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Availability Analysis of a Hybrid Boiler System using RPGT

Shamsher Singh Mor

Principal, Sarla Memorial Govt. Girls College, Safidon (Jind), Haryana

Email: morss1452@gmail.com

ABSTRACT: - This research report uses RPGT under certain conditions for system characteristics to analyses the profitability of a hybrid boiler Rico plant. The hybrid boiler consists of four units in the system out of a, b, c, & d which units a, b, & c have sub components in series, so if any of the sub components of a sub system fails leads to the failure of that sub system leads to the failure of that sub system leads to the failure of that sub system and the failure of the whole system. In a hybrid boiler system, Unit "D" has two cold standby redundant units. When every component is in good functioning order, the system is said to be in a working state. All subunits have access to a repair facility.Finally, numerical analysis is carried out for calculating the performance measures and their comparisons.

1. Introduction

The maintenance of higher levels or threshold levels of a reliability measure is necessary in the systems. Reliability performance measures play a significant role in industrial systems, fertilizer plants, power plants, manufacturing systems, and engineering systems. The majority of systems maintain these levels through effective repair and maintenance procedures, but it is still praised to preserve the highest level standby redundant units for a specific system. Sometimes a redundant unit in the system needs to be made plentiful as well as an online unit, for example in a hybrid better system where there may be these forms of input full.Gas, cool, liquid fuel initially, the furnace uses cool fuel, which can fail (due to a cool supply shortage or a local fault). The furnace unit in the heating system may then be set to operate with a standby gas supply unit, which can also fail (due to state exhaustion or a fault in the gas supply unit). In an emergency, liquid fuel (diesel or petrol) is then used. Therefore, it may be necessary to have more than one redundant unit; industrial systems might be one of many more examples.In this study, we looked at a system with four units connected in series, three of which have subsystems connected in series so that if one fails, the entire system fails. However, because the fan unit is so important, there are two cold standby redundant units available that may have the same failure modes as the fan unit. If the main online and both standby redundant units fail, the sub system will also fail, ultimately resulting in the breakdown of the entire system.The system has a single server that fixes all different kinds of units and is always operational. Distinct subsystems' repair rates follow different exponential distributions. The major goal of this work, according to Kumar et al. (2019), is to examine and analyses a washing unit used in the paper industry using RPGT.Kumar et al. (2018, 2017) have deliberated the behavior examination of a bread scheme and edible oil refinery plant. Kumar et al. (2019) analyzed a cold standby agenda with priority for PMcovers two identical subunits by server failure utilizing RPGT. Gupta (2008), Chaudhary et al. (2013), Goyal and Goel (2015), Yusuf (2012) and Gupta et al. (2016) have discussed conduct with perfect and imperfect switch-over of arrangementsby various techniques.Figure 1 below depicts a steady state transition diagram taking these transition rates into account. Transition probabilities, sojourn periods, state probabilities, and reliability metrics are modeled using RPGT expressions.

2. Assumptions and notations

- Failure/Repair rates are constant.
- The subsystem D functioned as a standby mode.
- A, B, C and D remain used aimed at working state.
- a, b, c, and d are used for unsuccessful state.
- m_i /h_i : Indicates the failure/repair rates

3. Transition Diagram

The system's Transition Diagram, which takes into account the aforementioned hypotheses and notations, is shown in Figure 1.

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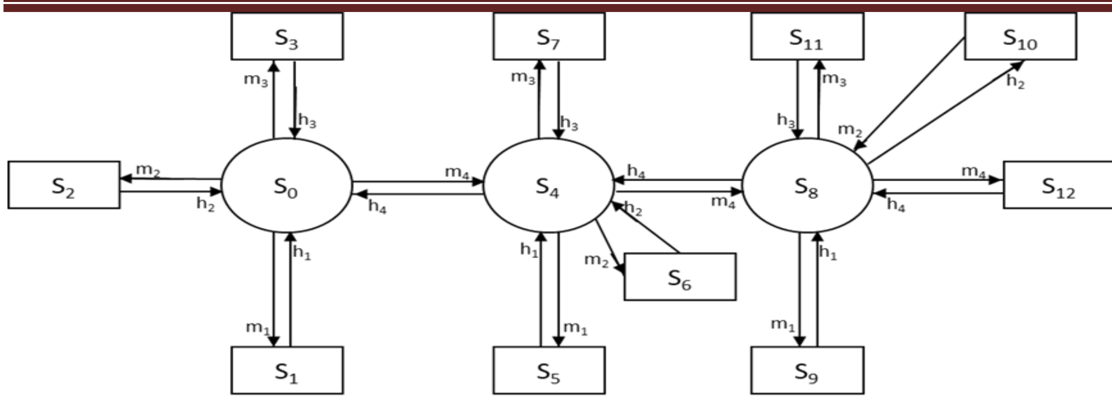

Figure 1: Transition Diagram

S_0 = ABCD,	S_1 =aBCD,	S_2 =AbCD,	S_3 =ABcD,
S_4 =ABCD$_1$,	S_5 =aBCD$_1$,	S_6 =AbCD$_1$,	S_7 =ABcD$_1$,
S_8 = ABCd$_2$,	S_9 =aBCD$_2$,	S_{10} = AbCD$_2$,	S_{11} = ABcD$_2$,
S_{12} = ABCd			

4. Transition Probabilities and the Mean Sojourn Time

$q_{i,j}(t)$**:** probability density capacity of main passage time from a state i to a regenerative state j or to a bombed state j without visiting some another state in.

$p_{i,j}$**:** consistent state transition likelihood from a state i to a regenerative state j without visiting some another state. $p_{i,j} = q_{i,j}^{*}(0)$.

State Transition Probabilities

$\mathbf{q_{i,j}(t)}$

$$q_{0,1}(t) = m_1 e^{-(m_1+m_2+m_3+m_4)t}$$

$$q_{0,2}(t) = m_2 e^{-(m_1+m_2+m_3+m_4)t}$$

$$q_{0,3}(t) = m_3 e^{-(m_1+m_2+m_3+m_4)t}$$

$$q_{0,4}(t) = m_4 e^{-(m_1+m_2+m_3+m_4)t}$$

$$q_{1,0} = h_1 e^{-h_1 t}$$

$$q_{2,0} = h_2 e^{-h_2 t}$$

$$q_{3,0} = h_3 e^{-h_3 t}$$

$$q_{4,0}(t) = h_4 e^{-(m_1+m_2+m_3+m_4+h_4)t}$$

$$q_{4,5}(t) = m_1 e^{-(m_1+m_2+m_3+m_4+h_4)t}$$

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$q_{4,6}(t) = m_2 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{4,7}(t) = m_3 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{4,8}(t) = m_4 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{5,4}= h_1 e^{-h_1 t}$

$q_{6,4}= h_2 e^{-h_2 t}$

$q_{7,4}= h_3 e^{-h_3 t}$

$q_{8,4}(t) = h_4 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{8,9}(t) = m_1 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{8,10}(t) = m_2 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{8,11}(t) = m_3 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{8,12}(t) = m_4 e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$q_{9,8}= h_1 e^{-h_1 t}$

$q_{10,8}= h_2 e^{-h_2 t}$

$q_{11.8}= h_3 e^{-h_3 t}$

$q_{12,8}= h_4 e^{-h_4 t}$

$\mathbf{p_{ij} = q^*_{i,j}(0)}$

$p_{0,1}= m_1/(m_1+m_2+m_3+m_4)$

$p_{0,2}= m_2/(m_1+m_2+m_3+m_4)$

$p_{0,3}= m_3/(m_1+m_2+m_3+m_4)$

$p_{0,4}= m_4/(m_1+m_2+m_3+m_4)$

$p_{1,0}= 1$

$p_{2,0}= 1$

$p_{3,0}= 1$

$p_{4,0}= h_4/(m_1+m_2+m_3+m_4+h_4)$

$p_{4,5}= m_1/(m_1+m_2+m_3+m_4+h_4)$

$p_{4,6}= m_2/(m_1+m_2+m_3+m_4+h_4)$

$p_{4,7}= m_3/(m_1+m_2+m_3+m_4+h_4)$

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$p_{4,8}$= $m_4/(m_1+m_2+m_3+m_4+f_4)$

$p_{5,4}$= 1

$p_{6,4}$= 1

$p_{7,4}$= 1

$p_{8,4}$= $h_4/(m_1+m_2+m_3+m_4+h_4)$

$p_{8,9}$= $m_1/(m_1+m_2+m_3+m_4+h_4)$

$p_{8,10}$= $m_2/(m_1+m_2+m_3+m_4+h_4)$

$p_{8,11}$= $m_3/(m_1+m_2+m_3+m_4+h_4)$

$p_{8,12}$= $m_4/(m_1+m_2+m_3+m_4+h_4)$

$p_{9,8}$= 1

$p_{10,8}$= 1

$p_{11,8}$= 1

$p_{12,8}$= 1

$p_{0,1}+p_{0,2}+p_{0,3}+p_{0,4} = 1$

$p_{4,0}+p_{4,5}+p_{4,6}+p_{4,7}+p_{4,8} = 1$

$p_{8,4}+p_{8,9}+p_{8,10}+p_{8,11}+p_{8,12} = 1$

Mean Sojourn Times

R_i(t)

R_0(t)= $e^{-(m_1+m_2+m_3+m_4)t}$

$R_1(t)$= $e^{-h_1 t}$

$R_2(t)$= $e^{-h_2 t}$

$R_3(t)$= $e^{-h_3 t}$

R_4(t)= $e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$R_5(t)$= $e^{-h_1 t}$

$R_6(t)$= $e^{-h_2 t}$

$R_7(t)$= $e^{-h_3 t}$

R_8(t)= $e^{-(m_1+m_2+m_3+m_4+h_4)t}$

$R_9(t)$= $e^{-h_1 t}$

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$R_{10}(t) = e^{-h_2 t}$

$R_{11}(t) = e^{-h_3 t}$

$R_{12}(t) = e^{-h_4 t}$

$\mu_i = R_i^*(0)$

$\mu_0 = 1/(m_1+m_2+m_3+m_4)$

$\mu_1 = 1/h_1$

$\mu_2 = 1/h_2$

$\mu_3 = 1/h_3$

$\mu_4 = 1/(m_1+m_2+m_3+m_4+h_4)$

$\mu_5 = 1/h_1$

$\mu_6 = 1/h_2$

$\mu_7 = 1/h_3$

$\mu_8 = 1/(m_1+m_2+m_3+m_4+h_4)$

$\mu_9 = 1/h_1$

$\mu_{10} = 1/h_2$

$\mu_{11} = 1/h_3$

$\mu_{12} = 1/h_4$

5. Evaluation of Path Probabilities:

Applying RPGT and using '0' as the initial-state of the system as under: The transition probability factors of all the reachable states from the base state 'ξ' = '8' are:

Probabilities from state '0' to different vertices are given as

$V_{0,0} = 1$

$V_{0,1} = p_{0,1}$

$V_{0,2} = p_{0,2}$

$V_{0,3}$……..Continuous

Probabilities from state '8' to different vertices are given as

$V_{8,0} = p_{8,4}p_{4,0}/(1-p_{4,5}p_{4,5})(1-p_{4,6}p_{6,4})(1-p_{4,7}p_{7,4})(1-p_{0,1}p_{1,0})(1-p_{0,2}p_{2,0})(1-p_{0,3}p_{3,0})$
$\{(1-p_{0,4}p_{4,0})/(1-p_{0,1}p_{1,0})(1-p_{0,2}p_{2,0})(1-p_{0,3}p_{3,0})\}$

$V_{8,1} = p_{8,4}p_{4,0}p_{0,1}/(1-p_{4,5}p_{4,5})(1-p_{4,6}p_{6,4})(1-p_{4,7}p_{7,4})(1-p_{0,1}p_{1,0})(1-p_{0,2}p_{2,0})(1-p_{0,3}p_{3,0})$

$\{(1-p_{0,4}p_{4,0})/(1-p_{0,1}p_{1,0})(1-p_{0,2}p_{2,0})(1-p_{0,3}p_{3,0})\}$

$V_{8,2}$ = …….Continuous

6. Modeling system parameters using RPGT

MTSF(T_0): The regenerative un-failed states to which the system can transit(initial state '0'), before entering any failed state are: 'i' = 0,4,8 taking 'ξ' = '0'.

$T_0 = (V_{0,0}\mu_0+V_{0,4}\mu_4+V_{0,8}\mu_8)/\{1-V(0,4,0)\}(1-p_{0,4}p_{4,0})$

Availability of the System(A_0): The regenerative states at which the system is available are 'j' = 0,4,8 and the regenerative states are 'i' = 0 to 8 taking 'ξ' = '8' the total fraction of time for which the system is available is given by

$A_0 = \left[\sum_j V_{\xi,j}\,,f_j\,,\mu_j\right] \div \left[\sum_i V_{\xi,i}\,,f_j\,,\mu_i^1\right]$

$A_0 = (V_{8,0}\mu_0+V_{8,4}\mu_4+V_{8,8}\mu_8)/D$

Where $D = V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3+V_{0,4}\mu_4+V_{0,5}\mu_5+V_{0,6}\mu_6+V_{0,7}\mu_7+V_{0,8}\mu_8+V_{0,9}\mu_9$
$+V_{0,10}\mu_{10}+V_{0,11}\mu_{11}+V_{0,12}\mu_{12}$

Busy Period of the Server: The regenerative states where server is busy are j = 1,2,3,4,5,6,7,8 and regenerative states are 'i' = 0 to 8, taking ξ = '0', the total fraction of time for which the server remains busy is

$B_0 = \left[\sum_j V_{\xi,j}\,,n_j\right] \div \left[\sum_i V_{\xi,i}\,,\mu_i^1\right]$

$B_0 = (V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,3}\mu_3+V_{0,4}\mu_4+V_{0,8}\mu_8)/D$

Expected Number of Inspections by the repairman: The regenerative states where the repairman visit is j = 1,2,3,4 the regenerative states are i = 0 to 8, Taking 'ξ' = '0', the number of visit by the repair man is given by

$V_0 = \left[\sum_j V_{\xi,j}\right] \div \left[\sum_i V_{\xi,i}\,,\mu_i^1\right]$

$V_0 = (V_{0,1}+V_{0,2}+V_{0,3}+V_{0,4})/ D$

Availability of the System(A_0):

Table 1: Availability of the system

P_0	h = 0.60	h = 0.70	h= 0.80
m = 0.10	523.23	525.27	527.35
m= 0.15	498.02	500.14	502.26
m= 0.20	478.29	480.04	482.53

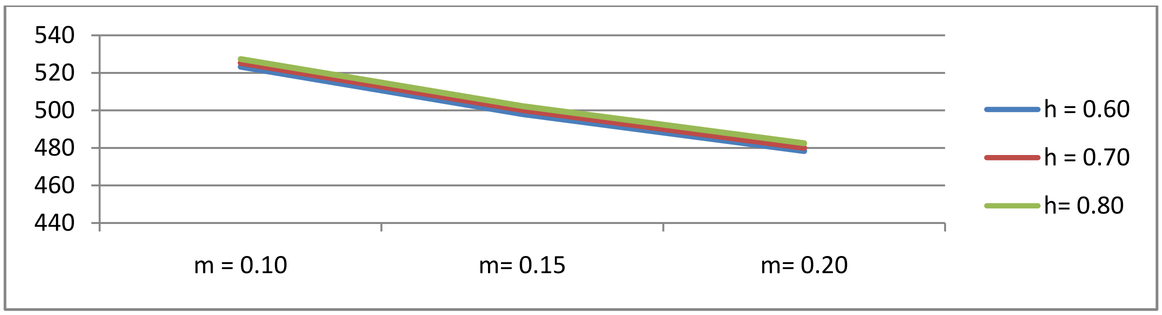

Figure 2:Availability of the system

7. Conclusion

The analysis of a hybrid boiler system's reliability, availability, and maintainability (RAM) becomes crucial for increasing the system's effectiveness and output. The calculations and figure 2 lead to the conclusion that the system's profit rises with higher repair rates and drops with higher failure rates. By raising the repair rate and lowering the failure rate, the plant's efficiency and dependability can be increased.

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