An illustrative Circuit Analysis for Fire PSA of a Domestic Nuclear Power Plant

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1. Introduction

Circuit analysis has been trained for more than 10 years as one of NRC/EPRI fire PRA training course in U.S.A. However, since the U.S electrical drawings, including schematic drawings and elementary wiring diagrams, used in the fire PRA training course are too old fashioned ones, and thus, too much different from Korean ones, it is not easy to use the knowledge acquired through the NRC/EPRI circuit analysis training course when a circuit analysis is performed with the Korean electrical drawings. In addition, Korean Nuclear Power Plants (NPPs) have optical cables which are not widely used in U.S NPPs.

Thus, an illustrative circuit analysis of MOV is introduced in this paper, to help a circuit analysis on Korean electrical drawings. In addition, it is described how the result of circuit analysis is used in the fire PSA.

2. Methods

2.1 Different Style Drawings in Korea

Since the schematic drawings of U.S NPPs are old fashioned, it is not easy to mark conductors with color according to their cables. One example of color marked schematic drawing for a MOV is shown in Fig. 1. Block diagram is also necessary for the color markup.

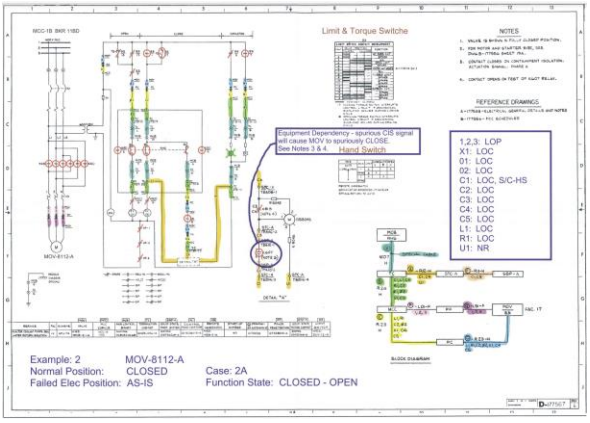


Fig. 1. U.S Color Markup Schematic Diagram for a MOV

However, as shown in the Korean NPP MOV drawing of Fig. 2, the conductors are already marked with their cable. For example, in Fig. 2, CABLE C has conductor X1, 2, and 1. Thus, color markup of conductors-cables and a separate block diagram are not necessary in the domestic NPP drawings.

Also, self-holding circuits are clearly shown in the U.S NPP drawings of Fig. 1.

However, the MOV operation shown in Fig. 1 and 2 are almost identical even though it seems that two drawings are very different each other. For example, magnetic coils '42-C' and '42-O' electromagnetically trigger the circuit breaker relay contacts '42-C' and '42-O' to close and open the MOV of Fig. 1 and 2, respectively.

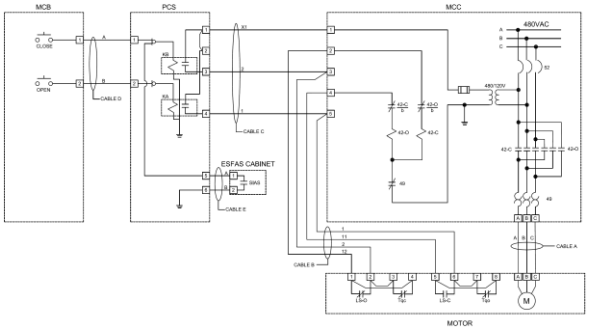


Fig. 2. Typical Korean Elementary Wiring Diagram for a MOV

2.2 Circuit Analysis

The following steps are necessary for circuit analysis on Korean NPPs drawings.

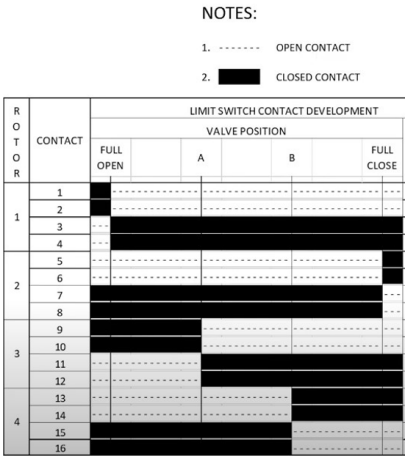
Step 1 - Contact Positions ;

Contact positions (open or closed) on drawing for "Initial" state are marked using limit switch legends and switch developments as shown in Table 1. In Table 1, there are 16 patterns for limit switches. We could say that there are 16 switches in a MOV, and among which we select several switches to make a smart MOV circuit.

In Korean drawings, the step which highlights schematic & block diagrams to show cables-

conductors relationship, is not necessary. The drawing of Fig. 2 shows the fully opened MOV during normal operation. Thus, the initial position is 'open', and the desired position is 'open' case. Also, when the power is lost, the MOV is still open.

Table 1. Limit switch contact development



Step 2 – Hot Probe Assessment;

Using hot probe and ground probe technique, failure modes for each conductor are identified. The result of hot probe assessment about the MOV of Fig. 2 is shown in Table 2.

Table 2. Hot probe assessment of MOV of Fig. 2

Cable No.	Conductor No.	Hot Probe	Ground Probe
Cable B	1	No Consequence	No Consequence
	11	No Consequence	No Consequence
	2	Spurious Close	No Consequence
	12	Spurious Close	No Consequence
Cable C	X1	No Consequence	Loss of Power due to a blown fuse
	1	No Consequence	No Consequence
	2	Spurious Close	No Consequence

Step 3 – Assign a Probability for Spurious Operation (SO);

After hot probe assessment, conditional probabilities for the SO cables are assigned using the probabilities as shown in Table 3 [1]. The MOV of Fig. 2 is a single break control circuit, thermoset cable, and the initial and desired position of the MOV is 'open' and 'open', respectively. Since CABLE C has 120V AC from the transformer, inter-cable and intra-cable SO (i.e., spurious close) can occur. However, since there is no electrical source through CABLE B, intra-cable SO cannot occur while only inter-cable SO is possible. Thus, the SO (i.e., spurious close) probability of CABLE C and CABLE B is 0.28 and 0.0088, respectively according to Table 3.

Table 3. Mean conditional probability of SO for single break control circuits [1]

Power Supply →			Grounded AC		
Target Cable Configuration		Device Type	Intra-Cable	Inter-Cable	Aggregate
			1	2	3
Thermoset-Insulated Conductor Cable	1	SOV	0.42	0.01	0.43
		MOV	0.27	8.8E-03	0.28
		Circuit Breaker			

2.3 Use of Circuit Analysis Results in Fault Trees

After SO probabilities are derived through circuit analysis, they should be used in the fault trees (FTs). An example of MOV is shown in Fig. 3 where the conditional probability (0.28) of 'spurious closed' is reflected in MOV (3451V0501) FT.

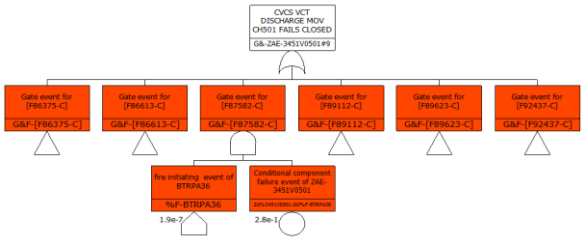


Fig. 3. Example of SO probability (0.28) reflected in FT

3. Conclusions

To understand the circuit analysis for fire PSA, we often take a circuit analysis course of NRC/EPRI fire PRA training. However, the difference of electrical drawings between U.S NPPs and Domestic NPPs bothers us in performing the circuit analysis of domestic NPPs.

In domestic drawings, since the conductors-cables relationship is already clearly indicated, the color marking step to clearly show the relationship between conductors-cables is not necessary in domestic drawings.

Also, circuit analysis process was described, and an example of no intra-cable SO was explained.

In addition, how conditional SO probability of a MOV is reflected in a fault tree is illustrated.

Acknowledgement

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REFERENCES

[1] NRC, Joint Assessment of Cable Damage and Quantification of Effects from Fire (JACQUE-FIRE), NUREG/CR-7150, Vol. 2, 2014