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Evaluation of Seismic Safety of Existing NPP
Part-II Seismic margin assessment

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- Seismic capacity of system
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Introduction

- Seismic margin (SM) is expressed in terms of how much larger must an earthquake be above the RBGM level before it compromises the safety of the plant.
- The general definition of seismic margin of a plant is expressed in terms of earthquake motion level that compromises the plant safety, especially leading to damage of core [Budnitz, 1984; Prassions1986].
- The ***measure*** of seismic margin is so called HCLPF margin, usually expressed in ***terms of*** **PGA of the response spectra of RBGM or RLE**

Introduction

- Once the components HCLPF capacity is known, seismic margin assessment involves with
  - Characterization of initiating events,
  - Finalization of system fault trees,
    - using the outcome of plant walk down and component capacity assessment
    - combining the fault tree of a frontline system with that of related support system and
    - introduction of human error wherever potential is evident
  - Derivation of system margin in term of HCLPF value of tope event (system failure) from fault tree, and
  - Seismic margin assessment of the plant from event trees.

Initiating event characterization

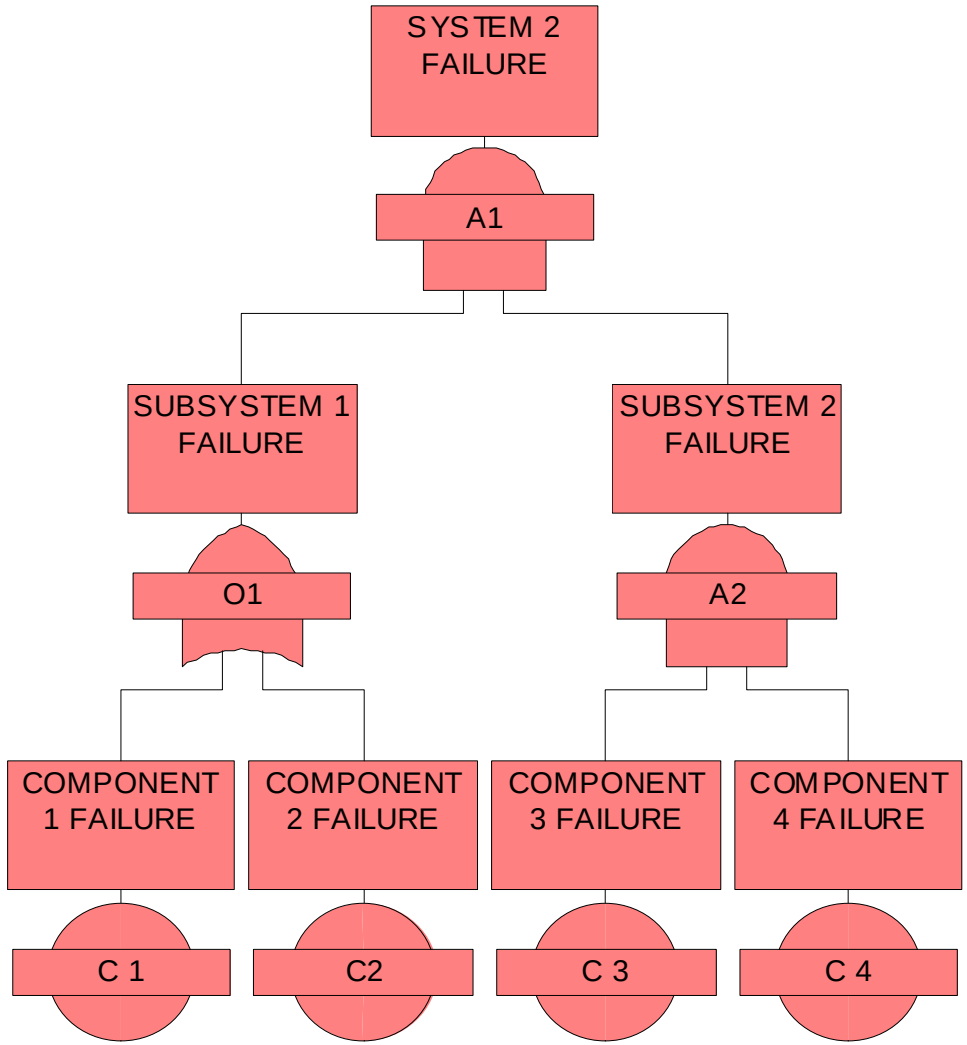
- Two approaches for postulating initiating events (IE) for seismic PSA
  - Earthquake itself is the initiating event
  - Earthquake induced ***failure of a basic component or system*** that originates plant transients resulting to propagation of accident scenario and leading to core damage, or breach of containment/confinement function
- Second approach was adopted for postulating initiating events for FBTR seismic re-evaluation. The IE is characterized by **HCLPF value**.

Initiating event characterization (FBTR)

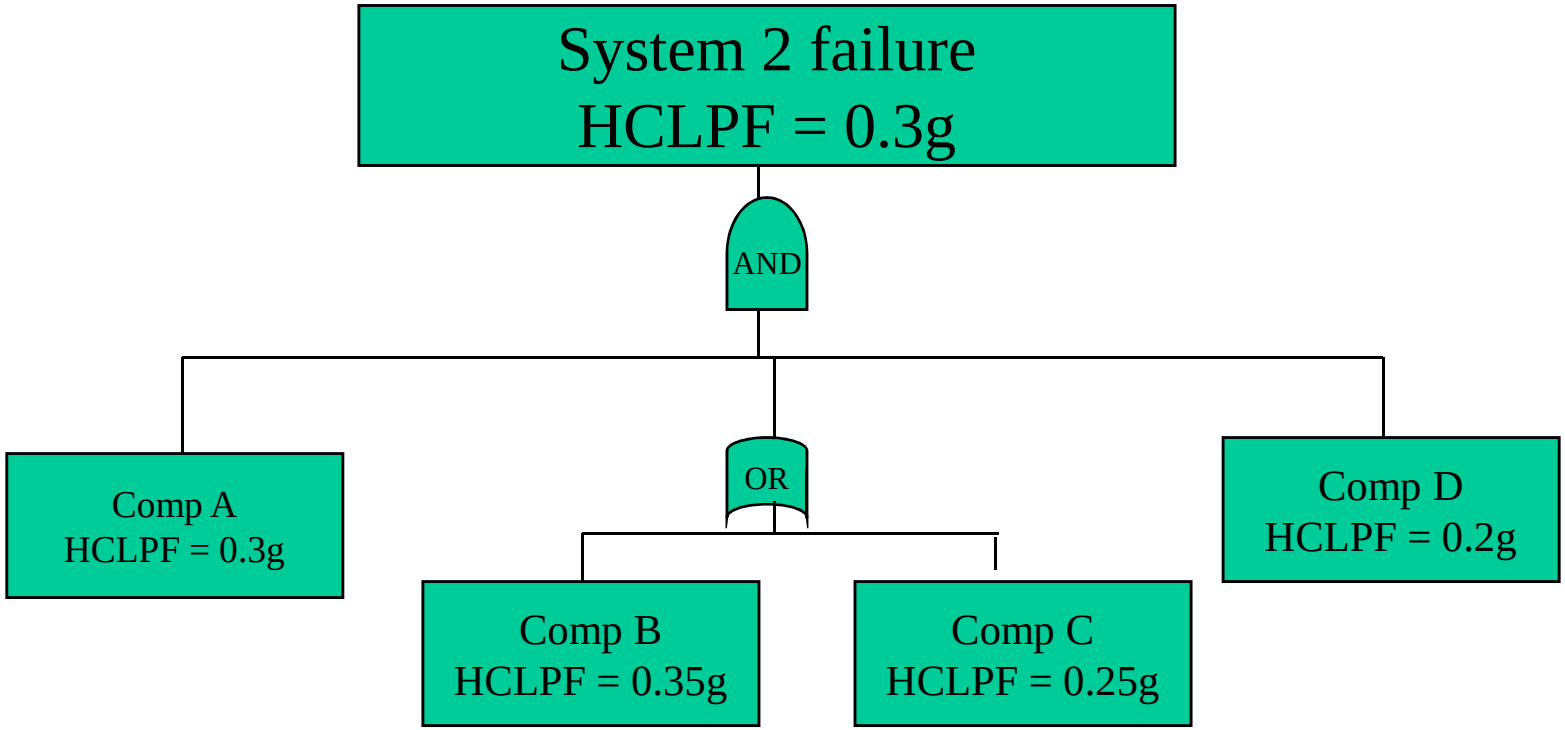
Initiating event	$A_{HCLPF}(g)$
Loss of offsite power	0.09
Seizer of primary sodium pump	1.03
Seizer of secondary sodium pump	1.03
SG tube leak in one loop	0.23
Primary Ward Leonard (WL) trip	0.66
Secondary Ward Leonard (WL) trip	0.66
Clad failure	-

Seismic capacity of system

System capacity is determined form the HCLPF capacity of **components** and using Boolean expression of the top event derived from fault tree of system



Seismic capacity of system



The HCLPF of plant is given by Boolean expression

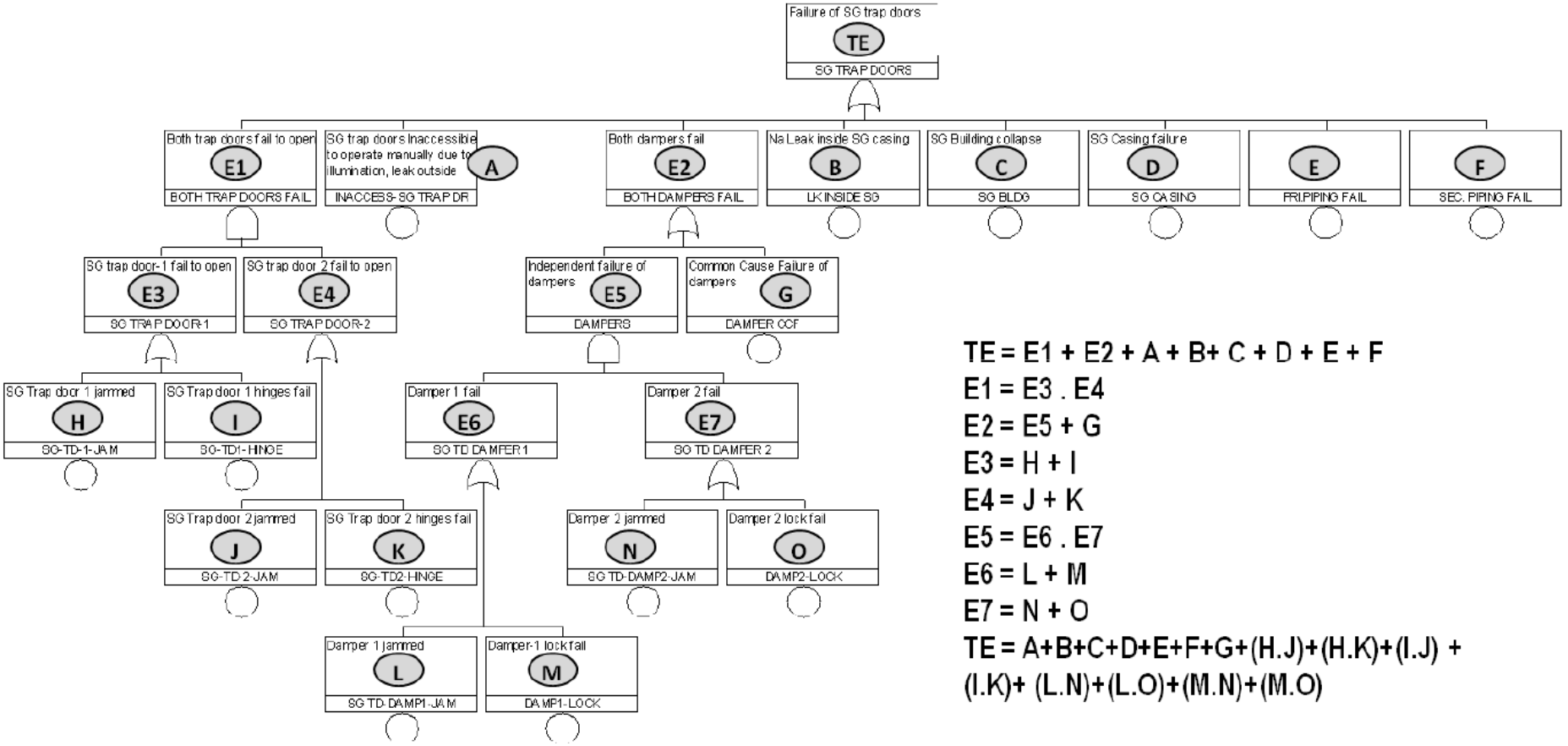
CM = A*(B+C)*D

= Max (A, min(B, C), D) = Max (0.3g, min(0.35g, 0.25g), 0.2g)

= Max(0.3g, 0.25g, 0.2g) = 0.3g

Seismic capacity of system

Fault tree of SG trap door failure (FBTR)



TE = E1 + E2 + A + B+ C + D + E + F
E1 = E3 . E4
E2 = E5 + G
E3 = H + I
E4 = J + K
E5 = E6 . E7
E6 = L + M
E7 = N + O
TE = A+B+C+D+E+F+G+(H.J)+(H.K)+(I.J) + (I.K)+ (L.N)+(L.O)+(M.N)+(M.O)

Top event (TE): **Failure of SG trap door opening**

Seismic capacity of system

Fault tree of SG trap door failure (FBTR)

Component ID	Description	HCLPF
A	Inaccessibility to SG trap door	0.66g
B	Leak inside SG	0.25g
C	SG building	0.60g
D	SG casing	0.25g
E	Primary piping	0.25g
F	Secondary piping	0.25g
G	Common cause failure of dampers	0.38g
H	SG trap door1 jammed	4.03g
I	SG trap door 1 hinges	4.03g
J	SG trap door 2 jammed	4.03g
K	SG trap door 2 hinges	4.03g
L	Damper 1 jammed	0.38g
M	Damper 1 lock	0.38g
N	Damper 2 jammed	0.38g
O	Damper 2 lock	0.38g
TE	Failure of SG trap doors	0.25g

Seismic capacity of system

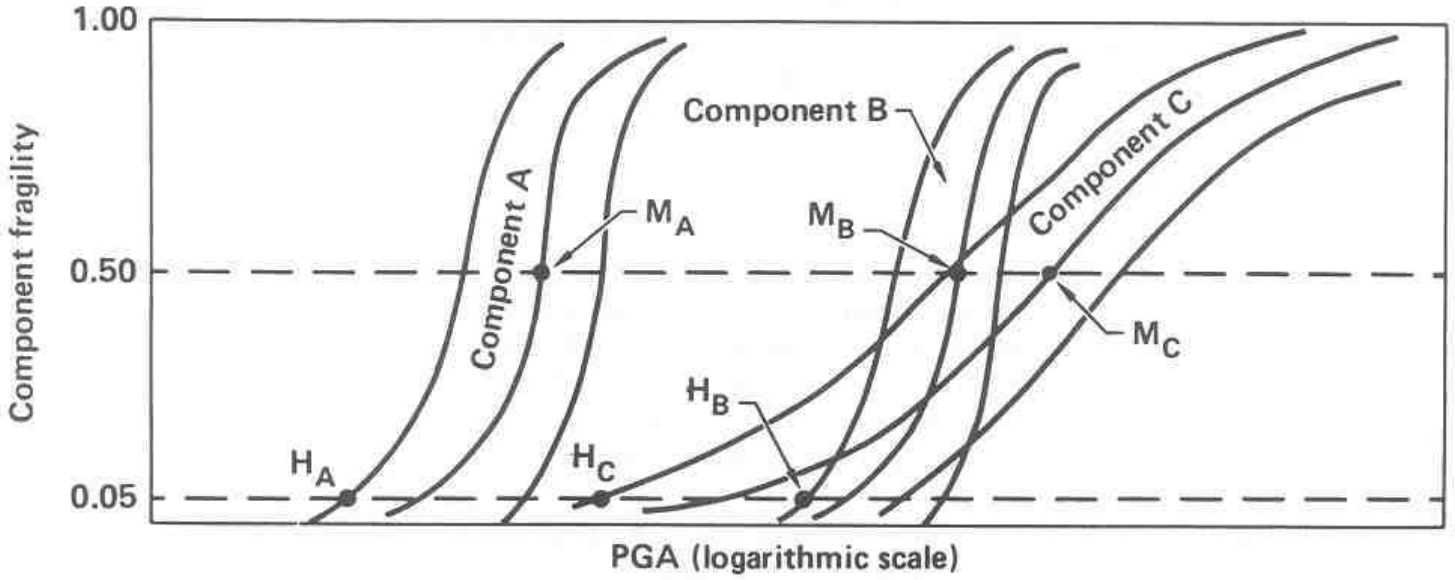
Fault tree of SG trap door failure (FBTR)

$$A_{HCLPF}^{TE} = min\left\{\begin{matrix} A_{HCLPF}^{A}, A_{HCLPF}^{B}, A_{HCLPF}^{C}, A_{HCLPF}^{D}, A_{HCLPF}^{E}, A_{HCLPF}^{F}, A_{HCLPF}^{G}, \\ max(A_{HCLPF}^{H}, A_{HCLPF}^{J}), max(A_{HCLPF}^{H}, A_{HCLPF}^{K}), max(A_{HCLPF}^{I}, A_{HCLPF}^{J}) \\ max(A_{HCLPF}^{I}, A_{HCLPF}^{K}), max(A_{HCLPF}^{L}, A_{HCLPF}^{N}), max(A_{HCLPF}^{L}, A_{HCLPF}^{O}) \\ max(A_{HCLPF}^{M}, A_{HCLPF}^{N}), max(A_{HCLPF}^{M}, A_{HCLPF}^{O}) \end{matrix}\right\}$$

Where A_{HCLPF}^{X} represents the HCLPF capacity of component X.

$$A_{HCLPF}^{TE} = min\left\{\begin{matrix} 0.66g, 0.25g, 0.60g, 0.25g, 0.25g, 0.25g, 0.38g, \\ max(4.03g, 4.03g), max(4.03g, 4.03g), max(4.03g, 4.03g) \\ max(4.03g, 4.03g), max(0.38g, 0.38g), max(0.38g, 0.38g) \\ max(0.38g, 0.38g), max(0.38g, 0.38g) \end{matrix}\right\} = 0.25g$$

Seismic margin of plant



Situation – 1: Failure occurs when any one of the three systems fail

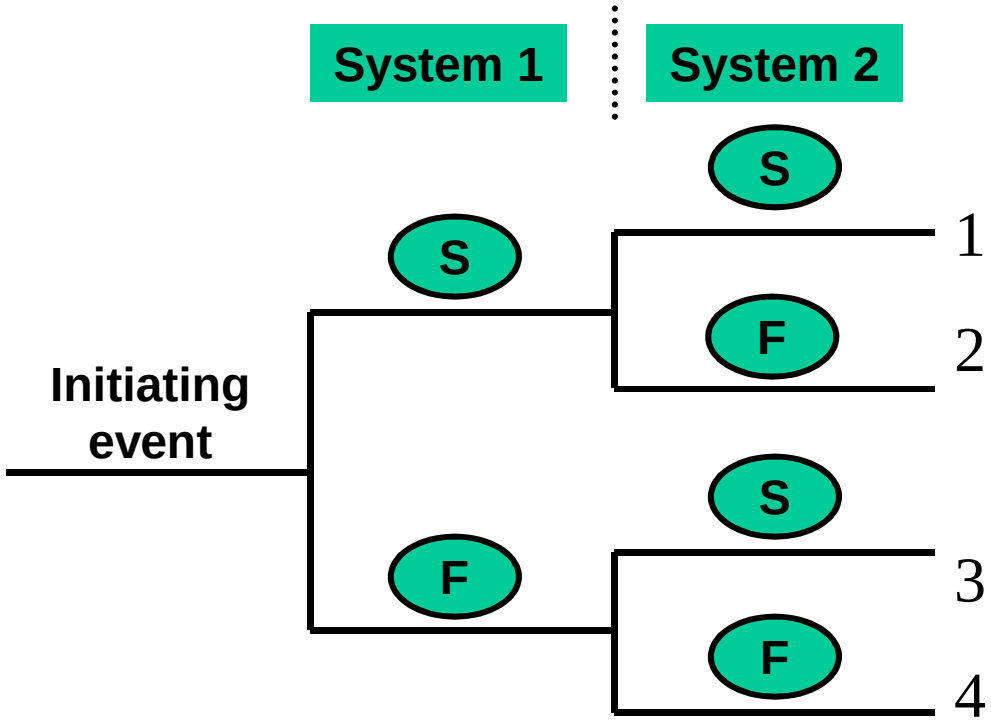
Overall median capacity = median capacity of A, the weakest link.

Situation – 2: Failure occurs only when all the three systems fail

Overall median capacity = median capacity of C, system of highest capacity.

Seismic margin of plant

Plant margin is evaluated form HCLPF capacity value or fragility of **systems** following failure path or success path deriving from the plant event tree.



Failure path:

Sq-2: IE*(sys-2)

Sq-4: IE*(Sys-1)*(Sys-2)

Overall failure:

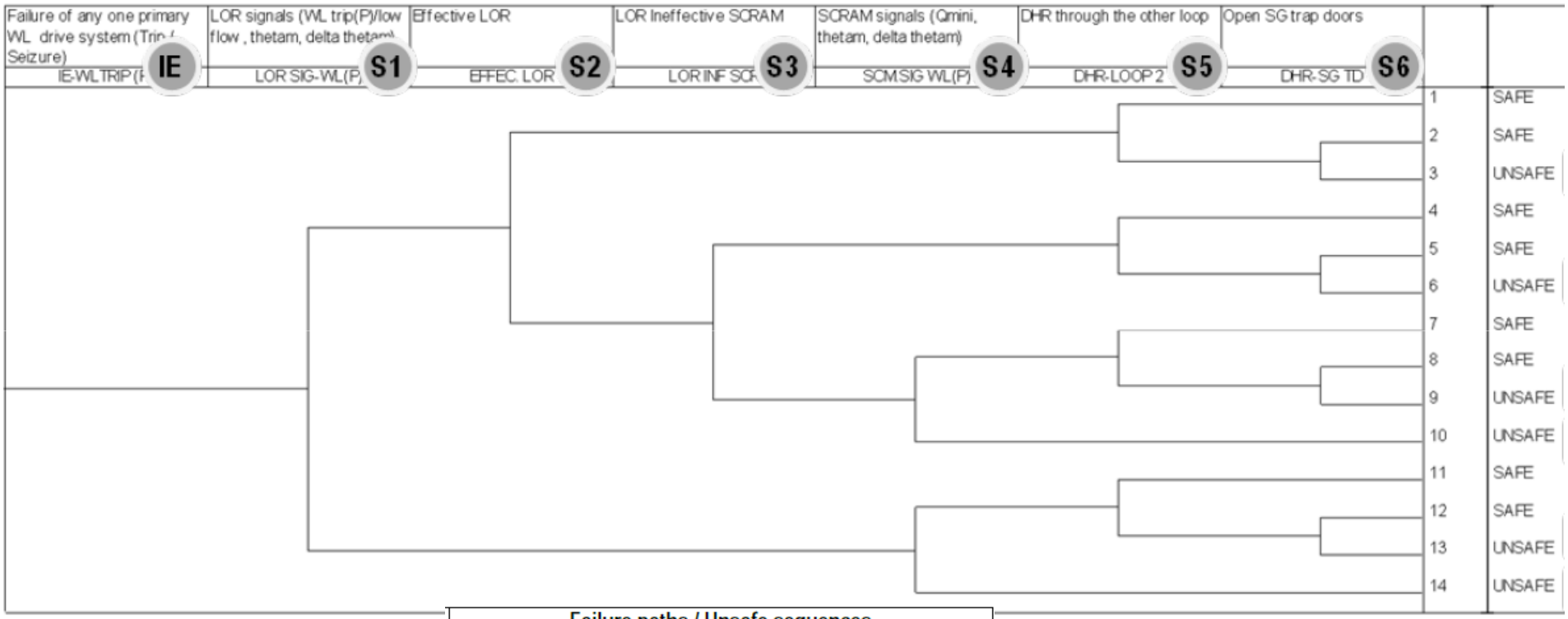
IE*(sys-2) +IE*(Sys-1)*(Sys-2)

Seismic Margin:

Min[Max(IE,Sys-2),
Max(IE,Sys-1,Sys-2)]

Seismic margin of plant

Primary WL trip (FBTR)



Failure paths / Unsafe sequences	
3	IE . S5 . S6
6	IE . S2 . S5 . S6
9	IE . S2 . S3 . S5 . S6
10	IE . S2 . S3 . S4
13	IE . S1 . S5 . S6
14	IE . S1 . S4

Seismic margin of plant

Primary WL trip (FBTR)

System ID	Description	HCLPF
IE	IE WL TRIP(P)	0.66g
S1	LOR SIG WL(P)	0.25g
S2	EFFEC LOR	0.25g
S3	LOR INF SCR	0.30g
S4	SCM SIG WL(P)	0.31g
S5	DHR-LOOP2	0.25g
S6	DHR-SG TD	0.25g

Seismic margin of plant

Primary WL trip (FBTR)

- HCLPF of sequence – 3; $A_{HCLPF}^{SQ3} = \max[0.66g, 0.25g, 0.25g] = 0.66\text{g}$
- HCLPF of sequence – 6; $A_{HCLPF}^{SQ6} = \max[0.66g, 0.25g, 0.25g, 0.25g] = 0.66\text{g}$
- HCLPF of sequence – 9; $A_{HCLPF}^{SQ6} = \max[0.66g, 0.25g, 0.30g, 0.25g, 0.25g] = 0.66\text{g}$
- HCLPF of sequence – 10; $A_{HCLPF}^{SQ6} = \max[0.66g, 0.25g, 0.30g, 0.31g] = 0.66\text{g}$
- HCLPF of sequence – 13; $A_{HCLPF}^{SQ6} = \max[0.66g, 0.25g, 0.25g, 0.25g] = 0.66\text{g}$
- HCLPF of sequence – 14; $A_{HCLPF}^{SQ6} = \max[0.66g, 0.25g, 0.31g] = 0.66\text{g}$

HCLPF capacity corresponding to the event tree

$$A_{HCLPF}^{ET} = \min(0.66g, 0.66g, 0.66g, 0.66g, 0.66g, 0.66g) = 0.66\text{g}$$

Seismic margin of plant

Primary WL trip (FBTR)

Seismic margin of the plant

$A_{HCLPF,\ Plant} = Min.[A_{HCLPF,j+}]$;

j = event tree number

$A_{HCLPF,\ FBTR} = 0.25g$

Note:

It is considered that those components are falling short of capacity will be upgraded for minimum capacity of 0.25g

Thanks

Question please