SYNOPSIS

The literature is abundant with a number of reliability design problems and their solutions through optimization techniques. Very often a cursory study of these problems and techniques leaves a reader highly confused over the suitability and usefulness of these techniques for a given design problem. Therefore the author of the present thesis assumed for herself a rather difficult task of a thorough study and review of the existing reliability design problems and techniques in order to be able to offer a reader with a clear recommendation of appropriate formulation and techniques for use. It is with this aim in mind that the present thesis begins with **Chapter-I**, devoted to an overview of the existing reliability design problems particularly of those which appeared in the literature during the last two decades. This chapter also describes the author's motivation for the present work and then outlines the design problems that are being addressed in this thesis.

In **Chapter-II**, the author critically reviews the mathematical techniques used in several reliability design problems, in particular, of the techniques of solving integer programming problems. Redundancy allocation (which belongs to this class of problems) is one of the commonly used means for improving system reliability, since it is the cheapest and the easiest method of doing so. An up-to-date review of the current literature has been presented in this chapter along with a discussion highlighting the merits and demerits of the existing methods.

Besides *redundancy allocation*, there are many other problems in the area of system reliability design, such as *spare-parts allocation*, *repairmen allocation*, etc., which necessitate an integer programming formulation. In other words, it would not be wrong to say that the integer programming plays an important role in system reliability design procedures. However, the exact optimization techniques that have been used in the past for solving these problems (except those which are strictly based on some heuristic criteria), are generally computationally difficult and sometimes unwieldly.

On the other hand, in many of the techniques, proposed in the literature, the decision variables have been conveniently assumed to be continuous, even though they must be integers and the solution has been obtained by rounding off the optimal real solution to an integer solution. This approach yield an approximate solution and suffers from the drawback that this solution does not always provide true optimum, although such an approach would be economically viable, besides being fast.

Consequently, an attempt has been made in **Chapter-III** to introduce a simple, fast and an efficient algorithm for solving a variety of integer programming problems arising in the area of system reliability design, with a view to provide an economical and efficient tool to reliability designers. Basically, this algorithm is a selective direct search technique involving function evaluations only and does not impose any conditions, like concavity, convexity, differentiability etc., on the objective functions or on the constraint functions. Infact this algorithm can also provide solution to a general class of integer programming problems in many areas of operations research.

This chapter also provides a list of reliability design problems which this technique can successfully solve. A number of illustrative examples (which have been considered in the literature by previous authors) have also been included to demonstrate the general applicability of the algorithm. The algorithm has been found to be faster and simpler than any of the earlier techniques.

In **Chapter-IV**, the author applies the algorithm presented in **Chapter-III** to the reliability design problems which usually arise in context of the design of non-maintained systems. In this chapter, the author provides application of the search algorithm to the design of series-parallel, non-series parallel system subject to linear and/or non-linear constraints. The results, that are obtained with the help of this algorithm, have been compared with those obtained by other techniques used by the earlier authors.

From the practical point of view, there exist very few engineering systems whose subsystems employ only one type of redundancy, viz., active-parallel, standby or partial alone. A large engineering system may employ any one kind or several kinds of redundancies, like standby, partial and active parallel at various subsystems. This type of a system is usually designated as a system with mixed redundancies. Therefore, in this chapter the author has provided the formulation and its solution using the search algorithm introduced in **Chapter-III**.

A special mention must be made of the ease with which parametric studies can be carried out using the present algorithm in comparison to the earlier approaches.

In **Chapter-V**, the author presents a more complete consideration of mathematical formulation of a maintained system than that has been provided by any of the earlier authors, i.e., we design a system where spares, redundancies and repair facilities are all optimized simultaneously in order to maximize its availability. To the best of author's knowledge, the problem formulation in this chapter is new and has not been considered to the extent presented here by any of the earlier researchers. This problem has been finally solved economically by the algorithm proposed in **Chapter-III**. This would help one to design all these three facilities, viz., spares, redundancy and repair, right at the design stage itself.

In **Chapter-VI**, the author extends the application of the search algorithm introduced in the thesis to the *mixed-integer* programming design problems. Here the term *mixed-integer* refers to the programming problems in which some of the decision variables may be integers and the other continuous. For example, in our problem the number of redundant components has to be an integer whereas component reliabilities would be continuous. In fact, to solve such a problem, the author makes use of the search algorithm for the discrete decision variables and a random search method for the continuous variables. The effectiveness of the procedures lies in the fact that these are very general and can be used to solve a variety of problems. It is observed here that this approach is definitely simpler and effective than the earlier approaches described in the literature.

A vast majority of papers on reliability optimization (see **Chapter I-IV**) deals with a design problem which involves a single objective function. Obviously, these problems have been formulated accepting the most important figure of merit in design, which in most of the cases happens to be system reliability, as the objective function of the design problem. Generally, in these problems, other system properties such as cost, weight, volume etc. are taken as constraints on the resources. Evans, in 1973 pointed out that the regions around the optimum points are equally important and it would be wise to achieve a best balance among all the properties rather than to optimize only with respect to one property. In other words, we seek the best alternative for system design in the feasible region of trade-offs.

With this consideration in view, **Chapter-VII** of the thesis is, therefore, devoted to the subject of multiobjective design problems including their formulation and the solution techniques. The state-of-the-art of this area, however limited, has been briefly reviewed.

During the survey of multiobjective reliability design problems, it has been observed that neither there exists a formulation, which considers a *mixed-redundancy*, *mixed-integer*, multi-objective programming problem nor does there exist an exact and efficient solution technique for solving such a problem.

Therefore in **chapter-VII**, a mathematical formulation of a multi-objective, *mixed-redundancy*, *mixed-integer* reliability optimization problem has been proposed. This chapter also provides two general, computer-amenable solution techniques for solving such a multi-objective reliability optimization problem, using the *min-max* approach and *Pareto optimum* in conjuction with the efficient direct search technique of **Chapter-III**.

Technological advancement has led to a rapid decrease in computer costs, resulting in a phenomenal increase in their use. It is a fact that users stand to benefit tremendously if computer facilities located at different places are networked, however the cost of networking being very high. Therefore, if reliable computer communication is a necessity for processing scientific, commercial and classified information, the design of an computer communication network which satisfies certain constraints and optimizes global reliability/availability becomes quite important to communication engineers.

A suvey of the existing literature reveals that several heuristic methods have been proposed in the past for obtaining an optimal network topology. Aggarwal et al. have provided heuristic methods for maximizing the reliability (terminal/global) of a computer communication network subject to a cost constraint, assuming that the links are not repairable.

However his assumptions make the problem mathematically quite tractable so that whatever be the system configuration, comparatively simple expressions are obtained for the objective function.

Therefore, the **Chapter-VIII** is devoted to a mathematical formulation of the optimal configuration problem of a computer communication network, where global reliability is of importance rather than the terminal reliability. In this chapter, the author provides several improved heuristic criteria for the above problem, particularly, when the system under consideration is very large. A comparative study of these heuristics along with the heuristic proposed by earlier authors has also been provided, in order to provide one an idea of effectiveness of improvement suggested. But there does not exist (to the best of author's knowledge) any method that provides an exact solution to the problem.

One of the exact technique for the solution is Lawler and Bell algorithm. This algorithm was used for the first time by Misra for solving a variety of reliability design problems and is considered till date to be the best exact technique for solving integer programming problems involving zero-one type variables. The absence and presence of a link in a network is represented by assigning 0 and 1, respectively, to the variables representing a link in the formulation. Therefore, this algorithm has been suitably modified and employed for solving the above-mentioned problem.

Further, identifying the potentiality of the algorithm introduced in **Chapter-III**, the author has extended this search technique to the optimal configuration problem of computer communication networks. This has made another thing also possible, viz., the modelling of networks having multiple choices for availabilities/reliabilities of its constituent links. Several problems have been solved by the proposed technique of **Chapter-III** and it has been observed that the algorithm when modified suitably provides a powerful solution technique for variety of design problems connected with communication networks.

Enormous amount of work exists in the area of system reliability evaluation [22-32,34-40,44-53,58-62,68-76,78-80], however, practically all of these contributions are very much based on an *unrealistic* assumption that the *failure and repair data - the essential ingredients of any reliability study of a system* - are precisely known. In reality, these data are not known precisely, partly due to the uncertainties associated with the methodology of generating or processing these data and partly due to the lack of information connected with the failure mechanism. Therefore, there is bound to exist uncertainty about the data being used, about the modelling and about the human factors.

Amongst the various techniques available to handle uncertainties of these kinds, the one based on the fuzzy set approach appears to be very promising. Since Zadeh profounded the theory of fuzzy-sets, several propositions to adapt this abstract mathematical concept to a variety of fields have been put forward by researchers [56-57].

Fuzzy sets provide a useful approach to solve some reliability problems which are otherwise difficult or sometimes impossible to tackle through the use of probabilistic or deterministic mathematical approaches. This not only provides a new direction to the literature on reliability assessment but preliminary investigations show that this approach appears to be the most effective way of dealing with uncertainties.

Therefore, finally, **Chapter-IX** is devoted to highlight the scope for future work. This chapter proposes, as a future research work, the use of fuzzy set theory for handling imprecisions. An indication of the use of fuzzy set theory for system reliability design is also provided in this chapter.

Lastly, **Chapter-X** summarizes the contributions of the present thesis. It is hoped that the various suggestions made in this thesis will help reliability analysts and designers, design more reliable systems efficiently with less and less effort without compromising on realistic assumptions.