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Technical Review of the 55th Multiple Spurious Operation (MSO) Generic Scenario in Appendix G of the NEI 00-01 Guidance

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1. Introduction

In this study, we reviewed mitigation strategies for the 55th multiple spurious operation (MSO) generic scenario, which is described in Appendix G of the NEI 00-01 guidance [1]. The combination of spurious motor-operated valve (MOV) operation and wire-to-wire shorts bypass torque and limit switches results in a valve failure in the 55th scenario [1].

As per NEI 00-01, the 55th generic MSO scenario has been addressed during the disposition of U.S. NRC Information Notice (IN) 92-18 [1-2]. Nevertheless, the generic list of MSOs in NEI 00-01 now includes the IN 92-18 as the 55th scenario, as it should be examined in the context of MSO and multiple hot shorts [1].

If the issues in IN 92-18 are not fully resolved, negative effects may occur on the safe shutdown function to meet the requirements of Appendix R. Accordingly, the technical issue of IN 92-18 should be reviewed in the post-fire safe shutdown analysis (PFSSA), including MSO treatments [1]. The purpose of this study is to review the simplified sample electric circuitry of the MOV related to the IN 92-18 issue and investigate the resolution strategy.

2. Discussions and Results

2.1 Background of IN 92-18

The licensee for Unit 2 at U.S. Washington Nuclear Plant (WNP-2) discovered a problem with a circuit failure of motor operated valves (MOVs) that were not considered in the post fire safe shutdown analysis (PFSSA) [2]. The WNP-2 highlighted the risk that, in the case of an MCR fire, a hot short could cause irreversible damage to some MOVs [2].

If operator habitability cannot be secured in the case of an MCR fire, operators must leave the MCR and relocate to a remote shutdown panel (RSP) in a remote shutdown room (RSR) to perform a safe shutdown. However, in the event that a hot short arises in the MOV's control circuitry during an MCR fire, the MOV may sustain mechanical damage if it lacks thermal overload protection device, such as a thermal overload relay [2].

Before the operator switches the MOV's control function from MCR to RSR, mechanical damage to the MOV may occur. In this situation, the operator will not be able to operate the MOV in the RSR. In addition, operators are unable to manually operate the MOV on-site due to mechanical damage to the valve. Therefore, to prevent hot shorts from harming the MOV mechanically, thermal overload protection is required. Guidance on thermal overload protection for electric motors on MOVs is provided in Regulatory Guide (RG) 1.106 [3].

It took a long time for U.S. nuclear industry to resolve the outstanding difficulties related to IN 92-18. In the initial stages of the corrective action, many U.S. licensees thought that the thermal overload protection in the MOV's circuitry could prevent the MOV from mechanical damage. However, more detailed studies indicated that, while the thermal overloads protection may prevent mechanical damage to the motor, the valve protection was not ensured.

As a result, many licensees modified the circuitry for some MOVs so that, in the case of an MCR fire, a hot short would not bypass the torque switch or limit switch [4-5]. In addition, an MOV analysis such as weak link analysis was used to show that the valve could be operated electrically or manually on-site [6].

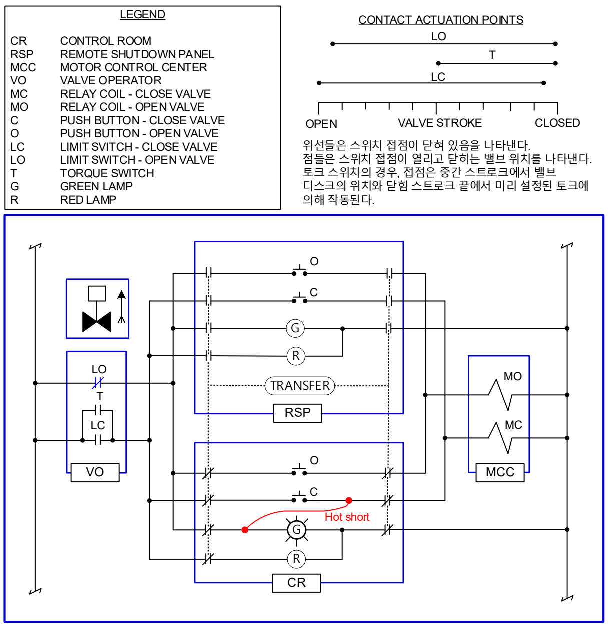

Fig. 1. Conceptual control circuitry showing a postulated hot short occurring while an MOV is closed (Redrawn from Figure 2 in Attachment 1 of IN 92-18 [2])

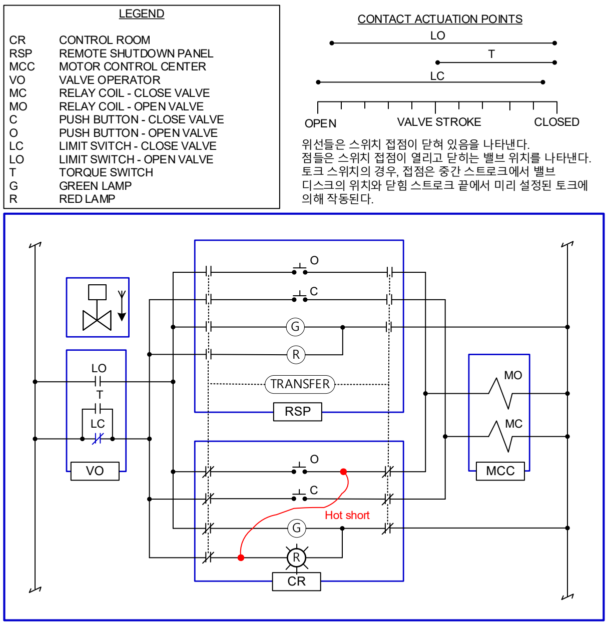

Fig. 2. Conceptual control circuitry showing a postulated hot short occurring while an MOV is opened (Redrawn from Figure 3 in Attachment 1 of IN 92-18 [2])

2.2 Hot Shorts in MOV control circuitry

The conceptual configuration of the MOV control circuitry found in Attachment 1of IN 92-18 is shown in Fig. 1. In front of CR (or MCR) and RSP is the valve operator (VO), which also enclosed the torque and limit switches (left portion of Fig. 1). With the limit switch LC being a Form A contact and LO being a Form B contact, the valve is fully closed in Fig. 1. In the CR and RSP, the contact points of push buttons C and O are all Form A contact points. If operators abandon the MCR in case of an MCR fire, the authority to control the MOV is transferred from the CR to the RSP through transfer function.

As depicted in Fig.1, there is a potential for a hot short to occur in the CR in the case of an MCR fire. Because of this hot short, the push button C downstream will be powered from the green lamp's upstream. Next, the relay coil MC for closing the valve will be energized. In this instance, the hot short bypassed the VO, allowing the valve motor to keep running until it stalls. When the motor stalls, current and torque become abnormally high, the motor windings become failed, and the valves are mechanically damaged. In the situation, operators will not be able to manually operate the valve on-site. Similarly, the fully opened valve will be mechanically damaged when it experiences the hot short. Fig.2 indicates the potential of the mechanical damage to the MOV when it is fully open.

As per NEI 00-01, potential hot shorts in such MCRs should be examined from the MSO perspective. Thermal overload protection devices are designed electrically to prevent damage to the MOV'S motor. Nevertheless, a hot short in the MCR can bypass the thermal overload protection device. This concern should be addressed in the context of multiple hot shorts.

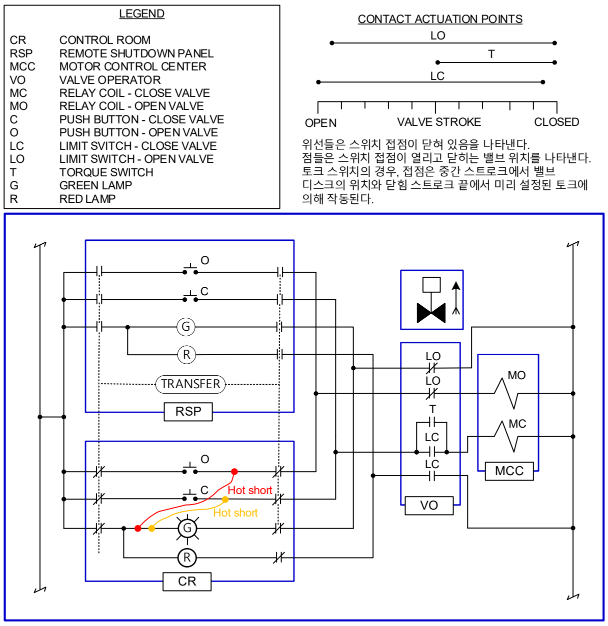

Fig. 3. Modified conceptual control circuitry showing a postulated hot short occurring while an MOV is closed (Redrawn from Figure 5 in Attachment 1 of IN 92-18 [2])

2.3 Hot shorts in Modified MOV control circuitry

The WPN-2 assessed that 15 MOVs in the residual heat removal system would likely to sustain mechanical damage owing to the fire scenario associated with IN 92-18. While the reactor was in shutdown, the WPN-2 verified this issue, notified the NRC, and implemented corrective actions. The WPN-2 performed preliminary analysis in order to modify the circuitry. Modifications were made to the MOV's circuitry to place the torque and limit switches of the VO between CR & RSP and MCC. Fig.3 shows the modified schematic diagram of the MOV control circuitry. In Fig. 3, the VO located between the CR and the MCC will prevent the valve motor from running nonstop in the case of a hot short.

Regardless of the push buttons O or C's contact location, in the event of a hot short, the green lamp G upstream will power the push buttons O or C downstream. The valve will spuriously open if the hot short powers the push button O downstream, energizing the relay coil MO. When the valve is fully opened, the contact of the limit switch LO is changed into Form A resulting in deenergizing the relay coil MO. Therefore, the mechanical damage to the valve motor will not happen due to the hot short. On the other hand, the limit switch LC in Form A contact prevents the relay coil MC from being energized when push button C downstream is powered.

Similarly, Fig. 4 shows a scenario where a hot short arises in the modified control circuit for the fully-opened MOV. The MOV is not mechanically damaged, even though hot shorts in the control circuitry may cause spurious operation.

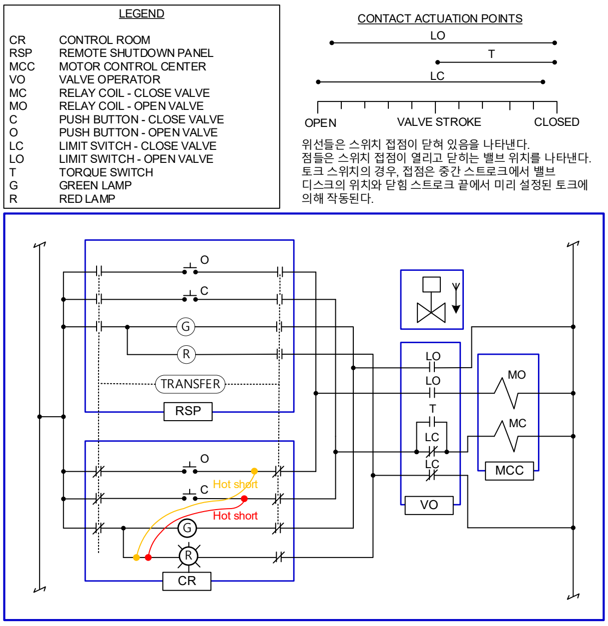

Fig. 4. Modified conceptual control circuitry showing a postulated hot short occurring while an MOV is opened (Redrawn from Figure 6 in Attachment 1 of IN 92-18 [2])

3. Conclusions

In this study, the 55th MSO generic scenario pertaining to IN 92-18 was reviewed. In the case of an MCR fire with the circuitry configuration where the VO is positioned before the MCR, a hot short could bypass the limit and torque switches, resulting in irreversible mechanical damage to the MOV. In the same manner, the hot short can damage the MOV, bypassing the thermal overload protection. Even when the fire-induced hot short does not bypass the thermal overload protection, it could result in the loss of power for the MOV by tripping the thermal overload protection device owing to the excessive current demand of the motors. The mechanical damage to MOVs by the fire-induced circuit failure might have a negative impact on the safe shutdown functions in case of an MCR fire event. As a result, suitable mitigation strategies will be required, such as design modifications to the MOV control circuitry. IN 92-18 describes how to change the control circuitry for MOVs. It was advised that the VO be positioned between MCR and MCC in the modified circuitry.

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