A reduction of Dynamic Fault Tree to a Simple Form

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Abstract. The dynamic fault tree expands fault tree by giving the design of complex system components' actions and crossings. Because DFT is high grade design and simple to use it is proving a rising not fail through reliability researchers. Unluckily, an issue of problems as yet stays when we using DFT These problems are (1) There are no formalities, (2) restriction in symbolic analysis and thus sensitiveness to increasing the trouble, and (3) there is a few of modular type- structure. Chain of Markov (I/O-IMC) input/output formularization are used to analyse DFT. I/O-IMC have accurate semantics and are expansion of uninterrupted-time Markov chains with output and input conducts.

1. Introduction
There are many diverse items of the dynamic fault tree analysis which are: dynamic gates, static gates and basic event. The determining the gates on dynamic fault tree analysis we become strong analysis of action and reaction through member of complex system which produce a dynamic fault tree analysis more developed than static fault tree analysis. Through figuring a DFT three major dynamic gates: stand by (spare) gate, primacy (priority) gate (PAND) and functional dependency gate which are usually used. FT were evolved to accelerate unreliability analysis of the minuteman skyrocket system, which stock a precise, schematic, conjunctural procedure to construe reliability. Conventional FT used Boolean gates to illustrate how the component fiascos fuse together make system fiasco which are analyze utilizing cut sets (or Boolean algebraic technique) or Monte Carlo emulation.

2. Preliminaries
In this Section some definitions about fault tree, dynamic fault tree, static fault trees are given

2.1 Definition [8]: A fault tree is formulation fugue impersonation of certain relationships which effect a system hazard back terms for all its possible causes.

2.2 Definition [5]: Static Fault Trees (briefly SFT or FT) are consisting of gates OR, AND, and K-out-of-N, they are combinatorial or fixed (static) gates.

2.3 Definition [5]: Dynamic Fault Trees (briefly DFT) consisting of in addition to the static gates (OR, AND, and K-out-of-N), basic events, and dynamic gates (PAND, FDEP, WSP, and SEQ).

2.4 Definition [7]: A fault tree is a figural exemplification of specific connections which effect a system hazard back terms for all its potential causes.
2.5 Definition [7]: A path set is a collection of fault tree commences which if none of them exist will surety that the top event not exist.

2.6 Definition [8]: A cut set is collection of synthesizes which that when the synthesizes in the cut are taken away the system there is no route from one station to the other.

2.7 Definition [8]: A minimal cut set is a least set of fault tree commences which if all happen, will give rise to the top event to happen

3. Dynamic gates

Pictorial display and explications of most usually used dynamic gates are presented in figure (1). Spare gates have one mine and one or several stand by (spare) inputs. When initial input event was fail, spare input substitutes it. Stand by gates make output when elementary and all stand by events fail. There are many kinds of spare gates: cool gates (CSP), snug (warm) gates (WSP) and spicy (hot) gates (HSP). If the amount of fault eventuality of particular component is equal to \( γ \), in state when component actions as stand by, value of failure probability equal to \( δγ \), if \( δ = 0 \), gate is cool(CSP) and it is inactive (quiescent) state. If \( δ = 1 \), gate is spicy (HSP). In other hands if \( 0 < δ < 1 \) gate is snug (WSP). Functional dependency gate (FDEP) contains of causative event (basic event or output for rational gate) and vassal events. All vassal (dependent) events rely on causative (trigger) event. When causative event occurs, all vassal events have occur. Output of gate (FDEP) is not taking into reckoning in computation of fiasco likelihood. Primacy gate (PAND) which has two input A and B, both of them can be basic or outputs of other logical gates. Primacy gates unsuccessful if all input components failure in the coincided row.

![Figure (1) Dynamic Gates](image_url)
4. Reduction method:
In this section we introduce a method to calculate the failure of some systems once in fault tree and in dynamic fault tree.

4.1 Reduction fault tree: Consider that the fault tree in the figure (2):

![Fault Tree Diagram](image)

By using Boolean algebra:
\[ T = H_1 \cdot H_2, \quad H_1 = L + H_3, \quad H_2 = N + H_4, \quad H_3 = M + N, \quad H_4 = L \cdot M \]

\[ T = [L + H_3] \cdot [N + H_4] \]

Substitute \( H_3 \) by \( M + N \)
\[ = [L + (M + N)] \cdot [N + H_4] \]
\[ = L \cdot N + L \cdot H_4 + N \cdot H_3 + H_3 \cdot H_4 \]
\[ = L \cdot N + L \cdot H_4 + N \cdot M + N \cdot N + M \cdot H_4 + N \cdot H_4 \]
\[ = (L \cdot N + N \cdot M + N \cdot N \cdot H_4) + L \cdot H_4 + M \cdot H_4 \]
\[ = N + L \cdot H_4 + M \cdot H_4 = N + L \cdot M + (L \cdot M) = N + L \cdot M + L \cdot M \]
\[ = N + L \cdot M \]

New the equivalent fault tree is:
4.2 Example (1):
Suppose that the fault tree in the figure (2) and assume that each component (L, M and N) has reliability (0.9) then the reliability of a system is as follow:

\[ T = H_1, H_2, \text{then from 5.1 we get that } : T = N + L.M \]

\[ T = 0.9 + (0.9 \times 0.9) = 0.729 \]

4.3 Reduction dynamic fault tree:
Assume that dynamic fault tree as showing in figure (4):

Figure (3) reduction fault tree

Figure (4) Dynamic Fault Tree
The Dynamic fault tree (DFT) in figure (4) can be consider as a Fault tree of type k-out-of –n or (4 out-of 7) as in figure (5) by replacing a set of OR gates one for each basic event instead of the functional dependency gate (FDFP) which easier in calculation of system reliability.

The fault tree in figure (5) can be represented as a parallel series system contains (35) paths since the combination \( \frac{7!}{(7-4)!4!} = \frac{7 \times 6 \times 5 \times 4!}{3! \times 4!} = 35 \)

We get the same numerical results for the two fault trees in figure (4) and (5).

For simplicity to engineers and technologists we can change DFT into equivalent SFT via replacing a set of OR gates one for each basic event instead of the dynamic gate (FDEP) i.e. \( M_i, i = 1, 2, 3, 4, 5, 6, 7 \) as shown in Figure (7) below:
For getting \( r \) successes out of \( n \) trials the reliability of \( r \) - out - of - \( n \) system \( R_S \) is:

\[
R_S = \sum_{x=r}^{n} \binom{n}{r} (R)^r (1-R)^{n-r}
\]

### 4.4 Example (2):

A space vehicle need three out of four engines to operate to achieve orbit. If every engine has a reliability of 0.97, then to calculate the reliability of achieving orbit.

Sol:

\[
R_S = \binom{4}{3}(0.97)^3(0.03)^{4-3} + \binom{4}{4}(0.97)^4(0.03)^{4-4}
\]

\[
= 4(0.97)^3(0.03) + (0.97)^4
\]

\[
= 4(0.912673)(0.03) + (0.88529281)
\]

\[
= 0.10952076 + 0.88529281
\]

Then \( R_S = 0.99481357 \)

## Conclusion

In this study a reduction method is used for a dynamic fault tree (DFT) to a simpler fault tree and we get the same numerical result since the DFT is an important tool in the reliability of complex systems for the analysis is of two cases quantitative and qualitative which have a great role to determine the system failure.

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