ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

RELIABILITY ANALYSIS FOR SUBSTATION EMPLOYING B. F. TECHNIQUE

Mohit Kumar[1], Ram Avtar Jaswal[2]

M.Tech Scholar, Department of Electrical Engg., UIET Kurukshetra University, Kurukshetra, Haryana, India[1]

Assistant Professor, Department of Electrical Engg., UIET Kurukshetra University,Kurukshetra, Haryana, India[2]

Abstract*:* In this paper, the reliability of 66kv/400v substation has been analysed. When more complexities increase in the system, the reliability evaluation becomes more difficult. Thus, the derivation of symbolic reliability expression is simplified. The general system for compact form is very helpful. Boolean function technique simplifies the complexity of any system. By Boolean function technique, a mathematical model for measuring reliability has been developed. In the terms of reliability for substation, the failure rate and mean time to failure are to be calculated.

KEYWORDS: Boolean Function Technique, Reliability, Failure Rate, M.T.T.F

I INTRODUCTION

Reliability of a unit (or product) is the probability that the unit performs its intended function adequately for a given period of time under the given stated operating conditions or environment. Reliability definition stresses four element: probability, intended function, time and operating conditions [1]. Gupta P.P, Agarwal S.C have considered a Boolean Algebra Method for Reliability calculations and again Gupta P.P Kumar Arvind, Reliability and M.T.T.F Analysis of Power Plant. Sharma, Deepankar Sharma, Neelam, Evaluation of some Reliability Parameters for Tele-communication system by Boolean Function Technique [2][3][4][5]. [6][7][8][9] The reliability of several electronic equipments by using various techniques has been calculated, but the method adopted by them lead to cumbersome and tedious calculation. Keeping this fact in view, for the evaluation of various factors of reliability of 66kv/400v substation., the authors have applied Boolean function technique.

The block diagram of 66kv/400v substation is shown in figure 1. Two 66kv incoming lines are connected to bus bars. Such an arrangement having two incoming lines is called double circuit. Any one of line can be utilised at one time or both can also be utilised. In 66kv substation in this arrangement by which 66kv double circuit supply is going out. To step down it to 11kv, there are two step down transformers unit connected in parallel. That means if one is under repair or faulty, other can work, not whole system shuts down. It is further connected with gang operating switch with current transformer and then to step down transformer to 400v [10].

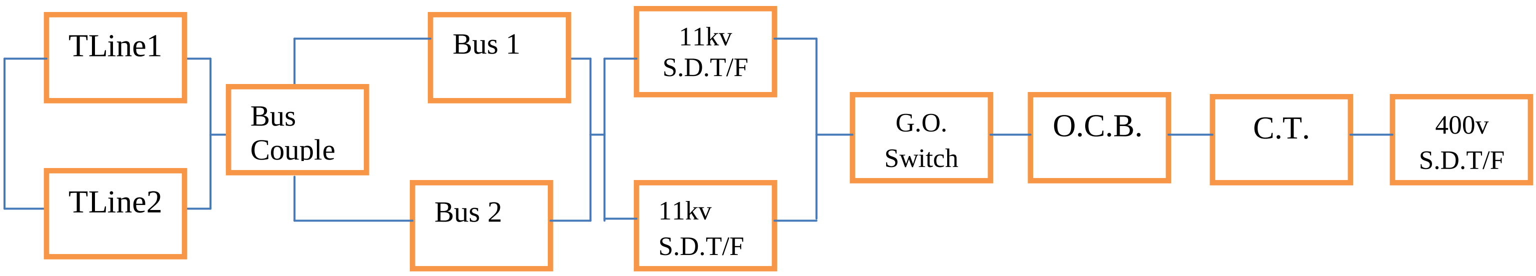

Figure 1: Block Diagram Representation of 66kv/400v Substation

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

II. RELIABILITY BY BOOLEAN FUNCTION TECHNIQUE

The reliability of substation is determined, mathematical model has been developed shown in figure2. The following assumptions are to be made for applying Boolean function technique:

1. First of all ,ensure that all the equipments are good and operable.
2. The state of all components of the system is statistically independent.
3. The state of each component and as whole system either operable, workable, good or fail.
4. There is no repair facility.
5. Supply between any two components of the system is hundred percent reliable and perfect ok .
6. The failure times of all components are arbitrary.
7. In advance, the reliability of each component shold be known .

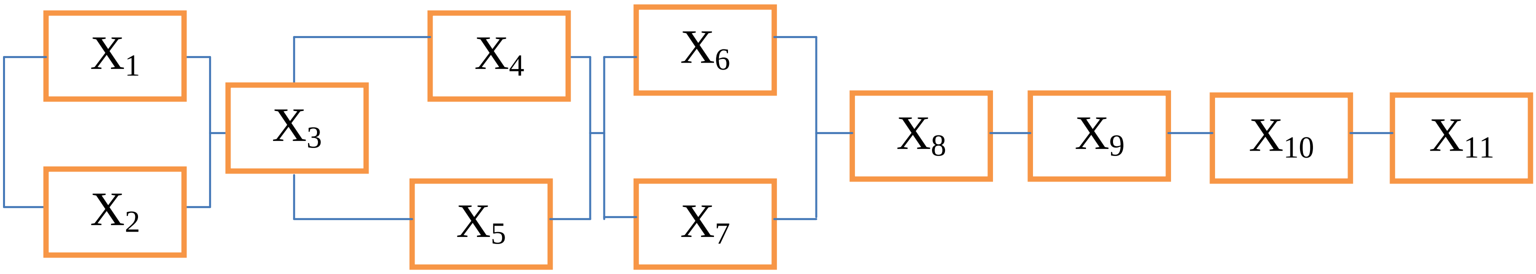

Figure 2: State Model of 66kv/400v Substation

Notations

X1, X2 = State of both transmission lines

X3 = State of Bus Coupler

X4, X5 = State of both buses

X6, X7 = State of 11kv step down transformers

X8 = State of G.O. Switch

X9 = State of oil circuit breaker

X10 = State of current transformer

X11 = State of 400v step down transformer

$X_i(i = 1,2,\ldots 11) = 1$ in good state and 0 in bad state

X_i' = negation of X_i

^ = Conjunction

| | = Logical Matrix

R_i = Reliability of i^th part of the system

$Q_i = 1-R_i$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

R_s = Reliability of Whole System

$R_{SW}(t)/R_{SE}(t)$ = Reliability of the system as a whole when failures follow Weibull /Exponential time distribution.

III. FORMULATION OF MATHEMATICAL MODEL

The successful operation of the system in terms of logical matrix is expressed as:

$$F(X_1 \quad X_2 \text{ ------------------------------ } X_{11}) = \left| \begin{array}{cccccccc} X_1 & X_3 & X_4 & X_6 & X_8 & X_9 & X_{10} & X_{11} \\ X_1 & X_3 & X_4 & X_7 & X_8 & X_9 & X_{10} & X_{11} \\ X_1 & X_3 & X_5 & X_6 & X_8 & X_9 & X_{10} & X_{11} \\ X_1 & X_3 & X_5 & X_7 & X_6 & X_9 & X_{10} & X_{11} \\ X_2 & X_3 & X_4 & X_6 & X_8 & X_9 & X_{10} & X_{11} \\ X_2 & X_3 & X_4 & X_7 & X_8 & X_9 & X_{10} & X_{11} \\ X_2 & X_3 & X_5 & X_6 & X_8 & X_9 & X_{10} & X_{11} \\ X_2 & X_3 & X_5 & X_7 & X_8 & X_9 & X_{10} & X_{11} \end{array} \right| \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$= (X_1\, X_2\, X_4\, X_5 X_6\, X_7) \wedge \left| \begin{array}{ccc} X_1 & X_4 & X_6 \\ X_1 & X_4 & X_7 \\ X_1 & X_5 & X_6 \\ X_1 & X_5 & X_7 \\ X_2 & X_4 & X_6 \\ X_2 & X_4 & X_7 \\ X_2 & X_5 & X_6 \\ X_2 & X_5 & X_7 \end{array} \right| = (X_1\, X_2\, X_4\, X_5\, X_6\, X_7) \wedge B \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$B = \left| \begin{array}{ccc} X_1 & X_4 & X_6 \\ X_1 & X_4 & X_7 \\ X_1 & X_5 & X_6 \\ X_1 & X_5 & X_7 \\ X_2 & X_4 & X_6 \\ X_2 & X_4 & X_7 \\ X_2 & X_5 & X_6 \\ X_2 & X_5 & X_7 \end{array} \right| = \left| \begin{array}{c} M_1 \\ M_2 \\ M_3 \\ M_4 \\ M_5 \\ M_6 \\ M_7 \\ M_8 \end{array} \right|$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

By Orthogonalisation algorithm, above equation can be written as

$$B = \begin{vmatrix} M_1 \\ M_1' \quad M_2 \\ M_1' \quad M_2' \quad M_3 \\ M_1' \quad M_2' \quad M_3' \quad M_4 \\ M_1' \quad M_2' \quad M_3' \quad M_4' \quad M_5 \\ M_1' \quad M_2' \quad M_3' \quad M_4' \quad M_5' \quad M_6 \\ M_1' \quad M_2' \quad M_3' \quad M_4' \quad M_5' \quad M_6' \quad M_7 \\ M_1' \quad M_2' \quad M_3' \quad M_4' \quad M_5' \quad M_6' \quad M_7' \quad M_8 \end{vmatrix} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Now using algebra of logics

$$M_1' M_2 = \left| X_1 \quad X_4 \quad X_6' \quad X_7 \right| \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$M_1' M_2' M_3 = X_1 \quad X_4' \quad X_5 \quad X_6 \quad X_7' \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$M_1' M_2' M_3' M_4 = \begin{vmatrix} X_1 \quad X_4' \quad X_5 \quad X_6 \quad |X_7 \\ X_1 \quad X_4' \quad X_5 \quad X_6' \quad X_7 \end{vmatrix} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$M_1' M_2' M_3' M_4' M_5 = \begin{vmatrix} X_1' \quad X_2 \quad X_4 \quad X_6 \\ X_1 \quad X_2 \quad X_4' \quad X_6' \quad X_7 \end{vmatrix} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$M_1' M_2' M_3' M_4' M_5' M_6 = \left| X_1' \quad X_2 \quad X_4 \quad X_6' \quad X_7 \right| \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$M_1' M_2' M_3' M_4' M_5' M_6' M_7 = \begin{vmatrix} X_1' \quad X_2 \quad X_4' \quad X_5 \quad X_6 \quad X_7 \\ X_1' \quad X_2 \quad X_4 \quad X_5 \quad X_6 \quad X_7' \end{vmatrix} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

$$M_1' M_2' M_3' M_4' M_5' M_6' M_7' M_8 = \left| X_1' \quad X_2 \quad X_4' \quad X_5 \quad X_6' \quad X_7 \right| \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

By using equation 3-10

$$B = \begin{vmatrix} X_1 \; X_4 \; X_6 \\ X_1 \; X_4 \; X_6' \; X_7 \\ X_1 \; X_4' \; X_5 \; X_6 \; X_7' \\ X_1 \; X_4' \; X_5 \; X_6 \; X_7 \\ X_1 \; X_4 \; X_5 \; X_6' \; X_7 \\ X_1' \; X_2 \; X_4 \; X_6 \\ X_1 \; X_2 \; X_4' \; X_6' \; X_7 \\ X_1' \; X_2 \; X_4 \; X_6' \; X_7 \\ X_1' \; X_2 \; X_4' \; X_5 \; X_6 \; X_7 \\ X_1' \; X_2 \; X_4 \; X_5 \; X_6 \; X_7' \\ X_1' \; X_2 \; X_4' \; X_5 \; X_6' \; X_7 \end{vmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(11)$$

By using equation 11 and equation 2

$$F = \begin{vmatrix} X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1 \; X_4 \; X_6 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1 \; X_4 \; X_6' \; X_7 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1 \; X_4' \; X_5 \; X_6 \; X_7' \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1 \; X_4' \; X_5 \; X_6 \; X_7 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1 \; X_4 \; X_5 \; X_6' \; X_7 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1' \; X_2 \; X_4 \; X_6 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1' \; X_2 \; X_4' \; X_6' \; X_7 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1' \; X_2 \; X_4 \; X_6' \; X_7 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1' \; X_2 \; X_4' \; X_5 \; X_6 \; X_7 \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1' \; X_2 \; X_4 \; X_5 \; X_6 \; X_7' \\ X_3 \; X_8 \; X_9 \; X_{10} \; X_{11} \; X_1' \; X_2 \; X_4' \; X_5 \; X_6' \; X_7 \end{vmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(12)$$

Finally the probability of successful operation i.e. reliability of the system as a whole is given by

$$\begin{aligned} R_S = \; & R_3 R_8 R_9 R_{10} R_{11} [R_1 R_4 R_6 + R_1 R_4 (1-R_6) R_7 + R_1 (1-R_4) R_5 R_6 (1-R_7) + R_1 (1-R_4) R_5 R_6 R_7 + \\ & R_1 R_4 R_5 (1-R_6) R_7 + (1-R_1) R_2 R_4 R_6 + (1-R_1) R_2 (1-R_4) (1-R_6) R_7 + (1-R_1) R_2 R_4 (1-R_6) R_7 + \\ & (1-R_1) R_2 (1-R_4) R_5 R_6 R_7 + (1-R_1) R_2 R_4 R_5 R_6 (1-R_7) + (1-R_1) R_2 (1-R_4) R_5 (1-R_6) R_7] \end{aligned}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(13)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

A. Some Particular Cases

Case1: When all failures follow Weibull's Criteria

Let λ_i will be the failure rate of components corresponding to system state X_i and it follows weibull time distribution. Then reliability function of considered system at time't' is given as:

$$R = e^{-(\lambda_3+\lambda_8+\lambda_9+\lambda_{10}+\lambda_{11})t^{\alpha}} [e^{-(\lambda_1+\lambda_4+\lambda_6)t^{\alpha}} + e^{-(\lambda_1+\lambda_4+\lambda_7)t^{\alpha}} (1- e^{-\lambda_6 t^{\alpha}}) + e^{-(\lambda_1+\lambda_5+\lambda_6)t^{\alpha}}$$

$$(1- e^{-\lambda_4 t^{\alpha}})(1- e^{-\lambda_7 t^{\alpha}}) + e^{-(\lambda_1+\lambda_5+\lambda_6+\lambda_7)t^{\alpha}}(1- e^{-\lambda_4 t^{\alpha}}) + e^{-(\lambda_1+\lambda_4+\lambda_5+\lambda_7)t^{\alpha}}(1- e^{-\lambda_6 t^{\alpha}}) +$$
$$e^{-(\lambda_2+\lambda_4+\lambda_6)t^{\alpha}}(1- e^{-\lambda_1 t^{\alpha}}) + e^{-(\lambda_2+\lambda_7)t^{\alpha}}(1- e^{-\lambda_1 t^{\alpha}}) (1- e^{-\lambda_4 t^{\alpha}}) (1- e^{-\lambda_6 t^{\alpha}}) +$$

$$e^{-(\lambda_2+\lambda_4+\lambda_7)t^{\alpha}}(1- e^{-\lambda_1 t^{\alpha}}) (1- e^{-\lambda_6 t^{\alpha}}) + e^{-(\lambda_2+\lambda_5+\lambda_6+\lambda_7)t^{\alpha}}(1- e^{-\lambda_1 t^{\alpha}}) (1- e^{-\lambda_4 t^{\alpha}}) +$$
$$e^{-(\lambda_2+\lambda_4+\lambda_5+\lambda_6)t^{\alpha}}(1- e^{-\lambda_1 t^{\alpha}}) (1- e^{-\lambda_7 t^{\alpha}}) + e^{-(\lambda_2+\lambda_5+\lambda_7)t^{\alpha}}(1- e^{-\lambda_1 t^{\alpha}}) (1- e^{-\lambda_4 t^{\alpha}}) (1- e^{-\lambda_6 t^{\alpha}})]$$

……………………..(14)

When $\lambda_1 = \lambda_2 =$ -------------- $\lambda_{11} = \lambda$ then from above equation

$$R_{sw}(t) = e^{-(5\lambda)t^{\alpha}}[2e^{-(3\lambda)t^{\alpha}} - 2e^{-(4\lambda)t^{\alpha}} + 2e^{-(5\lambda)t^{\alpha}} + e^{-(6\lambda)t^{\alpha}} + e^{-(2\lambda)t^{\alpha}}]$$

……………………..(15)

Case –II: When all failures follow Exponential time distribution

Exponential distribution is a particular case of weibull distribution for $\alpha = 1$. Hence the reliability of a whole system at an instant't' is given by

$$R_{se}(t) = e^{-(5\lambda)t} [2e^{-(3\lambda)t} - 2e^{-(4\lambda)t} + 2e^{-(5\lambda)t} + e^{-(6\lambda)t} + e^{-(2\lambda)t}]$$

……………………..(16)

and the expression for M.T.T.F in this case is

$$\text{M.T.T.F} = \int_0^{\infty} R_{se}(t)\,dt$$

$$= \frac{1}{4\lambda} - \frac{2}{9\lambda} + \frac{1}{5\lambda} + \frac{1}{7\lambda} + \frac{1}{11\lambda}$$

……………………..(17)

IV. NUMERICAL COMPUTATIONS

For a numerical computation, let us consider the values

i. Setting λ_i(i = 1,2,3….11) = 0.001 and $\alpha = 2$ in equation 15
ii. Setting λ_i(i = 1,2,3….11) = 0.001 in equation 16
iii. Setting λ_i(i = 1,2,3….11) = 0.001…….0.012 in equation 17 table 1 and table 2 has been computed and corresponding graphs are shown in figure 3 and 4 respectively.

Table 1: Reliability values showing for $R_{sw}(t)$, $R_{se}(t)$ with time

S. No.	t	$R_{sw}(t)$	$R_{se}(t)$
1	1	3.96416746133529	3.96416746133529
2	2	3.85865377977109	3.92866770132155
3	3	3.68922296098833	3.89349752772265
4	4	3.46488108094073	3.85865377977109
5	5	3.19705977877420	3.82413332785093
6	6	2.89862678586679	3.78993307318401
7	7	2.58284510680202	3.75604994751942
8	8	2.26239914738250	3.72248091282604

Table 2: M.T.T.F vs λ

S. No.	λ	M.T.T.F
1	0.001	461.544011544012
2	0.002	230.772005772006
3	0.003	153.848003848004
4	0.004	115.386002886003
5	0.005	92.3088023088023
6	0.006	76.9240019240019
7	0.007	65.9348587920017
8	0.008	57.6930014430015
9	0.009	51.2826679493346
10	0.010	46.1544011544012
11	0.011	41.9585465040011
12	0.012	38.4620009620010

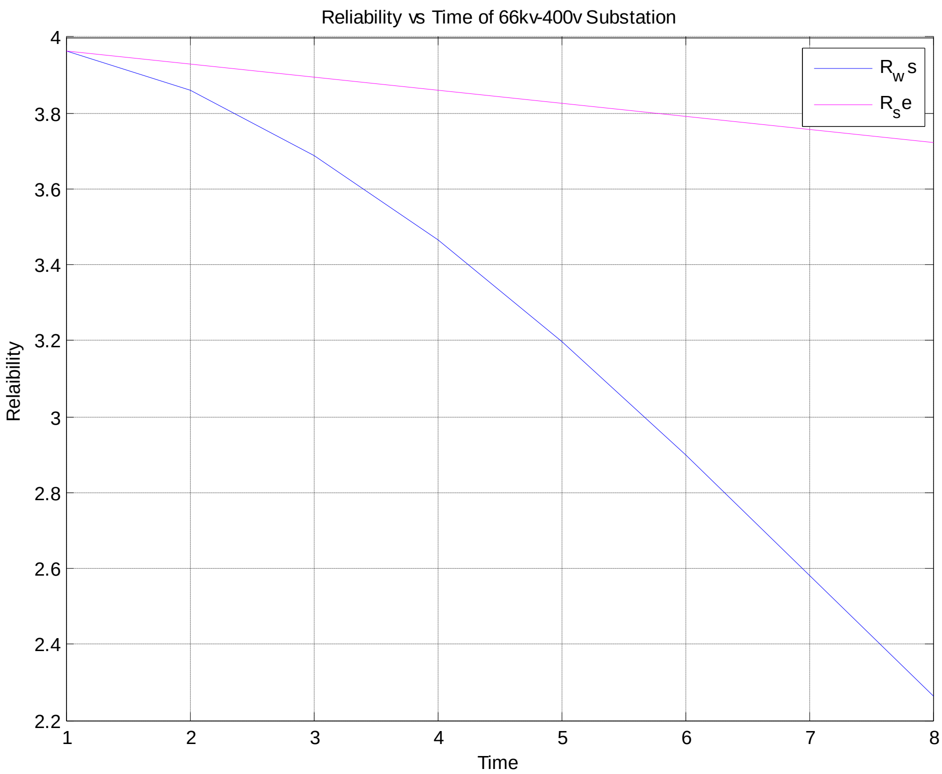

Figure 3: Graph showing Weibull distribution and exponential distribution with time

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

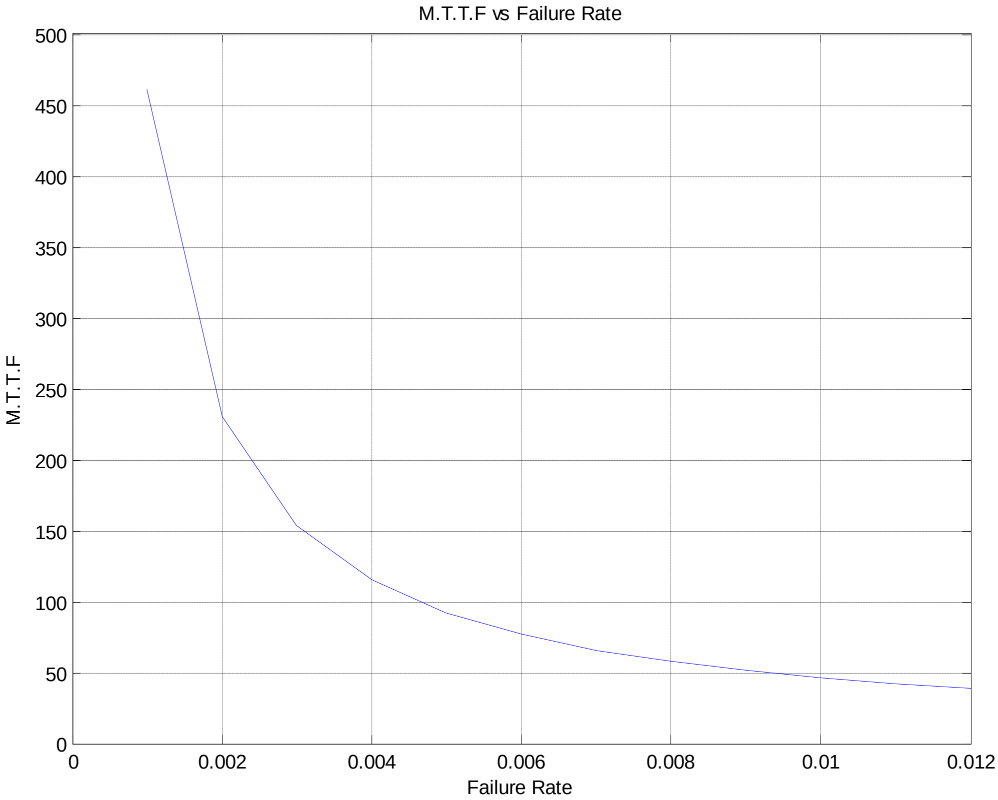

Figure 4: Graph showing M.T.T.F with failure rate

V. CONCLUSION

In this paper, we considered 66kv/400v substation for analysis of various reliability parameters by employing the Boolean function technique & algebra of logics. Table 1 computes the reliability of the system with respect to time when failures rates follow exponential and Weibull time distributions. An inspection of graph "Reliability Vs Time" (fig3) reveals that the reliability of the complex system decreases approximately at a uniformly rate in case of exponential time distribution, but decreases very rapidly when failure rates follow Weibull distributions. Table 2 and graph "MTTF V/S Failure Rate (fig-4) yields that MTTF of the system decreases catastrophically in the beginning but later it decreases approximately at a uniform rate.

REFERENCES

[1]. Jai Singh Gurjar ,"Relaibility Technology Theory and Applications", second edition, I.K. international Publishing House
[2]. Gupta PP, Agarwal SC. A Boolean Algebra Method For reliability Calculations (Published work style). Microelectronic Reliability 1983; 23: 863-865.
[3]. Gupta PP, Agarwal SC. A Boolean algebra method for reliability calculations, microelectron. Reliability 1983; 23: 863-886.
[4]. Gupta PP, Kumar A. Reliability and MTTF Analysis of a Power Plant Connected with Hundred Percent Reliable Cables by BF Technique Published work style. Microelectronic Reliability, 1986; 26: 825-834.
[5]. Gupta PP, Kumar A. Evaluation of Reliability and MTTF of a Power Plant with the Aid of Boolean Function Expansion Algorithm (Published Work style). Microelectronic Reliability 1986;821-824.
[6]. Dr. Nabil Hachem, Dr. jatinder bedi,"neural network implementation for reliability evaluation",IEEE,1996.
[7]. Pawan Gupta, Arvind Kumar Lal and Rajendra Kumar Sharma, Jai Singh "Numerical analysis of reliability and availability of the serial processes in butter-oil processing plant "International Journal of Quality &Reliability Management Vol. 22 No. 3, 2005 pp. 303- Emerald Group Publishing Limited.
[8]. Linmin Hu and Jiandong Li "reliability analysis of a three-unit system with vacation and priority", ICIC International °c 2009 ISSN 1881-803X pp. 171—176
[9]. D R Prescott1, R Remenyte-Prescott, S Reed, J D Andrews, and C G Downes," A reliability analysis method using binary decision diagrams in phased mission planning "journal of risk and reliability vol 223, 2009.
[10]. V.K.Mehta, Rohit Mehta,"Principles of Power System", S.Chand Publication