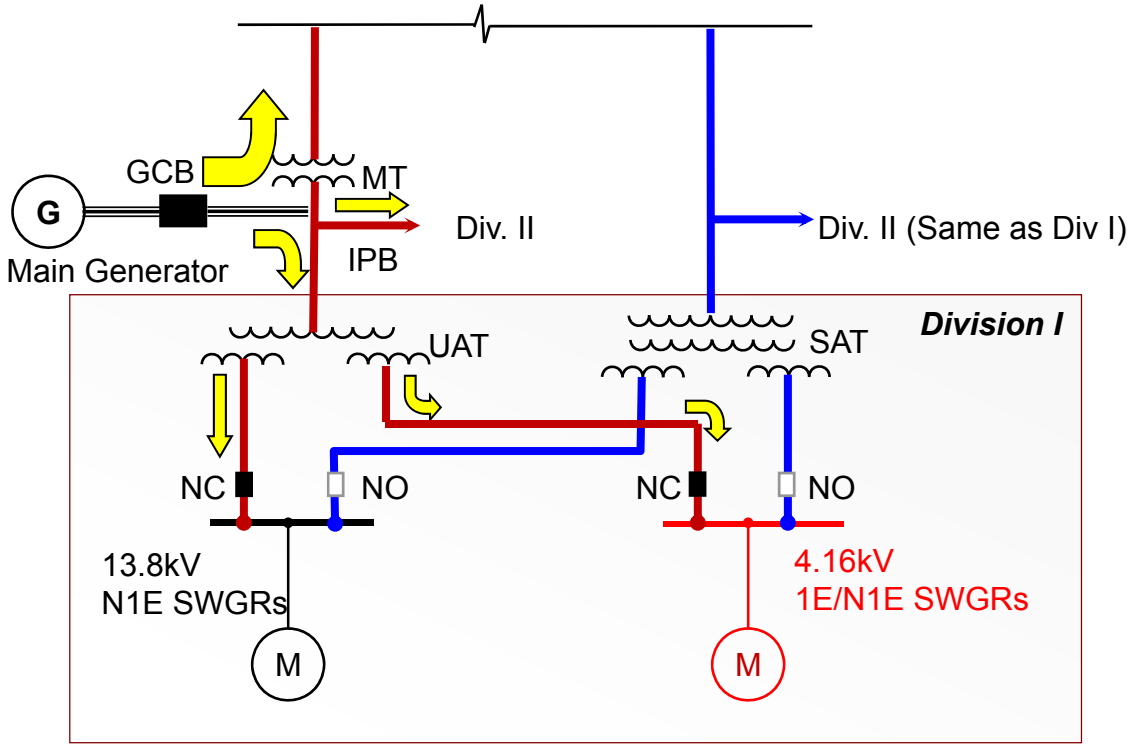
❖ **Transmission network and Switchyard**

- Not in the scope of the APR 1400 design.
- The transmission network should include **at least two physically independent circuits with sufficient capacity and capability** for the APR 1400. The COL applicant is to identify and provide information on the transmission circuits.
- The plant switchyard design is site-specific and not within the scope of the APR 1400 design. The COL applicant is to address the detailed design and required analyses including FMEA.

Design Features – Offsite Power System

❖ Offsite Power System Components and Circuits

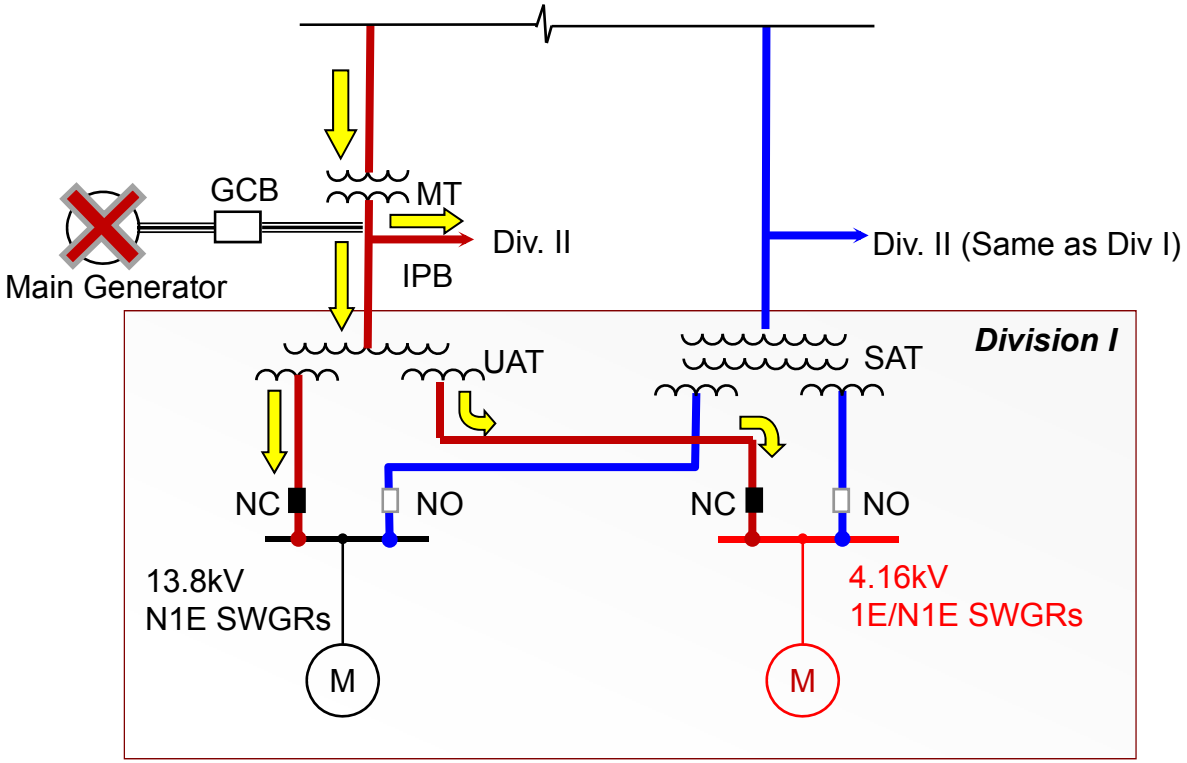
- During normal operation, MG generates electric power and delivers the generated output to transmission system and the station auxiliary loads.



Design Features – Offsite Power System

❖ Offsite Power System Components and Circuits (cont.)

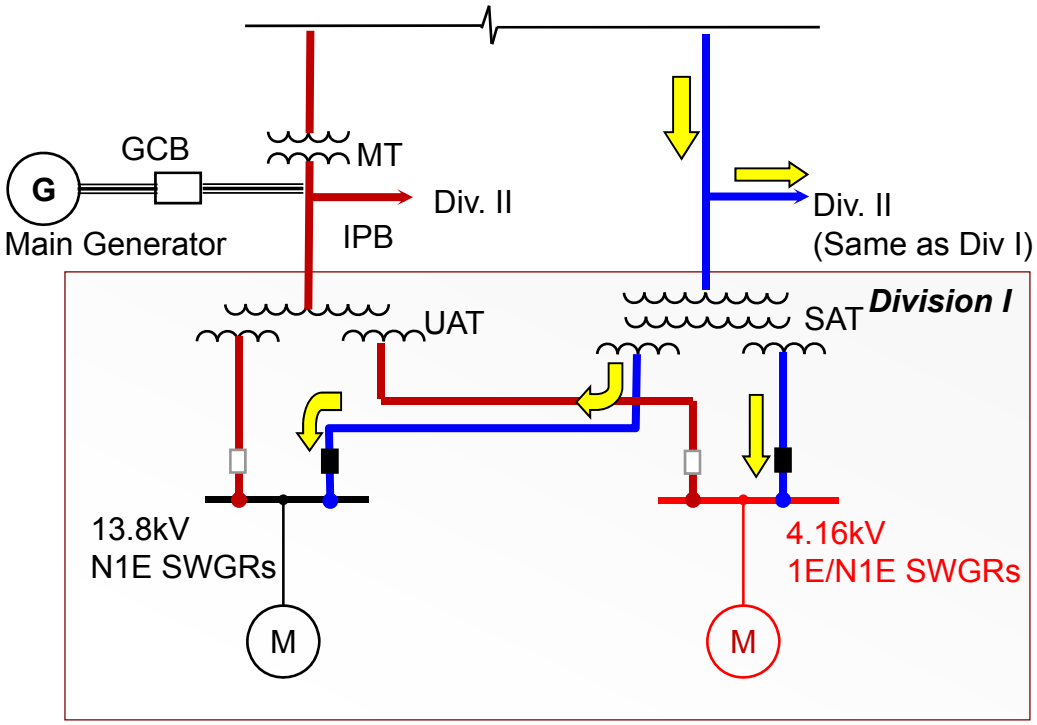
- In case MG is failed or not in service, normal PPS is secured by tripping/opening GCB (Normal PPS is available without interruption).



Design Features – Offsite Power System

❖ Offsite Power System Components and Circuits (cont.)

- In the event of fault at PPS I circuit, offsite power source to plant auxiliaries is switched to alternate PPS by **automatic bus transfer** (fast or residual voltage bus transfer); alternate PPS is available, normally, within 1 second.



- ✓ **Fast transfer**: automatic; within 100ms; transfer permitted if the voltage and angle differences between the switchgear bus and alternate PPS source is expected within the acceptable limits (per NEMA C50.41)
- ✓ **Residual voltage transfer**: automatic; back-up transfer to fast transfer.

Design Features – Offsite Power System

- Separation between normal and alternate PPS's

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Design Features – Onsite Power System

❖ Auxiliary Power System

- Main components: MV SWGR, LV L/Cs, MCCs, EDG and AAC GTG systems, and associated protection system.
- **Sufficient independence, redundancy, and testability** is required to perform their safety functions assuming a single failure (GDC 17).
- Consists of two divisions (Div. I and Div. II). In particular, the Class 1E AP system consists of four trains (A,B,C, and D) and each two trains (A plus C and B plus D) constitutes Div. I and Div. II, respectively.
- Located in separate rooms and different fire areas with adequate independence to provide reasonable assurance for plant safety assuming a single failure.

Design Features – Onsite Power System

❖ Emergency Diesel Generators (EDGs)

- Four Class 1E EDGs are designed, each corresponding to each train, to cope with a LOOP(loss of offsite power) or a LOOP concurrent with a DBA.
- Each EDG division, Div. I (Train A plus C) or Div. II (Train B plus D) has sufficient capacity and capability to supply emergency loads for safe shutdown during a LOOP concurrent with a DBA.
- Each of EDG Train A and B is capable of supplying sufficient power for decay heat removal and a safe shutdown during a LOOP.
- Each EDG is rated to have a continuous load rating plus margin, and sized to accelerate all of the loads in the loading sequence without exceeding the allowable voltage and frequency limits stated in RG 1.9:
  - ✓ 9,100 kW for Train A and Train B;
  - ✓ 7,500 kW for Train C and Train D.

Design Features – Onsite Power System

❖ Emergency Diesel Generators (EDGs) (cont.)

- Each Class 1E EDG automatically starts independently on a starting signals (e.g. loss of voltage, SIAS, CSAS, AFAS) and accepts loads in sequential manner by independent load sequencing logic.
- EDG design and performance requirements conform to RG 1.9 and IEEE 387.
- Each EDG unit has minimum reliability target, 0.95, in accordance with RG 1.9 and RG 1.155.
- Each EDG is housed in a separate room of seismic Category I buildings that is provided with an independent source of ventilation air and a fire protection system.

Design Features – Onsite Power System

❖ Alternate AC Gas Turbine Generator

- Provides alternate ac power to bring and maintain the plant to safe shutdown condition during an SBO (10CFR50.63).
- GTG is selected as the AAC source for diversity to EDGs.
- Started and manually aligned to a shutdown bus, Train A or Train B, from MCR/RSR within 10 minutes from the onset of an SBO condition.
- SBO coping duration: **16 hours** according to the methodology of RG 1.155, Regulatory Position C.3.1.
- Physical separation
  - ✓ Connection from the AAC-GTG to the shutdown buses via two normally open circuit breakers (Appendix B of RG 1.155)
  - ✓ Cables from AAC-GTG to the shutdown buses are separate from the cables from the PPS sources.

Design Features – Onsite Power System

❖ Alternate AC Gas Turbine Generator (cont.)

- Supply non-safety essential loads at PNS bus during a LOOP
- Other characteristics
  - ✓ Reliability: 0.95 (per NSAC-108)
  - ✓ Rating: 9,700 kW - for SBO loads (8,689 kW) and PNS loads (6,074 kW)

❖ Connection Provisions for mobile generators

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Design Features – Onsite Power System

❖ DC and IP (Instrumentation & Control Power) System

	DC System	IP System
Function	Supplies reliable 125Vdc and 250Vdc* power to various plant non-safety and safety equipment. **Non-Class 1E only*	Supplies reliable vital 120V ac power to plant safety and non-safety I&C equipment.
System Components	Battery, Battery Charger and Distribution Panel	Inverter, Regulating Transformer, Automatic/Manual Transfer Switch and Distribution Panel
Division and Train	Class 1E: four trains (Train A,B,C, and D) → Layout of DC/IP system component Non-Class 1E: two divisions (Div. I and II)	
Major loads	Motor operated valves; Solenoid for pneumatic valves; NSSS and BOP control and instrumentation systems; IP inverter; Turbine/generator emergency loads; DC emergency lighting system	Safety Consoles; Plant Protection System (PPS); ESF-CCS and P-CCS; Information Processing System (IPS); Qualified Indication and Alarm System (QIAS).

Design Features – Onsite Power System

❖ DC and IP (Instrumentation & Control Power) System (cont.)

- For each Class 1E train, redundant battery chargers are designed, that is **N+1 design for each train**, thereby allowing for OLM (on-line maintenance) of a battery charger without degraded operation below LCO condition.
- For non-Class 1E, one spare battery charger is commonly used for four different battery chargers.
- Each division of the Class 1E 125Vdc batteries has adequate capacity, without chargers, to provide the necessary dc power to perform the required safety functions.

TS

Design Features – Onsite Power System

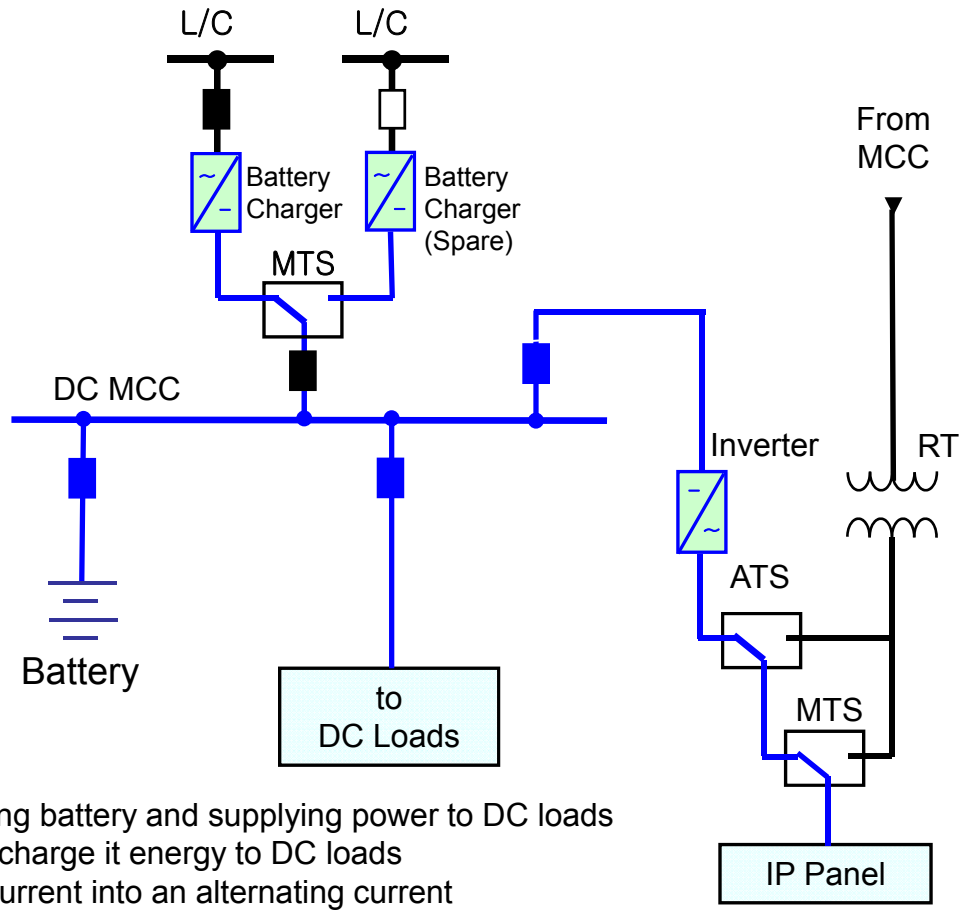
❖ DC and IP (Instrumentation & Control Power) System (cont.)

- DC and IP Conceptual Diagram

Normal Operation
DC loads and IP inverter are supplied through Charger

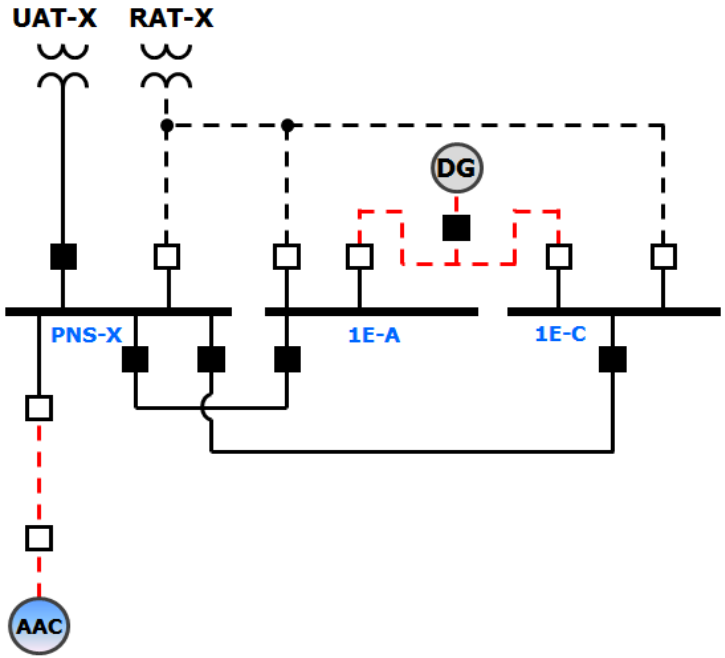
AC Power or Charger fail
Battery supply power to DC loads and IP Inverter

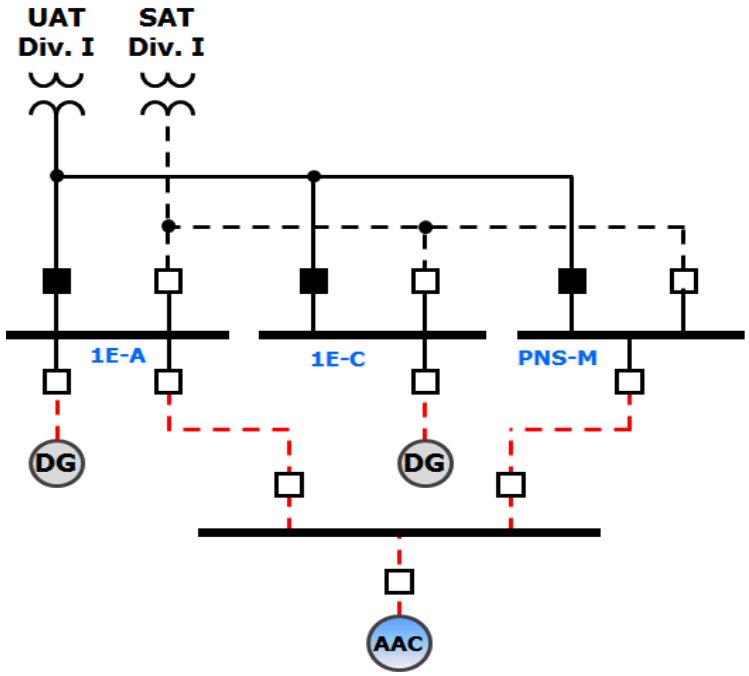
IP Inverter fail
Transfer to Alternate Source by ATS (for 24 hours)



- Battery Charger : Device used for charging battery and supplying power to DC loads
- Battery : In case of loss of AC power, discharge it energy to DC loads
- Inverter : Device for converting a direct current into an alternating current
- ATS/MTS : Automatic/Manual Transfer Switch
- RT(Regulating Transformer) : At any problems in Inverter or DC system, RT supply power to vital loads

Major Differences with System 80+ Electrical System





System 80+	APR 1400
• 2 EDGs for 4 safety (Class 1E buses)	• Dedicated EDG per train (Class 1E bus)
• PPS I&II is supplied from UAT&RAT through PNS bus • Additional direct connection from RAT to safety buses	• PPS I (from UAT) and PPS II (from SAT) are directly supplied
• AAC source supplies shutdown loads through PNS bus , supplies non-safety essential loads	• AAC source directly connected to a shutdown bus (Train A or B) during an SBO

Pending Issue – Open Phase Conditions

❖ Background of Open Phase Conditions (OPCs)

- Single phase open failure at Byron Station Unit 2 and 1 in Jan. and Feb. 2012, respectively.
- Failure of Unit 2 'C' phase insulator resulted in an open circuit and voltage imbalance, which propagated through the SATs through the ESF buses.

NB: The EDG was not initiated because the UV or DV relays were not picked up due to adequate voltage at phase 'A' and 'B'

❖ Regulatory Requirements

- BL 12-01 "Design Vulnerability in Electrical System"
- BTP 8-9 "Open Phase Conditions in Electric Power System"

Pending Issue – Open Phase Conditions

❖ Forward Action Plan

- Design vulnerability study including sufficient analyses needed to characterize and quantify the safety challenges of OPCs:
  - ✓ Loss of one phase with, and without, a high impedance ground fault conditions;
  - ✓ Loss of two out of three phase.
- Develop a (conceptual) design to detect, alarm, and protect against an OPC.

Summary

- **APR 1400 Electrical System** is designed in accordance with US NRC regulatory requirements, properly meets its endorsed codes & standards, and therefore provides reasonable assurance of reliable operation of the plant and safety functions for the plant.
- Currently working on the vulnerability study and (conceptual) design to address OPC conditions.

Back-up Slides

Security-Related Information – Withhold Under 10 CFR 2.390

Layout of DC/IP System Components