© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 08 Issue: 02 | January - March 2017
Paper is available at www.jrps.in | Email : info@jrps.in

Redundancy Allocation in an Industry using Multi-Objective Optimization – A Review

Priya Itoriya[1], Dr. Sanjay Jain[2]

1Research Scholar, S.A.T.I., Vidisha (Engg. College), Email: priya1212.pi@gmail.com
2Professor, Department of M E,, S.A.T.I., Vidisha (Engg. College), Email: sanjaysati_vds@yahoo.co.in

ISSN : 2278-6848
© International Journal for Research Publication and Seminar

ABSTRACT: Reliability engineering is engineering that highlights dependability in a product's lifecycle management. Dependability, or reliability, describes the ability of a system or component to function under stated conditions for a set time period. Reliability engineering represents a branch of systems engineering. Reliability can be defined as the probability of success as the frequency of failures; or in terms of availability, as a probability based on reliability, maintainability and testability. In engineering, redundancy is the duplication of critical components or functions of a system thus increasing system's reliability, usually in backup or fail-safe form, or actual system performance improvement, like in the GNSS receivers' case, or multi-threaded computer processing. In either case, inventory should contain some components or subsystems to replace the failed components. Factors like budget or storage space limits the number of components in inventory can be limited by. The redundancy allocation problem is a way to maximize reliability while minimizing the cost.

Keywords: Redundancy, RAN, Industry, Machines

1. INTRODUCTION

Machines, factory lines, vehicles etc. have a large number of components. Each component can fail at any given time. The chance that a component will be working at a given time defines reliability of a component. Failure of a component can cause failure of whole system. The component then has to be replaced. This is called standby redundancy. In certain situations where the components cannot be replaced like in satellites and probes entire system cannot be brought down for maintenance. In those cases we use active redundancy.

In either case, inventory should contain some components or subsystems to replace the failed components. Factors like budget or storage space limits the number of components in inventory can be limited by. The redundancy allocation problem is a way to maximize reliability while minimizing the cost.

2. LITERATURE REVIEW

[1] Jing Wang &Mian Li proposed an analytical model describing the failure rates with failure interactions. Then a Modified Analytic Hierarchy Process (MAHP) is proposed to solve the redundancy allocation problems for systems with failure interactions. This method decomposes the system into several blocks and deals with those down-sized blocks before diving deep into the most appropriate component for redundancy allocation. Being simple and flexible, MAHP provides an intuitive way to design a complex system and complex explicit objective functions for the entire system is not required in the proposed approach. More importantly, with the help of the proposed

analytical failure interaction model, MAHP can capture the effect of failure interactions. Results from case studies clearly demonstrate the applicability of the analytical model for failure interactions and MAHP for reliability design.

[2] ZhigangTian, Ming J. Zuo, presented an optimization model for a multi-state series-parallel system to jointly determine the optimal component state distribution, and optimal redundancy for each stage. The relationship between component state distribution, and component cost is discussed based on an assumption on the treatment on the components. An example is used to illustrate the optimization model with its solution approach, and that the proposed reliability-redundancy allocation model is superior to the current redundancy allocation models

[3] David W. Coit and Alice E. Smith presented a review of the different optimization approaches and present a new approach, a genetic algorithm (GA) which can solve the general class of the redundancy allocation problem. The GA is demonstrated on two different problems and compared with the other techniques. The natural extension of this work is to adapt the GA to problems where the component reliability values are governed by a probability density function. Constraints would then be based on a lower bound value for system reliability or cost. This represents a more realistic model of the design process. Also, it allows for the explicit consideration of risk-averse system designers and users.

3. Problem Definition

Productivity of an industry can be increased by maximizing the machines availability. It can be achieved only by regular maintenance and redundancy allocation to the component having higher failure rates.

3.1 Problem Formulation

Availability of machine individually defines the overall availability of the production system. But each machine is made of various components which can fail randomly without any warning due to many reasons.

In order to improve the availability of the system it is necessary to detect the most influencing failure and allocate an alternative to perform that task as early as possible. In order to solve this problem various methods are used but they consider basic factors like failure rate and cost. In order to provide a more efficient solution to the problems we need to consider more factors into observation.

Redundancy allocation number is used here to select the subsystem whose failure affects the most. All variables affecting the overall productivity are covered in it. These variables are as follows:

- Failure rate
- Operation time
- Number of total operations
- Repair cost of machines
- Overtime cost

4. METHODOLOGY

The study was done in Electro auto Industry, it is a leading manufacturer of the steam turbines and transformer tanks. The company is located in Govindpura Industrial area, Bhopal**.** Large numbers of products are manufactured at electro auto industry, out of then I selected a pipe flange for the analysis

© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 08 Issue: 02 | January - March 2017
Paper is available at www.jrps.in | Email : info@jrps.in

purpose. It is a part of transformer tanks manufactured here. Its analysis required tracing the operational flow and time consumed in machining.

Fig 1: Pipe Flange

This part is welded to the transformer tank to provide connection to other parts. The pipe of the flange is welded to the tank while the flange is connected to other parts through nuts and bolts. It is required that the face of the flange is smooth so the connection is air tight.

Casting and milling of the flange is not done in the industry. Only grooving, grinding, drilling and welding of the product are done in house. The machining process of the part is discussed below

Fig 4.2: Machining Process Of The Part

Different operations are performed on different machines in a production unit. Each machine used to fabricate the product is considered a subsystem and whole process is considered a system. The system consist various conventional and non-conventional machine. All machines perform certain specific operation in the fabrication of the part. The flow of the part on different machines is pre-decided. The sequence followed for machining of the part is shown below:

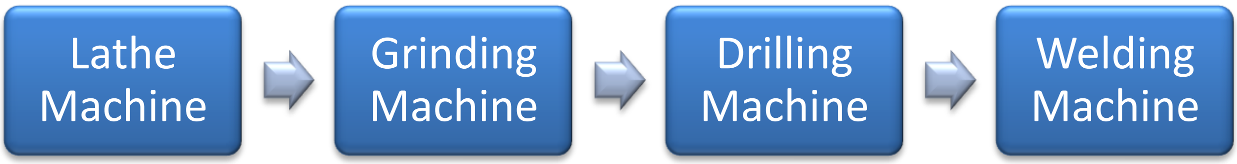

Fig4.3: System

Availability of Subsystem

Different type of failures can arise in a subsystem which is counted as downtime as it makes subsystem unavailable for production. Availability can be defined as the probability of working of subsystem when it is needed. Its availability highlights the system available for a particular operation based on various parameters like breakdown hours & failure rate. In an industry it’s a target to increase the availability as it shows fewer breakdowns.

© INTERNATIONAL JOURNAL FOR RESEARCH PUBLICATION & SEMINAR
ISSN: 2278-6848 | Volume: 08 Issue: 02 | January - March 2017
Paper is available at www.jrps.in | Email : info@jrps.in

It is denoted as the ratio of MTBF to the sum of MTBF and MTTR. In order to determine the MTBF and MTTR whole system should be observed for't' hours.

$$MTTR_i = \frac{T_{d_i}}{k_i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$MTBF_i = \frac{T_{up_i}}{k_i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Availability of Whole System

Availability of the subsystem defines the availability of the whole system. It is an important factor in order to confirm the significance of redundancy allocation. It should be kept as high as possible as it defines the efficiency of the system

$$A_{v_s} = \prod_{i=1}^{n} A_{v_i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Redundancy Allocation Number for Each Subsystem

Redundancy Allocation Number serves as the criteria for redundancy allocation in order to improve the availability of the system. Various factors are evaluated based on all subsystem performance to calculate the RAN. Factors considered are categorized as failure ratio rate, fraction of production, Utilization factor and failure impact

$$RAN_i = \left(\sum_{r=1}^{4} \propto_r F_{r_i}\right) \times 1000 + \phi \dots\dots\dots\dots\dots\dots\dots (4)$$

r	Influencing Factors (F_{r_i})	Weightage ($\propto$)
1	Failure Rate Ratio	4
2	Fraction of Production	2
3	Utilization Factor	1
4	Impact of Failure	3

Table 5.1 values of $\propto_r$

Failure Rate Ratio

The ratio between the system and subsystem failure rate is known as failure rate ratio. This is considered to be the most important factor with highest weightage. It can be defined as the frequency of the failure of the engineered system or component

Fraction of Production

An important criterion for RAN evaluation is Fraction of Production. In order to complete a part number of different operation are performed on different subsystems. Total number of operation and individual subsystem operation are considered to calculate this factor.

Utilization Factor

In order to evaluate RAN each subsystem's utility is needed. It can be represented as the ration between operation time on a subsystem and total operation time. Each part of the assembly is machined on different subsystem and overall productivity is affected by its performance.

Impact of Failure

Failure impact is calculated in terms of cost thus having a great importance in RAN calculation. It is represented by the ratio of sum of repair and overtime cost to the total production cost

In order to validate the adopted methodology input data containing downtime, uptime and frequency of failure and operation time, number of overtime hours, number of operation performed is collected. The production cost of the part was provided by the firm. Maintenance reports and graphs of performance of each subsystem for roughly around 1 year (total time of about 6000 hours) were studied to gather data.

S. no	Subsystem	Down Time (T_{di})	Failure Frequency (k_i)
1	Lathe Machine	100	4
2	Grinding Machine	200	20
3	Drilling Machine	150	15
4	Welding Machine	150	18

Table 1: Downtime and Frequency of Failure of Each system

S.no	Subsystem	Number of Operation (N_{i_a})	Operation Time (τ_{i_a})
1	Lathe Machine	1	10
2	Grinding Machine	1	10
3	Drilling Machine	4	25
4	Welding Machine	1	15

Table 2: Required Number of Operation and Time on the Pipe Flange

S. no	Subsystem	Overtime hours(T_{0_i})	Repair Cost (C_{R_i})
1	Lathe Machine	5	20000
2	Grinding Machine	1	4000
3	Drilling Machine	2	8000
4	Welding Machine	1	5000

Table 2: Overtime and Repair cost for the Pipe Flange Production System

5. RESULT

After doing all the necessary calculation RAN is allotted to each system as tabulated below

S.No	Subsystem	RAN
1	Lathe Machine	730.0292
2	Grinding Machine	1064.557
3	Drilling Machine	2009.604
4	Welding Machine	1035.81

Based on the RAN it was decided to allocate a redundant system for Drilling machine and after allocating the Redundant system calculations were done again

The results obtained from both calculations are discussed below

S.No	Subsystem	Availability of the Subsystem	Availability of the Subsystem After Redundancy Allocation
1	Lathe Machine	98.33%	98.33%

2	Grinding Machine	96.66%	96.66%
3	Drilling Machine	97.5%	99.16%
4	Welding Machine	97.5%	97.5%
Total Systems Availability		90.36%	91.9%

Availability increment % = $\frac{0.919-0.9036}{0.9036} \times 100$

= 1.70%

6. CONCLUSION

It can be concluded from the above study that allocating a redundant system to any subsystem of production chain increases the overall availability of the whole production system. This can be a very helpful tool for small scale industry to increase the availability of their system thus in turn their production. This will not only help in increasing their profit from production but will also reduce their losses due to failure of machines thus complete system.

REFERENCES

1. Jing Wang Mian Li "Redundancy Allocation For Reliability Design Of Engineering systems With Failure Interactions" Proceedings of the ASME 2014 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2014 August 17-20, 2014, Buffalo, New York, USA

2. Zhigang Tian, Ming J. Zuo, "Reliability-Redundancy Allocation for Multi-State Series-Parallel Systems" IEEE Transactions On Reliability, Vol. 57, No. 2, June 2008

3. David W. Coit and Alice E. Smith "Optimization Approaches To The Redundancy Allocation Problem For Series -Parallel Systems" *Proceedings of the Fourth Industrial Engineering Research Conference* (IERC) May 1995

4. Mani Sharifia, Pedram Pourkarim Guilani, Mohammad reza Shahriari "Using NSGA II Algorithm for a Three-Objective Redundancy Allocation Problem with k-out-of-n Sub-Systems" Journal of Optimization in Industrial Engineering 19 (2016) 87-95

5. FULYA GİZEM AYTAÇ "The Redundancy Allocation Problem: A Taxonomic Review" Başkent University Institute of Science and Engineering

6. Mani Sharifia, Mohsen Yaghoubizadeh "Reliability Modeling of the Redundancy Allocation Problem in the Series-parallel Systems and Determining the System Optimal Parameters" Journal of Optimization in Industrial Engineering 17 (2015) 67-77

7. Sadan Kulturel-Konak, Alice E. Smith, David W. Coit "Efficiently Solving the Redundancy Allocation Problem Using Tabu Search" *IIE Transactions* September 2002

8. Jose E. Ramirez-Marquez, David W. Coit "A heuristic for solving the redundancy allocation problem for multi-state series-parallel systems" Reliability Engineering and System Safety 83 (2004) 341–349

9. Yun-Chia Liang, Chia-Chuan Wu "A Variable Neighbourhood Descent Algorithm for the Redundancy Allocation Problem" IEMS Vol. 4, No. 1, pp. 94-101, June 2005

10. Khalili-Damghani, Amiri M, "Solving binary-state multi objective reliability redundancy allocation series-parallel problem using efficient epsilon-constraint, multi-start partial bound enumeration algorithm, and DEA", Reliability Engineering and System Safety 103 (2012)35–44.

11. Soltani R., Sadjadi S. J., Tofigh A.A. (2014). A model to enhance the reliability of the serial parallel systems with component mixing. Applied Mathematical Modelling,38(3), 1064–1076.

12. Garg H, Rani M, Sharma S.P, Vishwakarma Y (2014). Bi objective optimization of the reliability-redundancy allocation problem for series-parallel system. Journal of Manufacturing Systems 33, 335–347

13. Zoulfaghari H, Zeinal Hamadani A, Abouei Ardakan M.(2014). Bi-objective redundancy allocation problem for a system with mixed repairable and non-repairable components, ISA Transactions 53, 17–24.

14. ZaretalabA ,Hajipour, V., Sharifi M , Shahriari M.R.(2015). A knowledge-based archive multi-objective simulated annealing algorithm to optimize series–parallel system with choice of redundancy strategies, Computers& Industrial Engineering 80, 33–44.

15. Tavakkoli-Moghaddam, R.; Safari, J.; Sassani, F., (2008), Reliability optimization of series-parallel systems with a choice of redundancy strategies using a genetic algorithm. Reliability Engineering and System Safety, 93(4), 550-556.