4. **Double Break - Probabilities of Spurious Actuations**

Double Break Ungrounded AC Powered from a CPT*						
Cable Configuration	Conductor shorting modes of interest					
	Intra + Intra cable short	Intra + Inter cable short	Inter + Inter cable short	Intra + ground cable short	Inter + ground cable short	Aggregate result
	1	2	3	4	5	6
1. TS insulated source and target cables	P_DB_AC_ 01_01 = **0.46 (0.25, 0.46, 0.8)**	P_DB_AC_ 01_02 **= 0.0006 (1E-04, 0.0006, 0.01**	N/A	P_DB_AC_ 01_04 **= 0.04 (0.01, 0.04, 0.2)**	N/A	P_DB_AC_ 01_06 = Boolean Sum
2. TP insulated source and target cables	P_DB_AC_ 02_01 **= 0.46 (0.25, 0.46, 0.8)**	P_DB_AC_ 02_02 **= 0.0003 (1E-04, 0.0003, 0.005)**	P_DB_AC_ 02_03 **N/A**	P_DB_AC_ 02_04 **= 0.02 (0.01, 0.02, 0.1)**	P_DB_AC_ 02_05 **= 0.006 (0.0001, 0.0006, 0.06)**	P_DB_AC_ 02_06 = Boolean Sum
3. Cable includes a grounded metal foil shield wrap	P_DB_AC_ 03_01 **= 0.24 (0.05, 0.24, 0.6)**	N/A	N/A	P_DB_AC_ 03_04◊ **= 0.02 (0.01, 0.02, 0.1)**	N/A	P_DB_AC_ 03_06 = Boolean Sum
4. Armored 7/C cable	P_DB_AC_ 04_01 **= 0.4 (0.1, 0.4, 0.8)**	N/A	N/A	P_DB_AC_ 04_04◊ **= 0.04 (0.01, 0.04, 0.2)**	N/A	P_DB_AC_ 04_06 = Boolean Sum

*Shaded black cells are considered implausible but not incredible. Cells marked "N/A" are considered incredible or physically impossible.

◊ Intra cable shorts that mimic the fault mode of ground fault equivalent hot shorts are included under the intra + intra cable short column.

DWH Analysis – Double Break Ungrounded AC Powered from a CPT:

The following references case numbers from NUREG/CR-7150, Appendix C.

P_DB_AC_01_01, P_DB_AC_02_01, P_DB_AC_03_01, P_DB_AC_04_01: Based on Case 6 on page C-7, the intra-cable failures are on the same cables and circuits.

Grounded AC TS Cable: Based on the data in Case 1, 26 of 53 shorted the C5 contact while 27 of 53 shorted the C6 contact, with a total of 32 of 53 shorting either. Based on this, 21 of the tests resulted in both C5 and C6 being actuated (via intra-cable HS). This results in an estimated probability for two intra-cable HSs as 0.40. However, Case 1-1 includes a 20% reduction due to source centered testing, which is also applicable here. The resulting probability is 0.32 (0.2, 0.32, 0.5). Alternately, a reduction factor from Case 1-1 is estimated as 0.32/0.40 = 0.8. This is the condition probability of the second intra-cable HS.

Ungrounded AC TS Cable: ungrounded AC gets higher values for overlap of C5 and C6 targets, since both occurred 6/8 times, and always at the same time. However, since this data is limited to only 8 tests, the grounded AC probability (0.8) appears to be more applicable. Using this value, the following is derived:

P_DB_AC_01_01 = 0.58 * 0.8 = 0.46 (0.25, 0.46, 0.8)

Ungrounded AC TP Cable: Testing shows 5 of 5 for C5 target and 4 of 5 for the C6 target, with 4 of 5 for both. Based on this, the 80% value above appears applicable.

P_DB_AC_02_01 = 0.58 * 0.8 = 0.46 (0.25, 0.46, 0.8)

Cable includes a grounded metal foil shield wrap: No overlap between C5 and C6. However, there does not appear to be any reason that this would be different than the TP/TS cable above.

P_DB_AC_03_01 = 0.3 * 0.8 = 0.24 (0.05, 0.24, 0.6)

Similar to the above, Armored Cable (ungrounded) has significant overlap for grounded AC and DC power, but not data for ungrounded AC. A value of 0.8 for the conditional second event is used:

P_DB_AC_04_01 = 0.5 * 0.8 = 0.4 (0.1, 0.4, 0.8)

P_DB_AC_01_02 and P_DB_AC_02_02: Based on case 4. Since Cases 1-5 and 2-5 are considered unlikely; this case is also considered unlikely. Also, since the data does not show any dependency between the intra-cable and inter-cable hot shorts, the probability for this event can be calculated based on the multiplication of Case 1-4 and Case 1-5 (or 2-4 and 2-5). This is calculated as

P_DB_AC_01_02 = 0.58 * 0.001 = 0.0006 (1E-04, 0.0006, 0.01).

P_DB_AC_02_02 = 0.58 * 0.0005 = 0.0003 (1E-04, 0.0003, 0.005)

P_DB_AC_02_03: Should be considered **NA** - similar to 01-03 (two inter-cable are considered highly unlikely).

P_DB_AC_01_04, P_DB_AC_02_04, P_DB_AC_03_04, and P_DB_AC_04_04: Case 7: This case requires multiple shorts to ground as well as an intra-cable HS. The single HS probabilities does not include a MSTG probability for ungrounded AC. MSTG is estimated based on the Jeffries non-informative prior = 0.5/(8+1) = 0.06

P_DB_AC_01_04 = 0.58 * 0.06 = 0.04 (0.01, 0.04, 0.2)

P_DB_AC_02_04 = 0.3 * 0.06 = 0.02 (0.01, 0.02, 0.1)

- UB and LB based on multiplying each event's UB/LB, with rounding.

P_DB_AC_03_04 = 0.3 * 0.06 = 0.02 (0.01, 0.02, 0.1)

P_DB_AC_04_04 = 0.5 * 0.06 = 0.02 (0.01, 0.04, 0.2)

P_DB_AC_02_05: Case 8: equals the inter-cable probability times MSTG (above = 0.06).

P_DB_AC_02_05 = 0.01 * 0.06 = 0.006 (0.0001, 0.0006, 0.06). UB/LB based on Eng. Judgment

P_DB_AC_01_06 and other aggregates: Aggregate is just the Boolean Sum

Double Break Ungrounded DC*						
Cable Configuration	Conductor shorting modes of interest					
	Intra + Intra cable short	Intra + Inter cable short	Inter + Inter cable short	Intra + ground cable short	Inter + ground cable short	Aggregate result
	1	2	3	4	5	6
1. TS insulated source and target cables	P_DB_DC_ 01_01 **= 0.15 (0.09, 0.15, 0.36)**	P_DB_DC_ 01_02 **= 0.0006 (1E-04, 0.0006, 0.01)**	N/A	P_DB_DC_ 01_04 **= 0.06 (0.001, 0.06, 0.18)**	N/A	P_DB_DC_ 01_06 = Boolean Sum
2. TP insulated source and target cables	P_DB_DC_ 02_01 **= 0.2 (0.1, 0.2, 0.4)**	P_DB_DC_ 02_02 **= 0.0003 (1E-04, 0.0003, 0.005)**	P_DB_DC_ 02_03 **= NA**	P_DB_DC_ 02_04 **= 0.06 (0.001, 0.06, 0.18)**	P_DB_DC_ 02_05 **= 0.001 (0.0001, 0.001, 0.01).**	P_DB_DC_ 02_06 = Boolean Sum
3. Cable includes a grounded metal foil shield wrap	P_DB_DC_ 03_01 **= 0.2 (0.1, 0.2, 0.4)**	N/A	N/A	P_DB_DC_ 03_04◊ **= 0.12 (0.001, 0.12, 0.4)**	N/A	P_DB_DC_ 03_06 = Boolean Sum
4. Armored 7/C Cable	P_DB_DC_ 04_01 **= 0.56 (0.25, 0.56, 0.8)**	N/A	N/A	P_DB_DC_ 04_04◊ **= 0.02 (0.01, 0.04, 0.2)**	N/A	P_DB_DC_ 04_06 = Boolean Sum

*Shaded black cells are considered implausible but not incredible. Cells marked "N/A" are considered incredible or physically impossible.

◊ Intra cable shorts that mimic the fault mode of ground fault equivalent hot shorts are included under the intra + intra cable short column.

DWH Analysis Ungrounded DC:

The following references case numbers from NUREG/CR-7150, Appendix C.

P_DB_DC_01_01, P_DB_DC_02_01, P_DB_DC_03_01, P_DB_DC_04_01: Based on Case 6 on page C-7, the intra-cable failures are on the same cables and circuits.

Ungrounded DC TS Cable: Most of the DC testing involved circuits with a single target. However, the DC MOV included multiple targets with 2 possible spurious actuations. The data is as follows for the DC MOVs:

- 13 Intermediate Scale (IS) Tests and 12 Penlight Tests
- 6 IS tests with 1 or more actuations and 9 penlight tests.
- 2 IS tests with both targets actuated and 1 penlight with both actuated.
- Conditional probability of the second actuation given the first is 3/15 = 0.2

Based on this review, the second event is considered independent of the first for DC circuits.

A similar review for TP shows no IS tests with a second actuation and 3 penlight test out of 17 total tests (12 Actuations). For armored, there is a 1 of 2 actuation of both targets, and for metal foil cable, there were no actuations in two tests. Overall, the evidence is the second target is independent of the first.

P_DB_DC_01_01 = 1-07 * 1-07 = 0.39 * 0.39 = 0.15 (0.09, 0.15, 0.36)

P_DB_DC_02_01 = 2-07 * 2-07 = 0.45^2 = 0.2 (0.1, 0.2, 0.4)

P_DB_DC_03_01 = 3-07 * 3-07 = 0.43^2 = 0.2 (0.1, 0.2, 0.4)

P_DB_DC_04_01 = 4-07 * 4-07 = 0.75^2 = 0.56 (0.25, 0.56, 0.8)

Uncertainty bounds are based on the square of each bound.

P_DB_DC_01_02 and P_DB_DC_02_02: Based on case 4. Since Cases 1-5 and 2-5 are considered unlikely; this case is also considered unlikely. Also, since the data does not show any dependency between the intra-cable and inter-cable hot shorts, the probability for this event can be calculated based on the multiplication of Case 1-4 and Case 1-5 (or 2-4 and 2-5). This is calculated as

P_DB_DC_01_02 = 0.58 * 0.001 = 0.0006 (1E-04, 0.0006, 0.01).

P_DB_DC_02_02 = 0.58 * 0.0005 = 0.0003 (1E-04, 0.0003, 0.005)

P_DB_DC_02_03: Should be considered **NA** - similar to 01-03 (two inter-cable are considered highly unlikely).

P_DB_DC_01_04, P_DB_DC_02_04, P_DB_DC_03_04, and P_DB_DC_04_04: Case 7: This case requires multiple shorts to ground as well as an intra-cable actuation. MSTG is based on 1-9 (2-9, etc.), and intra-cable is based on 1-7 (2-7, etc.).

A “coincidence review” was performed to see if there was significant overlap between the intra-cable actuation and the MSTG. For TS target, the Intra-cable actuation occurred in 43 of 87 circuits, and the MSTG occurred in 10 of 87, with no overlap. This would indicate that the failures were mutually exclusive (in this case means they would not occur at the same time). For TP, there were 2 spurious actuations where overlap occurred (35/64 + 5/64 = 38/64). This indicates that it is not entirely mutually exclusive. For

this analysis, it is assumed the actuations are independent, but not mutually exclusive. However, the LB is reduced (using engineering judgment) based on the possibility of the events being mutually exclusive. For armored, there is significant overlap (9/12 + 5/12 = 11/12), but the ratio appears to indicate the failures are independent (e.g., of the 3 events not experiencing intra-cable failures, 2 experienced MSTG).

P_DB_DC_01_04 = 0.39 * 0.16 = 0.06 (0.001, 0.06, 0.18)

P_DB_DC_02_04 = 0.45 * 0.14 = 0.06 (0.001, 0.06, 0.18)

P_DB_DC_03_04 = 0.43 * 0.29 = 0.12 (0.001, 0.12, 0.4)

P_DB_DC_04_04 = 0.75 * 0.42 = 0.02 (0.01, 0.04, 0.2)

P_DB_DC_02_05: Case 8: equals the inter-cable probability times MSTG.

P_DB_DC_02_05 = 0.01 * 0.14 = 0.001 (0.0001, 0.001, 0.01). UB/LB based on Eng. Judgment

P_DB_DC_01_06 and other aggregates: Aggregate is just the Boolean Sum