APR1400 Electric System Design

KHNP

KEPCO E&C

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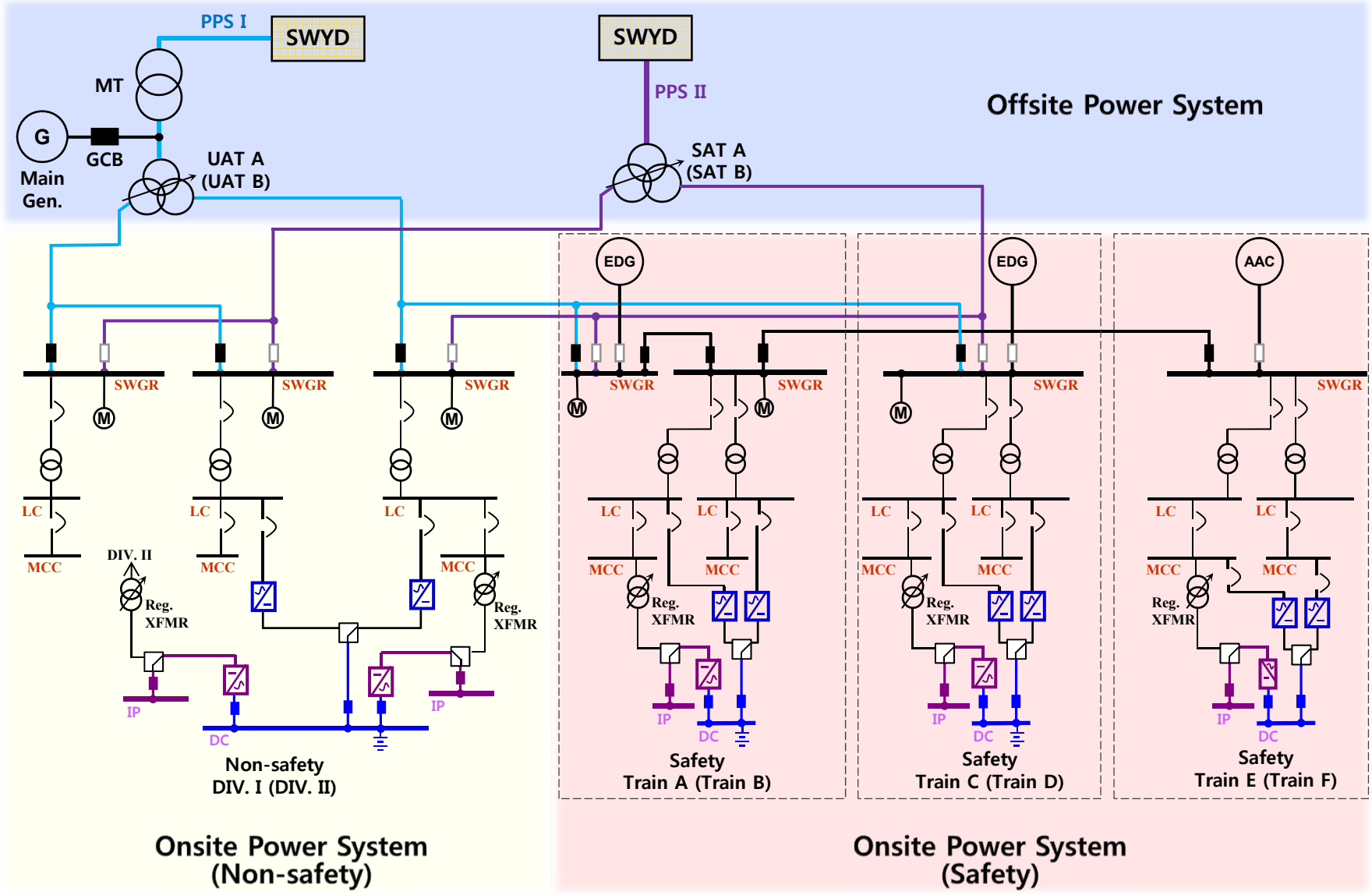
Contents

1. Introduction

- **Electrical power system of EU-APR consists of;**
  - **Offsite Power System**
  - **Onsite Power System consists of;**
    - Auxiliary Power System (AP)
    - DC Power System (DC)
    - Instrumentation and Control Power System (IP)

1. Introduction



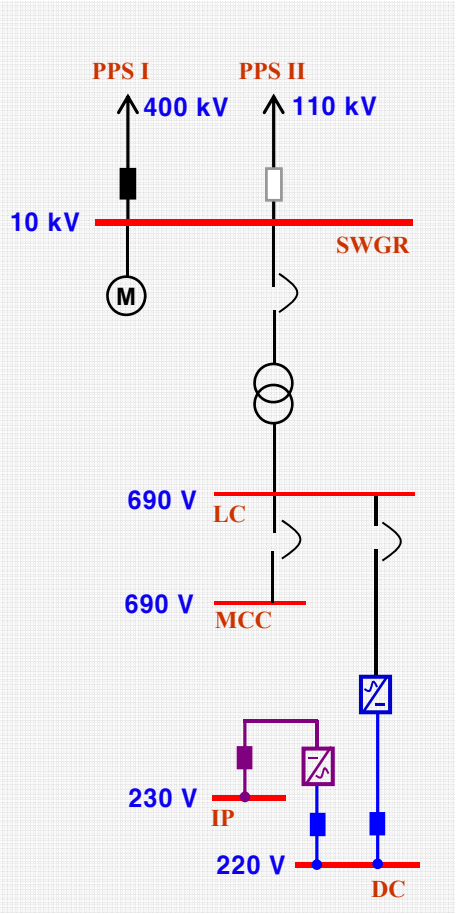
1. Introduction

- **Voltage Level and Frequency**
  - **Voltage level and frequency of electrical power system**

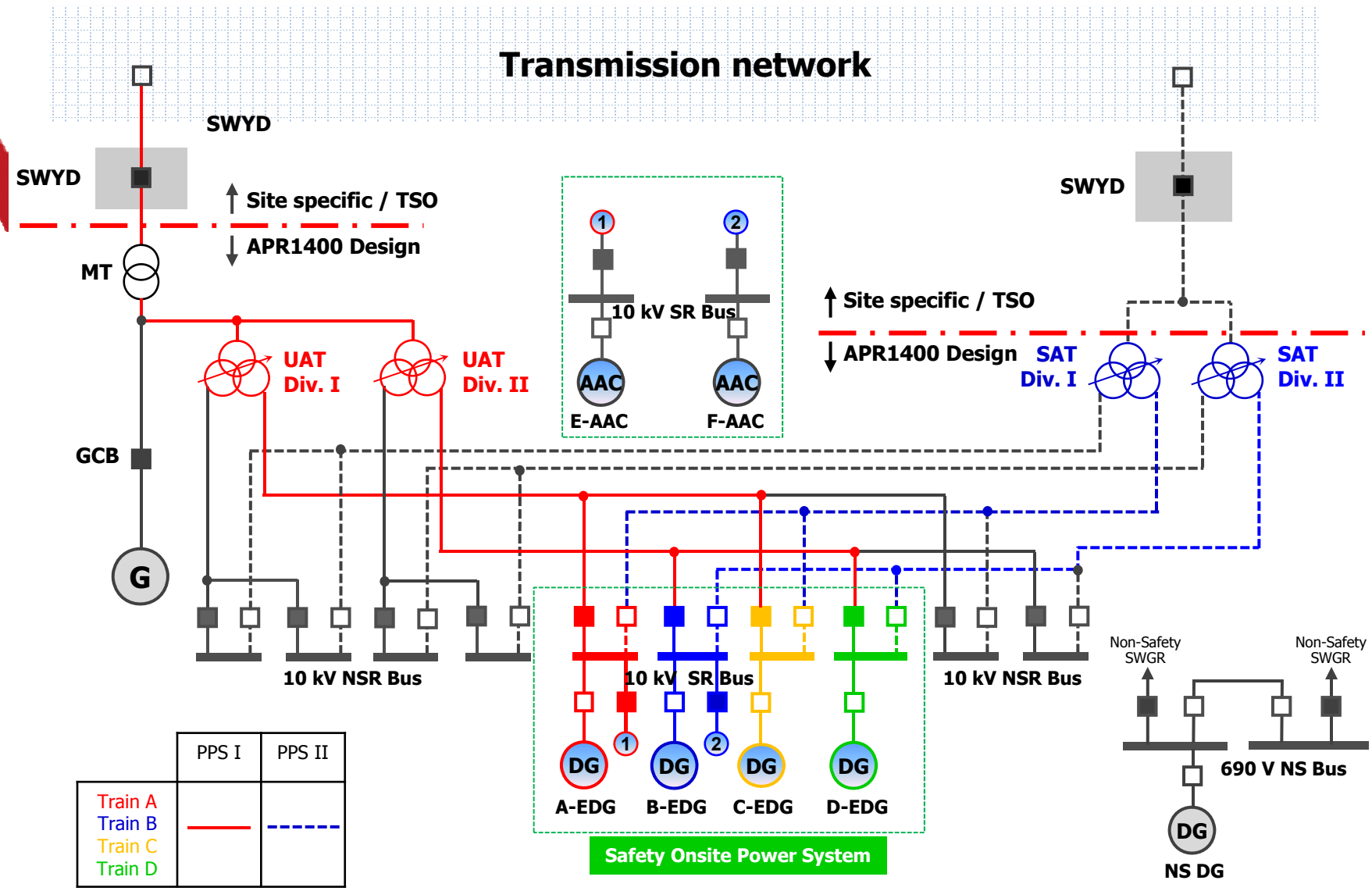
Power System		Voltage Level & Frequency
Offsite Power System	Preferred Power Supply I	400 kV*
	Preferred Power Supply II	110 kV*
Onsite Power System	Switchgear	10 kV
	Load Center	690 V
	Motor Control Center	690 V
	DC power distribution system	220 Vdc
	IP distribution system	230 V
Frequency		50 Hz

In accordance with IEC Std. 60038.

**Site specific*

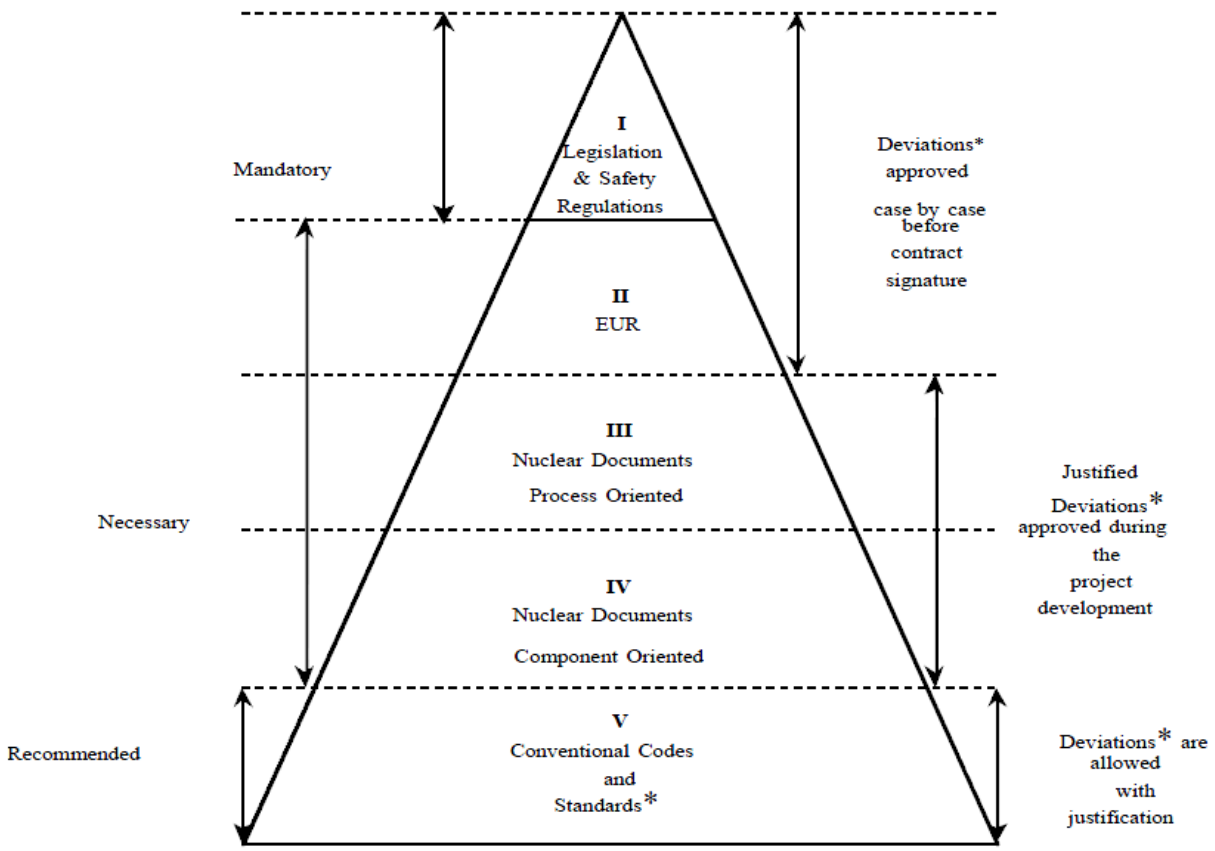


1. Introduction



1. Introduction

- **Design Requirements**



*EUR (Rev.D) Vol. 2 Ch. 5 Figure 1

2. Offsite Power System

- **Design Requirements**
  - **EUR, Vol.2 Chapter 3**
  - **EUR, Vol.2 Chapter 8, 3.7.2**
    - The power transmission and auxiliaries normal supply system shall be designed so that, in case of failure or unavailability of the normal power transmission circuit, off-site power supply shall remain available. An independent auxiliary standby circuit (including Auxiliary Stand-by Transformer (AST)) shall therefore be provided to operate the plant safety and non-safety loads. A single failure affecting grid equipment shall not affect both the normal power transmission line and the auxiliary standby line.
  - **10CFR50, Appendix A (GDC) 17**
    - Two physically independent circuits
    - Sufficient capacity and capability for all safety functions
    - 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).
    - IEEE std. 765

2. Offsite Power System

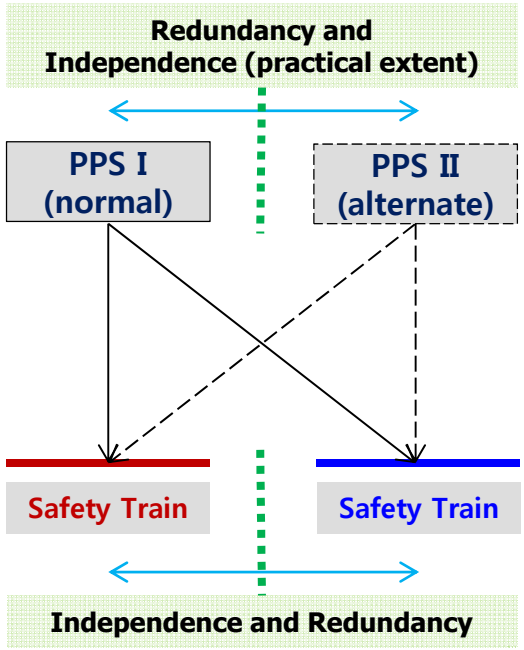
Offsite Power System Design

- The normal and alternate preferred power circuits to the SWYD are designed to be independent and physically separated each other to ensure their availability and to minimize the probability of simultaneous failure under normal and postulated accident conditions.

- Consists of main generator (MG), generator circuit breaker (GCB), isolated phase bus (IPB), main transformer (MT), two unit auxiliary transformers (UATs), two stand-by auxiliary transformers (SATs), and associated protection & control facilities.

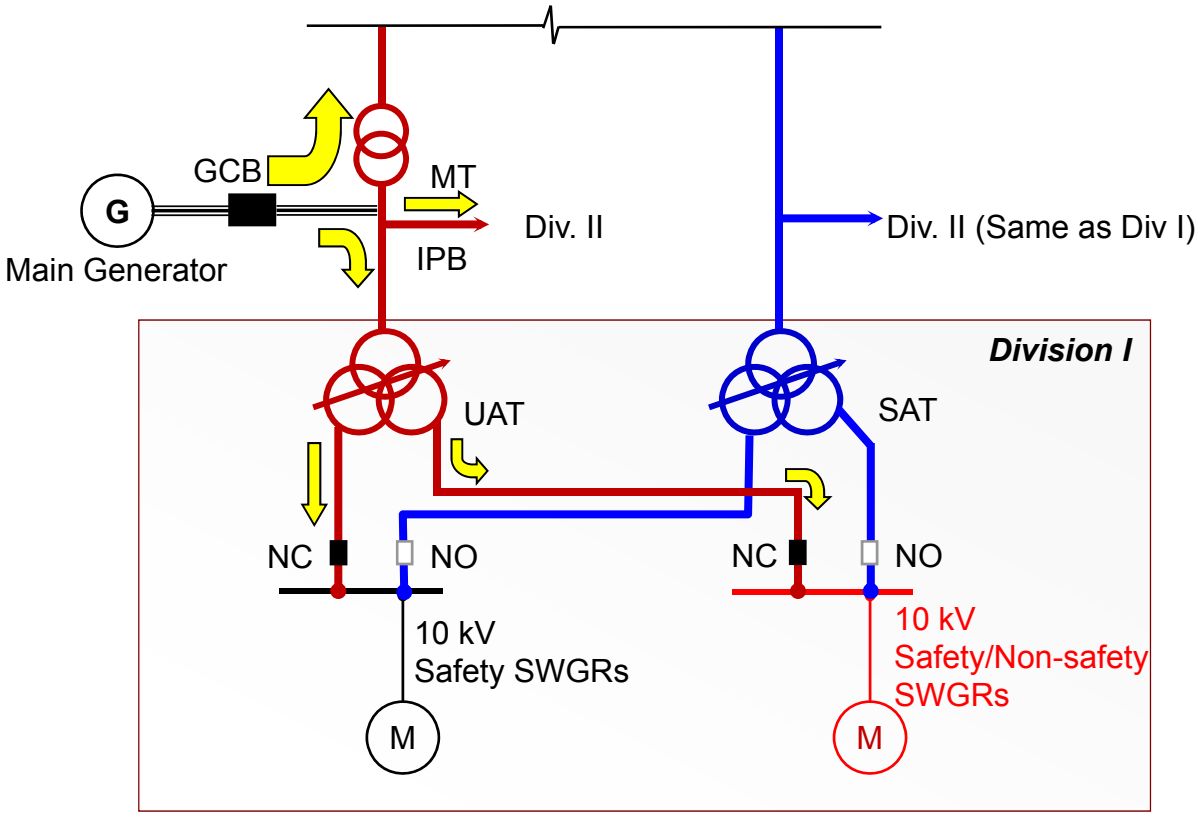
- The transmission network should include at least two physically independent circuits with sufficient capacity and capability for the APR1400.

- Two UATs (Div. I and II) and two SATs (Div. I and II), each sized to provide the required power for the worst case loading during normal, abnormal, and DBA conditions.



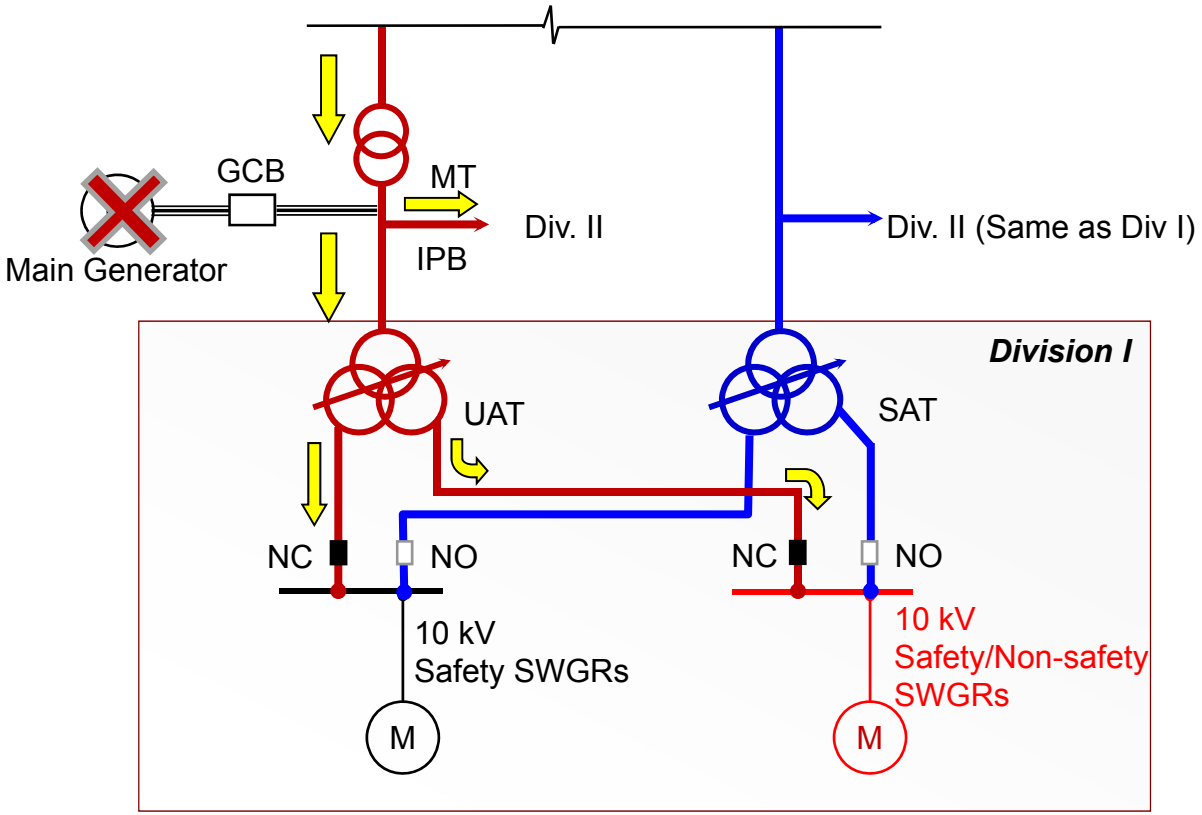
2. Offsite Power System

- **Offsite Power System Components and Circuits (cont.)**
  - During normal operation, the MG produces electric power and delivers the generated output to transmission system and also supplies the plant auxiliary loads.



2. Offsite Power System

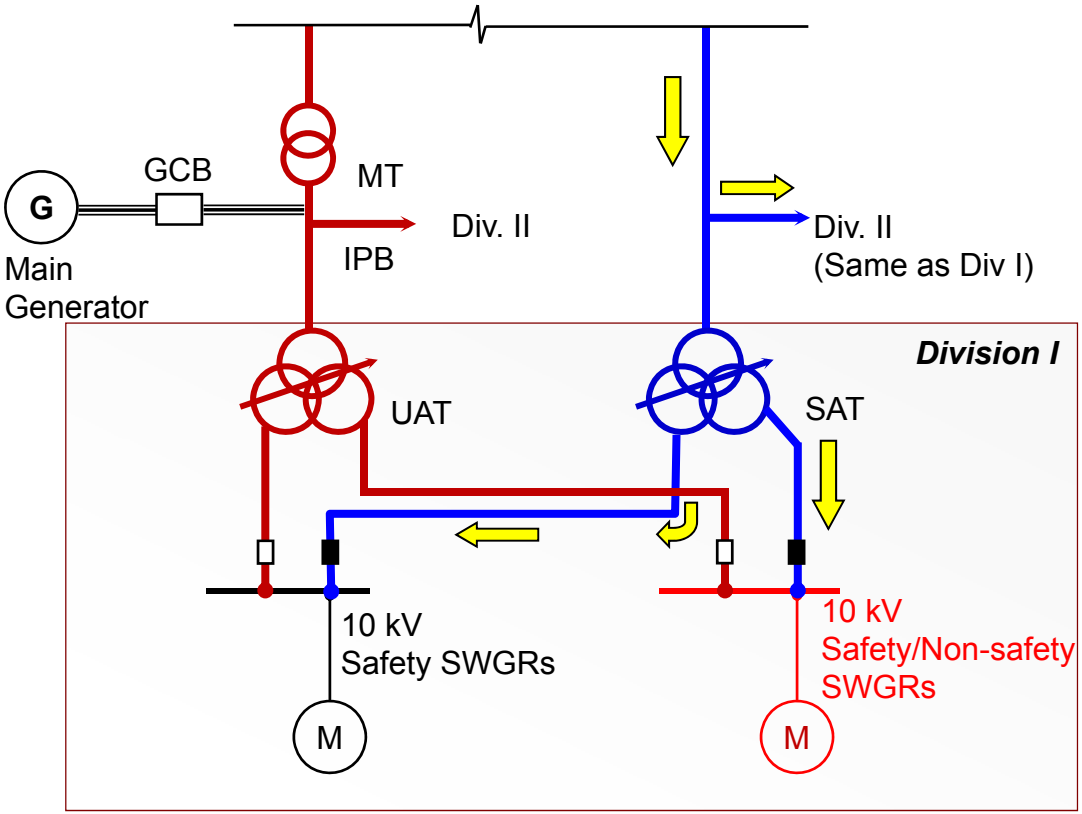
- **Offsite Power System Components and Circuits (cont.)**
  - In case the MG is failed or not in service, normal path of offsite power supply is secured by tripping/opening GCB (offsite power supply is available without interruption).



2. Offsite Power System

Offsite Power System Components and Circuits (cont.)

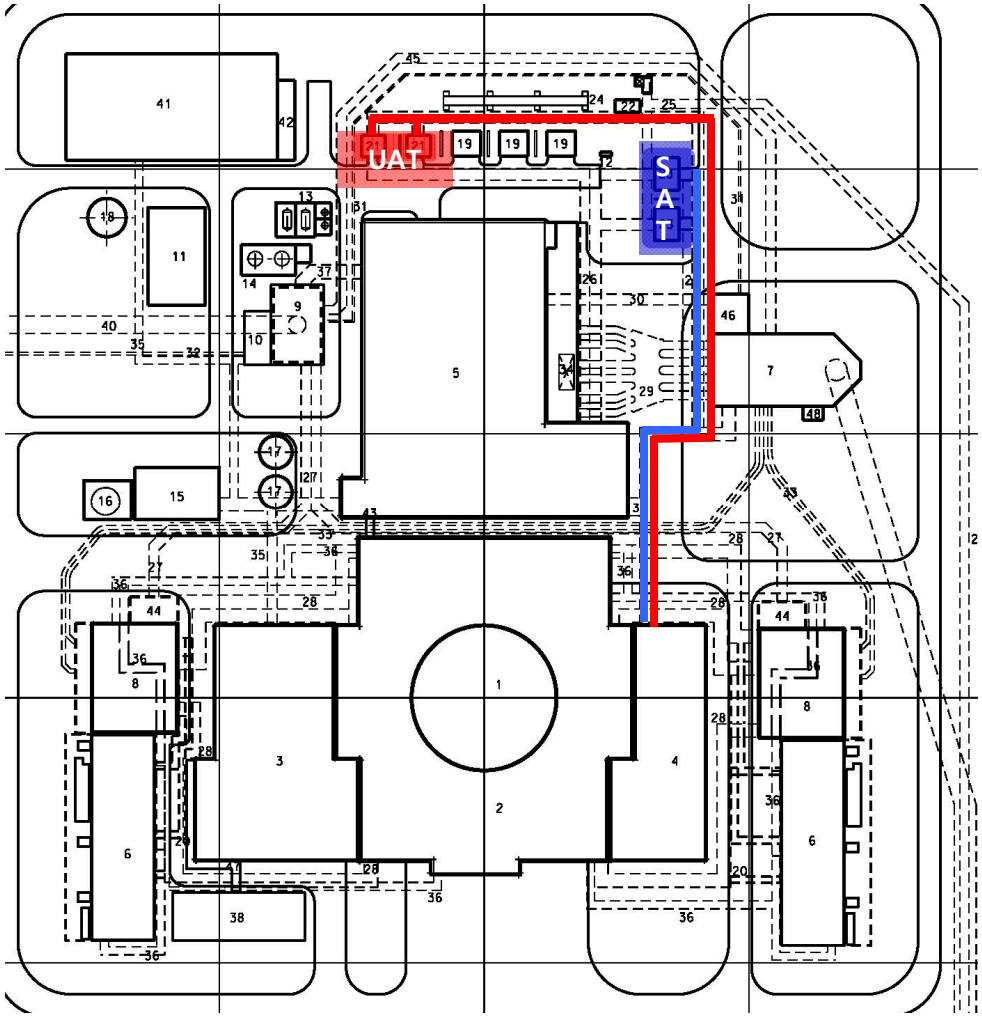
- In the event of a fault at normal offsite power circuit, offsite power supply to plant auxiliaries is switched to alternate path by automatic bus transfer (fast or residual voltage bus transfer); alternate path is available, normally, within 1 second.



- ✓ **Fast transfer**: automatic; transfer permitted if the voltage and phase angle differences between the switchgear bus and alternate offsite power source not exceed the acceptable limits (NEMA C50.41).
- ✓ **Residual voltage transfer**: automatic; back-up transfer to fast transfer.

2. Offsite Power System

- **Separation between Normal and Alternate PPS**



3. Onsite Power System

- **Design Requirements (Auxiliary Power System)**
  - **EUR Vol.2 Chapter 1, 6.2**
    - Certain design measures shall be used, if necessary in combination, to achieve and maintain the required reliability commensurate with the importance of the Safety Functions to be performed.
  - **EUR Vol.2 Chapter 8, 3.7.3**
    - The on-site standby power sources for safety loads shall be provided in accordance with the requirements for Redundancy, Independence and separation of Divisions, Diversity and Equipment Qualification.
  - **10CFR50, Appendix A (GDC) 17**
    - The onsite electric power supplies, including the batteries, and the onsite electric distribution system, shall have sufficient independence, redundancy, and testability to perform their safety functions assuming a single failure.
    - GDC 2, GDC 17, RG 1.53, RG 1.6, RG 1.75, IEEE Std. 603, IEEE Std. 384

3. Onsite Power System

Onsite Auxiliary Power System (Safety)

- Redundancy, Single failure criterion (SFC):
  - ✓ four redundant load groups (Train A, B, C, and D)
    - 10 kV switchgears, L/Cs, MCCs, and EDGs.
  - ✓ two redundant load groups (Train E and F)
- - 10 kV switchgears, L/Cs, MCCs, and AACDGs.

- Independence, Separation:
  - ✓ Physical and electrical independence from the offsite power system and the non-safety buses or loads
  - ✓ Physical separation between equipment of redundant trains including cables and raceways
  - ✓ No electrical connections or load share between safety trains.

- Each safety train (A, B, C, or D) has connections to both offsite power circuits (from UATs and SATs) and one connection to a safety onsite standby power source (EDG).
- Two AAC sources are connected to Train A and B respectively to cope with an SBO and to their respective train (Train E and F) for SA mitigation.

3. Onsite Power System

Onsite Auxiliary Power System (Non-safety)

- Major components: 10 kV switchgears, L/Cs, MCCs, and non-safety DG.
- Consists of two divisions (Div. I and Div. II), which evenly share the plant non-safety loads.
  (redundancy and independence requirements do not apply between non-safety divisions)
- MV switchgears of each division have connections to both offsite power circuits (from UATs and SATs)
- When the offsite power from UATs is lost, the alternate offsite power from SATs is provided by an automatic bus transfer.
- In the event of a LOOP, the non-safety DG is aligned to non-safety LCs to supply essential non-safety loads (e.g. T/G auxiliaries, DC&IP loads; essential lighting.)

3. Onsite Power System

- **Power Supplies based on Defense in Depth Concept**

DiD Level	Source and Path	Plant Condition	Remark
DiD 1	Normal PPS (from MG – UAT)	Normal operation	
DiD 2	Normal PPS (from Grid – MT - UAT)	Anticipated operational occurrences (MG not in service)	
	Alternate PPS (from Grid - SAT)	Anticipated operational occurrences (Loss of normal PPS)	
DiD 3a	EDG	Postulated single initiating events (LOOP)	Train A thru D
DiD 3b	AACDG	Postulated multiple failure events (SBO)	Train A and B
DiD 4	AACDG	Postulated core melt accidents (SA)	Train E and F

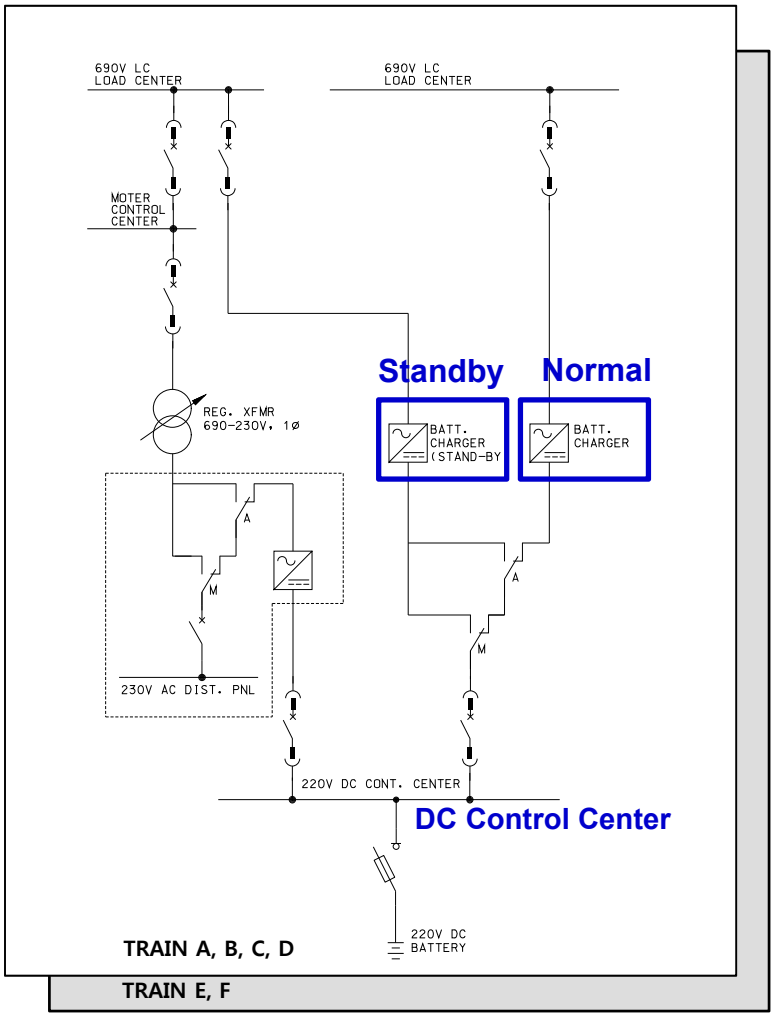
3. Onsite Power System (DC & IP System)

- **Design Requirements (DC & IP System)**
  - **EUR Vol.2 Chapter 8, 3.7.5**
    - The DC and AC low-voltage power supply system shall provide continuous and reliable electrical power for I&C loads such as the reactor protection and ESF actuation system and to other loads required for DBC and DEC.
    - Batteries backing up the operation of electrical systems important to safety shall maintain their capability to operate at least for two hours in case any operational situation including the single failure.
  - **10CFR50, Appendix A (GDC) 17**
    - The onsite electric power supplies, including the batteries, and the onsite electric distribution system, shall have sufficient independence, redundancy, and testability to perform their safety functions assuming a single failure.
    - GDC 2, GDC 17, RG 1.53, RG 1.6, RG 1.212, RG 1.75, IEEE Std. 603, IEEE std. 485, IEEE Std. 384

3. Onsite Power System (DC & IP System)

Onsite DC Power System (Safety)

- Safety 220 Vdc Power System

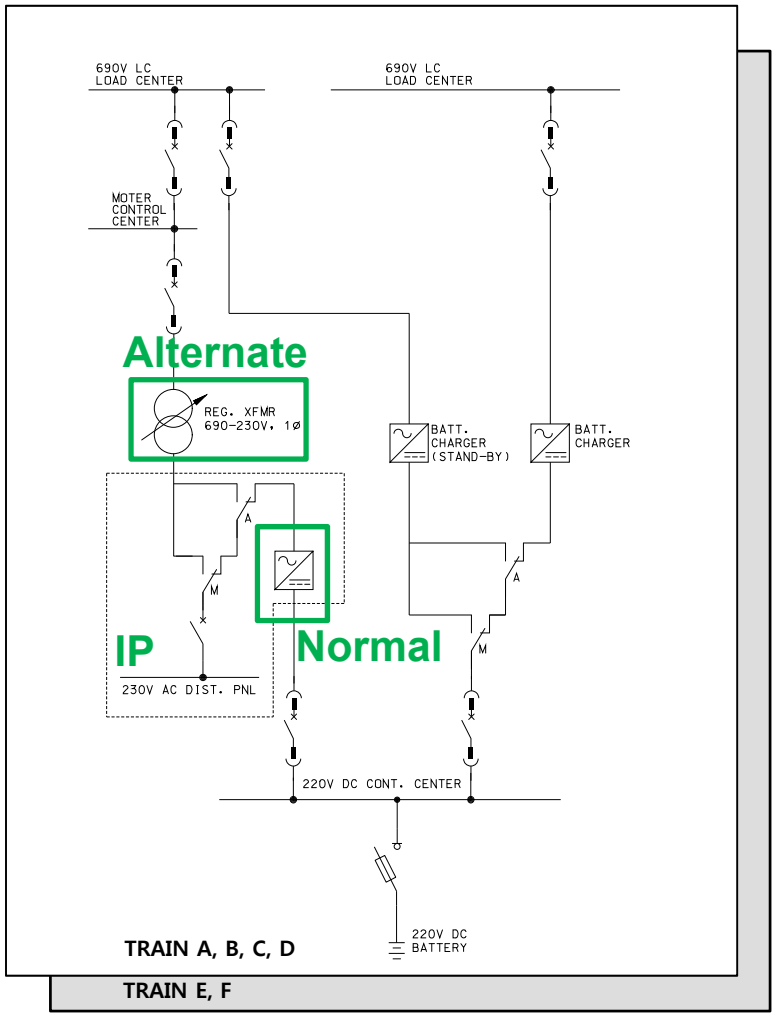


- ✓ Functions: supplies reliable 220 Vdc power to various plant safety equipment.
- ✓ Components: battery, battery chargers (N+1), DC control center, Automatic/Manual Transfer Switch, and distribution Panels
- ✓ Major loads:
  - ➢ Safety motor operated valves;
  - ➢ Solenoid for pneumatic valves;
  - ➢ NSSS and BOP safety control and instrumentation systems;
  - ➢ IP inverter.
- ✓ Redundancy: four redundant trains (Train A, B, C, and D), two redundant trains (Train E, F)
- ✓ Independence:
  - ➢ Located in separate location
  - ➢ No interconnection or load share between trains
  - ➢ Physical separation meets IEEE Std. 384.

3. Onsite Power System (DC & IP System)

Onsite Instrumentation and Control Power System (Safety)

- Safety 230 Vac Instrumentation and Control Power (IP) System



- ✓ Functions: supplies reliable uninterruptible 230 Vac power to plant safety I&C equipment.
- ✓ Major components: Inverter, Regulating Transformer, Automatic/Manual Transfer Switch and Distribution Panel
- ✓ Major components (e.g., inverters, regulating transformers) have sufficient capacity and capability to perform their intended function
- ✓ Major loads:
  - ➢ Safety Consoles;
  - ➢ Plant Protection System (PPS);
  - ➢ ESF-CCS;
- ✓ Normal feed: inverter (with battery back-up)
- ✓ Alternate feed: regulating transformer (no battery back-up)

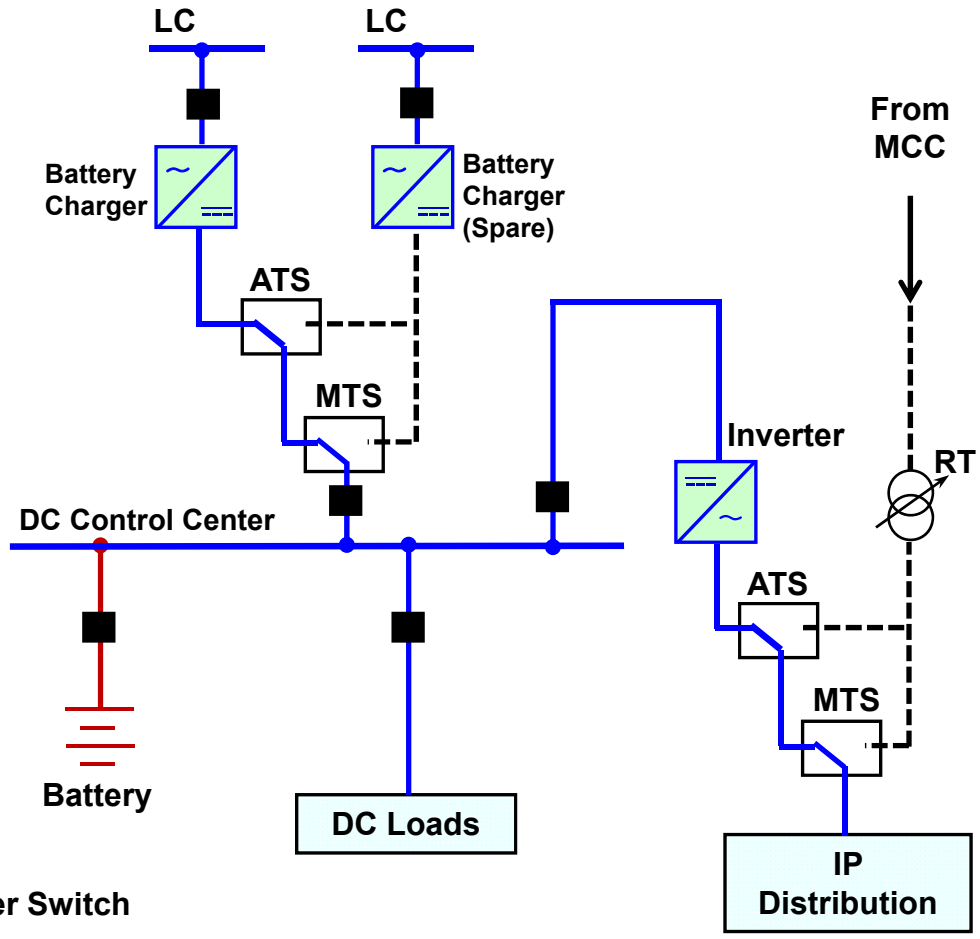
3. Onsite Power System (DC & IP System)

- **Operation Characteristics of DC & IP System**

Normal Operation
DC loads and IP inverter are supplied through normal Charger

AC Power or Charger fail
DC loads and IP inverter are supplied through standby Charger

IP Inverter fail
Transfer to Alternate Source



- ATS/MTS : Automatic / Manual Transfer Switch
- RT : Regulating Transformer

3. Onsite Power System (EDG)

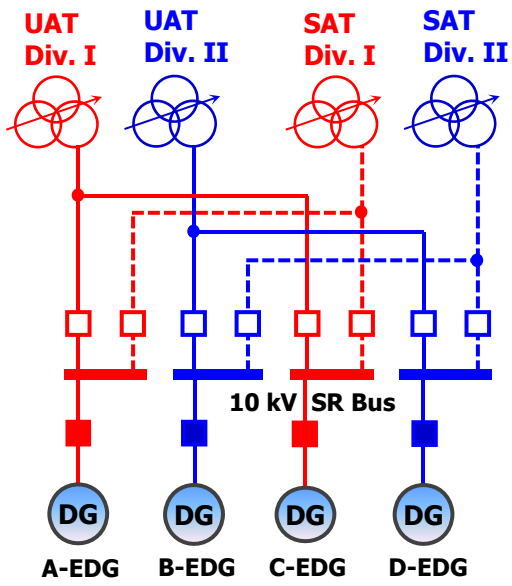
- **Design Requirements (Onsite Standby Power Source-EDG)**
  - **EUR Vol.2 Chapter 8, 3.7.3**
    - The on-site standby power sources for safety loads shall be provided in accordance with the requirements for Redundancy, Independence and separation of Divisions, Diversity and Equipment Qualification.
    - The onsite standby AC power supply system shall be designed to supply standby power to the plant safety functions in case of DBC and DEC for accident mitigation.
    - The autonomy considerations require that the emergency diesel generators shall have the on-site capability to be in operation equivalent to three days at full power.
  - **EUR Vol.2 Chapter 7, 13**
    - Requirements of sizing, instrumentation and control principles, operating conditions and performance, ancillary systems.

3. Onsite Power System (EDG)

- **Design Requirements (Onsite Standby Power Source-EDG)**
  - **10CFR50, Appendix A (GDC) 17**
    - The onsite electric power supplies, including the batteries, and the onsite electric distribution system, shall have sufficient independence, redundancy, and testability to perform their safety functions assuming a single failure.
    - RG 1.9, IEEE 387

3. Onsite Power System (EDG)

Emergency Diesel Generators



	PPS I	PPS II
Div. I	———	------
Div. II	———	------

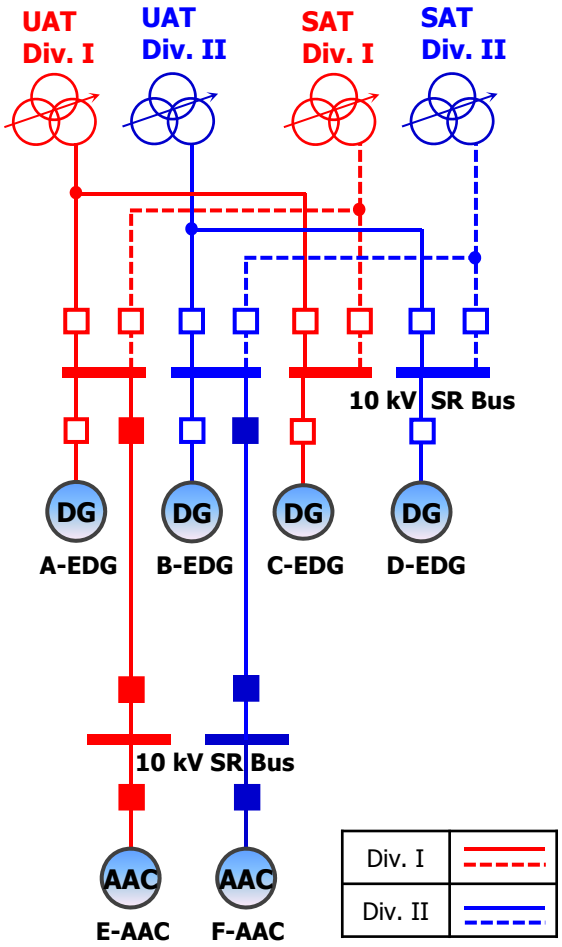
- Four 10 kV safety EDGs provide backup power to the corresponding safety 10 kV buses in the event of a LOOP or a LOOP concurrent with a DBA.
- EDG starting signals: ESF actuation signals (SIAS, AFAS, CSAS) and an under-voltage signal.
- Each EDG is designed to be started automatically and attain a rated voltage and frequency within 20 seconds after receipt of a start signal.
- The EDG load sequencers automatically sequence the required loads on the safety 10 kV buses and the required safety loads are connected to the buses in the predetermined order and interval time.
- Each EDG with its own control and protection system has no physical and functional interfaces with other trains.

3. Onsite Power System (AACDG)

- **Design Requirements (Onsite Standby Power Source-AACDG)**
  - **EUR Vol.2 Chapter 8, 3.7.3**
    - An onsite power supply Unit shall be provided which is independent of Normal Operation power supply systems, auxiliaries standby supply system and emergency diesels. It shall be available in DEC.
  - **Design Requirements – 10 CFR 50.63**
    - Sufficient capacity and capability to ensure that the core is cooled and appropriate containment integrity is maintained in the event of a station blackout for the specified duration.
    - Acceptable capability to withstand station blackout provided an analysis is performed which demonstrates that the plant has this capability from onset of the station blackout until the alternate ac source(s) and required shutdown equipment are started and lined up to operate.
    - RG 1.155

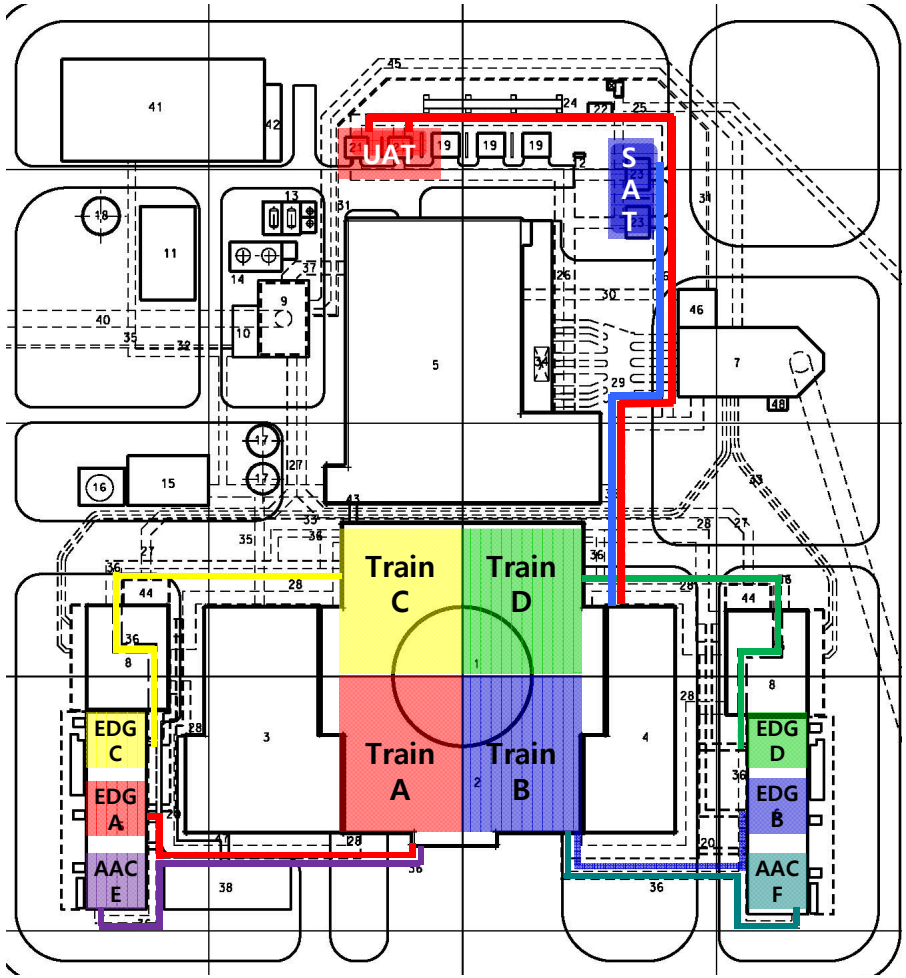
3. Onsite Power System (AACDG)

Onsite Alternate AC Diesel generators



- The AACDG is started automatically and designed to attain rated voltage and frequency after receipt of a starting signal.
- The loads required for plant safe shutdown or SA mitigation are manually connected by the operator in the main control room and remote shutdown room.
  - ✓ Manually connected to the designated 10 kV safety switchgear (Train A and Train B) by the operator during an SBO event.
  - ✓ Manually connected to the designated 10 kV safety switchgear (Train E and Train F) by the operator to mitigate SA.
- To minimize the potential for common-cause failures with the onsite safety EDGs, the AACDG is diverse from EDG.

4. Equipment Layout



- Each Train of the safety power system in a seismic category S1 structure
- Quardrant separation
- No interconnection between redundant trains
- Cables of each train run in separate raceways are physically separated from cables of the other trains and so do raceways.

5. Summary

- The design features of the electric power system of APR1400 complies with European Utility Requirements which assures the reliable operation of the plant, and safety functions for the plant.

- Country specific regulatory requirements will be met and US regulatory requirements and codes & standards will be used some areas where the European codes & standards do not cover.