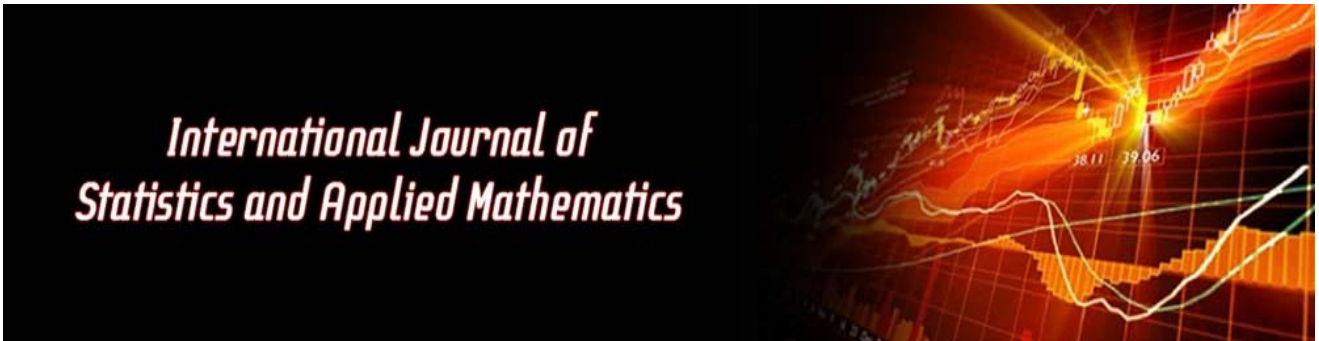

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Analysis of various factors of reliability using Boolean function technique in refinery unit

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Abstract
For the system of multistation elements, the problems of developing Boolean reliability model has acknowledged on the basis of algebra of groups of incompatible events. The objective of this paper to find the various reliability factor of refinery unit which is a subunit of Vacuum Distillation Unit (VDU). The subunits used in the considered unit are Pump, Desalter, Furnace, atmospheric fractionator and gas separator and these subunits are connected through pipes. The reliability factor and mean time to failure (MTTF) is Exponentially and weibully distributed. We illustrate the use of technique by means of examples and introduce numerical results.

Keywords: Boolean function, reliability, vacuum distillation unit (VDU), MTTF, Desalter, refinery

Introduction
About 80% of the refineries have a vacuum distillation unit. A secondary processing unit consisting of VDU. In the refining process, the atmospheric distillation unit is separate the lighter hydro carbon from the heavier oil based on the boiling point. The ADU is capable of boiling crude oil fraction to the temperature of 750ºF. Above this temperature the oil will be thermally crack impedes the distillation process. The lighter products are boiled up and the heavier oil called bottoms remain at the bottom of ADU. These bottoms are run through a vacuum distillation column for further refinement.

These vacuum distillation columns are less than atmospheric pressure of 760 mm of mercury. Gas oils are slightly heavier than middle distillates such as jet fuel, Diesel, Kerosene. These gas oils are further refined to make such light cycle oil, gasoline.

The desalted crude enter the heat exchange network which use the vapour of column condenser, the pump around the circuits streams and the products are cooled and then enters the furnace where it is heated to about 340-372 ºC.

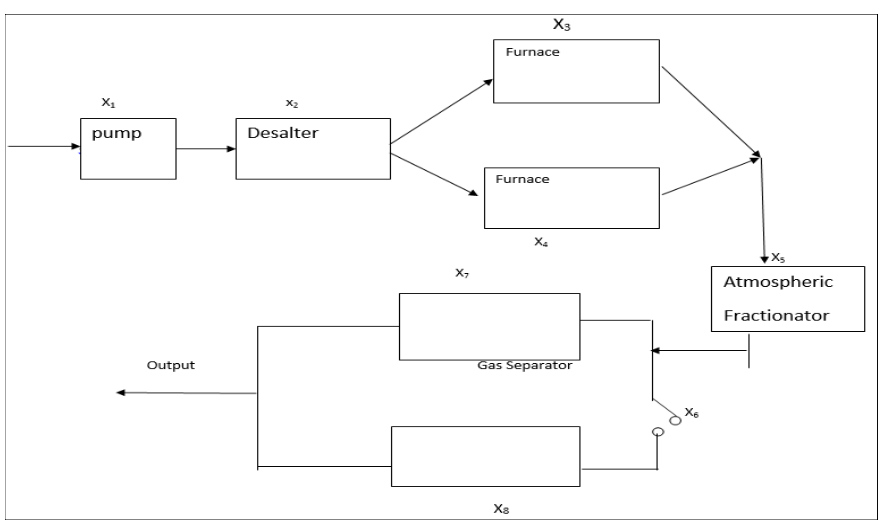

Fig 1

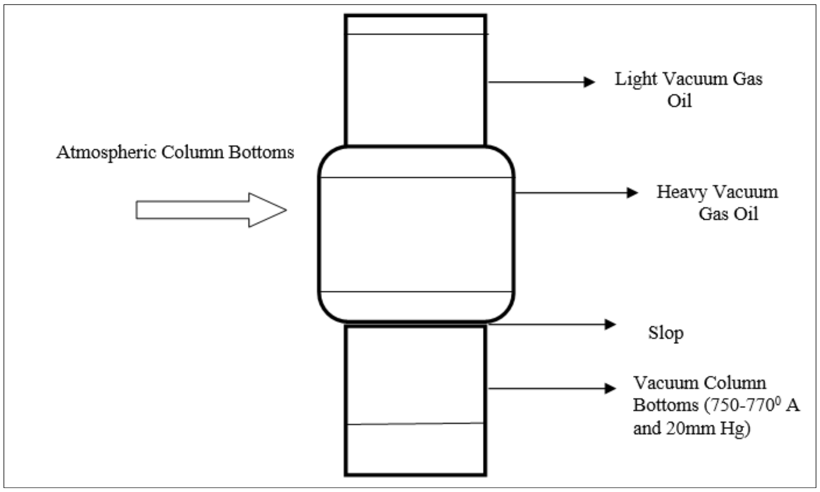

Fig 2

Assumptions
The following assumption have been associated with this model:
a) Initially, the whole system is good and operable.
b) Every component of the system remains either in good or bad state.
c) There is no repair facility to repair a failed component.
d) The whole system can fail due to failure of any one of its units.
e) Failures are statistically-independent.

Notations

x_1	:	state of pump
x_2	:	state of desalter
x_3,x_4	:	states of furnace
x_5	:	state of atmospheric fractionator
x_6	:	state of switching device
x_7,x_8	:	states of gas separator
$x_i(i=1,2,3.......8)$	:	1 in good state;0 is bad state.
$x^{`i}$	:	negation of for $x^{`i}$all i
$\wedge / \vee$	:	conjunction/disjunction
| |	:	this notation has used to represent logical matrix.
R_i	:	Reliability of ith part of the system, $\forall$ i=1,2…….8.
Q_i	:	1-R_i
R_s	:	Reliability of the whole system.
$R_{sw}(t)/R_{SE}(t)$	:	Reliability of the system as a whole when failures follow weibull/Exponential time distribution.

Formulation of mathematical model
By making use of Boolean function technique, the condition of capability of successful operation of the system in terms of logical matrix are expressed as shown below:

$$F\,(x_1.......x_8) = \begin{vmatrix} x_1 & x_2 & x_3 & x_5 & x_7 & \\ x_1 & x_2 & x_4 & x_5 & x_7 & \\ x_1 & x_2 & x_3 & x_5 & x_6 & x_8 \\ x_1 & x_2 & x_4 & x_5 & x_6 & x_8 \end{vmatrix} \qquad (1)$$

Solution of the model
By using algebra of logics, we may write eq^n (1)again as,
$$F(x_1, x_2, ..., x_8)=(x_1\, x_2\, x_5) \wedge f(x_1,x_2\, ..., x_8) \qquad (2)$$

where

$$f(x_1, x_2, \ldots\ldots, x_8) = (x_1 \quad x_2 \quad x_5) \wedge \begin{vmatrix} x_3 & x_7 & \\ x_4 & x_7 & \\ x_3 & x_6 & x_8 \\ x_4 & x_6 & x_8 \end{vmatrix} \tag{3}$$

Let

$$B_1 = | x_3 \quad x_7 | \tag{4}$$

$$B_2 = | x_4 \quad x_7 | \tag{5}$$

$$B_3 = | x_3 \quad x_6 \quad x_8 | \tag{6}$$

$$B_4 = | x_4 \quad x_6 \quad x_8 | \tag{7}$$

$$\Rightarrow \; | x_1 \quad x_2 \quad x_5 | \wedge \begin{vmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{vmatrix} \qquad \text{[from eq. (4),(5),(6),(7)]}$$

Using orthogonalization process

$$\begin{vmatrix} B_1 & & & \\ B_1' & B_2 & & \\ B_1' & B_2' & B_3 & \\ B_1' & B_2' & B_3' & B_4 \end{vmatrix} \tag{8}$$

Where

$$B_1' = \begin{vmatrix} x_3' & \\ x_3 & x_7' \end{vmatrix} \tag{9}$$

$$B_1' B_2 = | x_3' \quad x_4 \quad x_7 | \tag{10}$$

$$B_1' B_2' B_3 = \begin{vmatrix} x_3 & x_4' & x_6 & x_7' & x_8 \\ x_3 & x_4 & x_6 & x_7' & x_8 \end{vmatrix} \tag{11}$$

Using all these values in equation (8), we obtain

$$f(x_3, x_4, x_6, x_7, x_8) = \begin{vmatrix} x_3 & x_7 & & & \\ x_3' & x_4 & x_7 & & \\ x_3 & x_4' & x_6 & x_7' & x_8 \\ x_3 & x_4 & x_6 & x_7' & x_8 \\ x_3' & x_4 & x_6 & x_7' & x_8 \end{vmatrix} \tag{13}$$

Using equation(13), equation (2) becomes

$$F(x_1, x_2, \ldots\ldots\ldots, x_8) = \left| \begin{matrix} x_1 & x_2 & x_3 & x_5 & x_7 & & & \\ x_1 & x_2 & x_3' & x_4 & x_5 & x_7 & & \\ x_1 & x_2 & x_3 & x_4' & x_5 & x_6 & x_7' & x_8 \\ x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7' & x_8 \\ x & x_2 & x_3' & x_4 & x_5 & x_6 & x_7' & x_8 \end{matrix} \right| \quad (14)$$

since equation (13) is the disjunction of disjoint conjunction, therefore, the reliability of the whole system is given by
$R_s = P_r\{F(x_1, x_2, \ldots\ldots, x_8)\}$ Or

$R_s = R_1R_2R_5[R_3R_7 + R`_3R_4R_7 +_{.} R_3R`_4R_6R`_7R_8 + R_3R_4R_6R`_7R_8 + R`^3R_4R_6R`_7R_8]$

$= R_1R_2R_5[R_3R_7 + (1-R_3)R_4R_7 + R_3(1-R_4)R_6(1-R_7)R_8 + R_3R_4R_6(1-R_7)R_8 + (1-R_3)R_4R_6(1-R_7)R_8]$

$= R_1R_2R_5[R_3R_7 + R_4R_7 - R_3R_4R_7 + R_3R_6R_8(1-R_4)(1-R_7) + R_3R_4R_6R_8(1-R_7) + R_4R_6R_8(1-R_3)(1-R_7)]$
$= R_1R_2R_5[R_3R_7 + R_4R_7 - R_2R_4R_7 + R_3R_6R_8 - R_3R_7R_6R_8 - R_4R_6R_3R_8 + R_3R_4R_6R_7R_8 + R_3R_4R_6R_8 - R_3R_4R_6R_7R_8 + R_4R_6R_8 - R_3R_4R_6R_8 - R_4R_6R_7R_8 + R_3R_4R_6R_7R_8]$
$= R_1R_2R_3R_5R_7 + R_1R_2R_4R_5R_7 - R_1R_2R_3R_4R_5R_7 + R_1R_2R_3R_5R_6R_8 - R_1R_2R_3R_7R_5R_6R_8 - R_1R_2R_4R_5R_6R_3R_8 + R_1R_2R_3R_4R_5R_6R_7R_8 + R_1R_2R_3R_4R_5R_6R_8 - R_1R_2R_3R_4R_5R_6R_7R_8 + R_1R_2R_4R_5R_6R_8 - R_1R_2R_3R_4R_5R_6R_8 - R_1R_2R_4R_5R_6R_7R_8 + R_1R_2R_3R_4R_5R_6R_7R_8$

Some Particular Cases
Case 1: When reliability of each component is R.
$$2R^5 - 3R^7 + R^6 + R^8 \quad (15)$$
Case 2: When failure rates follow weibull distribution
$$R_{SW}(t) = \sum_{i=1}^{7} e^{-\alpha_i t^b} - \sum_{j=1}^{6} e^{-\beta_j t^b} \quad (16)$$
$\alpha_1 = c + a_3 + a_7$
$\alpha_2 = c + a_4 + a_7$
$\alpha_3 = c + a_4 + a_6 + a_8$
$\alpha_4 = c + a_3 + a_4 + a_6 + a_7 + a_8$
$\alpha_5 = c + a_3 + a_4 + a_6 + a_8$
$\alpha_6 = c + a_4 + a_6 + a_8$
$\alpha_7 = c + a_3 + a_4 + a_6 + a_7 + a_8$
$c = a_1 + a_2 + a_5$
$\beta_1 = c + a_3a_4 + a_7$
$\beta_2 = c + a_3 + a_4 + a_6 + a_8$
$\beta_3 = c + a_4 + a_6 + a_7 + a_8$
$\beta_4 = c + a_3 + a_4 + a_6 + a_7 + a_8$
$\beta_5 = c + a_3 + a_4 + a_6 + a_8$
$\beta_6 = c + a_4 + a_6 + a_7 + a_8$

Case 3: When failure rate follow exponential time distribution
Exponential distribution is nothing but a particular case of weibull distribution for b=1 and is very useful for practical problems purpose. Therefore, the reliability of considered system as a whole at an instant's' is expressed as:

$$R_{SE}(t) = \sum_{i=1}^{7} e^{-\alpha_i t} - \sum_{j=1}^{6} e^{-\beta_j t} \quad (17)$$

Where α_i and β_j's have mentioned earlier.
Also, an important reliability parameter, viz; M.T.T.F., in this case is given by

$$\text{M.T.T.F} = \int_0^{\infty} R_{SE}\, dt$$

$$= \sum_{i=1}^{7} \frac{1}{\alpha_j} - \sum_{i=1}^{7} \frac{1}{\beta_j} \quad (18)$$

Numerical Example

For a numerical computation,setting:

(A) a_i(i= 1,2,…….7) = 0.001, α= 2 and t=0,1,2,…. In eq. (16)

(B) a_i(i=1,2…….7) =0.001, and t=0,1,2……..in eq.(17)

(C) a_i(i=1,2,……..7)=0,0.1,………..1.0 in eq. (18)

one can compute the table 1 and 2. The corresponding graph have been shown through fig. 3 and 4. Respectively

Table 1

T	R_{SW}(t)	R_{SE}(t)
0	1	1
1	0.9970015085	0.9970015085
2	0.9940060676	0.9880245381
3	0.9910137276	0.9731275449
4	0.9880245381	0.9524173155
5	0.985038548	0.9260614724
6	0.9820558059	0.8943031027
7	0.9790763598	0.8574750472
8	0.9761002572	0.8160112371
9	0.9731275449	0.7704526549
10	0.9701582693	0.7214460083

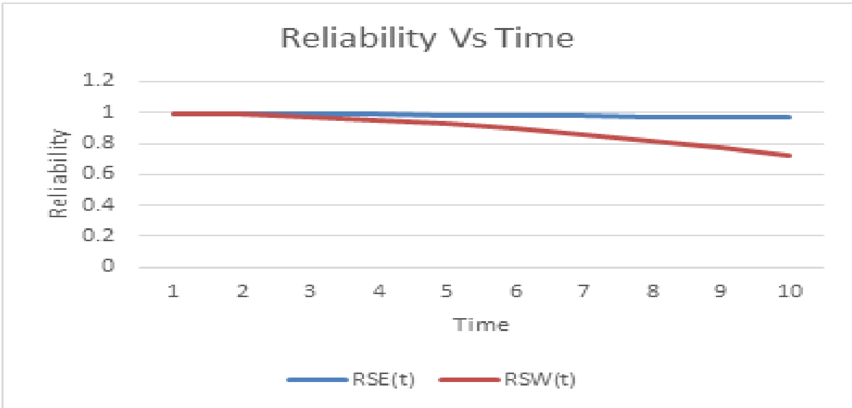

Fig 3

Table 2

A	MTTF
0	∞
0.1	2.4920634921
0.2	1.3154761905
0.3	.86984127
0.4	.3005952381
0.5	0.2404761905
0.6	0.2003968254
0.7	0.1717687075
0.8	0.150297619
0.9	0.1335978836
1	0.1202380952

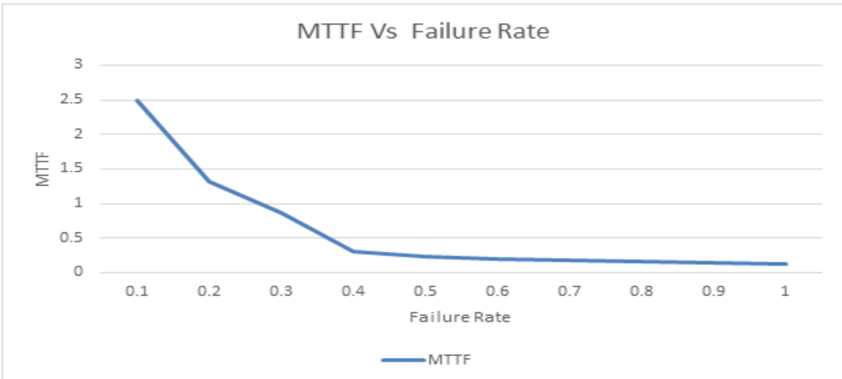

Fig 4

Results and Discussion

In this paper the author has acknowledged a refinery unit which is a subunit of vacuum distillation unit for the analysis of various reliability parameter by utilizes the Boolean function technique and algebra of logics.

Table 1 computes the reliability of system with respect to time when failure rate is exponential and weibull distribution. An inspection of graph 'Reliability Vs time'fig. 3 compute that in case of exponential distribution, reliability of the complex system decreases approximately at uniform rate but in case of weibull distribution,failure rate decreases rapidly.

Table 2 and graph "M.T.T.F Vs failure rate" produce that M.T.T.F of the system decreases catastrophically in the beginning but after that it decreases approximately at a uniform rate.

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