Journal of Advances and Scholarly Researches in Allied Education
Vol. 16, Issue No. 5, April-2019, ISSN 2230-7540

Reliability Analysis of Manufacturing Plant via Fault Tree Analysis

Sarita Devi[1]* Dr. Deepika Garg[2]

[1,2] G. D. Goenka University, Gurugram - 122103, Haryana, India

Abstract – Fault Tree Analysis (FTA) is a graphical and logical way that focused on the failure mode of the system. This method analyze the probability of an admissible event resulting from combination and sequences of faults. A Redundancy Allocation Problem (RAP) is solved with the help of FTA in this paper. RAP is a NP hard problem (Chern, 1992) which estimate system reliability under given constraints. The goal of this paper is to analyze the reliability of the system using FTA. This method is easy to understand and there is no need of mathematical modeling so this method is more efficient comparatively other methods.

Keywords: FTA, Reliability, RAP

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INTRODUCTION

In the field of engineering, the main motive is to achieve the desired level of system reliability. RAP becomes very interesting and important problem in this field. This is a complex mathematical programming problem. We have studied many methods for reliability analysis like matrix method, Matlab tool, Genetic Algorithm, Decision support system, Heuristic Algorithm, Hybridization of constraint Optimization Genetic algorithm with Particle Swarm Optimization which involve high level of calculations (Kumar et al., 2009, Meenu et al., 2010, Singh et al., 2010, Devi and Garg D, 2017). We live in a world where things are unexpected and not certain which happens every day. Failure is very common thing which is not certain in this field. These failures may be of many kinds like poor manufacturing technique, poor maintenance, design errors, lack of quality control, wear out, sub stand and components and human factors etc. There is a need to analyze these failures to achieve the desired level of system reliability.

FTA is a logical top-down deductive method to access or find the probability of the top event with the help of given information. FTA was introduced by H.A Watson at Bell Laboratories in 1962. Firstly, FTA was utilized by Nuclear Power Generation yet after that it wound up well known in all parts of security estimates in numerous fields (Marko et.al. 2009). It shows good results in Nuclear power generation after that it became popular in chemical process industry (Glickman, 2007, Ju et al., 2003, Zhao-Mei, 2011, Ale, 2003, Svedung et al., 2008). This technique was also used in analyzing the occupational hazards with the top event injury, staircase slipping hazard etc.(Hauptmanns et. al., 2005). A potential computer aided technique to construct FT is developed (Wang et. al., 2002). It works directly from the block diagram. This algorithm is based on loop by loop or node by node basis. Some new techniques are developed to improve the software pack of PROFAT (Probabilistic Fault Tree) initial tool to overcome these problems related to complexity of system's nature and in constructing the FTA of these complex systems (Khan et. al., 2000). A new concept of time analysis of safety assessment is introduced and used with FTA to reduce the complexity of computation (Magott et al., 2012). With the help of this upgrading technique, we are able to estimate the actual time dependent risk profile and it increases the applicability of FTA. Some hybrid techniques of FTA were also developed with Fuzzy logic to handle the probability of human error effectively (Kumar and Yadav, 2012, Tyagi et.al., 2010) to describe the imprecision or vagueness of events in FTA (Cheng and Mon, 1993, Chen and Yuan, 1994, Liang and Wang, 1993, Guth, 1991, Liao and Yuan, 1993, Singer, 1990, Tanaka et. al., 1983).

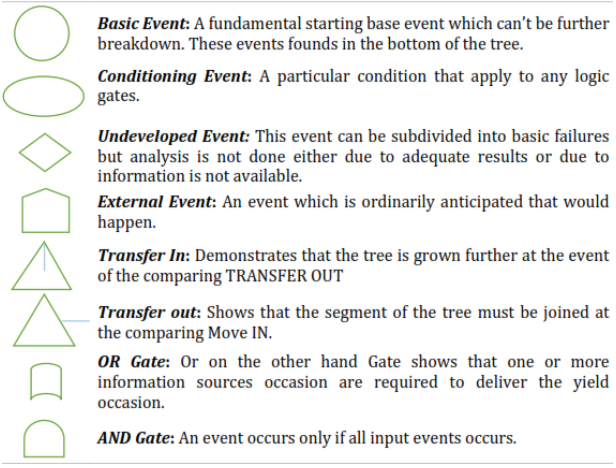
This is most favored method for understanding logically the technique of instance of a single well-defined inadmissible event. Here inadmissible event means non-operation of the system. This method has a different way of analyzing the problem to diagnose how the system 'may fail to function'. As we called it is a top-down method, and we can find the failure probability of top event with the use of given failure probabilities of the subsystems. There is need to identify the event

combination which result in the instance of this inadmissible event.

Procedure of FTA

A successful FTA depends upon the following steps:

- Find the objective for the FTA
- Represent the top event of the fault tree
- Describe the scope of FTA
- Describe the rules for FTA on which it is based
- Make the fault tree
- Calculation of FTA
- Interpret and present the result



***Basic Event*:** A fundamental starting base event which can't be further breakdown. These events founds in the bottom of the tree.

***Conditioning Event*:** A particular condition that apply to any logic gates.

Undeveloped Event: This event can be subdivided into basic failures but analysis is not done either due to adequate results or due to information is not available.

***External Event*:** An event which is ordinarily anticipated that would happen.

***Transfer In*:** Demonstrates that the tree is grown further at the event of the comparing TRANSFER OUT

***Transfer out*:** Shows that the segment of the tree must be joined at the comparing Move IN.

***OR Gate*:** Or on the other hand Gate shows that one or more information sources occasion are required to deliver the yield occasion.

***AND Gate*:** An event occurs only if all input events occurs.

Notations:

n_i : name of subsystem

r_i: Reliability of subsystem

E_i: failure probability of each subsystem.

F: failure probability of whole system

FTA Calculation using AND & OR Gates

System consists of 7 units as defined in (Devi et al. , 2017 25) paper, n_i (n_i, 1≤ i≤ 7) where n_1 has 2 identical units which have same reliability and connected with parallel namely n_{11}, n_{12} and n_2 has 3 identical units namely n_{21}, n_{22}, n_{23} which have also same reliability. In the same manner n_3 has 2 identical units, n_4 has 5 identical units, so on which represented in the below table. Table 2 represents the subsystems, their reliabilities and corresponding units which these subsystems have contained.

Subsystem (n_i)	n_1	n_2	n_3	n_4	n_5	n_6	n_7
Reliability of subsystems (r_i)	0.99	0.9762	0.9188	0.8155	0.8655	0.9287	0.9453
No. of units	2	3	2	5	1	3	5

Table 2. Reliability and no. of units of each subsystem (n_i)

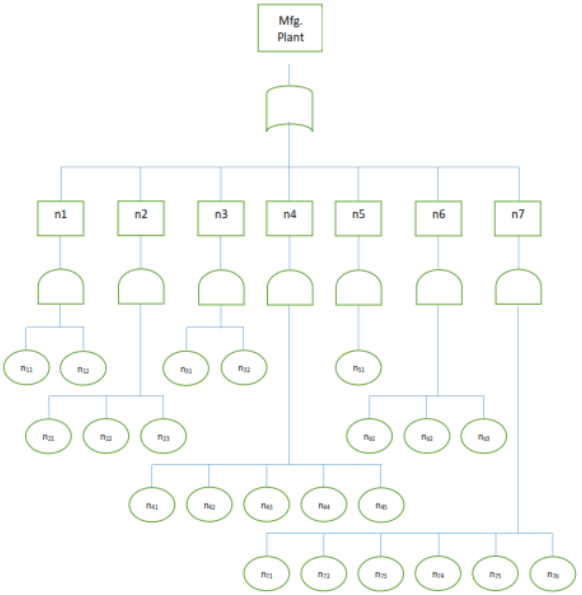


Figure 1. Fault Tree Diagram

Following events used in analysis as follows and shown in **Figure 1**:

E_1: represent the event that whole subsystem n_1 fails when n_{11} and n_{12} are connected with AND Gate.

E_2: represent the event that whole subsystem n_2 fails when n_{21}, n_{22} and n_{23} are connected with AND Gate.

E_3: represent the event that whole subsystem n_3 fails when n_{31} and n_{32} are connected with AND Gate.

E_4: represent the event that whole subsystem n_4 fails when n_{41}, n_{42}, n_{43}, n_{44} and n_{45} are connected with AND Gate.

E_5: represent the event that whole subsystem n_5 fails and it has single unit n_{51},.

E_6: represent the event that whole subsystem n_6 fails when n_{61}, n_{62} and n_{63} are connected with AND Gate.

E_7: represent the event that whole subsystem n_7 fails when n_{71}, n_{72}, n_{73}, n_{74} and n_{75} are connected with AND Gate.

Now E_1 event means subsystem n_1 fails when n_{11} and n_{12} both fails because they are connected with AND Gate, so the probability of E_1 is

$$E_1 = (1-n_{11})(1-n_{12}) = (1-0.99)^2 = 0.0001$$

Similarly failure probabilities of other subsystems are calculated below in the same manner.

$$E_2 = (1-0.9762)^3 = 0.000013$$
$$E_3 = (1-0.9188)^2 = 0.006593$$
$$E_4 = (1-0.8155)^5 = 0.000213$$
$$E_5 = (1-0.8655)^1 = 0.1345$$
$$E_6 = (1-0.9287)^3 = 0.000362$$
$$E_7 = (1-0.9453)^5 = 0.004465$$

As shown in FTA diagram E_1, E_2, E_3,…,E_7 are the failure probabilities of the subsystem n_1, n_2, n_3,…, n_7 which are connected with OR Gate. The failure probability of the top event i.e. whole system is denoted by F so that.

$$F = E_1 + E_2 + E_3 + E_4 + E_5 + E_6 + E_7$$
$$= 0.0001 + 0.000013 + 0.006593 + 0.000213 + 0.1345 + 0.000362 + 0.000362$$
$$= 0.146246$$

CONCLUSION

FTA has been applied in this paper to estimate the failure probability of the top event of Production Machine. We got the probability of failure of production machine that is 0.146246 with the help of basic events**.** Considering various concepts like Marko modeling, matrix method, which have used for reliability analysis. In all mentioned approaches, difficult modeling problem, mathematical calculation and various assumption, deep knowledge and interrelationship between the subsystems makes the problem very difficult to solve. But in this paper FTA approach has overcome these problems.

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Corresponding Author

Sarita Devi*

G. D. Goenka University, Gurugram - 122103, Haryana, India

sarita.fame@gmail.com