Conceptual Analysis of Reliability Aspect for Various Process Industries: A Critical Review

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Abstract The reliability field has gone through fruition development and burst through during previous four decades. The current paper reflects a historical outlook of momentous expansion and methodically spells out the contributions in reliability field since its commencement. The paper additionally looks into the significance and advancement of a range of numerical methods for the analysis of reliability, diagrammatical models, logical, and other reliability tools that had fashioned the appearance of reliability concept. Higher productivity and maximum profitability have nowadays become very essential for the processing industries to ensure their survival. To meet this challenge, all the systems and subsystems of these industries should have high reliability and availability. If the manufacturing systems are of improved quality and are having higher availability levels, this will definitely lead to enhancement of productivity and hence profitability. It has been realized that reliability and availability have great importance in all the processing industries and complex plants. Reliability concept is of great importance at design stage, development stage, procurement stage, operation stage, and maintenance stage. The study has been undertaken by many researchers for recognizing the performance behavior of systems in various process industries. A critical review has been conducted to present the brief overview of performance behavior and optimization of different systems related to various process industries. Lastly, the paper emphasizes the restrictions with on-hand methods for analysis of reliability and make out a small number of latent openings for more research.

Keywords Availability · Maintainability · Reliability · Performance evaluation

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1 Introduction

For the improvement in quality as well as quantity of curriculum concerned with manufacturing segment, real focus is required on the operational management. Excellent performance based on qualitative and quantitative production is the key to success for a process plant or processing industry. However, due to poor design, use of wrong manufacturing techniques, and poor maintenance policies, these systems undergo random failures. It leads to loss of prestige and sometimes threat to national security also. Therefore, to survive in the global market, the quality of industrial systems must be good, operation wise as well as performance wise. This can only be achieved by maintaining these systems failure free for long durations. This will, in turn, provide higher system availability. Therefore, all the related activities must be well organized and coordinated so as to ensure optimum utilization of men, machine, material, and supporting resources. If the manufacturing systems are of improved quality and are having high availability level, this will definitely lead to enhancement of productivity.

During the last four decades, the concept of availability of systems has been developed. In late 1940s and early 1950s, reliability engineering appeared on the scene. Military aircraft manufacturing is one of the fields in which reliability engineering has been focused for several years. Transportation sector is one other area where the reliability found major success. The concept of reliability has also shown a significant impact in space programs. The observers also realized that the success rate of space launching projects is now increasing in a spectacular manner. Presently, it has become the concern for all those who are working in the industries. Availability concept has greater worth in modern industries. The role of reliability and availability is significant at all stages starting from design and development to operation, procurement, and maintenance.

The systems and subsystems of process industries are very large and complex generally. The arrangement of these systems/subsystems may be in the series or may be in parallel or a combination of these two is also possible. For the process plant to operate in most efficient and most economic manner, it becomes vital that all the systems/subsystems should run without failures for prolonged hours under the specified conditions of working in the industry. Therefore, in order to achieve the above, there should be proper and effective utilization of 5Ms (man, method, machine, material, money) in the process industries. A proper coordination and organization of all these resources are also required to develop optimum strategies to meet the production targets. It increases production volume and hence profitability of the industry concerned. This will lead to increase in production volumes and profitability of the industry in a noticeable manner.

2 Conceptual Analysis of Reliability Aspect

Ouhbi and Limnious [1] presented the reliability and availability analysis of a turbo-generator. They observed the set of data in a real situation of engineering. This data was provided by Electricite de France. They used this set of data and performed the modeling for the rotor using semi-Markov approach. This model was used further for reliability and availability estimation.

Khobare et al. [2] presented the analysis of reliability for microcomputer circuit modules and the control systems. These control systems are of great importance for safety purpose of nuclear power plants. They developed a model of fault tree for comparator system. The comparator system taken by them was programmable and integrated. They tried to establish the quantitative values of reliability for standardized hardware modules of microcomputer circuit and for C and I systems.

Yang et al. [3] applied genetic algorithm to the issue related to the reliability allocation for a typical water reactor under pressure. They stated that defining the real objective function is the basic problem for reliability allocation. They suggested that the cost involved for the improvement and/or degradation of the system must be included in the process of reliability allocation in order to optimize the system reliability.

Ni and Zhang [4] established a new method of analysis of fatigue reliability under two-stage loading. They used the probabilistic Miner's rule for carrying out this analysis. Large eight samples of testing data were used. Experimental verification was then done for two-stage cyclic loading, i.e., high–low and low–high.

Cizelj et al. [5] developed a Bayesian approach-based method that clearly contains linguistic and numerical information for the assessment of failure rate. Generic database was used to select prior distribution selected, while theory of fuzzy set was used for the assessment of likelihood. Fuzzy inference system was used to develop a model that shows the influence of operating conditions on failure rate of the components.

Arulmozhi et al. [6] provided a method of calculating the system reliability of K-out-of-N systems with the help of an expression and algorithm. They stated the expression provided by them was fast and easy to implement. The algorithm given was memory efficient, and the efficiency of computation can also be considerably improved by using this expression.

Ebrahimi [7] introduced a technique for the assessment of reliability of a system that mainly uses the failure rate data. They also emphasized on a process which evaluates reliability of the system having components that are highly reliable for which the collection of failure data is very difficult. Failure time as well as reliability of system can be expressed in terms of numerous explanatory variables using this method.

Ramirez-Marquez et al. [8] worked on a multi-state series–parallel having binary component from which different levels of multi-state performance can be attained. They proposed that there should be a proper supply of different levels of demand

during the operation period of the system. This will lead to multi-state character of that system, and also, new method of solution will provide different benefits.

Ramirez-Marquez et al. [9] used Monte Carlo simulation technique for the estimation of reliability of a network having multiple states. They dealt with the problem involving Multi-state-two-terminal reliability calculation. In their study, the issues concerned with the computing the reliability on the basis of minimal cut with multi-state vectors had been conferred.

AlSalamah et al. [10] dealt with reliability of the pumping station for cooling of sea water that pumps the water of sea to the refineries and petro-chemical industries in Kuwait country. In the insensitive operating environment and in the absence of other substitute sources of water, the higher value of reliability is essential for pumping system.

Levitin [11] suggested a method for evaluation of reliability and the performance parameters for systems having multiple states with exposed failures. It is a modification of the generalized reliability block diagram method. The proposed method allows the performance of complicated multi-state-series–parallel system having exposed failures that are to be achieved by applying a recursive approach which is a straightforward.

Lyonnet and Toscano [12] concluded that many reliability models are useful at the time of designing and these models are based on the analysis of lifetime data. But these are not of much use during the operational phases because the conditions at operational phases are changing constantly. These models are not prepared for estimation of reliability of systems under dynamic conditions of operations. So, they proposed a dynamic model for reliability that was able to consider the history of running process.

Khanduja et al. [13] discussed about the study of bleaching system of a paper industry. They studied the steady-state behavior of the bleaching system. Maintenance planning was the other area of their study on the same system. For this, a mathematical model was developed for the system using Markov birth–death technique and probabilistic approach. On this basis, they derived an expression for the steady-state availability. On the basis of available maintenance data, they explicate that how the availability of the system get affected with the performance of each working unit.

Kajal et al. [14] developed a decision support system for a butter oil unit of the dairy plant. The Markov process was applied to develop differential equation related to the transition diagram. The solution using normalizing conditions was made for expanding the expression for availability under steady state. The performance of butter oil unit can be measured in terms of this availability.

Kumar and Tewari [15] applied Markov birth–death process and developed a mathematical model for one of the systems of fertilizer plant. Using probabilistic approach, the differential equations connected with the transition diagram of CO_2 cooling system were developed. After doing the analysis of availability, they applied genetic algorithm technique to optimize the performance of CO_2 cooling system.

Garg and Sharma [16] worked on complex and repairable system of a process industry using uncertain data. Membership functions of reliability indices of this

system were determined by using a very new PSOBLT technique. Utilization of in-hand information and use of uncertain data were done in calculating the reliability indices. Providing the compressed search freedom for each reliability index was the major benefit of this technique.

Wang et al. [17] analyzed the reliability and availability of building cooling, heating and power system. The state-space method technique combined with probabilistic approach of Markov model was applied for analyzing the reliabilities. The reliability of all three energy forms involving heat, cool, and electric form was analyzed. The failure and repair rates, availability and mean time between failures were figured out and analyzed for both redundant and the non-redundant building cooling, heating, and power system.

Doostparast et al. [18] applied simulated annealing technique for developing a model for planning the maintenance, periodically. The model was developed for feeding unit in a sugar plant, and it was based on reliability. The purpose of this work was to reduce the overall maintenance cost to a minimum level. Further, they developed decision support system for the same system which was used for deciding the maintenance priority level of various subsystem of the feeding system.

Hou et al. [19] introduced the application of random set theory for assessment of availability of the systems. They suggested that pseudo-system observations can be directly constructed from the observations of components. They did not use the probabilities of failures by observing each component. Systems undergoing rare failures were selected for analysis of availability. Operations that were characterized in the framework of random set were applied for obtaining the upper bound, lower bound, and also the confidence intervals of the availability of the system. No assumption was done regarding previous distribution of failures of the components.

Sabouhi et al. [20] developed the model for reliability and analyzed the availability of combined cycle power plants. Firstly, they develop the reliability models for both the gas turbine and steam turbine power plants. By doing this, they get the input for evaluating the reliability of combined cycle power plants. After that, the sensitivity indices oriented with reliability were given for identifying the critical components of the plant in order to decide the strategies for maintenance which were efficient and effective. Steam turbine power plants were found to be comparatively more reliable than gas turbine power plants and combined cycle power plants.

Kumar and Tewari [21] presented the analysis of performance and its optimization for carbonated soft drink glass bottle filling system at a beverage plant by applying particle swarm optimization method. This system has mainly seven subsystems that are arranged in series arrangement. Exponential distribution was considered for the possible failures as well as repairs. Mathematical model was then made by using Markov approach (MA).

Kumar [22] proposed the simulated annealing technique for the redundancy optimisation of a power plant that was coal fired. They carried out a balanced integration of operational availability, thermal performance, and the cost analysis module of the power plant for achieving profitable funds investment in thermal power plant.

Wang et al. [23] proposed a novel model of reliability for a system having multiple states, with performance sharing. The multi-state system comprises N number

of multi-state units that are linked in series configuration. Every unit has random performance level and has a random demand as well. If the level of performance of any unit becomes more than its requirement, the excess performance can be passed on to its neighboring units via halfway transmitters. Every transmitter is having a random level of capacity, and only, a restricted value of performance transmission is possible. For evaluation of reliability value, an algorithm that works on the basis of universal generating function was developed through their work.

Panchal et al. [24] proposed a framework that was based on fuzzy methodology and was able to analyze the failure of a transmission unit of a commercial vehicle. Identification of critical components of system was done using risk priority number and through failure mode and effect analysis. The results were helpful in intelligent decision making of components that are risky.

3 Conclusions and Future Scope

In modern years, there is a great enhancement of automation and the necessity for better cost-effectiveness in the industries. This has drawn the attention of process industries toward the fact that the maintenance services are the integral part of the production system and these cannot be considered just as a supporting service. After the study of obtainable literature, it is clear that there is no stiff system that can be universally applied in the process industries for accommodating every condition related to maintenance. Therefore, design and development of a proper maintenance system must be done that will outfit the necessity of that particular industry. The analysis of behavior of the systems and maintenance planning in a scientific manner would be helpful for keeping the equipments/systems available for extended duration of time.

Proper application of reliability, availability as well as maintainability techniques can help to overcome most of the above-mentioned problems. Conducting an availability assessment of the system helps in optimizing the inherent performance of the system. The availability assessment identifies those components of the system which have maximum contribution to most of the downtimes. It also helps to determine the outcomes of design changes on the performance of the system in a cost-effective way. Continuous monitoring technique and proper maintenance planning of equipment/system in an industry by introducing precautionary measures and diagnosis methods are the various technologies or approaches which cope with these problems. Proper maintenance decisions also affect the reliability of industrial systems, their availability, lifespan, and lifecycle cost. These can all be quantified, predicted, and evaluated. An outlook of key developments and the role in the area of reliability presented in the present paper would definitely identify some latent openings for further research in the sector of reliability engineering.

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