Journal of Science and Technology
ISSN: 2456-5660 Volume 06, Issue 04, July-August 2021

www.jst.org.in *DOI: https://doi.org/10.46243/jst.2021.v6.i4.pp04-11*

Profit Analysis and Modeling of a Power Plant with Boolean Function Algorithm

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To Cite this Article
Vikas Kumar, Ashish Kumar Arora, "Profit Analysis and Modeling of a Power Plant with Boolean Function Algorithm", Journal of Science and Technology, Vol. 06, Issue 04, July-August 202, pp13-20

Article Info
Received: 26--01-2021 Revised: 25-05-2021 Accepted: 28-05-2021 Published: 06-06-2021

Abstract: *In this model, we are conducting the analysis of a power plant is quite often subjected to the generators with their respective redundancies. The governing equations are solved by using the technique. Variations of these quantities with different parameters involved in the matrices have been studied and their solutions have been obtained. The effects of reliability on power plant with repair facilities are investigated and permeability parameters have been discussed with the help of graphs.*

Keywords*: Function techniques, redundancy, Reliability function, M.T.T.F., and logical matrices*

I. Introduction

In this chapter, the authors have studied a power plant for its reliability analysis. In this system, there are two generators G_1 and G_2, working in standby redundancy. On failure of online generator, the standby generator can be online through a switching device S.D. In this power plant, there are 2-two way main switches $TWMS_1$ and $TWMS_2$. Both the switches are working in parallel redundancy and their aim is to supply power to output main switch OPMS which has been shown in fig-1 and BLOCK diagram of considered system has been given in fig-1.2. $C_1, C_2 --, C_7$ are the cables used for intermediate connections. These cables are hundred percent reliable. Our aim is obtain reliability of the whole system. Boolean function technique has been used for mathematical procedure at this system. The employer solved this model by algebra of logics. The entire system of Reliability R_S has been calculated and here failures follow exponential and weibull distribution have been obtained. Mean time to system failure has also been calculated to boost practical value of the model. At end the most important result of the study, a numerical calculation was included to follow by this graphical representation.

Assumptions: First of all full system is good and operable.

The two generators G_1 and G_2 are in standby sacking and only one generator is enough to feed output.

There is no repair facility available.

Cables used for intermediate connections, are hundred percent reliable.

Reliability of all the components is familiar in proceed.

The states of all components and of the full system are either good (operating) or bad (non-operating).

Notations:

x_1, x_2	:	States of generators $G_1 \& G_2$, respectively.
x_3	:	State of switching device S.D.
x_4, x_5	:	States of two method main switches $TWMS_1$ and $TWMS_2$, respectively.
x_6	:	State of output main switch OPMS.

$C_1, C_2, ---, C_7$	:	Cables used for intermediate connections.
x_i	:	$\begin{cases} 1 & \text{in good state} \\ 0 & \text{in bad state} \end{cases}$, where $i = 1,2,--6$
$\Pr(f = 1)$	:	The possibility of the successful operation of function 'f'.
$\wedge / \vee / '$	:	Conjunction/Disjunction/Negation.
$R_{SW}(t) / R_{SE}(t)$	:	Reliability function when failures follow Weibull/exponential time distribution.

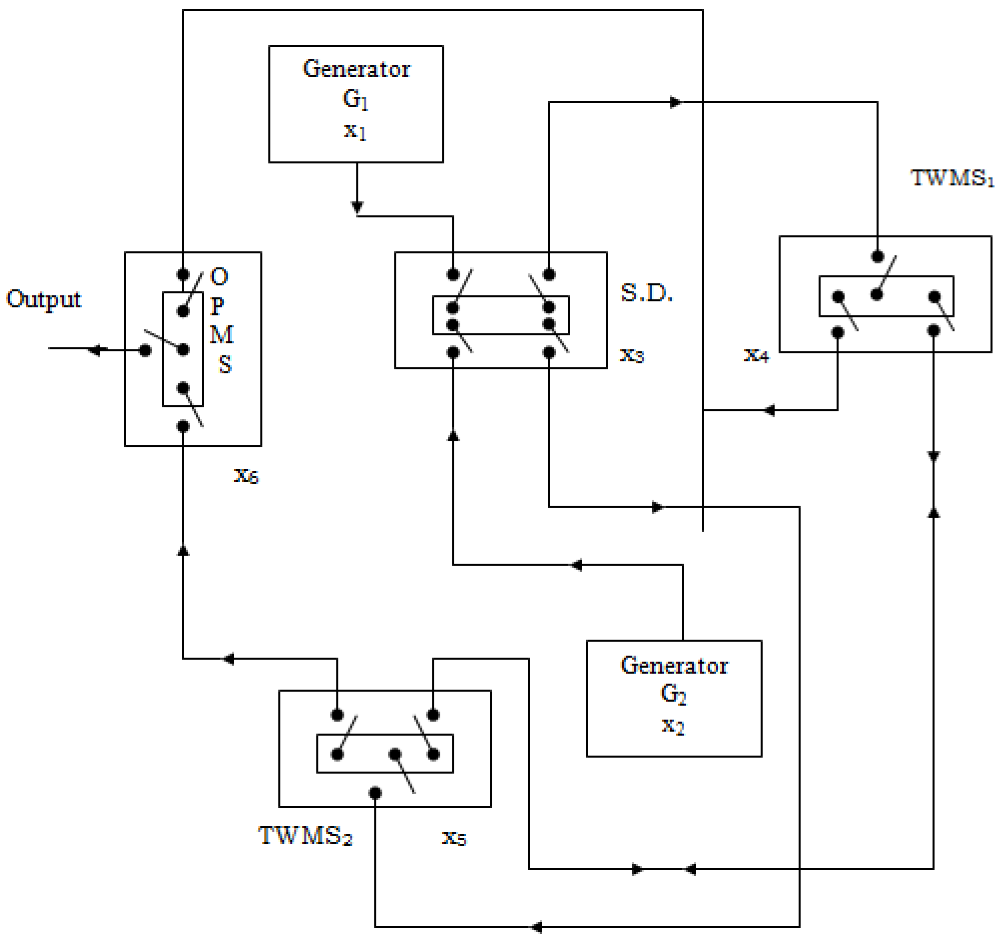

Figure No. 1: Flow chart of system configuration

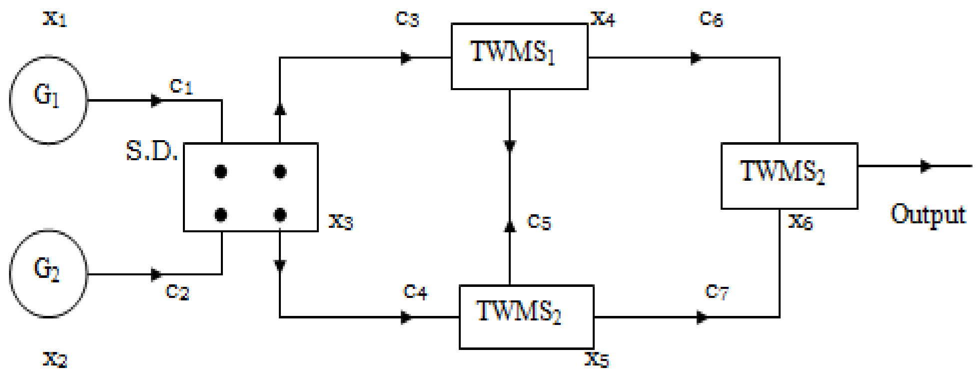

Figure No. 2: Flow chart of block diagram

II. Mathematical Model

To use of this technique, the conditions of capability for the successful operation of the complex system is represented in form of a logical matrix, has been given as under:

$$F(x_1, x_2, ---, x_6) = \begin{bmatrix} x_1 & x_3 & x_4 & x_6 & \\ x_1 & x_3 & x_5 & x_6 & \\ x_1 & x_3 & x_4 & x_5 & x_6 \\ x_2 & x_3 & x_4 & x_6 & \\ x_2 & x_3 & x_5 & x_6 & \\ x_2 & x_3 & x_4 & x_5 & x_6 \end{bmatrix} \quad (1)$$

Equation (1) may be rewritten as

$$F(x_1, x_2, ---, x_6) \longrightarrow [x_3 \; x_6 \wedge f\,(x_1, x_2, x_4, x_5)] \quad (2)$$

where,

$$f\,(x_1, x_2, x_4, x_5) = \begin{bmatrix} x_1 & x_4 & \\ x_1 & x_5 & \\ x_1 & x_4 & x_5 \\ x_2 & x_4 & \\ x_2 & x_5 & \\ x_2 & x_4 & x_5 \end{bmatrix} \quad (3)$$

Substituting

$T_1 = [x_1, \quad x_4]$

$T_2 = [x_1, \quad x_5]$

$T_3 = [x_1, \quad x_4, \quad x_5]$

$T_4 = [x_2, \quad x_4]$

$T_5 = [x_2, \quad x_5]$

$T_6 = [x_2, \quad x_4, \quad x_5]$

in equation (3), we obtain:

$$f(x_1, x_2, x_4, x_5) = \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \end{bmatrix} \tag{4}$$

Now, by using orthogonalisation algorithm, equation (4) becomes:

$$f(x_1, x_2, x_4, x_5) = \begin{bmatrix} T_1 & & & & & \\ T_1', & T_2 & & & & \\ T_1', & T_2', & T_3 & & & \\ T_1', & T_2', & T_{3,}' & T_4 & & \\ T_1', & T_2', & T_3', & T_4', & T_5 & \\ T_1', & T_2', & T_3', & T_4', & T_5', & T_6 \end{bmatrix} \tag{5}$$

Now we have $T_1 = \begin{bmatrix} x_1 & x_4 \end{bmatrix}$ (6)

So, $T_1' = \begin{bmatrix} x_1' & \\ x_1, & x_4' \end{bmatrix}$

$$\therefore T_1' \; T_2 = \begin{bmatrix} x_1' & \\ x_1, & x_4' \end{bmatrix} \wedge \begin{bmatrix} x_1 & x_5 \end{bmatrix}$$
$$= \begin{bmatrix} x_1, & x_4', & x_5 \end{bmatrix} \tag{7}$$

Similarly, we draw the following conclusions:

$$T_1' \; T_2' \, T_3 = 0 \tag{8}$$

$$T_1' \; T_2' \; T_3' \, T_4 = \begin{bmatrix} x_1' & x_2 & x_4 \end{bmatrix} \tag{9}$$

$$T_1' \; T_2' \, T_3' \, T_4' \, T_5 = \begin{bmatrix} x_1' & x_2 & x_4' & x_5 \\ x_1 & x_2 & x_4' & x_5 \end{bmatrix} \tag{10}$$

And $T_1' \;\; T_2' \;\; T_3' \;\; T_4' \;\; T_5' \;\; T_6 = 0$ (11)

By using equations (6) through (11), equation (5) becomes:

$$f(x_1, x_2, x_4, x_5) = \begin{bmatrix} x_1 & x_4 & & \\ x_1 & x_4' & x_5 & \\ x_1' & x_2 & x_4 & \\ x_1' & x_2 & x_4' & x_5 \\ x_1 & x_2 & x_4' & x_5 \end{bmatrix} \tag{12}$$

Substituting value of $f(x_1, x_2, x_4, x_5)$ from equation (12) in equation (2), we obtain:

$$F(x_1, x_2, ---, x_6) = \begin{bmatrix} x_1 & x_3 & x_4 & x_6 & & \\ x_1 & x_3 & x_4' & x_5 & x_6 & \\ x_1' & x_2 & x_3 & x_4 & x_6 & \\ x_1' & x_2 & x_3 & x_4' & x_5 & x_6 \\ x_1 & x_2 & x_3 & x_4' & x_5 & x_6 \end{bmatrix} \qquad (13)$$

Now, R.H.S. of equation (13) is combination of pair-wise disjoint conjunctions, then if, R_i denotes the reliability corresponding to system state $x_i\left(\forall\, i = 1,2,--6\right)$, Finally Reliability of the system is given by eq.n (13) as follows:

$$R_S = \Pr.\{F(x_1, x_2, ---, x_6) = 1\}$$
$$= R_3R_6\left[R_1R_4 + R_1R_5(1-R_4) + (1-R_1)R_2R_4 + (1-R_1)(1-R_4)R_2R_5 + (1-R_4)R_1R_2R_5\right]$$
$$\text{or, } R_S = R_3R_6\left[R_1R_4 + R_1R_5 + R_2R_4 + R_2R_5 - R_1R_4R_5 - R_1R_2R_4 - R_2R_4R_5\right] \qquad (14)$$

III. Some Special Cases

Case1: If the reliability of each component of the system is R:
here, the equations (14) yields

$$R_S = 4R^4 - 3R^5 \qquad (15)$$

Case2: Here failure rates follow weibull distribution
Here λ_i is the failure rate of the system states follow weibull distribution and reliability for the system at time t, in this case, can be obtained from equation (14) are:

$$R_{SW}(t) = \sum_{i=1}^{4} \exp.\{-a_i t^{\alpha}\} - \sum_{j=1}^{3} \exp.\{-b_j t^{\alpha}\} \qquad (16)$$

where, α is a real positive parameter and we have

$$a_1 = \lambda_1 + \lambda_3 + \lambda_4 + \lambda_6$$

$$a_2 = \lambda_1 + \lambda_3 + \lambda_5 + \lambda_6$$

$$a_3 = \lambda_2 + \lambda_3 + \lambda_4 + \lambda_6$$

$$a_4 = \lambda_2 + \lambda_3 + \lambda_5 + \lambda_6$$

$$b_1 = \lambda_1 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6$$

$$b_2 = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_6$$

$$b_3 = \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6$$

Case3. When failure rates follow exponential time distribution
Exponential distribution is a corollary of weibull distribution for $\alpha = 1$. Therefore, we may obtain, from equation (16), the reliability function for considered system at time t by $\alpha = 1$ will be

$$R_{SE}(t) = \sum_{i=1}^{4} \exp.\{-a_i t\} - \sum_{j=1}^{3} \exp.\{-b_j t\} \qquad (17)$$

where a_i' s and b_j' s have been mentioned earlier. Also, M.T.T.F of the considered system is given by:

$$M.T.T.F. = \sum_{i=1}^{4} \frac{1}{a_i} - \sum_{j=1}^{3} \frac{1}{b_j} \qquad (18)$$

Numerical Computation: For a numerical calculation, we have

(a) $\lambda_i (i = 1,2,---,6) = \lambda = 0.02,\ \alpha = 2$ and $t = 1,2,----$.putting back in equation (16), we construct the table-1.

(b) $\lambda_i (i = 1,2,---,6) = \lambda = 0.02$ and $t = 1,2,----$.Putting back in equation (17), we construct the table-1.

(c) $\lambda_i (i = 1,2,---,6) = \lambda = 0, 0.01, 0.02 ----$. Using these values in equation (18), we compute the table-2. The corresponding graph has been given in fig-4.

IV. Results and Discussions

Table-1 gives the values of $R_{SW}(t)$ and $R_{SE}(t)$ for different values at time 't'. The graph has been shown in fig-2. Analysis of table-1 and fig-3 yields that the values of $R_{SE}(t)$ remains better as compared to $R_{SW}(t)$ as we make increase in the values of time 't'. The values of $R_{SW}(t)$ decrease rapidly for higher values of 't' which satisfies the basic assumptions of reliability engineering.

Table-2 contains the values of M.T.T.F. for different values of failure rate λ. The graph has been shown in the fig-3. Checking the table-2 and fig-4 reveals that for lower values of λ, M.T.T.F. decreases in constant manner but for higher values of λ, M.T.T.F. decreases catastrophically.

Table No. 1: The values of $R_{SW}(t)$ and $R_{SE}(t)$ for different values at time 't'

t	$R_{SW}(t)$	$R_{SE}(t)$
0	1	1
1	0.977953	0.977953
2	0.893636	0.952383
3	0.727300	0.924057
4	0.50646	0.893636
5	0.295086	0.861688
6	0.142568	0.828699
7	0.057025	0.795080
8	0.18919	0.761183
9	0.005225	0.72730
10	0.001206	0.693678

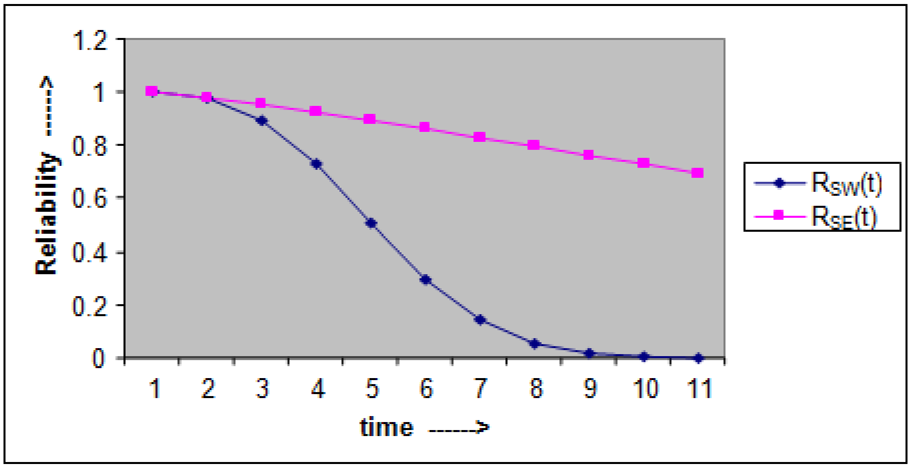

Figure No. 3: The values of $R_{SE}(t)$ vs $R_{SW}(t)$ for different values of 't'

Table No. 2: The values of M.T.T.F. for different values of failure rate (λ)

λ	M.T.T.F.
0	∞
0.01	40.00
0.02	20.00
0.03	13.33
0.04	10.00
0.05	8.00
0.06	6.67
0.07	5.71
0.08	5.00
0.09	4.44
0.10	4.00

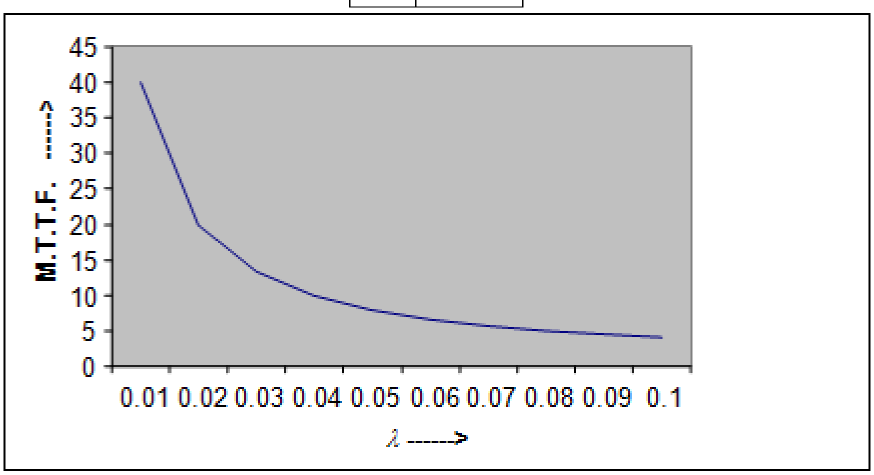

Figure No. 3: The values of M.T.T.F. for various values of failure rate (λ)

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