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A new model of multi-objective redundancy allocation problem for multi-state systems

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***Abstract*— This paper involves developing a new model for the multi-state redundancy allocation problem of series-parallel systems. The system consists of subsystems in series, where components are used in parallel for each subsystem. There are various types of components as candidates for allocation. These components are characterized by their cost, weight, and reliability. Besides, they have various levels of performance ranging from functioning perfectly to fail completely. The aim is to find the redundancy that minimizes the cost while maximizes the reliability. A NSGA-II algorithm is used to solve the multi-objective problem, where the universal generating function for multi-state components is used to obtain the reliability of a given system. In addition, a penalty function that encourages the solution algorithm to explore within infeasible solutions is proposed. At the end, a numerical example is used to validate the solution and to assess the performance of the proposed methodology under different configurations.**

Keywords- Reliability; Redundancy allocation problem; Multi-State; Universal Generating Function

I. INTRODUCTION

The reliability of a system is directly related to the reliabilities of its components. One of the best and the most efficient methods to improve system reliability is to use redundant components along with the main components [1]. The redundancy allocation problem (RAP) with many applications in industries is a complex combinational optimization problem that is shown to be NP-hard [2]. Electronic systems, power stations, and manufacturing systems are some examples of the RAP applications [3].

A series-parallel system consists of some subsystems that work in series each containing some components that are arranged in parallel. The RAP of these system involves obtaining an optimal number of components in each subsystem such that the total system availability is maximized while the constraint(s) (usually the system weight) is (are) satisfied.

Multi-objective optimization refers to the solution of problems with two or more objectives to be satisfied simultaneously. Often, such objectives are in conflict with each other and are expressed in different units. Because of their nature, multi-objective optimization problems normally have not one but a set of solutions, which are called Pareto-optimal solutions or non-dominated solutions [8], [5]. When such solutions are represented in the objective function space, the graph produced is called the Pareto-front or the Pareto-optimal set. Then, a solution is said to be *Pareto-optimal* if it is not dominated by any other possible solution. Thus, the Pareto-optimal solutions to a multi-objective optimization problem form the Pareto front or Pareto-optimal set [5]. There are two general approaches for the solution of a multi-objective problem. The first approach involves determining the relative importance of the attributes, and aggregating the attributes into some kind of overall composite objective function, sometimes called a value or utility function. Alternatively, the second approach involves populating a number of feasible solutions along a Pareto frontier, and the final solution is a set of non-dominated solutions. The multi-objective evolutionary algorithm of non-dominated sorting genetic algorithm (NSGA-II) is the most notable method of this second approach.