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Original article

Cost minimization of butter-oil processing plant using artificial bee colony technique

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Abstract

For achieving the goal of high production and hence more profit in an organization, the system reliability is an important issue, i.e. each system/subsystem must remain operative for long duration. The industrial systems are complex in configuration so it is very difficult to analyze their failure pattern. The available information about these equipments is imprecise, incomplete, vague and conflicting. Therefore, management decisions are based on experience. The objective of this paper is to improve the design efficiency and to find the optimal policy for mean time between failures (MTBF), mean time to repair (MTTR) and related costs. This paper presents an application of Artificial Bees' Colony (ABC) in order to solve a series-parallel system (here, butter-oil processing plant) availability allocation problem. In addition to maximization of system availability, the decision maker also oftenly requires that the cost of the system is minimized simultaneously. So the objective is to obtain a minimum cost configuration of the system that satisfies the given availability constraints. ABC algorithm has been used for computing the optimal design parameters at which system cost is minimized and results are shown to be statistically significant by means of pooled *t*-test with PSO results.

Keywords: Artificial bee colony algorithm; Series-parallel system; Availability optimization

1. Introduction

The reliability of a system decreases to zero when its operating time tends to infinity (i.e. very large), and in that case its availability decreases to a value called asymptotic availability. The main requirements for complex systems to be operating are usually specified in terms of cost and availability. For determining the appropriate reliability of each of its components, these requirements are to be taken in to account and are generally expressed by the owner of the system, corresponding to the global dependability objective assigned to each component of the system by the designer. For repairable system, availability is one of the more meaningful measures than reliability for measuring the effectiveness of maintained systems, because it includes reliability as well as maintainability. There are two kinds of procedure for calculating the availabilities of a system and its components. These are (i) to develop an availability model to appraise system availability, and (ii) to allocate the availabilities for each component based on the system's

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requirement or objectives. A lot of researchers have investigated the theoretical problems of availability modeling [5,32,38,42,43] and many others [11,17,19,31,35,37] have their studies on the specific applications.

Instead of concentrating exclusively on redundancy allocation, the minimum required reliability for each component of a system will be estimated in order to achieve a system reliability goal with minimum cost. Thereafter, the engineer can decide whether this minimum required component reliability will be achieved via fault avoidance or redundancy. The model allocates reliability to a component according to the cost of increasing its reliability. Dhillon [12] described applications of reliability engineering principles for carrying out stochastic analysis of parallel systems with common cause failure and critical human errors. Cafaro et al. [4] explained the use of markov chains in evaluating the reliability and availability of a system with time-dependent transition rates using analytical matrix-based methods. The reliability of a series-parallel system has drawn continuous attention in both problem characteristics and solution methodologies. For the framework of series-parallel system, it is very difficult to find out an optimal solution under multiple constraint conditions [8]. Under an increasingly complex and diversified system environment, Yuen and Katafygiotis [47] have used simulation methods to evaluate the reliability or availability of a complex system, as common estimation methods are subjected to strict assumptions. Under repairable series-parallel system framework, there are many methods in the past to determine the optimal parameters of components such as dynamic programming, integer programming, nonlinear integer programming and heuristic or meta-heuristic algorithms. Such collection are collected in two books [30,40].

Wang [41] suggested two methods for the estimation of availability. The first method is applicable when the allocation of MTBF and MTTR is subjected to exponential distribution, while the second one is to estimate the interval of availability when none of them is subjected to exponential distribution. These two methods were examined and compared by the Monte Carlo simulation. Yamada and Takata [45] proposed a novel method for improving reliability of manufacturing facilities by optimizing operating conditions. Based on theoretical condition for obtaining the optimal allocation in a series-parallel system developed two resolution approaches [44]. Ramirez-Marquez and Coit [36] formulated a redundancy allocation problem with the objective of minimizing design cost. Sometimes the heuristic techniques offer more efficient and straightforward analysis. Many authors used heuristic techniques, genetic algorithm (GA), differential evolution (DE), particle swarm optimization (PSO), etc., to solve the redundancy allocation problems for different types of systems considering the cost and weight as constraints [10,14,16,18,29].

Li et al. [33] proposed a new efficient exact method for solving both pure and mixed-integer nonlinear programming problems arising from reliability optimization in complex systems using a convexification scheme. Caserta and Nodar [6] proposed a Cross Entropy-based algorithm for reliability optimization of complex systems, where one wants to maximize the reliability of a system through optimal allocation of redundant components while respecting a set of budget constraints. Gen and Yun [18] employed a soft computing approach for solving various reliability optimization problems. This method combined rough search (RS) technique and local search (LS) technique, which can prevent the premature convergence situation of its solution. Coelho [10] presented an efficient PSO algorithm based on Gaussian distribution and chaotic sequence (PSO-GC) to solve the reliability–redundancy optimization problems. Garg and Sharma [15] solved the multi-objective optimization problem of crystallization unit of a fertilizer plant using PSO. Chen [7] presented a penalty-guided PSO to solve the redundancy allocation problem. They applied the proposed PSO on four small-size examples with three types of systems as series, series-parallel, and complex (bridge) systems. They showed the solutions obtained by PSO and other meta-heuristics to be very close to each other.

ABC is one of the most recently defined algorithms by Karaboga in 2005 [23], motivated by the intelligent behavior of honey bees and further developed by Karaboga and its coauthors [1,2,24–26]. As compared with other metaheuristics ABC does not employ crossover operators to produce new or candidate solutions from the present ones. It produces the candidate solution from its parent by a simple operation based on taking the difference of randomly determined parts of the parent and a randomly chosen solution from the population. Moreover, ABC employs less number of control parameters than others as it employs only population size (colony size) and maximum cycle number. Due to these features and have the advantages of memory, multi-character, local search and solution improvement mechanism, ABC is able to discover an excellent optimal solution. Recently, Yeh and Hsieh [46] and Hsieh and Yeh [21] shows that the solution of series-parallel problem found by ABC is better than the other meta-heuristic techniques. Motivated by this, the present paper considers the reliability optimization problem of a butter-oil processing plant in which we minimize the total cost of the system (manufacturing and repairing cost) retaining the preassigned system availability. The preassigned availability which may be the optimized availability of the system as obtained by some other technique acts as a constraint and the problem is solved by ABC technique. The remaining paper is organized as follows. Section 2