Analysis of MOV Spurious Operation and Final Valve Position

[redacted]

1. PURPOSE

The purpose of this analysis is to use the existing Grounded AC Circuit data to analyze the probability that an MOV will spuriously operate into a non-fail safe position. For a normally closed MOV, this is assumed as opened or in mid-position. The analysis will account for factors beyond the basis spurious operation probability values, including account for hot short duration, MOV stroke time, the probability of both open and closed coils being actuated.

2. DISCUSSION

Existing Spurious Operation analysis generally assumes that once a spurious operation occurs, the MOV will travel to its failed position 100% of the time. In reviewing the test data; there are several factors that may affect this estimate.

1) Generic Letter 92-18 protection involves a circuit design to ensure a hot short will not result in the MOV motor continuing to operate once the valve travels to its end of stroke. The circuit design can vary, and in many cases, the 92-18 protection will protect only part of the circuit failures such as a due to a fire in the control room. However, fires in other locations (e.g., at the MCC) may still bypass the protection. Additionally, many valves do not have 92-18 protection, especially those included in a Fire PRA model which were not included in the original Fire Safe Shutdown Analysis. The issue is important since a closed valve receiving a close signal may continue to try to further close, with a subsequent open signal not affecting the valve position. On the other hand; if the MOV receives an open signal; the valve may continue to try to open until the hot short clears.
2) In most MOV circuit failures, the MOV will continue to stroke to its final end position once the hot short clears. However, this depends on where the hot short occurs and the circuit design. In some cases, clearing the hot short (typically through a fuse blow) will result in the valve stopping at whatever position it is currently.
3) Stroke time; MOVs stroke times (from full closed to full open, or open to closed) range from less than a second to more than 10 or even 20 seconds. Stroke time depends on a number of factors including valve size and motor size/speed. The stroke time impacts the valve position for short duration hot shorts, but with long duration hot shorts; it is more difficult to predict the final valve position.
4) Hot Short Duration; the hot short duration impacts the final position, given the impact of stroke time is accounted for in the analysis. For short hot short durations; the valve position can be determined by comparing the stroke time and hot short duration.
5) Simultaneous Open/Closed signals: In a majority of the recorded AC hot shorts, both the open and closed coil were energized. Additionally; the clearing of the hot short occurred at

the same time for both coils in a majority of the simultaneous hot shorts. With 92-18 protection, the valve would then continue to cycle opened and closed until the hot short clears. Without 92-18 protection; the first coil energized would likely determine the final valve position. For example, if the closed coil were energized first, the valve would not open if both hot shorts cleared simultaneously.

3. ASSUMPTIONS

1) The MOV is initially closed, with a fail-safe position of closed.
2) Failure open is considered if the valve is either in the full open position or in mid-position.
3) An MOV with 92-18 protection which is impacted by a hot short on both the open and closed coil is assumed to travel continuously opened and closed until the hot short clears.
4) MOV motor failure, motor heater failure or similar where the motor stops operating after either driving into the valve seat or following constant operation over an extended period of time is not included in the analysis. For an MOV without 92-18 protection (see below), the MOV would likely fail in whatever position it initially travels. In this case, the assumption doesn't affect the analysis outcome, since it is conservative for an initial MOV closure signal and non-conservative for an initial MOV open signal; but with equal probability outcome. For valves with 91-18 protection; the valve is assumed to travel open and closed continuously, with the final failure position unknown. Since the motor current is highest at the end of travel, the valve failure position is more likely at its position. However; without extensive analysis; the final position cannot be predicted.
5) An MOV with a circuit design such that clearing the hot short results in the valve failing as-is; is assumed to fail in the mid-position (considered open).
6) A MOV with a circuit design such that the valve continues to stoke once the hot short clears is assumed to end in the closed position 50% of the time and the open position 50% of the time when the hot short time is longer than 30 seconds.

4. DATA DEVELOPMENT

The following provides some discussion and analysis of data used to analyze the impacts of various factors on the final MOV position given a spurious operation.

<u>Base Numbers: T-Set; Grounded AC</u>

The following is not used in the final conditional probabilities, but is the base HS probability for a MOV spurious operation. It is issued to be the probability of a closed MOV spuriously opening or an open valve spuriously closing.

Intra-cable: 26 of 53 shorted C5 and 27 of 53 shorted C6. Average = 26.5/52 or 0.50 (0.37, 0.50, 0.63)

Inter-Cable: 0 of 23 shorted C5 and 0 of 23 shorted C6. Average = 0.5/23 = 0.022 (0.0005, 0.018, 0.15)

Total = 26/52 = 0.50 (0.36, 0.51, 0.70)

Simultaneous Open/Closed HS:

Both C5 and C6 Hot Shorted 21 of the Intra-cable. This is a total of 21 of the 26.5 average hot shorts where both C5 and C6 were shorted = 0.79 (0.59, 0.79, 0.92). For calculational purposes, this is rounded to 0.8 (0.6, 0.8, 0.9) below.

Duration:

The Grounded AC duration Data was analyzed a few different ways (different groupings) for duration intervals. The following provides an example grouping of the duration:

Time	0-1	1 to 3 seconds	3 to 5 seconds	5 to 7 seconds	7 to 10 seconds	10 to 20 seconds	20-30 seconds	>30 seconds
Prob.	3.8%	1.9%	3.8%	9.4%	5.7%	11.3%	15.1%	49.1%

The above is used below for analysis of potential estimates of the final valve position given various MOV stroke times.

Probability of Valve Position, Given both Open and Closed HS occurs

Using the above data, assumed stroke time for MOVs (variable), and assuming the MOV was initially closed; an estimate of whether the MOV ended as open, closed or unknown was performed. For example, with a stroke time of exactly 10 seconds, the hot short durations of 0-10 seconds would result in the valve being open, a stroke time of 10-20 seconds would result in a closed valve, 20-30 seconds would again be open, and beyond 30 seconds would be unknown. The 49.1% of the hot shorts greater than 30 seconds is important for the analysis below, since regardless of the stroke time; about ½ of the hot shorts will result in an unknown position. Roughly 1/3 of these > 30 second stroke times were between 30 and 60 seconds, and the other 2/3 range up to the maximum listed time of 231 seconds.

Further assuming that half of the unknowns resulted in an open valve, and half resulted in closed valve; the following results were derived:

Stroke Time (Seconds)	Open	Closed
< 1	51.9%	48.1%
2	50.9%	49.1%
4	49.1%	50.9%
6	45.3%	54.7%
8	58.5%	41.5%
10-20	49.1%	50.9%
20-30	60.4%	39.6%
> 30	**75.5%**	**24.5%**
Average	55.1%	44.9%

The above estimates will vary, depending on the grouping. Additionally; these estimates have inherent statistically uncertainty (See analysis of the duration data). As a result; the following is recommended for the detailed MOV analysis:

Closed MOV, with 92-18 protection, and continues stroking once HS clears:

Prob (Closed) = 0.25

Prob (open) = 0.75

Effect of MOV stopping once HS Clears

For many control circuits; clearing of the HS results in the MOV continuing to stroke to its final position. However, in some cases; clearing the hot short will result in the MOV failing at its present position. Where it ends up depends on stroke time, time for the MOV to move from its open or closed position, or other circuit timing issues. These factors are not analyzed here. An assumption is made that the MOV will fail in mid position (99% is used in the analysis), with this assumption reviewed further later.

MOV Open Signal Occurs first; given both open/close signals

For this analysis, it is assumed there is an equal probability of an open or close coil being hot shorted first.

Initial Hot Short Clears Simultaneously or last:

Given the initial signal is either open or closed, if the hot shorts clear simultaneously or the initial signal is the last to clear, the valve position will remain in whatever the position the initial signal occurred. This is applicable only if the valve does not have 92-18 protection.

Analysis of the hot shorts that occurred on both open and close circuits resulted in the following:

C5 Occurs First: 8

C6 Occurs First: 5

Simultaneous: 8

Given either C5 or C6 could be the open circuit, the order of the data doesn't matter for the analysis. Given the above occurred, the following data is developed:

First Circuit Clears First: 6

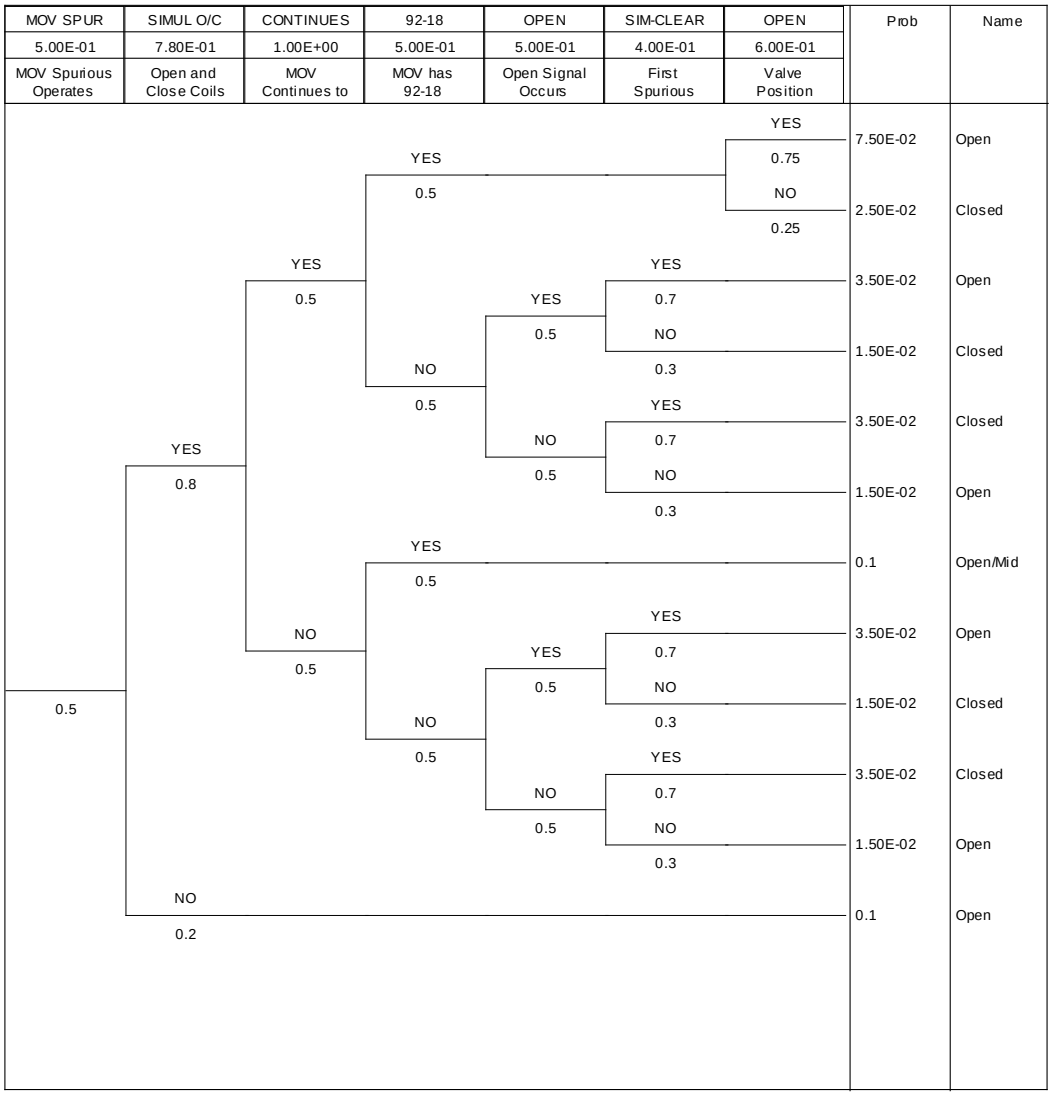
Circuits Clear Simultaneous: 5

First circuit clears last: 10

Given the data shows 15 of 21 circuits would result in the second circuit not impacting the MOV direction, a probability of 0.7 (15/21) is used to estimate this event in the analysis. Consequently; there is a 0.3 probability of the second hot short resulting in the valve changing position in the opposite direction, given the first hot short clears. However, based on the analysis below, this probability does not greatly affect the results.

5. ANALYSIS

A generic event tree was developed using the above factors. This includes a "dummy" value of 0.5 for MOV design conditions including 92-18 protection and whether the valve will continue to stroke once the hot short continues. The event tree is shown below.



Using the above event tree, several cases result which is discussed in the following sections.

5.1 No 92-18 Protection

Regardless of other factors; if the valve does not have 92-18 protection, the valve will stroke in whatever direction the initial hot short dictates. This is modeled as 50% in the open direction and 50% in the closed direction. In 30% of the time, the initial hot short clears, and the valve moves in the opposite direction. However, this affects the end probability (of open or closed) equally.

As a result, 50% of the time when a valve does not have 92-18 protection and the valve sees spurious operation for both the open and closed coil (78% of the time), the valve will end up in the open position with an equal probability of ending in the closed position. When combined with the 22% of the time the open circuit will see a spurious operation without a close spurious operation signal; the following is developed:

P-Open (no 92-18) = 0.2 + 0.8 * .5 = 0.6

P-Close (no 92-18) = 0.8 * .5 = 0.40

Conditions not accounted for:

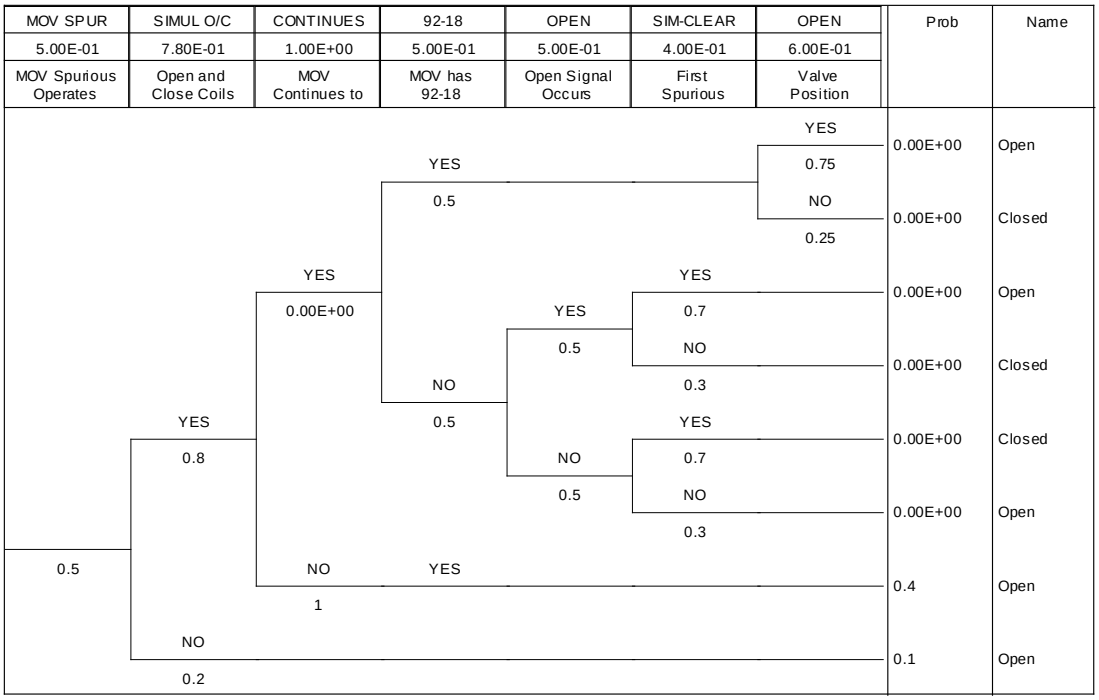
1) Without 92-18, and a long duration hot short, the MOV motor will likely burn out or burn out the motor heater or similar circuit. As a result, the modeling of whether the valve will change position once the first hot short clear is inaccurate. Since this affects the valve in either direction; this does not impact the final position probabilities.

5.2 92-18 Protection, Valve does not continue to final position

Given the valve will cycle back and forth until the final hot short clears; generally the valve will fail in mid-position. This is modeled, in this analysis, as open. Therefore; 100% of the hot shorts are assumed to result in an open valve.

Conditions not accounted for:

1) Without 92-18, and a long duration hot short, the MOV motor will likely burn out or burn out the motor heater or similar circuit. In the case of a valve traveling back and forth, this failure could occur anywhere in the stroke. However, given the motor current is highest at the very end and beginning of the stroke; the valve will most likely fail in one end position or another. Without extensive research and modeling, this would be difficult to include in the above probability model.



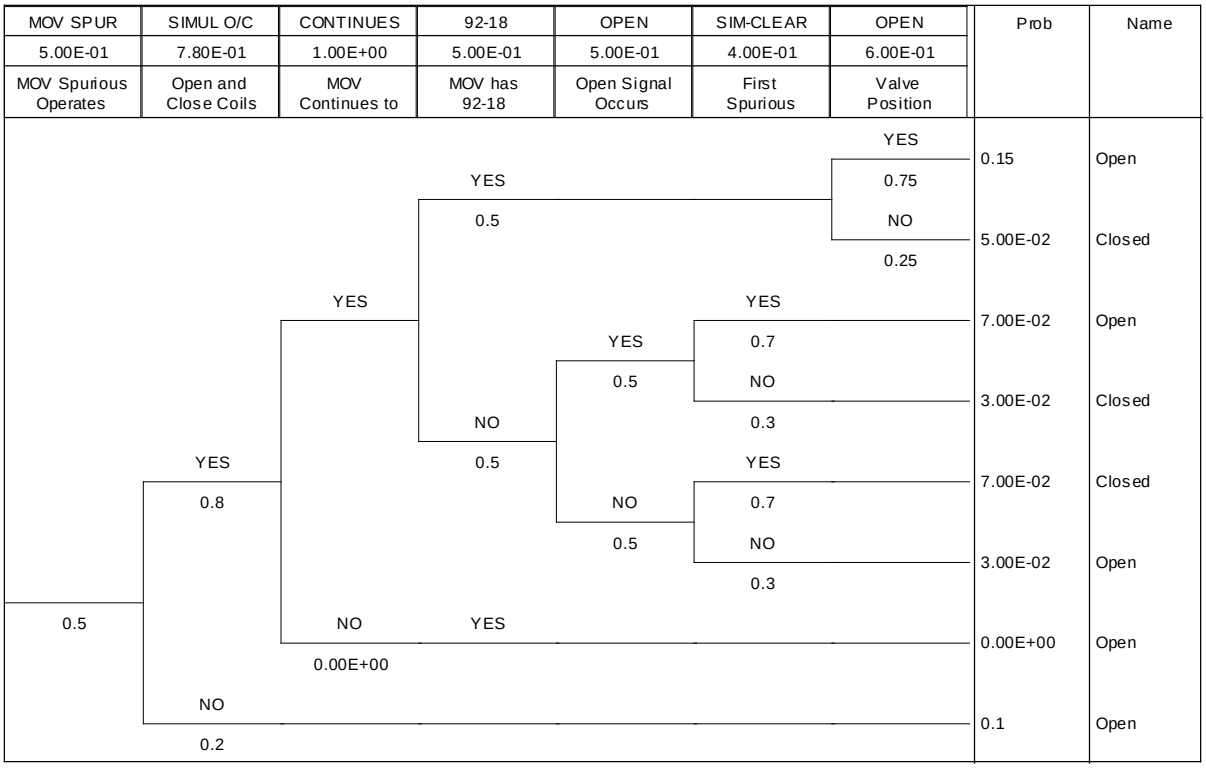
5.3 92-18 Protection, Valve continues to final position

With the valve continuing to stroke open and then closed, and ending in one or the other final position once the hot short clears, the analysis of the stroke time versus the hot short duration above impacts the probability of whether the valve ends up as finally open or closed. The probabilities for each are determined as follows:

P-Open (92-18) = 0.2 + (0.75 * .5 + 0.7*0.5)*0.8 = 0.7

P-Close (92-18) = (0.25 * .5 + 0.3*0.5)*0.8 = 0.3

Similar to the above, the motor burn-out is not modeled, but can impact the final results. However, in general, it is equally likely to burn out in either the open or closed position, although mid-position is possible.


MOV SPUR
SIMUL O/C
CONTINUES
92-18
OPEN
SIM-CLEAR
OPEN
Prob
Name
5.00E-01
7.80E-01
1.00E+00
5.00E-01
5.00E-01
4.00E-01
6.00E-01
MOV Spurious Operates
Open and Close Coils
MOV Continues to
MOV has 92-18
Open Signal Occurs
First Spurious
Valve Position
0.5
YES
0.8
NO
0.2
NO
0.00E+00
YES
0.5
NO
0.5
YES
0.5
NO
0.5
YES
0.7
NO
0.3
YES
0.7
NO
0.3
YES
0.75
NO
0.25
0.15
Open
5.00E-02
Closed
7.00E-02
Open
3.00E-02
Closed
7.00E-02
Closed
3.00E-02
Open
0.00E+00
Open
0.1
Open

6. SUMMARY

The above analysis results in the following results.

Valve Continues to Stroke once HS Clears?	Valve has 92-18 protection	Conditional probability of Being Open	Conditional Probability of being Closed
N/A	No	0.6	0.4
No	Yes	100%	0%
Yes	Yes	0.70	0.30

However, for simplification; the following is recommended:

Valve Continues to Stroke once HS Clears?	Conditional probability of Being Open	Conditional Probability of being Closed
No	100%	0%
Yes	0.70	0.30

This would be applied to the Hot Short Probability (for a given direction) as basically a 30% reduction for the final spurious operation probability.

However, the above data is based on the TS data, without reduction for the source-centered or other testing factors. In the DWH analysis; a reduction of 20% is recommended to account for the testing configuration providing a higher than expected hot short probability. Given the uncertainty associated with applying this 20% reduction, and an additional 30% reduction for MOVs; it is recommended that the MOV factor be reduced to a 20% reduction if other factors (like the source-centered reduction factor) are applied.