Probability Subtraction Method Implementation into SAREX

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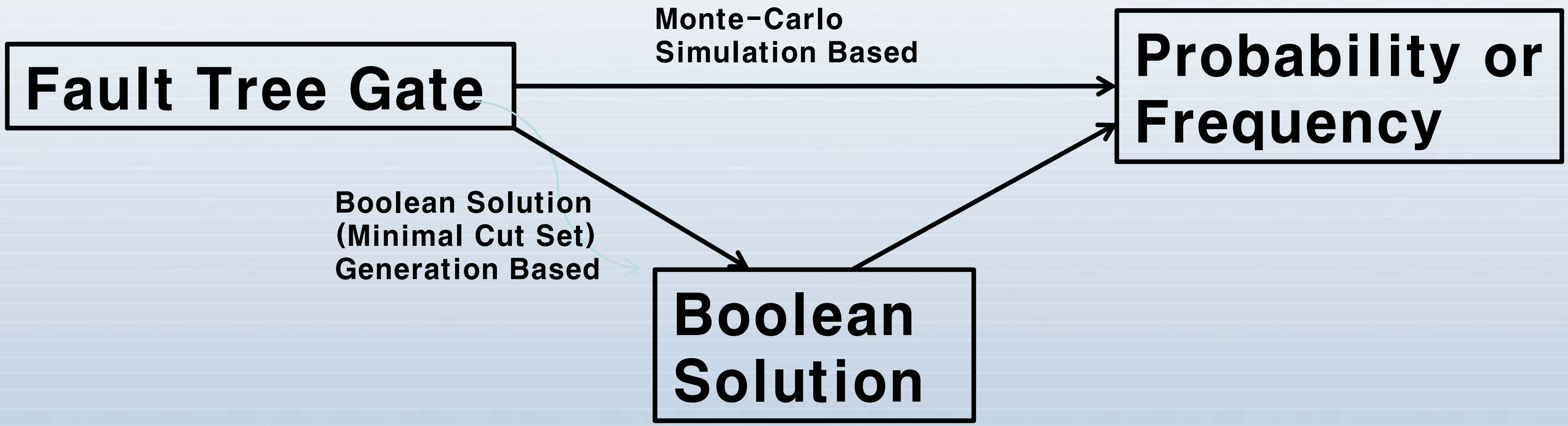
Contents

Introduction

- Fault Tree Quantification
  - A process to calculate probability or frequency for a fault tree gate.



Introduction

- Source of Uncertainty in Current Fault Tree Quantification Methods
  - Truncation during MCSs Generation
  - Delete-Term Approximation for MCSs Generation
  - MUCB or REA application for MCSs Probability Calculation
- Truncation
  - PRA-Standard QU-B3
    - Convergence can be considered sufficient when successive reductions in truncation value of one decade result in decreasing changes in CDF or LERF, and the final change is less than 5%.
  - Current Practice ➔ O.K.
    - Successive reductions in truncation value of one decade result in decreasing changes in CDF or LERF, and the final change is less than 1%.

Introduction

- MUCB or REA application
  - PRA-Standard QU-B4
    - Where cutsets are the means used in quantification, USE the minimal cutset upper bound or an exact solution. The rare event approximation may be used when basic event probabilities are below 0.1
  - Current Practice ➔ O.K.
    - The MCUB or REA is used for internal event PRA
    - En exact solution (for exact probability or frequency) is used for seismic PRA.
    - MCSs conversion into BDD is used as needed basis

Introduction

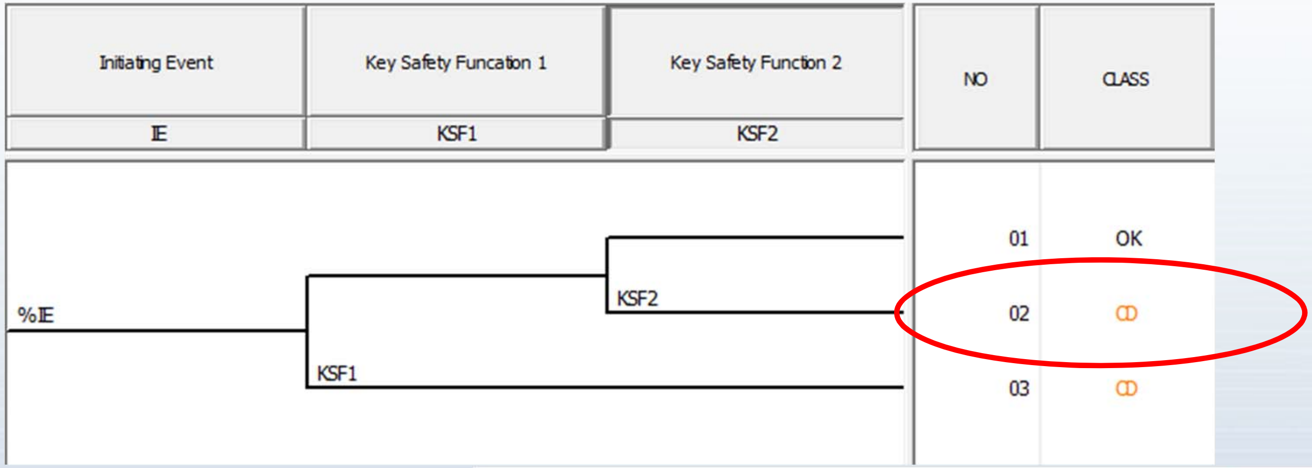
- MUCB or REA application
  - Example, MCSs = AB + BC
    - REA: P(AB+BC) = P(AB) + P(BC)
    - MCUB: P(AB+BC) = 1− [1−P(AB)]*[1− P(BC)]
    - Exact: P(AB+BC) = P(AB) + P(BC) – P(ABC)
  - Case 1: P(A)=P(B)=P(C)=0.01
    - REA: P(AB+BC) = 2.00E−4
    - MCUB: P(AB+BC) = 1.99990E−4
    - Exact: P(AB+BC) = 1.990E−4
  - Case 2: P(A)=P(B)=P(C)=0.5
    - REA: P(AB+BC) = 0.50
    - MCUB: P(AB+BC) = 0.438
    - Exact: P(AB+BC) = 0.375

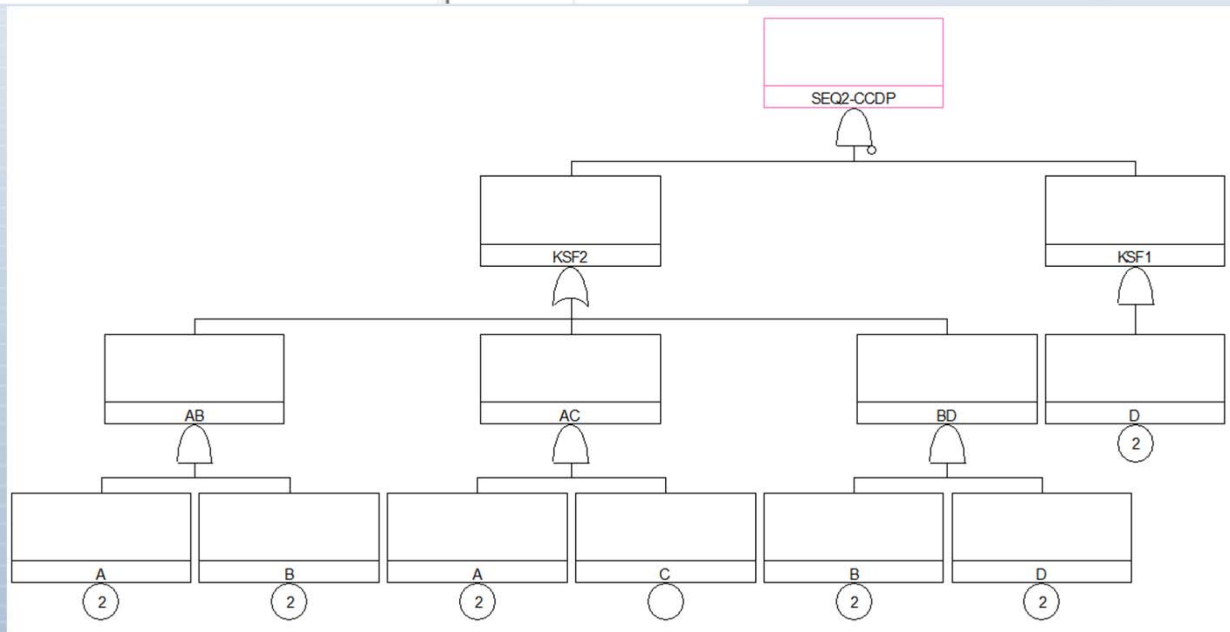
Introduction

- Delete Term Approximation application: PRA-Standard QU-B6
  - ACCOUNT for system successes in addition to system failures in the evaluation of accident sequences to the extent needed for realistic estimation of CDF. This accounting may be accomplished by using numerical quantification of success probability, complementary logic, or a delete term approximation and includes the treatment of transfers among event trees where the "successes" may not be transferred between event trees.
  - Current Practice ➔ Sometimes NOT O.K.
    - Delete-Term approximation is used for internal event PRA
    - Numerical quantification is used for PDS ET as needed basis
    - Complementary logic is used for Seismic PRA
      - Possible for a very small seismic fault tree for example, fault trees for primary seismic event tree
      - Not possible for a very big fault tree

Delete Term Approximation

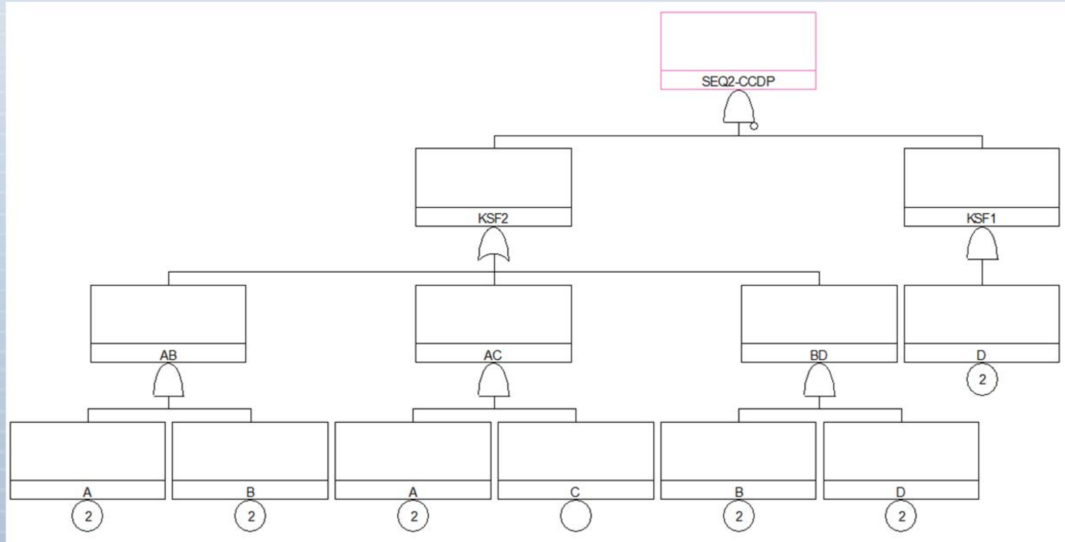
- Delete Term Approximation





Delete Term Approximation

- Delete Term Approximation
  - Delete-Term Approximation Process
    - Cutset Generation for Failure Gate KSF2: AB + AC + BD
    - Cutset AB can't make KSF1 TRUE
    - Cutset AC can't make KSF1 TRUE
    - Cutset BD CAN make KSF1 TRUE ➔ Cutset BD is discarded because it makes the gate SEQ2-CCDP FALSE
    - Finally, MCS AB and AC are selected as final MCS



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Delete Term Approximation

- Delete Term Approximation
  - MCSs Probability for AB + AC by DTA and AB/D + AC/D by Exact Solution
  - Case 1: P(A)=P(B)=P(C)=0.01 for AB+BC
    - REA: P(AB+BC) = 2.00E−4
    - MCUB: P(AB+BC) = 1.99990E−4
    - Exact: P(AB+BC) = 1.990E−4
  - Case 2: P(A)=P(B)=P(C)=P(D)=0.01 for AB/D+BC/D
    - REA: P(AB/D+BC/D) = 1.98E−4
    - MCUB: P(AB/D+BC/D) = 1.97990E−4
    - Exact: P(AB/D+BC/D) = 1.970E−4

Delete Term Approximation

- Delete Term Approximation
  - MCSs Probability for AB + AC by DTA and AB/D + AC/D by Exact Solution
  - Case 3: P(A)=P(B)=P(C)=0.5 for AB+BC
    - REA: P(AB+BC) = 0.50
    - MCUB: P(AB+BC) = 0.438
    - Exact: P(AB+BC) = 0.375
  - Case 4: P(A)=P(B)=P(C)=P(D)= 0.5 for AB/D+BC/D
    - REA: P(AB/D+BC/D) = 0.25
    - MCUB: P(AB/D+BC/D) = 0.2344
    - Exact: P(AB/D+BC/D) = 0.1875

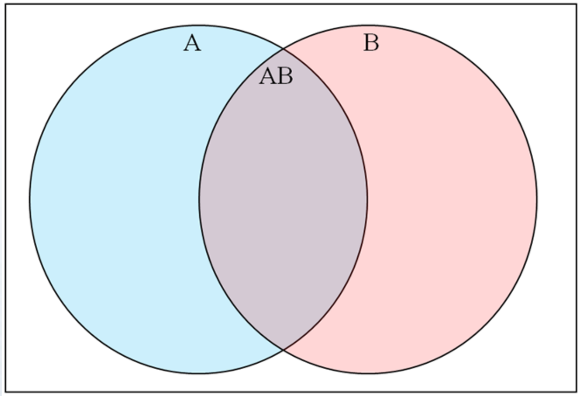
PSM Method

- Issues with Delete Term Approximation
  - Can cause Big over-estimation error for fault tree with non-rare events in negates

- Solutions for the issues with Delete Term Approximation
  - Complementary logic development ➔ Not possible for fault tree of actual PSA
  - Probability Subtraction Method is suggested BECAUSE IT IS POSSIBLE to generate EXACT BOOLEAN SOLUTIONs from a fault tree if there are no negates in Fault tree.

PSM Method

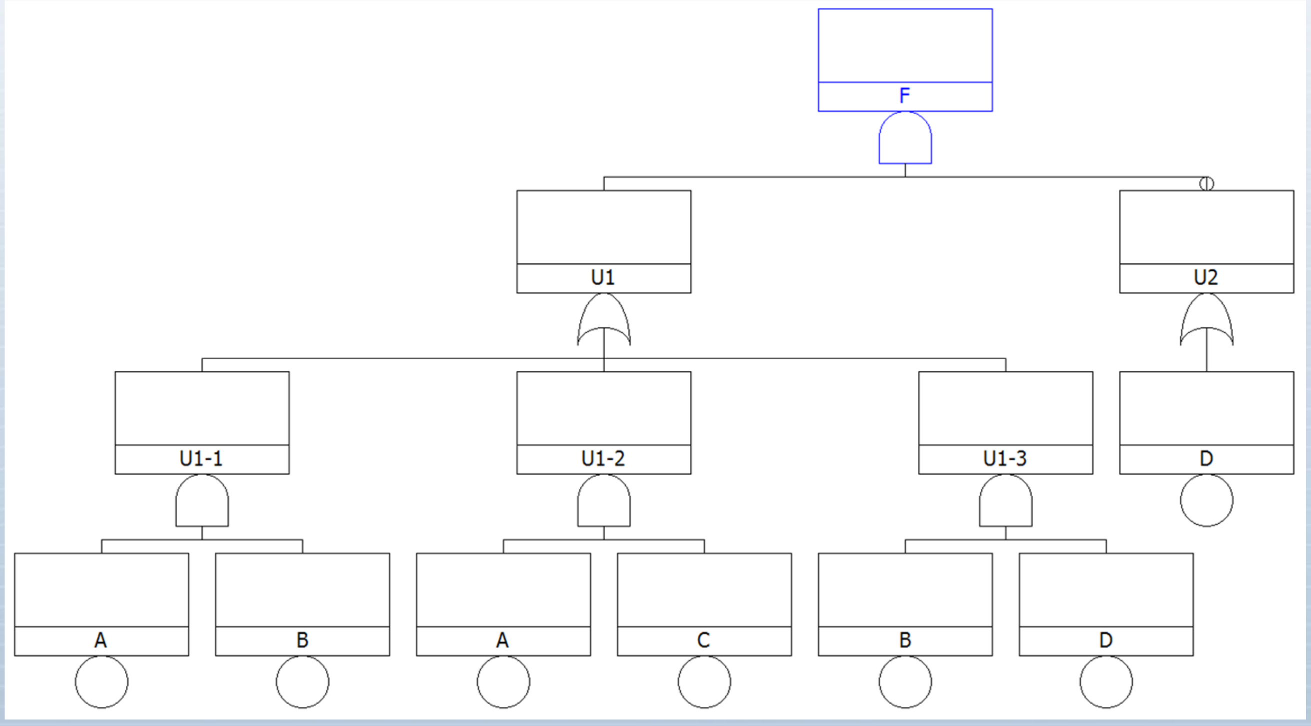
- Principle
  - A = A * 1 = A* (B + /B) = AB + A/B
  - P(A) = P(AB) + P(A/B)
  - P(A/B) = P(A) – P(AB)   (1)



- PSM uses the equation (1) above for exact fault tree gate probability with Negates
  - Equation (1) is valid when A and B are fault tree gates instead of basic events
  - Equation (1) is valid when A and B are not independent

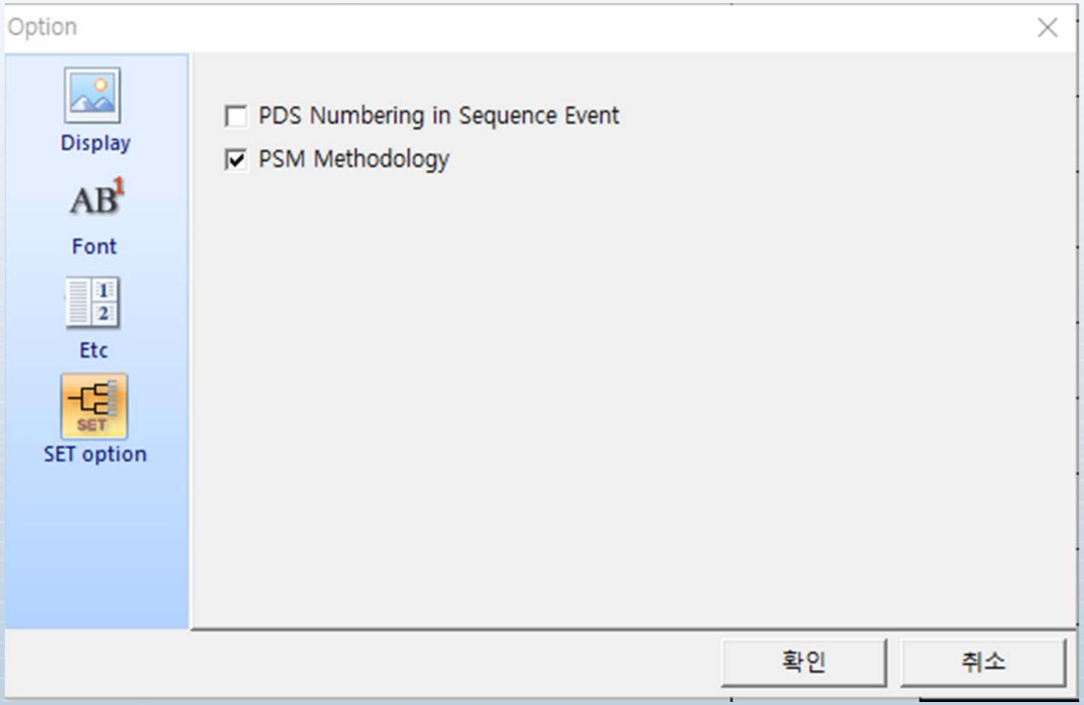
PSM Method

- PSM with Fault Tree F = U1/U2
  - U1 = U1 * (U2 + /U2) = U1U2 + U1/U2
  - P(U1) = P(U1U2) + P(U1/U2)
  - P(U1/U2) = P(U1) – P(U1U2)



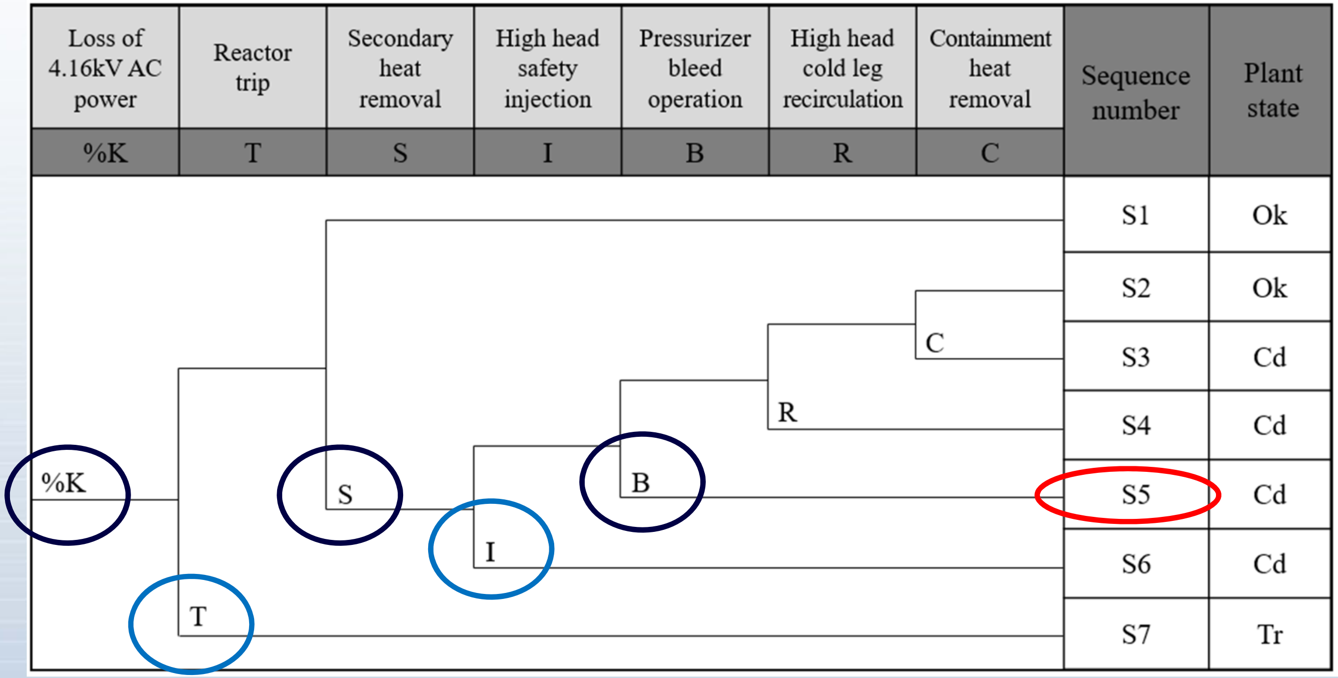
PSM Implementation into SAREX

- PSM was implemented into SAREX which can be selectively used during fault tree quantification with an option below



PSM Implementation into SAREX

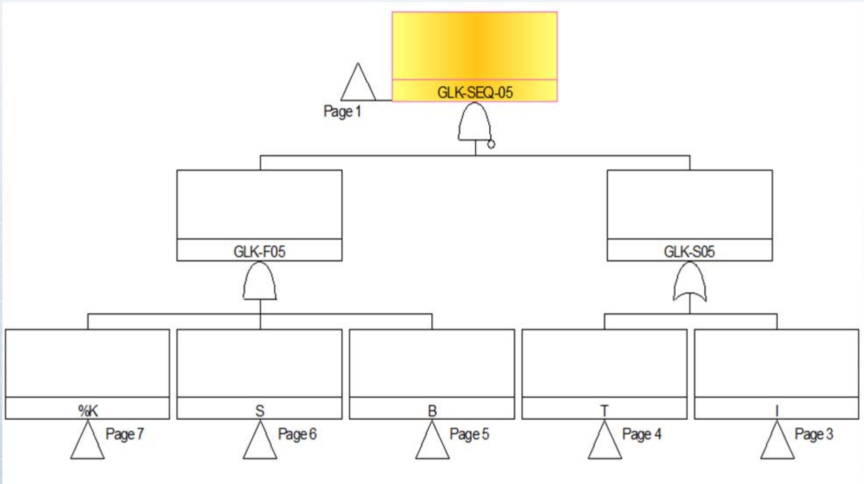
- PSM to a SUPSA CD Sequence

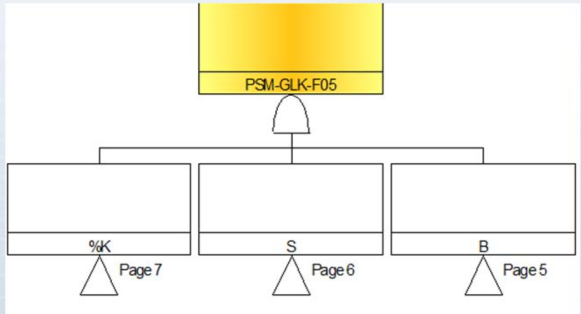


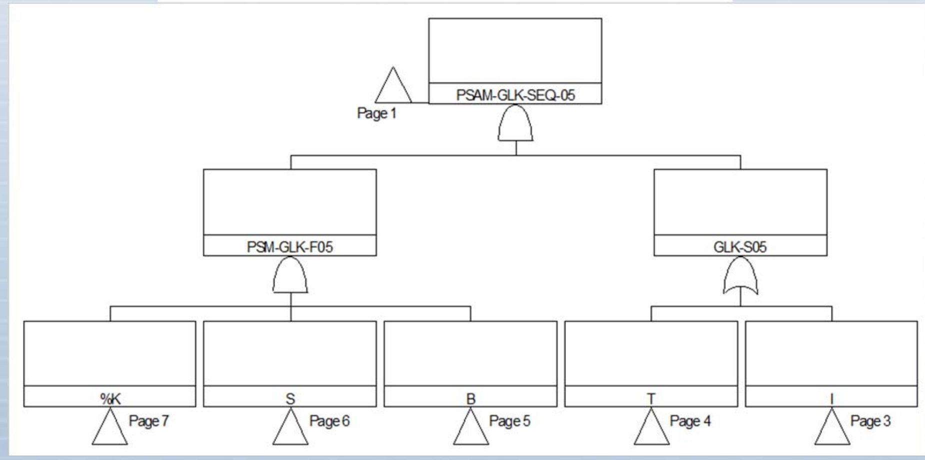
- S5 = %K * /T * S * /I * B = (%K * S * B) * /(T + I)
- P(S5, PSM) = P(%K*S*B) – P[%K*S*B*(T+I)]

PSM Implementation into SAREX

- $S5 = \%K * /T * S * /I * B = (\%K * S * B) * /(T + I)$
- $P(S5, DTA) = P[DTA(\%K*S*B, T+I]$
- $P(S5, PSM) = P(\%K*S*B) - P[\%K*S*B*(T+I)]$







PSM Implementation into SAREX

- Generated Cutsets

1LOFW_003_#F.RAW	2022-01-28 오후 1:30	RAW 파일
1LOFW_003_#S.RAW	2022-01-28 오후 1:30	RAW 파일
1LOFW_004_#F.RAW	2022-01-28 오후 1:30	RAW 파일
1LOFW_004_#S.RAW	2022-01-28 오후 1:30	RAW 파일
1LOFW_005_#F.RAW	2022-01-28 오후 1:30	RAW 파일
1LOFW_005_#S.RAW	2022-01-28 오후 1:30	RAW 파일
1LOFW_006_#F.RAW	2022-01-28 오후 1:30	RAW 파일
1LOFW_006_#S.RAW	2022-01-28 오후 1:29	RAW 파일
1LOFW_007_#F.RAW	2022-01-28 오후 1:29	RAW 파일
1LOFW_007_#S.RAW	2022-01-28 오후 1:30	RAW 파일

PSM Implementation into SAREX

- By PSM implementation into SAREX, it is possible to quantify fault trees with non-rare events in negates in a more accurate manner
- Future Works with SAREX for complete PSM implementation
  - Linking Exact MCSs Probability Calculation Software

PSM Implementation into SAREX

- SAREX with PSM is especially useful for
  - PDS ET quantification to eliminate the frequency gap between Level 1 CD sequences and PDS sequences.
  - Fire PSA fault tree with a number of non-rare events (Fire induced spurious operation)
  - Internal event PSA fault tree with a number of non-rare events (FLEX related component failure and human failure event)
  - Seismic PSA fault tree with a number of non-rare events (Seismic induced failure)

Conclusion

- PSM was suggested to resolve big overestimation error caused by the application of Delete Term Application during a fault tree quantification with non-rare events in negates
- PSM process was implemented into SAREX which can be used selectively with the functions below,
  - Fault tree gate linking (Failure Gate, Failure-Success Gate)
  - MCSs Generation (Failure Gate, Failure-Success Gate)
  - MCSs Probability Calculation by REA or MCUB

Conclusion

- Future Works with SAREX for complete PSM implementation
  - Linking Exact MCSs Probability Calculation Software

- Future applications to fault tree quantifications with non-rare events in negates
  - Internal event PSA with MCST
  - Seismic PSA with a number of seismic induced failure events
  - Fire PSA with a number of spurious actuation events
  - PDS event tree quantification

Thank You

Q/A

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