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Boolean function approach for reliability of dual channel logic communication system

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Abstract

In this paper the author has tried to consider a Dual channel logic communication system. The purpose of this paper is to accomplished the reliability of dual channel logic *communication system using Boolean* function technique the failure and repair rates of the subsystem. The whole system consists of five main parts. First part of the system is a type I and it has three sections in a parallel redundancy .Second part of the system is a Transmitter. Third part of the system is Communication Channel which has two sections in parallel redundancy. Fourth part of the system is receiver .The fifth part of the system consists of the three parallel outputs; these five parts are connected in series. The author has been used the Boolean functions to evaluate ability measures of the considered system. Reliability of the whole system has obtained in three different cases as when the reliability of each component of the system is R, if failure rates follow Weibull time distribution and the failures follows exponential time distribution.

Keywords

Boolean function, Reliability, Dual channel, Logic communication system.

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Contents

1. Introduction

[1] Gupta P.P. Agarwal S.C. has applied a Boolean Algebra Method for Calculations of Reliability [2] Gupta P.P. Kumar Arvind, M.T.T.F Analysis and Reliability of Power Plant. [5] Sharma, Deepankar, Sharma, Neelam, some Reliability Parameters for Dual channel logic communication system By Boolean function Technique and Sharma Deepankar, [6] Sharma Neelam, find the Reliability and M.T.T.F. of Solar voltaic cell. In this paper, the author has considered a Dual channel logic communication System. The whole system consists of five main parts. First part of the system is a sender it has three sections type I (k_1), type II (k_2), type III (k_3) in parallel redundancy. Second part of the system is Transmitter (k_4) once the source signal has been converted into an electric signal, the transmitter will modify this signal for efficient transmission. Third part of the system is communication channel it has two sections k_5 and k_6 it modifies simply referring to the medium by which a signal travels. Fourth part is Receiver is the destination of the message. The receiver task is to interpret the sender message both verbal and nonverbal with as little distortion as possible and it is denoted by k_7 and the last is output is represented by k_8, k_9, k_{10}. All these five parts are connected in series. Therefore, the failure of any of the five parts causes the total failure of the system. To avoid the tedious calculations, the author has used the Boolean function and algebra of logics to evaluate ability measures for considered system of the whole system has obtained in two different cases as the failures follow exponential time distribution and the failures follow Weibull time distribution.

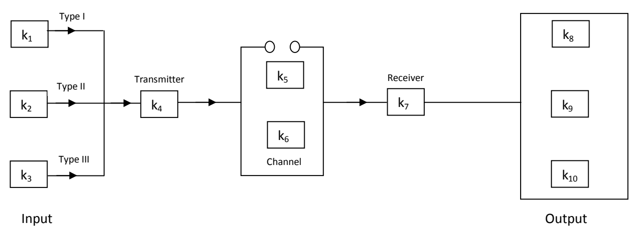

Figure 1

2. Notations

The following notations have been used throughout this model:

k_1, k_2, k_3: States of Input Type I, Type II, Type III respectively.

k_2: States of Transmitter.

k_5, k_6: States of channel.

k_7: States of Receiver.

k_8, k_9, k_{10}: States of Output.

k_i $(i = 1, 2, \ldots, 10)$: Negation of k_i

$\wedge$: Conjunction, disjunction.

II: This notation has used to represent logical matrix.

R_i $(i = 1, 2, \ldots, 10)$: Reliability of ith component of the system.

3. Formulation of the Model

By using Boolean Algebra, the condition of capability of the successful operation of this Dual channel logical communication system in terms of logical matrix is expressed as under:

$$\text{Matrix} \begin{vmatrix} k_1 & k_4 & k_5 & k_7 & k_8 \\ k_1 & k_4 & k_6 & k_7 & k_8 \\ k_2 & k_4 & k_5 & k_7 & k_9 \\ k_2 & k_4 & k_6 & k_7 & k_9 \\ k_3 & k_4 & k_5 & k_7 & k_{10} \\ k_3 & k_4 & k_6 & k_7 & k_{10} \end{vmatrix} \tag{3.1}$$

4. Solution of the Model

By using laws of algebra of logics, equation (3.1) may be written as:

$$F(k_1, k_2, k_3, \ldots, k_{10}) = k_4, k_7 \wedge f(k_1, k_2, k_3, k_5, k_6, k_8, k_9, k_{10}). \tag{4.1}$$

where

$$F(K_1, k_2, \ldots, k_{10}) = \begin{vmatrix} k_1 & k_5 & k_8 \\ k_1 & k_6 & k_8 \\ k_2 & k_5 & k_9 \\ k_2 & k_6 & k_9 \\ k_3 & k_5 & k_{10} \\ k_3 & k_6 & k_{10} \end{vmatrix} = \begin{vmatrix} M_1 \\ M_2 \\ M_3 \\ M_4 \\ M_5 \\ M_6 \end{vmatrix} \tag{4.2}$$

$$M_1 = \begin{vmatrix} k_1 & k_5 & k_8 \end{vmatrix} \tag{4.3}$$

$$M_2 = \begin{vmatrix} k_1 & k_6 & k_8 \end{vmatrix} \tag{4.4}$$

$$M_3 = \begin{vmatrix} k_2 & k_5 & k_9 \end{vmatrix} \tag{4.5}$$

$$M_4 = \begin{vmatrix} k_2 & k_6 & k_9 \end{vmatrix} \tag{4.6}$$

$$M_5 = \begin{vmatrix} k_3 & k_5 & k_{10} \end{vmatrix} \tag{4.7}$$

$$M_6 = \begin{vmatrix} k_3 & k_6 & k_{10} \end{vmatrix} \tag{4.8}$$

$$M'_1 = \begin{vmatrix} K'_1 & & \\ K_1 & K'_5 & \\ K_1 & K_5 & K'_8 \end{vmatrix} \tag{4.9}$$

$$M'_2 = \begin{vmatrix} k'_1 & & \\ K_1 & k'_6 & \\ K_1 & k_6 & k'_8 \end{vmatrix} \tag{4.10}$$

$$M'_3 = \begin{vmatrix} k'_2 & & \\ K_2 & k'_5 & \\ K_2 & k_5 & k'_9 \end{vmatrix} \tag{4.11}$$

$$M'_4 = \begin{vmatrix} k'_2 & & \\ K_2 & k'_6 & \\ K_2 & k_6 & k'_9 \end{vmatrix} \tag{4.12}$$

$$M'_5 = \begin{vmatrix} k'_3 & & \\ K_3 & k'_5 & \\ K_3 & k_5 & k'_{10} \end{vmatrix} \tag{4.13}$$

$$M'_6 = \begin{vmatrix} k'_3 & & \\ K_3 & k'_6 & \\ K_3 & k_6 & k'_{10} \end{vmatrix} \tag{4.14}$$

Using orthogonalisation algorithm , equation (4.2) may be written as:

$$F(k_1, k_2, \ldots, k_{10}) = \begin{vmatrix} M_1 & & & & & \\ M'_1 & M_2 & & & & \\ M'_1 & M'_2 & M_3 & & & \\ M'_1 & M'_2 & M'_3 & M_4 & & \\ M'_1 & M'_2 & M'_3 & M'_4 & M_5 & \\ M'_1 & M'_2 & M'_3 & M'_4 & M'_5 & M_6 \end{vmatrix} \tag{4.15}$$

$$M'_1 M_2 = \begin{vmatrix} k'_1 & & \\ K_1 & k'_5 & \\ K_1 & K_5 & K'_8 \end{vmatrix} \wedge \begin{vmatrix} k_1 & k_6 & k_8 \end{vmatrix} \tag{4.16}$$

$$= \begin{vmatrix} k_1 & k'_5 & k_6 & k_8 \end{vmatrix} \tag{4.17}$$

Similarly

$$M'_1 M'_2 M_3 = \begin{vmatrix} k'_1 & k_2 & k_5 & k_9 & & \\ k_1 & k_2 & k_5 & k'_6 & k'_8 & k_9 \\ k_1 & k_2 & k_5 & k_6 & k'_8 & k_9 \end{vmatrix} \tag{4.18}$$

$$M'_1 M'_2 M'_3 M_4 = \begin{vmatrix} k'_1 & k_2 & k'_5 & k_6 & k_9 & \\ k_1 & k_2 & k'_5 & k_6 & k'_8 & k_9 \end{vmatrix} \tag{4.19}$$

$$M_1'M_2'M_3'M_4'M_5 = \left| \begin{array}{llllllll} k_1' & k_2' & k_3 & k_5 & k_{10} & & & \\ k_1' & k_2 & k_3 & k_5 & k_6' & k_9' & & \\ k_1' & k_2 & k_5 & k_6 & k_9' & k_{10} & & \\ k_1 & k_2' & k_3 & k_5 & k_6' & k_8' & k_{10} & \\ k_1 & k_2 & k_3 & k_5 & k_6' & k_8' & k_9' & k_{10} \\ k_1 & k_2' & k_3 & k_5 & k_6 & k_8' & k_{10} & \\ k_1 & k_2 & k_3 & k_5 & k_6 & k_8' & k_9' & \end{array} \right| \tag{4.20}$$

$$M_1'M_2'M_3'M_4'M_5'M_6 = \left| k_1' \quad k_2 \quad k_3 \quad k_5 \quad k_6 \quad k_9' \quad k_{10} \right| \tag{4.21}$$

Using all these values in equation (4.15) one can obtain:

$$\left| \begin{array}{llllllll} k_1 & k_5 & k_8 & & & & & \\ k_1 & K_5' & k_6 & k_8 & & & & \\ k_1' & k_2 & k_5 & k_9 & & & & \\ k_1 & k_2 & k_5 & K_6' & K_8' & k_9 & & \\ k_1 & k_2 & k_5 & k_6 & K_8' & k_9 & & \\ k_1' & k_2 & K_5' & k_6 & k_9 & & & \\ k_1 & k_2 & K_5' & k_6 & K_8' & k_9 & & \\ K_1' & k_2 & k_3 & k_5 & k_{10} & & & \\ K_1' & k_2 & k_3 & k_5 & K_6' & K_9' & k_{10} & \\ K_1' & k_2 & k_5 & k_6 & K_9' & k_{10} & & \\ k_1 & K_2' & k_3 & k_5 & k_6 & K_8' & k_{10} & \\ k_1 & k_2 & k_3 & k_5 & K_6' & K_8' & K_9' & k_{10} \\ k_1 & K_2' & k_3 & k_5 & k_6 & K_8' & k_{10} & \\ k_1 & k_2 & k_3 & k_5 & k_6 & K_8' & K_9' & \\ K_1' & k_2 & k_3 & k_5 & k_6 & k_9' & k_{10} & \end{array} \right| \tag{4.22}$$

Using this result in equation (4.1) we have

$$F(k_1, k_2, \ldots, k_{10}) =$$

$$\left| \begin{array}{llllllllll} k_1 & k_4 & k_5 & k_7 & k_8 & & & & & \\ k_1 & k_4 & k_5' & k_6 & k_7 & k_8 & & & & \\ k_1' & k_2 & k_4 & k_5 & k_7 & k_9 & & & & \\ k_1 & k_2 & k_4 & k_5 & k_6' & k_7 & k_8' & k_9 & & \\ k_1 & k_2 & k_4 & k_5 & k_6 & k_7 & k_8' & k_9 & & \\ k_1' & k_2 & k_4 & k_5' & k_6 & k_7 & k_9 & & & \\ k_1 & k_2 & k_4 & k_5' & k_6 & k_7 & k_8' & k_9 & & \\ k_1' & k_2 & k_3 & k_4 & k_5 & k_7 & k_{10} & & & \\ k_1' & K_2 & K_3 & K_4 & K_5 & k_6' & K_7 & k_9' & K_{10} & \\ K_1 & k_2' & K_3 & K_4 & K_5 & k_6' & K_7 & k_8' & K_{10} & \\ K_1 & k_2 & k_3 & k_4 & k_5 & k_6' & k_7 & k_8' & k_9' & k_{10} \\ k_1 & K_2' & k_3 & k_4 & k_5 & k_6 & k_7 & k_8' & k_{10} & \\ k_1 & k_2 & k_3 & k_4 & k_5 & k_6 & k_7 & k_8' & k_9' & \\ k_1' & k_2 & k_3 & k_4 & k_5 & k_6 & k_7 & k_9' & k_{10} & \end{array} \right| \tag{4.23}$$

Since R.H.S. Of equation (4.23) is the disjunction therefore the reliability of considered dual channel logic communication system is given by

$$\begin{aligned} R_s &= P_r(f(K_1, K_2, K_{10}) = 1) \\ &= R_4R_7[R_1R_5R_8 + R_1(1-R_5)R_6R_8 \\ &\quad + (1-R_1)R_2R_5R_9 + R_1R_2R_5(1-R_6)(1-R_8)R_9 \\ &\quad + R_1R_2R_5R_6(1-R_8)R_9 + (1-R_1)R_2(1-R_5)R_6R_9 \\ &\quad + R_1R_2(1-R_5)R_6(1-R_8)R_9 + (1-R_1)R_2R_3R_5R_{10} \\ &\quad + (1-R_1)R_2R_3R_5(1-R_6)(1-R_9)R_{10} \\ &\quad + (1-R_1)R_2R_5R_6(1-R_9)R_{10} \\ &\quad + R_1(1-R_2)R_3R_5(1-R_6)(1-R_8)R_{10} \\ &\quad + R_1R_2R_3R_5(1-R_6)(1-R_8)R_{10} \\ &\quad + R_1(1-R_2)R_3R_5R_6(1-R_8)R_{10} \\ &\quad + R_1R_2R_3R_5R_6(1-R_8)(1-R_9) \\ &\quad + (1-R_1)R_2R_3R_5R_6R_7(1-R_9)R_{10}] \end{aligned}$$

5. Particular Cases

Case I: If the reliability of each component of the given system is then equation yields

$$R_s = 4R^5 + 2R^6 - 7R^7 + 4R^8 - R^9 - R^{10}$$

CASE II: if we assume failure rate of each component of the complex system be a, then the

Reliability of the whole system at time t, is given by

$$\begin{aligned} A_{sw}(t) &= 4\exp(-5at^p) + 2\exp(-6at^p) \\ &\quad - 7\exp(-7at^p) + 4\exp(-8at^p) \\ &\quad - \exp(-9at^p) - \exp(-10at^p) \end{aligned}$$

CASE III: If failure rates follow exponential distribution Exponential distribution is a particular case of Weibull distribution for $p = 1$ and is very useful in numerous daily life problems. Therefore the reliability of this dual channel logic communication system is given by:

$$\begin{aligned} A_{SE}(t) &= 4e^{-5at} + 2e^{-6at} - 7e^{-7at} + 4e^{-8at} \\ &\quad - e^{-9at} - e^{-10at} \end{aligned}$$

The expression for M.T.T.F. in this case is given by

$$\begin{aligned} M.T.T.F. &= \int A_{SE}(t)dt \\ &= 1/a(4/5 + 2/6 - 7/7 + 4/8 - 1/9 - 1/10) \\ &= 0.42222/a \end{aligned}$$

6. Result and Conclusion

Let $a = 0.02$ and $p = 2$ then comparing Weibull and Exponential distribution with increasing time

Table 1

T	A_{SE}	A_{sw}
0	1	1
0.5	0.836	0.913
1	0.703	0.703
1.5	0.594	0.464
2	0.503	0.269
2.5	0.428	0.137
3	0.365	0.061
3.5	0.312	0.024
4	0.267	0.00816

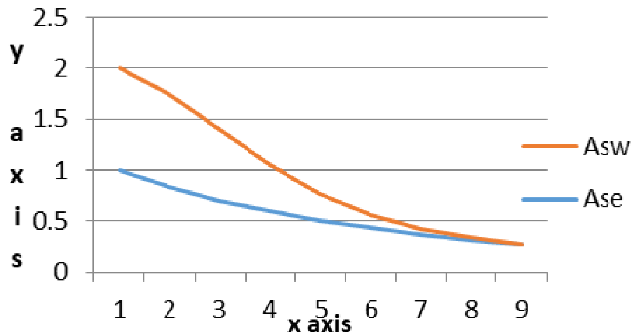

Figure 2

Table 2

A	M.T.T.F.
0.001	422.2
0.002	211.11
0.003	140.74
0.004	105.555
0.005	84.444
0.006	70.37
0.007	60.317
0.008	52.7775
0.009	46.913

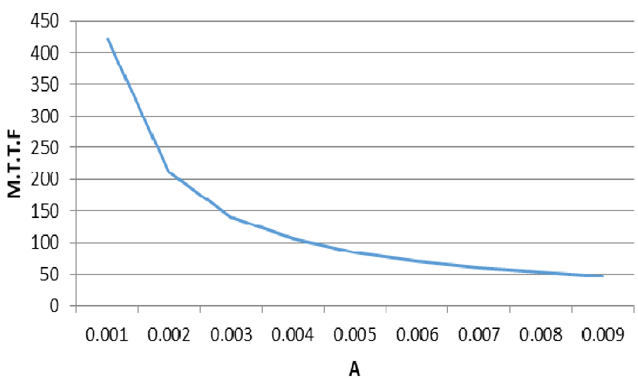

Figure 3

Figure 2 represents the reliability of the whole system at any time t when failure rates follow exponential and weibull distribution critical examination of the graph, reliability Vs time indicates that the reliability of the system decreases at a uniform rate in case exponential distribution whereas it decreases rapidly when failure rate follows weibull distribution.

The mean time to failure of the system for different values of failure rates as impression of graph M.T.T.F. Vs failure rates, shows that in the beginning M.T.T.F. decreases approximately at a uniform rate.

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