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Design of Electric Power System for EU-APR1400 according to EUR

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1. Introduction

In the global nuclear market, the design requirements of NPP have been largely divided into the US and the European ones.

The APR1400 design was developed to comply with the US regulations for advanced light water reactor and the EPRI URD. It is an evolutionary advanced light water reactor whose design includes technologies proven through experiences and lessons learned of OPR1000(optimized power reactor 1000) construction and operation.

In order to enlarge and diversify the export market of APR1400, the EU-APR1400 design has been developed on the basis of APR1400 design to comply with European Utility Requirements(EUR) [1]. This paper describes the major European design requirements of electric power system and the design characteristics of EU-APR1400 power system which is based on the European design requirements.

2. Major EUR of electric power system

The EUR provides the technical specifications for new reactors to be built in Europe. European major design requirements of electric power system based on EUR are as follows [1].

2.1 Redundancy requirements

- Redundancy shall be considered to meet the single failure criterion(SFC) in safety systems.
- The N+2 concept shall be applied to the safety system which requires preventive maintenance during plant normal operation condition.

2.2 Independence requirements

- Disturbances in the non-safety categorized parts of the systems shall not impair the function of the safety categorized part.
- Two independent off-site power supply shall be available.

2.3 Diversity requirements

- Diversity shall be applied to redundant systems or components that perform the same safety function by incorporating different attributes into the systems or components.

2.4 Requirements for dedicated severe accidents power supply system

- Equipment needed to mitigate a severe accident should be independent of the equipment provided to fulfill DBC requirements.

2.5 Requirements for emergency power supply system

- The on-site 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.
- An on-site power supply unit shall be provided which is independent of normal operation power supply systems, auxiliaries standby supply system and emergency diesels.
- Batteries backing up the operation of electric systems important to safety shall maintain their capability to operate at least for 2 hours in case any operational situation.

3. Major design characteristics of EU-APR1400 electric power system

In order to comply with the European design requirements on electric power system described above, EU-APR1400 on-site power system was designed as follows [2].

3.1 Redundancy designs

EU-APR1400 on-site power system was designed to satisfy the SFC and N+2 concept of safety systems. According to the European requirement of considering SFC as well as 1 train out of operation due to maintenance during normal operation, on-site power system was designed not only mechanically 4-train but also electrically 4-train [2].

N+2 concept of fully 4-train design was developed as shown in Fig. 1. There are 4 EDGs and 2 AAC DGs in EU-APR1400 design. N+2 concept was applied to EDGs considering SFC plus on-line maintenance while N+1 concept was applied to safety-classified AAC DG considering SFC.

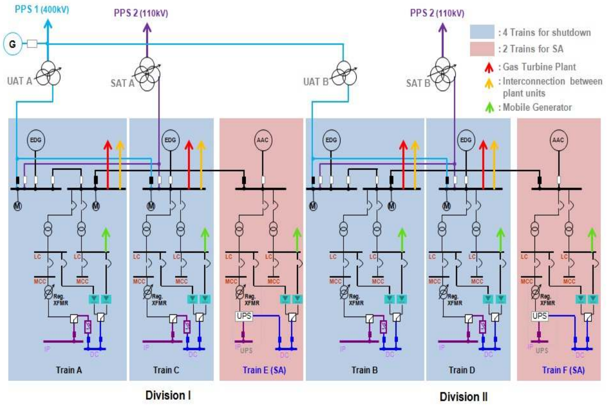

Fig. 1. 4-train design of EU-APR1400 on-site power system

3.2 Independence designs

In EU-APR1400 design, safety-related bus and non-safety-related bus are totally separated. Accordingly, safety-related equipments and non-safety equipments are also separated. So even though the disturbance occurs in non-safety system, that result does not interfere with the function of safety system.

Normal power for the station auxiliary loads is supplied through the unit auxiliary transformer(UAT) from main generator when the unit is operating or from the 400 kV transmission system via the main transformer when the generator circuit breaker(GCB) is open.

Stand-by power for the station auxiliary loads is supplied from the grid via the stand-by auxiliary transformer(SAT) when the normal power supply from UAT is not available.

3.3 Diversity designs

In preparation for common cause failure(CCF) of 4 EDGs, 2-train of safety-classified AAC DG was designed to perform the same safety function that EDG performs. So even if the CCF of EDGs occurs, AAC DG supplies emergency power to 10 kV MV bus. Also, as preventive measure of CCF, 10 kV MV safety-related bus for EDG and AAC DG was separated as shown in Fig. 2. As a result, the CCF of EDG bus does not disturb AAC DG bus.

The diversity between EGD and AAC DG was also designed by adopting different engine starting system. AAC DG has motor staring system in comparison with EDG's air starting system. Moreover, the diversity was taken into consideration by adopting different manufacturers between EDG and AAC DG [3].

As another diversity design, the safety-related bus of 690 V load center(LC) was separated in order to prevent CCF of 690 V LC. As shown in Fig. 3, the 690 V LC bus connected to the inverter was separated with the 690 V LC bus connected to the battery charger. Thus, the safety-related 690 V LC was designed against CCF.

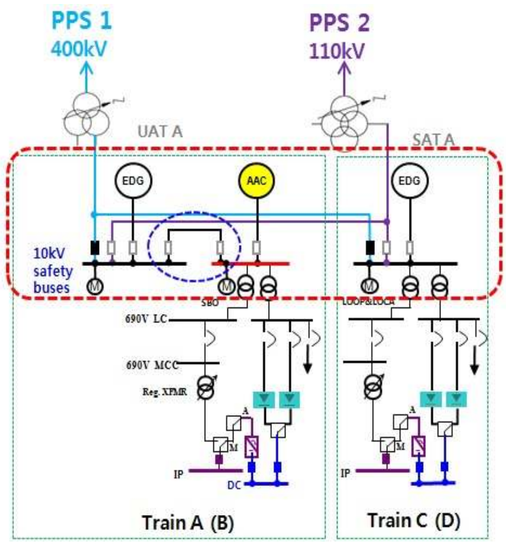

Fig. 2. Separation design for the 10 kV MV safety-related bus of EDG and AAC DG

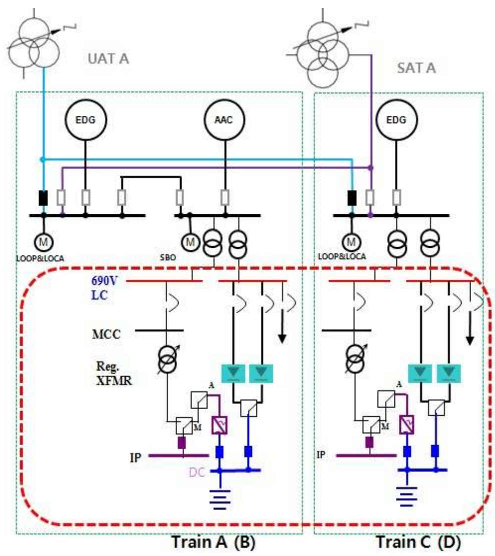

Fig. 3. Separation design of safety-related 690 V LC bus

3.4 Designs for dedicated SAs power supply system

EU-APR1400 on-site power system was designed to be equipped with the dedicated SAs power supply system which is independent of the equipment provided to fulfill DBC and DEC requirements [2].

AAC DG and battery were designed to supply emergency power to loads that performs the mitigation of SAs. AAC DG was designed as safety-classified 2-train and the battery was designed to perform the safety function for mitigating SAs for 24 hours without recharging. When SAs occur, AAC DG and battery are supposed to supply emergency power to SAs dedicated systems.

3.5 Designs for emergency power supply system

When a loss of off-site power(LOOP) occurs and the power supply from main generator is not available, each train of the safety-related auxiliary power system is supplied from an independent on-site emergency power supply system, which was designed to be available in DBC and DEC.

If both the off-site power and the EDGs are unavailable, one train of safety-related auxiliary power system is supplied from an AAC DG. AAC DG was designed to cope with DEC when EDG is not available in DEC.

In EU-APR1400 design, I&C power system supplies a continuous and reliable AC power to the plant I&C equipments which must remain operational in DBC, DEC and SA.

The inverter is the preferred power source and regulating transformer serves as an alternate source when the inverter fails. When DC control center is out of service or an inverter is out of service, inverter loads is automatically transferred to a standby power supplied by regulating transformer. And the battery of DC power system was designed to operate at least for 8 hours without recharging in DBC and DEC [2].

4. Conclusions

In this paper, the European design requirements associated with electric power system were introduced and corresponding design characteristics of EU-APR1400 power system were described.

Through the redundancy, independence and diversity design of EU-APR1400 power system, the safety and reliability for supplying electric power were improved.

And through the design of dedicated SAs power supply system, EU-APR1400 on-site power system became to be able to mitigate the SAs. The plant safety was also enhanced by designing emergency power supply system in various ways.

Consequently, the EU-APR1400 power system developed on the basis of European design requirements is expected to get competitiveness and enhance the license feasibility in the European nuclear market.

ACKNOWLEDGEMENTS

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