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Optimization Techniques for Network Reconfiguration in Distribution System

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***Abstract*: Network reconfiguration is an operation to modify the network topology. The implementation of network reconfiguration has many advantages such as loss minimization, increasing system security and others. In this paper, two topics about the network reconfiguration in distribution system are briefly described. The first topic summarizes its impacts while the second explains some heuristic optimization techniques for solving the network reconfiguration problem.**

***Keywords*: Network Reconfiguration, Optimization Techniques, Distribution System.**

I. INTRODUCTION

Network reconfiguration is an import means for optimal operation of distribution network. It is an operation in configuration to alter the network structure of distribution feeders. The network reconfiguration is implemented via a number of normally closed switches (sectionalizing switches) and normally opened switches (tie switches) in a distribution system [1]. The topology of the systems is modified by changing the open or closed status of both switches. Although the configuration of distribution system is varied, loads are transferred among the feeders while the radial configuration format of electrical supply is still maintained and all load points are not interrupted. The advantages obtained from feeder reconfiguration are, for example, [2-4].

1) Minimization of the system's power loss;

2) Minimization of the deviation of nodes voltage;

3) Minimization of the branch current constraint violation;

4) Load balancing among various feeders.

5) Balancing service of important customer.

6) Increase system security.

7) Improve power quality such that the operating constraints are satisfied.

II. IMPACTS OF NETWORK RECONFIGURATION

A. Loss Minimization:

Network reconfiguration can reduce line losses while maintaining the load balance [5]. It allows the transfer of loads from heavily loaded feeders to relatively less loaded feeders. Such transfers of loads are effective in reducing the system power losses. When network reconfiguration minimizes real power losses under normal operating conditions, it simultaneously avoids transformer overload, feeder thermal overloads, and abnormal voltages while [6].

B. Loss Reduction and Capacitor Placement/Control:

To reduce losses and to improve voltage profiles, network reconfiguration achieves this goal by optimizing active power flow in the system while capacitor control achieves this goal by reducing reactive power flow in the system. It is clear that these two means have different properties and limitations, but more important is that these properties will strengthen each other for better optimization results in distribution systems [7].

It can be seen that the jointly optimal switch configuration and capacitor settings that minimize losses while satisfying voltage constraints [8]. Efficiency of this strategy mainly depends on the capacity and location of the installed capacitors. The size of the capacitors in service could be varied, employing the switched capacitors [9].

C. Voltage Stability Enhancement:

As the distribution systems normally have a combination of industrial, commercial, residential and lighting loads and the peak load on the substation transformers and feeders occur at different times of the day, the systems become heavily loaded at certain times of the day and lightly loaded at other times. If the distribution loads are rescheduled more efficiently by network reconfiguration, the voltage stability in the system can be improved. Reconfiguration also allows smoothening out the peak demands, improving the voltage profile in the feeders and increasing the network reliability [10].

D. Service Restoration:

Service restoration is in respond to a fault by 1) isolating the faulted area(s), 2) supplying power to the non-faulted out-of-service area(s), and 3) minimizing the inevitable load shedding [11]. Service restoration to as many customers as possible during the restorative state following a scheduled or forced outage, can be partly treated as a special load balancing problem. Network reconfiguration can also be used in planning studies in order to determine the optimum configuration of the network during one step of the overall planning procedure [12].

E. Feeder Load Balancing:

Networks are reconfigured to relieve overloads in the networks. This operation transfers loads from one feeder to another, which will significantly improve the operating condition of the overall system. Then network reconfiguration is executed in the distribution system to get the maximum improvement in load balancing [13].

F. Load Ability Maximization:

The maximum load ability index (MLI) that gives a measure of the proximity of the present state of a line in the Radial distribution system (RDS) to maximum load ability. MLI gives an estimate of additional load as a factor of the existing load that may be drawn before reaching the point of maximum load ability.

The value of MLI may be computed at each bus of the RDS. A value of MLI close to 1.0 indicates that the feeder would be unable to supply any more apparent power. Using the proposed index, the buses close to maximum load ability maybe identified and appropriate action for improvement may be initiated through an optimal reconfiguration scheme [14].

G. Reliability Maximization:

Reliability index assessment (RIA) for network reconfiguration in distribution systems is to model each system contingency and compute the reliability impact of each contingency. It may be carried out through various approaches, such as analytical approach based on component contributions, failure mode and effect analysis [15].

The impacts of automated switching devices and restoration procedure on the reliability should also be considered in distribution system planning and operation [16].

H. Protection Devices Coordination:

Network reconfiguration, it is usually assumed that the protective devices are still properly coordinated when the feeder configurations are changed by switch operations. On the other hand, protective device planning and coordination are usually carried out for a fixed configuration. The concept of maximum circuit for the design of a protection system which encompasses all possible circuit configurations [17].

III. SOLUTION TECHNIQUES

The network reconfiguration problem can be defined as an optimization problem, consisting of finding a configuration that maximize/minimize a certain objective function. It is a very difficult problem to be solved, since the number of candidate configurations grows exponentially with the number of available tie switches, leading to a combinatorial explosion and an impractical computational effort to achieve the best configuration. Many heuristic methods have been proposed in the literature. They usually lead to good quality, near optimal solutions [18].

A. Tabu Search:

Tabu search algorithm is one of the heuristic algorithms to solve the complex and multiple objectives optimization problems [19]. It is a strategy for solving combinatorial optimization problem with reasonable computing time. Tabu Search is built upon a descent mechanism which moves toward lower objective value. In the mean time, special features can also be added to avoid being trapped in the local optimum. This is can be realized by recording reverse move in a data structure, such as a finite length first-in-first-out, called tabu list. Elements lie in tabu list are called tabu moves. With the help of tabu moves, we can keep the search bias toward point with lower objective function values as well as escape from being trapped. However, the tabu list may forbid certain worthy moves possibly leading to a better solution at times.

An aspiration criterion is used to allow tabu moves to be released if they are judged to be excellent. In other words, tabu moves would be selected if the aspiration level is attained [20].

TS is built upon a descent mechanism which moves toward lower objective value. Meanwhile, special features are added to avoid being trapped in local optimum. This is realized by recording reverse move in a tabu list. However, in certain conditions, the tabu list may forbid some worthy moves which possibly lead to a better solution. So the tabu moves would be selected if the aspiration level is reached .

B. Ant Colony Optimization **[1]:**

Ant colony optimization (ACO) imitates the behaviors of real ants which are capable of finding the shortest path from food sources to the nest without using visual cues. Also, they are capable of adapting to changes in the environment, for example, finding a new shortest path once the old one is no longer feasible due to a new obstacle. Moreover, the ants manage to establish shortest paths through the medium that is called "pheromone." The pheromone is the material deposited by the ants, which serves as critical communication information among ants, thereby guiding the determination of the next movement. By the guidance of the pheromone intensity, the ants select preferable path. Finally, the favorite path rich of pheromone become the best tour, the solution to the problem.

C. Simulated Annealing Algorithm:

The idea of simulated annealing comes from thermodynamics and metallurgy: when a melting metal is cooling lowly enough (annealing), it tends to solidify in a minimum energy structure. The same principle is used in simulated annealing: at the beginning of the process almost every action are allowed (with a very high probability). This permits to jump from local minimum and visit other solutions eventually better than the present one. During the procedure the process temperature decreases, making the algorithm more selective (it accepts less solutions worst). Reaching the end of the procedure, almost only better solutions are accepted. The acceptance factor provides a way of calculating a value between 0 and 1, which will be compared with a random generated value, to determine if a worst solution will or not be accepted. The acceptance ratio for the worst solution depends on the cost difference between the present and the new generated solution, as well as on the temperature parameter. This parameter is responsible for the success of the search process and allows escaping from local minimum.

D. Genetic Algorithm:

Genetic Algorithm (GA) is computational models which simulate the procedure of biologic evolve. GA is a particular class of evolutionary algorithms (also known as evolutionary computation). GA is applied widely because it has the character of independent of grad in whole search and optimization. GA can find exact or approximate solutions to optimization and search problems.

Traditionally, solutions are represented in binary as strings of 0's and 1's, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. Initially, the chromosomes are defined according to the fitness function and then undergo the selection according to the random selection method or roulette wheel method. Finally, crossover and mutation take place and the best solution is obtained.

***E. Fuzzy Optimization* [26]:**

In the fuzzy domain, each objective is associated with a membership function. The membership function indicates the degree of satisfaction of the objective. In the crisp domain, either the objective is satisfied or it is violated, implying membership values of unity and zero, respectively. On the contrary, fuzzy sets entertain varying degrees of membership function values from zero to unity. Thus, fuzzy set theory is an extension of standard set theory [27]. The membership function consists of a lower and upper bound value together with a strictly monotonically decreasing and continuous function.

IV. CONCLUSION

Network reconfiguration has many impacts on distribution systems. For example, it can reduce line losses while maintaining the load balance. In addition, voltage profile improvement can be obtained. To achieve these benefits, the optimization problem should be solved to define the optimal switching actions. Many different heuristic optimization techniques have been applied as shown in the past studies.

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