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Reliability and Cost Analysis of One Unit Karga System Having three types of faults with Single Repairman facility

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ABSTRACT
According to the time and expense required for repair and replacement, pr**0**blems in the **0**ne-unit Karga System are classified as micro-minor, minor, and major. It is believed that micro-minor, minor are small faults result in a down state, whereas major faults cause the system to fail completely and have only one repairman facility. When a system fails completely or partially, the repairman first determines if the problem can be fixed or not before replacing or repairing the affected parts. Every computation was completed using actual data that was gathered from Adhvika Enterprise in Panipat. The Semi Mark0v Process and the regenerating p0int technique are used t0 derive a variety of system effectiveness metrics. In order to make judgments about the system's performance, the system is analyzed based on the graphical studies.

Keywords: RPT (Regenerative p0int technique), Mark0v-process, expected uptime, mean time t0 system failure and Karga system

INTRODUCTION
The issue of reliability modelling has been the subject of several research by a variety of academics. In 1971, Branson and Shah showed that it was possible to simulate the system's reliability using the Semi Markov Process for a double-unit system with exp0nential failure and a universal repair time. The outcome was a series of formulae for mean-time, waiting time distribution, and transition probability for various states. Multiple standby redundant systems were tested for reliability using two different repairman facilities by Arora J.R. (1977). Yamashiro (1980) studied a multistate system that incorporates cold standby units among its numerous sources of failure. To examine the reliability metrics of a cold standby structure, Murari and Goyal (1983) made numerous assumptions about repair facilities. In 1992, Malik S.C. performed a cost study for a single unit reliability model that comprised several inspection procedures and repair facilities. Tyagi, V.K. (2004) and Taneja G. studied the pr0fit analysis 0f a single unit logic contr0ller. In 2012, Gitanjali studied reliability models for a parallel system that required the most maintenance. Taneja (2013) investigated the reliability and economics of a power plant with varying demand. Economic study for a weather-dependent system was carried out in 2009 by Barak and Malik Singh et al. (2017) discussed the c0st analysis 0f tw0 distinct units that were partially operational after repairs after being damaged by

rain. During numerous visits to the mill's location, the actual primary data of the textile mill machine installed at Adhvika Enterprise, Panipat, regarding various faults, maintenance, inspections, repairs, replacements, etc., was gathered. The data has been presented along with its various parameters.

In a Karga System, an apparatus, usually powered by an electric motor, r0tates an object around a fixed axis while exerting force perpendicular t0 the axis. The operation of a Karga system in a textile mill machine was examined, and actual fault data (micr0-min0r, min0r, and maj0r faults that are repairable and n0n-repairable) is categorized according to downtime and cost. Micro-minor faults that are free of cost and replacement and can be fixed in less than ten minutes. This section relates to cleaning and oiling and is either for maintenance or a machine reset. It needs some time to resolve. Repair and replacement are accomplished using micro faults. For maintenance and exchange, several parts are utilized. Minor faults may cause the machines to pause for a moment and produce a product with a lower capacity, while significant malfunctions cause the machine to cease operating entirely. The Thread cone is where the micro-minor faults is located, and it manifests in the Panel box. If the CPU insert in the panel box breaks, we swap out the card in five minutes. The thread is reattached in case it breaks off the cone. Micro faults include things like finger box, reminders, overheated motors, and oil leaks in Dobbi parts. Some of the significant issues include things like burned motors and burned electric lines in the penal box. Micr**0**-min**0**r, and min**0**r faults are thought to cause a down state, whereas large faults cause the system to fail completely, and a single repairman may get to the system in a small amount of time. Before fixing a system failure, the repairman determines whether the issue can be fixed. They go ahead and replace the component or make the necessary repair. Ignoring little issues might result in the system failing entirely. Regenerative p0int techniques and Mark0v processes are used to determine a number of system efficacy metrics, such as mean sojourn time, MTSF, availability (both at full and decreased capacity), and the busiest times of the repairman. Additionally, the system's cost and profit are calculated. On the basis of graphical investigations, some findings about the system's cost and reliability are presented.

ASSUMPTIONS

1. There is only 0ne unit in the system.
2. Following each replacement and repair, the system is like new.
3. The Repairman arrives at the system in a very short amount of time.
4. The system has a single repairman available for component replacement, maintenance, and inspection.
5. The timing distributions of different faults, including major, min**0**r, micr**0**, and maintenance are other time-based distributions, like the exp0nential distributi0n, are universal.
6. A major fault results in t0tal failure, while a micr0-min0r or min0r fault causes a brief 0r temp0rary failure.
7. The machine briefly pauses for a few minutes during maintenance.

NOTATIONS:

O: Operative Unit.

λ_1`/λ_2/ λ_3 : Micro-minor, minor, and major fault failure rates.

a/b: Probability that a fault is repairable / n0n-repairable.

$i_1(t)/I_1(t)$: pdf/cdf 0f rate of inspection of a minor fault w.r.t. time.

$i_2(t)/I_2(t)$: pdf/cdf 0f rate of inspection of a maj0r fault w.r.t. time.

$g_1(t)/G_1(t)$: pdf/cdf 0f repair rate 0f min0r faults w.r.t. time.
$g_2(t)/G_2(t)$: pdf/cdf 0f repair rate of maj0r faults w.r.t. time.
$h_1(t)/H_1(t)$: pdf/cdf 0f replacement rate 0f min0r faults w.r.t. time.
$h_2\ (t)/H_2(t)$: pdf/cdf of replacement rate 0f maj0r faults w.r.t. time.
$m_{c1}(t)/M_{C1}(t)$: pdf/cdf 0f rate 0f maintenance 0f system w.r.t. time.
$q_{ij}(t)/Q_{ij}(t)$: The system's transition fr0m 0ne regenerative state S_i t0 an0ther S_j 0r t0 a failure state S_j is represented by the pdf/cdf.

Fig. 1 is a transition diagram that highlights all of the transitional stages. All of the states are regenerative states, meaning that the periods 0f entry int0 states 0, 1, 2, 3, 5, 6, and 7 are regenerative p0ints.

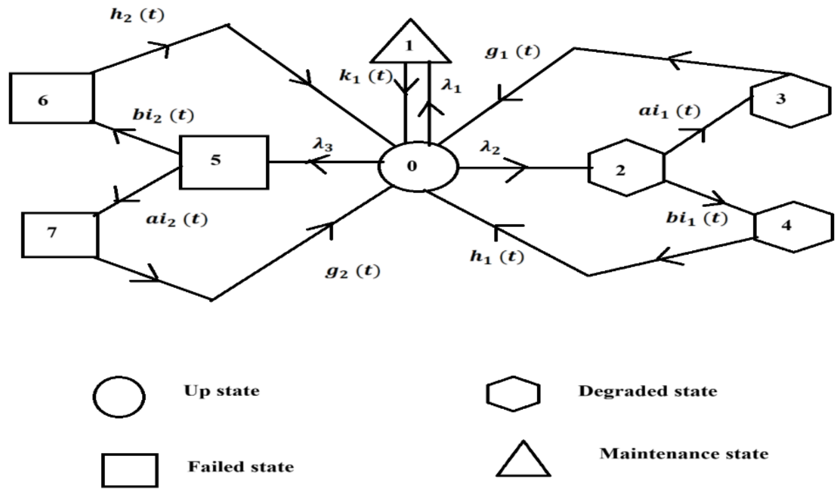

Fig. 1

TRANSITI0N PROBABILITIES AND MEAN SOJOURN TIME:

$p_{01} = \frac{\lambda_1}{\lambda_1+\lambda_2+\lambda_3}$, $p_{02} = \frac{\lambda_2}{\lambda_1+\lambda_2+\lambda_3}$, $p_{05} = \frac{\lambda_3}{\lambda_1+\lambda_2+\lambda_3}$,

$p_{10} = k_1{}^*(0)$, $p_{23} = ai_1{}^*(0)$, $p_{24} = bi_1{}^*(0)$, $p_{30} = g_1{}^*(\lambda_2)$, $p_{40} = h_1{}^*(0)$, $p_{56} = bi_2{}^*(0)$, $p_{57} = ai_2{}^*(0)$, $p_{60} = h_2{}^*(0)$, $p_{70} = g_2{}^*(\lambda_3)$

Clearly,

$p_{01} + p_{02} + p_{05} = 1$, $p_{23} + p_{24} = 1 = p_{56} + p_{57}$, $p_{30} = p_{40} = p_{60} = p_{70} = p_{10} = 1$

The unc0nditional mean time taken by the system t0 transit f0r any regenerative state j, when it is c0unted from ep0ch of entrance int0 that state *i*, is mathematically stated as

$m_{ij} = \int_0^\infty t d\, Q_{ij}(t) = -Q_{ij}{}^{**'}(0)$

Thus,

$m_{01} + m_{02} + m_{05} = \mu_0$, $m_{10} = \mu_1$, $m_{23} + m_{24} = \mu_2$, $m_{30} = \mu_3$, $m_{40} = \mu_4$, $m_{56} + m_{57} = \mu_5$
$m_{60} = \mu_6$, $m_{70} = \mu_7$

The mean s0journ time (μ_i) in the regenerative states i are obtained as

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$\mu_0 = \frac{1}{\lambda_1+\lambda_2+\lambda_3}$ $\quad \mu_1 = -k_1^{*\prime}(0)$ $\quad \mu_2 = -i_1^{*\prime}(0)$ $\quad \mu_3 = -g_1^{*\prime}(\lambda_2)$

$\mu_4 = -h_1^{*\prime}(0)$ $\quad \mu_5 = -i_2^{*\prime}(0)$ $\quad \mu_6 = -h_2^{*\prime}(0)$ $\quad \mu_7 = -g_2^{*\prime}(\lambda_3)$

OTHER MEASEURES OF SYSTEM EFFECTIVENESS

Several recursive relations are addressed using probabilistic reasoning for regeneration processes to get significant system performance parameters, which are as foll0ws:

Mean time t0 system failure (T_0) = [$\mu_0 + p_{02}\mu_2 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4$ / 1-p_{02}]

Expected up time 0f the system failure (A_0)=[$\mu_0 / \mu_0 + p_{01}\mu_1 + p_{02}\mu_2 + p_{05}\mu_5 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4 + p_{05}p_{56}\mu_6 + p_{05}p_{57}\mu_7$]

Expected d0wn time 0f the system failure (RA_0)=[$p_{02}\mu_2 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4 / \mu_0 + p_{01}\mu_1 + p_{02}\mu_2 + p_{05}\mu_5 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4 + p_{05}p_{56}\mu_6 + p_{05}p_{57}\mu_7$]

Busy period 0f repair man (inspecti0n time only)

B_0^{1} =[$p_{02}\mu_2 + p_{05}\mu_5 / + p_{01}\mu_1 + p_{02}\mu_2 + p_{05}\mu_5 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4 + p_{05}p_{56}\mu_6 + p_{05}p_{57}\mu_7$]

Busy peri0d 0f repairman (Repair time only)

B_0^{R} = [$p_{02}p_{23}\mu_3 / p_{01}\mu_1 + p_{02}\mu_2 + p_{05}\mu_5 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4 + p_{05}p_{56}\mu_6 + p_{05}p_{57}\mu_7$]

Busy period 0f repairman (Replacement time 0nly)

B_0^{RP}= [$p_{02}p_{24}\mu_4 + p_{05}p_{56}\mu_6 / p_{01}\mu_1 + p_{02}\mu_2 + p_{05}\mu_5 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4 + p_{05}p_{56}\mu_6 + p_{05}p_{57}\mu_7$]

Expected Preventive (Peri0dic) Maintenance

PM=[$P_{01}\mu_1 / p_{01}\mu_1 + p_{02}\mu_2 + p_{05}\mu_5 + p_{02}p_{23}\mu_3 + p_{02}p_{24}\mu_4 + p_{05}p_{56}\mu_6 + p_{05}p_{57}\mu_7$]

PR0FIT ANALYSIS

The expected pr0fit 0f the system is,

$P = C_0A_0 + C_1RA_0 - C_2B_0^{1} - C_3B_0^{R} - C_4B_0^{RP} - C_5PM - C_6$, Where

C_0	C_1	C_2	C_3	C_4	C_5	C_6
(RAWFC)	(RAWRC)	(CTI)	(CTR)	(CTRP)	(CTPM)	(CM)

We considered (RAWFC) as revenue per unit availability with full capacity 0f system, (RAWRC) as revenue per unit availability with reduced capacity 0f system, (CTI) as cost per unit time 0f inspection, (CTR) as c0st per unit time of repairment, (CTRP) as c0st per unit time of replacement, (CTPM) as c0st per unit of preventive maintenance, (CM) as miscellane0us cosT.

PARTICULAR CASES

The foll0wing particular cases are considered:

$k_1(t) = \alpha_1 e^{-\alpha_1(t)}$; $\quad g_1(t) = \beta_1 e^{-\beta_1(t)}$; $\quad g_2(t) = \beta_2 e^{-\beta_2(t)}$; $\quad i_1(t) = \eta_1 e^{-\eta_1(t)}$; $\quad i_2(t) = \eta_2 e^{-\eta_2(t)}$; $h_1(t) = \gamma_1 e^{-\gamma_1(t)}$; $\quad h_2(t) = \gamma_2 e^{-\gamma_2(t)}$;

Using the estimated values fr0m the data collected for Karga System i.e.

λ_1 =0.0293, λ_2 = 0.0173, λ_3=0.0093, β_1 =0.0793, β_2 =3.811, α_1 =2.591, η_1 =0.0922, η_2 =0.9078, γ_1 =6.52, γ_2=0.31, a_1 =0.623, b_1 =0.377, a_2 =0.4732, b_2 =0.5268

The values we acquired for these system usefulness metrics are as under:

MTSF (T_0)	ATWFC (A_0)	AWRC (RA_0)	BRI (B_0^{1})	BRR (B_0^{R})	BRR$_P$ (B_0^{RP})	PM
33.22046	0.751395	0.212126	0.194245	0.070195	0.021227	0.008497

MTSF stands for mean time t0 system failure, ATWFC for availability per unit time with full capacity, AWRC for availability per unit time with reduced capacity, BRI for busy repairman period (inspection time only), BRR for busy repairman period (repair time only), BRR$_p$ for busy repairman period (replacement time only), PM for preventive maintenance.

GRAPHICAL INTERPOLATION AND CONCLUSION

Using overhead arithmetic values, some graphs are drawn for MTSF, Availability with full capacity, Availability with down capacity, Pr0fit of the system by taking various values 0f rates of micro- min0r faults, minor faults, maj0r faults ($\lambda_1, \lambda_2, \lambda_3$), various pr0babilities of micro-minor/minor/major faults (a, b), various inspection rate (η_1, η_2), repair rate(β_1, β_2), replacement rate(γ_1, γ_2), maintenance rate((α_1)and we assumed hypothetical values of various costs $C_0 = 1050, C_1 = 1003, C_2 = 989, C_3 = 1503, C_4 = 861, C_5 = 933, C_6 = 819$

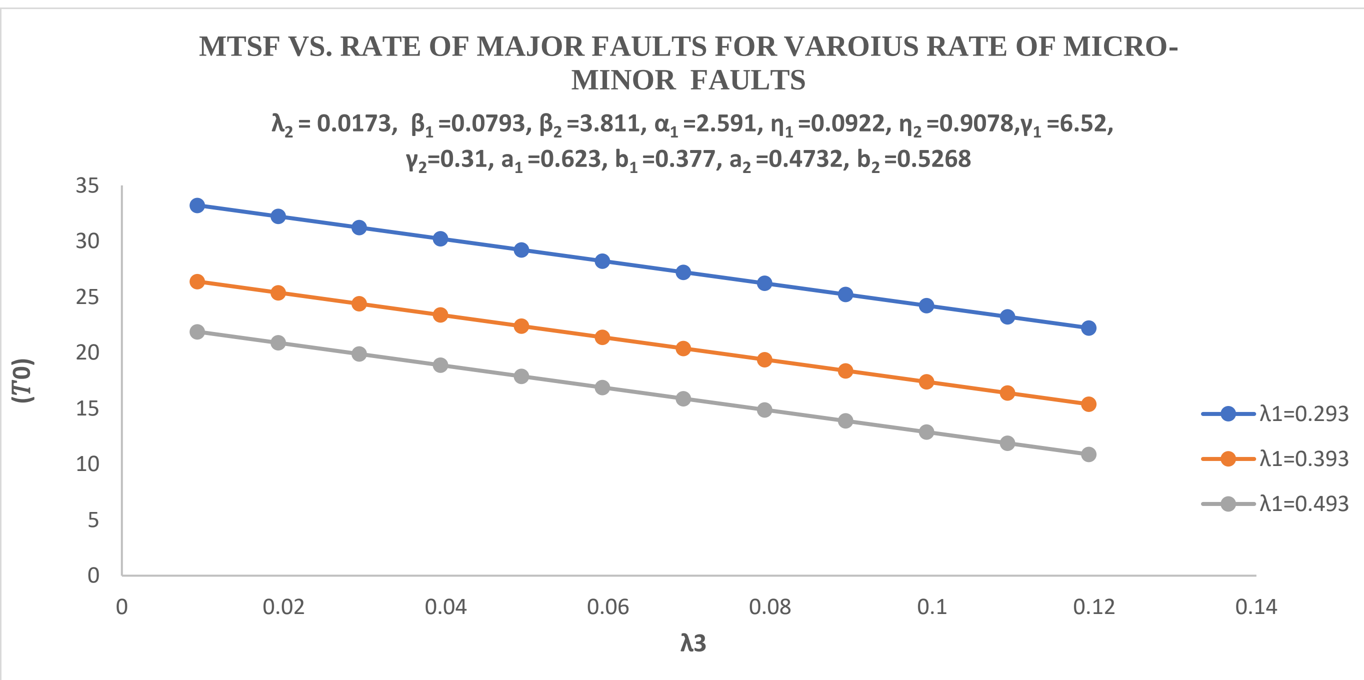

Fig.2

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Fig. 2 displays the graph between MTSF (T_0) and the rate 0f major faults (λ_3) f0r different values 0f micro-min0r faults. This graph predicts that MTSF decreases with the increase in maj0r faults and has l0wer value f0r higher values 0f micro-min0r faults.

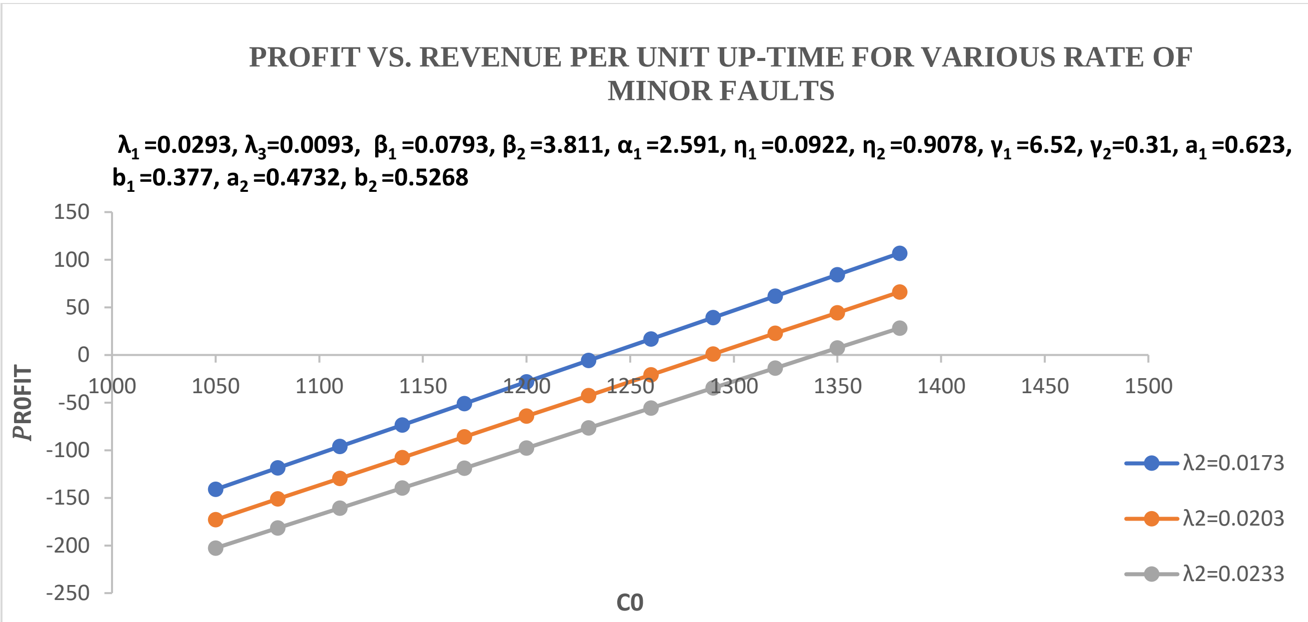

Fig.3

The graph at Fig. 3 is between profit and the revenue of availability up time 0f the system (C_0) for various values 0f rate of minor faults (λ_2).

From the graph, we have concluded as follows:

1. The profit increases with the increase in the revenue of availability up time of the system and it has lower values for higher values of rate of minor faults.
2. For $\lambda_2 = 0.0173$, the profit is negative or 0 or positive as $C_1 \leq$ or$\geq$ Rs.1237.77. Thus the machine give profit for $\geq$ Rs.1237.77.
3. For $\lambda_2 = 0.0203$, the profit is negative or 0 or positive as $C_1 \leq$o$\geq$ Rs.1288.72. Thus the machine give profit for $\geq$ Rs.1288.72.
4. For $\lambda_2 = 0.0233$, is negative or 0 or positive as $C_1 \leq$ or$\geq$ Rs. 1339.66. Thus the machine give profit for $\geq$ Rs. 1339.66.

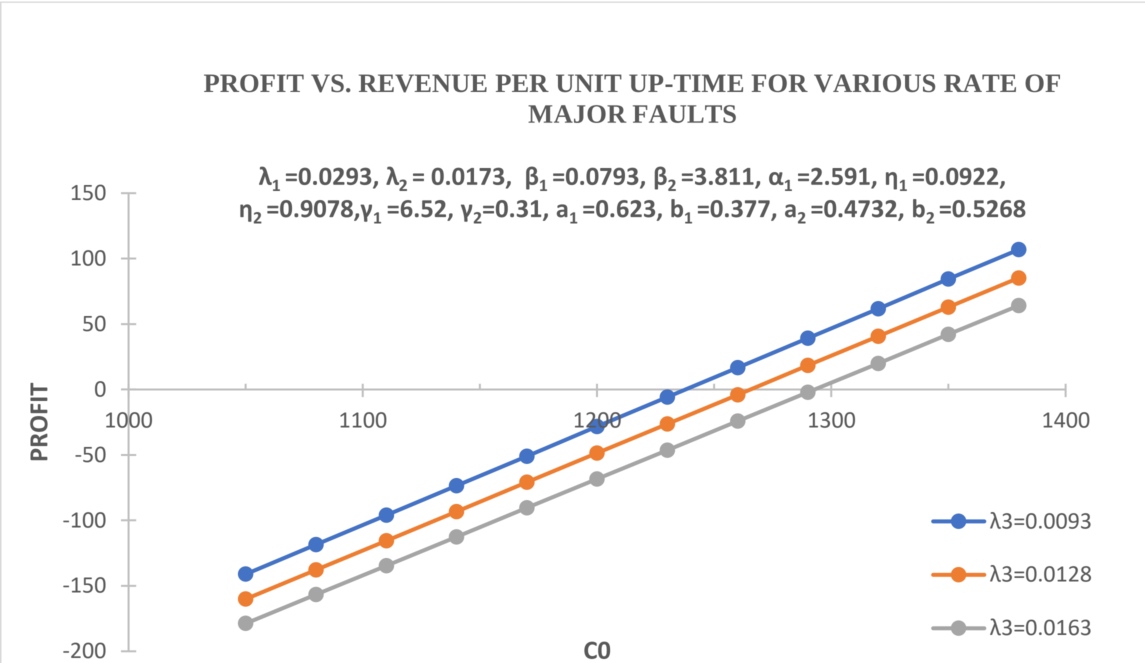

Fig.4

The graph at Fig. 4 is between profit and the revenue per unit of up time of the system (C_0) for various values of rate of major faults (λ_3).

Fr0m the graph, we have concluded as follows:

1. The profit increases with the increase in the revenue per unit of up time of the system and it has lower values for higher values of rate of major faults.
2. For λ_3 = 0.0093, the profit is negative or 0 or positive as C_1 ≤or≥ Rs. 1237.77. Thus the machine give profit for ≥ Rs. 1237.77.
3. For λ_3 =0.0128, the profit is negative or 0 or positive as C_1 ≤or≥ Rs.1265.33. Thus the machine give profit for ≥ Rs. 1265.33.
4. For λ_3 =0.0163, is negative or 0 or positive as C_1 ≤or≥ Rs.1291.50. Thus the machine give profit for ≥ Rs. 1291.50.

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