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Design of an advanced electric power distribution systems using seeker optimization algorithm

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ABSTRACT

The power distribution network design problem has a growing impact on secure and economical operation of distribution power system. This issue is well known as a non-linear, multi-modal and multi-objective optimization problem where global optimization techniques are required in order to avoid local minima. In this study, a new approach using seeker optimization algorithm (SOA) is proposed for distribution system planning problem with simultaneous placement of automatic reclosers (RAs), considering total system economic cost, overall system reliability, system power losses and voltage deviations as an objective functions. Normally, conventional power distribution systems (CPDS) are radial in nature and momentary fault in the system causes large area of the grid to be blacked out, which leads to huge load interruptions. Reliable distribution system minimize this effect by allowing faults to clear themselves by protection device operations such as automatic reclosers (RAs) and quickly restores the power through system reconfiguration by minimizing the loads affected. Thus, in order to prevent the system from momentary faults, simultaneous placement of RAs has been also done which leads to a design of an advanced power distribution system (APDS). Thus, the reliability issues are of major importance for effective planning of an APDS. For evaluation of reliability measure, the contingency-load-loss index (CLLI) is assessed in this paper, which is independent of the failure rate and fault repair duration of the feeder branches. The performance of the proposed algorithm is extensively assessed and comparisons are made with Particle Swarm Optimization (PSOs), Genetic Algorithm (GA) and graph theoretical approach (GTA) applied on the 54 and 100-bus primary power distribution systems. The simulation results show that the proposed approach performed better than the other listed algorithms and can be efficiently used for the optimal design of an advanced power distribution system.

Introduction

Planning of power distribution network is highly complex as it has to consider various important issues including technical and environmental constraints while meeting the customer needs. The deregulation in power industry has opened a competitive market for power industries to hold market while keeping customers satisfied. This affects more to distribution sector due to their direct link with the customers. Thus an efficient planning of distribution network is essential for all the utilities. Mostly, the distribution networks are designed to be radial for operational convenience and lower protection cost [1–15]. The distribution system planning is basically an optimization process that considers simultaneous optimization of overall system cost and network reliability.

Overall system cost (total installation and operational cost) is minimized by optimizing the number of feeders, their routes, and the number and locations of the automatic reclosers. Past researchers have considered network reliability evaluation using non-delivered energy due to faults [10–13,16–18]. Computation of non-delivered energy is very difficult as the estimation of it depends upon the actual failure rates and repair duration of the feeder branches. Also, most of these heuristic based approaches have considered average failure rates and the repair durations of all the feeder branches for evaluation of reliability based on expected energy not served (EENS). In some works [19,20], the outage cost due to faults, as seen by utilities, is also used to optimize network reliability. These reliability objectives are basically functions of failure rate and fault repair duration of each feeder branch. Hence, they are generally optimized by choosing the branch conductor sizes with lower failure rates. Further, the fault in the feeder branches is unpredictable and it occurs due to various non-technical reasons, such as short circuit due to contact of small tree branches, animals etc. [19]. Moreover,

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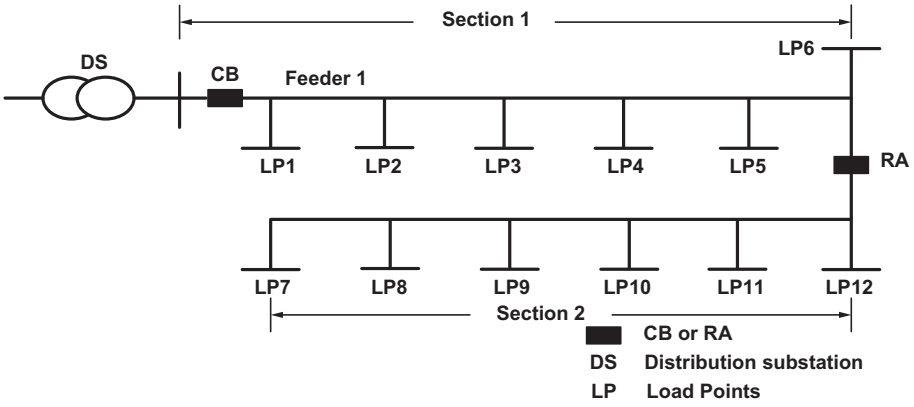

Fig. 1. Single feeder radial network with/without RA.

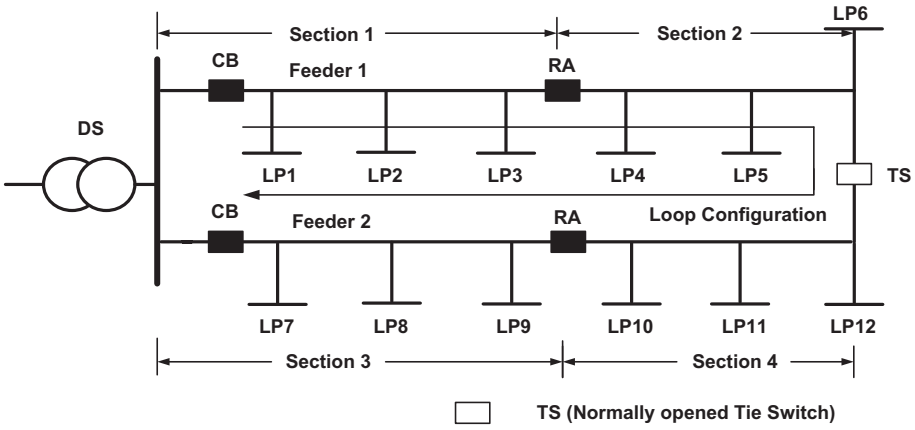

Fig. 2. Multi feeder radial network with two RA and a TS.

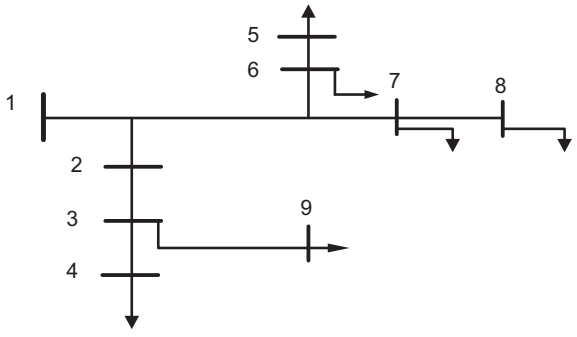

Fig. 3. Single line diagram of a sample radial distribution network.

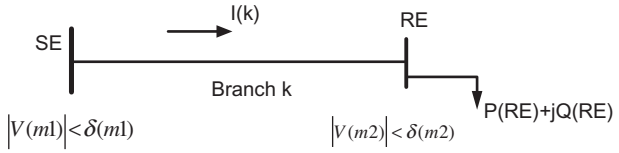

Fig. 4. Equivalent diagram of one branch of a radial distribution network.

the fault repair duration varies with the location and severity of the fault. Thus, this reliability evaluation may suffer from considerable inaccuracy. Thus, a new reliability index is assessed in this proposed work called contingency-load-loss index (CLLI) [19].

The distribution system planning problem is a non-linear, non-convex, non-differentiable, constrained optimization problem with integer and continuous decision variables. Research works reported using classical optimization techniques such as simplex programming [2], Branch and bound algorithm [3,4], Lagrange method [5], and quadratic programming [6] etc. for designing power distribution system. However, these classical optimization techniques have limited scope in practical applications as almost all the practical problems involves objective function that are non-linear, non-convex, and non-differentiable in nature. In this regard, the heuristics-based algorithms have distinct advantages, i.e., they can handle non-linear, non-convex problems, and do not require any gradient information. Some of the heuristics-based algorithms proposed for this planning problem are: genetic algorithm (GA) [11,13–16], network flow programming [12], and Tabu search [18] etc. Another powerful heuristics based algorithm, successfully used in many complex problems, is the particle swarm optimization (PSO) [20]. The advantages of the PSO over the other evolutionary algorithms are easy implementation, effective

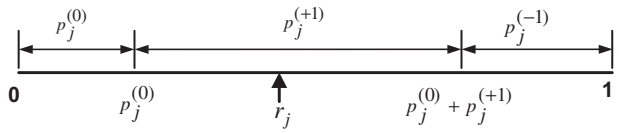

Fig. 5. The proportional selection rule of search direction.