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A Duplication Method for a Single Fuse in the Reactor Protection System

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1. Introduction

Reactor protection system (RPS) is responsible for the role of the rapid safety trip of nuclear power plants when the plant safety is threatened by exceeding the safety limits defined in FSAR. One of the safety trip functions in RPS is to take advantage of the reactor trip relay and the low voltage relay. The power source of the relays is provided through a single fuse. Accordingly, if the single fuse fails, the function using the relays will not work properly in operation. This paper presents a duplication method of this single fuse to enhance the reliability of RPS functions in case of a faulty fuse.

2. Fuse Duplication Methods

Duplication of components or equipment is used as a method to increase systems' safety and reliability. However, duplication that does not consider the characteristics and environment of candidate components, equipment or systems might make problems with risks or failures. Especially, in electrical circuits, component duplication should be considered carefully. We will point out common mistakes in fuse duplication and propose an effective duplication method related to fuses.

2.1 Design easy to make mistakes

Simply, the duplication of a fuse can be arranged in parallel as shown in Fig. 1. F1 is the existing fuse and F2 is the added fuse in duplication. Each of the fuses has a capacity of 10 A-current. This design looks simple but has some anticipated problems.

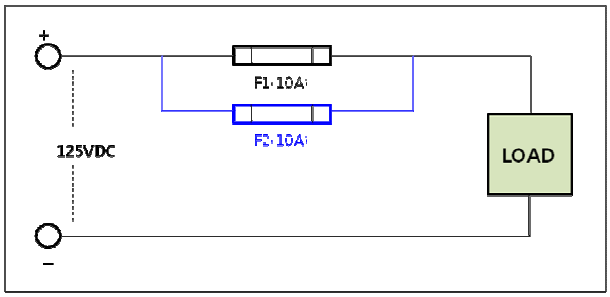

Fig. 1. Wrong design in fuse duplication

The anticipated problems are that there is current division, and a half current of original input current flows in the parallel part. The fuse's role is to break the over-current when the current within the circuit exceeds fuse capacity. However, in this design, it needs more than double current to meet the role of the fuses as in Table I. Also, if an over-current of 10 A to 20 A flows in this circuit, the fuses will not blow in the parallel part of the circuit but after that, the divided current will go back again, it can affect systems (load) negatively. If the capacity of each fuse (F1, F2) lowers to less than a 10 A-current, in the event of one fuse fault, the requirement of a 10 A-current capacity is not satisfied. Therefore, this design cannot satisfy the advantage of duplication; on the contrary, it may bring about risks to the system.

Table I: Theoretical current value for blowing fuses with the 10 A-current capacity in Fig. 1

current (A)	Before Duplication	After Duplication	
	Fuse (F1)	Fuse (F1)	Fuse (F2)
6	6	3	3
8	8	4	4
10	Blow	5	5
14	Blow	6	6
16	Blow	8	8
22	Blow	Blow	Blow

2.2 Proposed Duplication Design

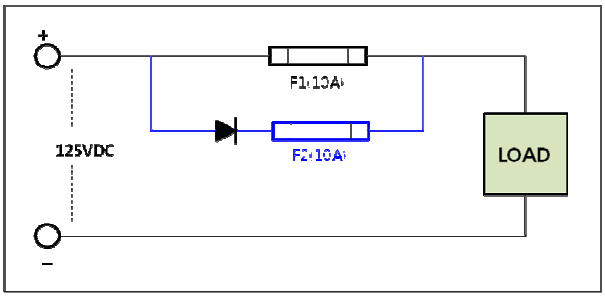

Fig. 2. Proposed duplication method

Fig. 2 shows a fuse duplication design considering a faulty fuse as well as the fuse original function which has to be blown under the over-current conditions. Fuse (F2) in Fig. 2 is for the stand-by in case of a fault in fuse (F1). A diode is linked directly to the front of fuse (F2). Diodes have general characteristics that pass current when there is a voltage difference between both sides of a diode [1]. Due to such a characteristic of diodes, current flows only into fuse (F1) in a normal state in Fig. 2 [2]. If there is any occurrence of the fuse (F1) fault itself in a normal state, the current flows into fuse (F2) since both sides of the diode have voltage differences. Consequently, in spite of the fuse (F1) fault, the circuit can work normally. As a matter of course, both of the

fuses (F1, F2) will be blown when an over-current of more than 10 A flows in the circuit

3. Application to RPS

The reactor trip relay and the low voltage relay in RPS play the role to be able to trip the reactor automatically and/or manually in abnormal states which threaten plant safety. That is to say, when reactor protection signals enter into the "Logic Matrix" in RPS, the reactor trip relay is actuated and the low voltage relay is de-energized at once, as a result, it makes the drop of control rods for plant safety trip. Also, in case of an electrical power failure, control rods get to drop for plant safety trip

In Fig. 3, there is one fuse (F1) to prevent over-current by input in front of the relays and the other fuse (F3) to prevent over-current caused by the system. Incidentally, if a fail is caused by the fault of the single fuse (F1 or F3), it results in dropping control rods and reactor trip even though there is neither an over-current nor a loss of electrical power. Therefore it is necessary for the single fuse to be duplicated in order to prevent a failure caused by the fuse fault itself [3].

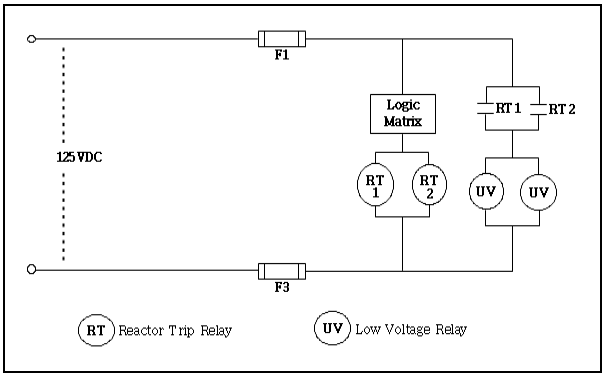

Fig. 3. Single fuses in RPS

Fig. 4 shows a fuse duplication applied to RPS according to the fuse duplication method proposed in section 2.2 above. In a normal state, current flows through fuses (F1 and F3), not the fuses (F2 and F4) because the sides of fuses (F2 and F4) with diodes need more voltage differences compared to the sides of fuses (F1 and F2) as mentioned at previous section.

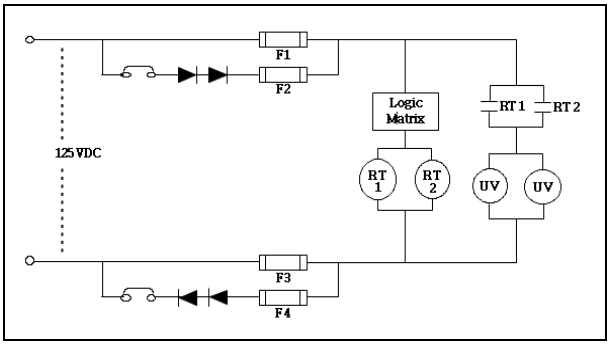

Fig. 4. Fuse duplication applied to RPS

However, in the event of a fuse (F1 or F3) fault, current flows through another fuse (F2 or F4), and consequently, the current to RPS can be sustained. Accordingly, by duplicating the single fuse (F1, F3) as proposed, the function of RPS can be enhanced more safely and reliably. The use of dual diodes is for duplication in case of diode fault. According to our logic circuit test, there is a little voltage reduction around 0.6 V by a diode in the system, but this reduction can be disregarded as compared with the whole voltage (125 V).

4. Conclusions

Reactor protection system (RPS) is a most important system which carries out a rapid safety trip in nuclear power plants. In this paper, a method of fuse duplication to enhance the function of RPS was introduced, considering fuse fault and fuse original function which has to be blown under the over-current conditions. Currently, technical review of fuse duplication in RPS is ongoing so that fuse duplication can be applied to existing nuclear power plants in Korea.

The proposed fuse duplication is also possible to apply to other systems in plants. It is expected to improve economical efficiency as well as reliability of plants.

REFERENCES

[1] "Preventive Maintenance Template", KHNP Technical Report, November 2008
[2] EPRI TR-107025 "Improving the reliability of class 1E power distribution", Final Report, September 1995
[3] Y. G. Choi, C. G. Jeong, "Technical Review of Fuse Duplication in RPS", KHNP Technical Report, July 2010