A Study on the Determination of Power Supply Class for HVAC System in KJRR

Hagtae Kim [a*], Minjin Kim [a], Yong-Suk Suh [a], Jun-Yeon Kim [a], Hee-Taek Chae [a]
[a]*Korea Atomic Energy Research Institute*
[*]*Corresponding author: hagtae@kaeri.re.kr*

1. Introduction

The KIJANG Research Reactor (KJRR) which started on the 1st of April 2012 is an open pool type reactor with 15 MW of thermal power. The main goals of KJRR are to self-sufficiently supply radioisotopes (RI), improve the production capacity in neutron transmutation doping (NTD), and conduct research on reactor-related technologies [1].

A Heating, Ventilating, and Air Conditioning (HVAC) system is installed in research reactors including a KJRR to control the temperature and humidity for radiation workers and prevent the indoor accumulation of radioactive materials occurring during normal or abnormal operations.

The purpose of this paper is to propose an appropriate electrical class, power supply class, and operation logic for the major equipment of the HVAC system such as a Confinement Isolation Damper (CID), Fission Molybdenum Isolation Damper (FID), Air Handling Unit (AHU), Air Cleaning Unit (ACU), and Contaminated Air Purification System (CAPS) in light of their functional requirements and importance.

2. System Description

The HVAC system retains pressure in radiation areas lower than atmospheric pressure at all times to prevent the leakage of radioactive materials, and makes air flow patterns from high levels of contamination to low levels by making a pressure difference. In addition, the HVAC system maintains a suitable temperature, humidity, and cleanliness in the reactor building and radiation controlled area, and removes the heat from various equipment for the system performance. In this section, a description of the major equipment of the HVAC system is explained.

2.1 Isolation Damper

Safety class isolation dampers are installed at all HVAC ducts penetrating the pressure boundary of the reactor building and fission molybdenum production building in the KJRR. When the fuel damage is detected, CID is operated automatically by receiving the signal from the Reactor Protection System (RPS) or Alternate Protection System (APS), or manually by operators in the Main Control Room (MCR). When a radiation accident occurs while at work, the FID is operated automatically by receiving the signal from the Fission Molybdenum Radiation Monitoring System (FRMS), or manually by operators in the MCR.

2.2 AHU, ACU, and CAPS

Pure air is supplied for the reactor building and fission molybdenum production building through the filter, coil, and fan of the AHU to maintain the suitable temperature and humidity. When the applicable building is isolated by the CID or FID, contaminated air is released within the derived limits through the filter and stack by operating the ACU and CAPS, if a decrease in the activity concentration is needed.

3. Analysis for the Power Supply Class

The classification for the overall HVAC system of the KJRR is a safety class NNS, Non-Seismic category, quality class S, and electrical class Non-1E. Exceptionally, the CID and FID are safety class 3, seismic category I, and quality class Q. The electrical class for the major equipment of the HVAC system should be determined considering the operation concept during Loss of Normal Electric Power (LOEP) regardless of the safety class.

In the case of a fail open, unnecessary operations are decreased during the LOEP by the operator's judgment. Specifically, when fuel damage is not detected during an LOEP, operators do not operate the isolation dampers. In this case, as soon as the normal electric power is recovered, the reactor shall be reoperated without procedures for the status identification of the isolation dampers. This concept is convenient for the operation of research reactors. On the other hand, in the case of a fail closed, isolation dampers are automatically operated without the operator's judgment when an LOEP occurs. This concept is excellent in terms of safety, because human error is fundamentally prevented.

A fail closed is applied because the HVAC System of the KJRR puts the safety before convenience. The electrical class Non-1E is determined to implement a fail closed, and an analysis for the power supply class considering the functional requirement of each system or equipment is described in sections of this chapter.

Table I shows the classification of the HVAC system of the reactor building and fission molybdenum production building in the KJRR including the electrical and power supply class proposed in this paper. As the power supply classes, Class IV, Class III, Class II, and Class I indicate normal electric power, diesel generator

power, uninterruptible AC power, and DC battery power, respectively.

Table I: Classification for HVAC system of KJRR

System/Equipment	Classification				
	Safety	Seismic	Quality	**Electrical**	**Power Supply**
Reactor Building HVAC	NNS	Non	S	**Non-1E**	**IV**
- CID	3	I	Q	**Non-1E**	**III**
- CAPS	NNS	Non	S	**Non-1E**	**III**
- AHU	NNS	Non	S	**Non-1E**	**IV**
FMPF Building HVAC	NNS	Non	S	**Non-1E**	**IV**
- FID	3	I	Q	**Non-1E**	**III**
- ACU(Only for hot cell exhaust)	NNS	Non	S	**Non-1E**	**III**
- AHU	NNS	Non	S	**Non-1E**	**IV**

3.1 CAPS and ACU

When isolation dampers are closed during a radiation accident, the CAPS and ACU release the contaminated air into the exterior of the confinement for a decrease in the activity concentration. In the case of LOEP, CAPS and ACU shall be continuously operated for a considerable amount of time to prevent the spread of contamination to other areas and a cross contamination among hot cells. Available power supplies during an LOEP are the Uninterruptible Power Supply (UPS) power and the Diesel Generator (DG) power. The duration of the power supply is 1 hour (UPS) and 24 hours (DG). Therefore, DG power is more suitable than UPS power in terms of the continuity of the power supply.

3.2 Isolation Damper

When the CAPS and ACU release contaminated air into the exterior, isolation dampers should be open. If isolation dampers are closed, the CAPS and ACU should not be operated. To solve this problem, the interlock logic is implemented by installing the limit switch at isolation dampers, and the DG power identical to the CAPS and ACU is supplied for isolation dampers. Isolation dampers are a fail closed type. While the electric power is supplied, isolation dampers are open by a hydro-motor. When the electric power is interrupted by control signals of RPS, APS, or FRMS, isolation dampers are closed by a spring.

3.3 AHU

If the DG power is supplied only for the CAPS and ACU, indoor air is continuously released and negative pressure in the confinement continues to become lower. The proper control of negative pressure is needed in terms of the structural stability because this phenomenon causes damage to the confinement or a failure of the exhaust fans. A simple solution is to continuously supply pure air to the inside of the confinement by supplying DG power for an AHU identical to the CAPS, ACU, and isolation dampers. However, the capacity of the DG is considerably increased.

Therefore, in the KJRR, normal electric power is supplied for the AHU, and the CAPS and ACU are frequently operated depending on the degree of negative pressure. In this case, the CAPS and ACU are operated automatically using a differential pressure meter in the confinement, or manually by the operators.

4. Operation Strategy

When normal electric power is interrupted, the DG shall achieve the rated voltage and frequency and be completely ready to supply electric power to the loads within 20 seconds after the starting signal is received. The CAPS, ACU, and isolation dampers are able to be reoperated after 20 seconds by the DG power.

However, the CID and CAPS in the reactor building are not operated automatically. After the operators check the accident situation and push the reset button, the CID is reopened and the CAPS is started up for safe reoperation. On the other hand, the FID and ACU in the fission molybdenum production building are operated automatically after 20 seconds by the DG power without procedures for checking the accident status, because operators do not stay around the clock unlike those in the reactor building.

5. Conclusion

In this paper, the electrical and power supply class is determined and the operation logic is proposed for the major equipment of the HVAC system for the KJRR such as the CID, FID, CAPS, ACU, and AHU.

The electrical class Non-1E is determined to implement a fail closed for the enhancement of safety. The power supply class is based on the functional requirements of each equipment. The CID, FID, CAPS, and ACU are Class III, but the AHU is Class IV by reflecting the importance and electrical load. After the recovery of the power supply, there is a difference in the operation concept for the HVAC system between the reactor building and fission molybdenum production building depending on the operator's residence time. The CID and CAPS are operated manually through procedures for checking the accident status, and the FID and ACU are operated automatically without special procedures.

The results of this paper are expected to be used for the design of the HVAC system for research reactors composed of several confinements similar to the KJRR.

REFERENCES

[1] Hagtae Kim, Jun-Yeon Kim, Seung-Gyu Doo, Yong-Su Cho, Conceptual Design of Electrical System for KJRR, Transactions of the Korean Nuclear Society Spring Meeting, May 29-30, 2014.