CONFIGRATION MANAGEMENT OF ELECTRIC DISTRIBUTION NETWORK

Mohammed Abd El-Latif BADR Faculty of Engineering. Ain Shams university- Egypt
malbadr@yahoo.com

Salwa Ali Ahmed El BELAWY
Egyptian Electricity Holding Company (EEHC) – Egypt
eng_salwa_2010@hotmail.com

ABSTRACT

In the present paper a proposed planning management method for MV (medium voltage) distribution networks is formulated. This proposed method takes into consideration combined effect of voltage drop, overloads and a technical power loss based on the worst network conditions, and proposes the main constraints of mathematical calculation of the presented case studies. A genetic algorithm (GA) with multi-criteria optimization technique is applied for solving the problem of system reconfiguration in a distribution system. The GA has been tested with promising results on a real radial distribution system. The proposed algorithm can be applied efficiently to large systems, and the connectivity of the network can be easily described. The central role of Information Technologies (IT) in asset management is emphasized with supportive examples. The planning of MV distribution networks involves a master plan of the MV network applied to a real network of a city in Egypt.

INTRODUCTION

The configuration management (reconfiguration) of an electrical network includes the modification of the existing network configuration, and exchanging the functioning links between elements to improve one or more measures of network performance. In general, Electrical Distribution Networks (EDN^S) operate in radial configurations. The reconfiguration problem is one of multi-criteria optimization, where the solution is chosen after the evaluation of a group of indices. To eliminate the subjectivity of the above method, the reconfiguration problem is formulated as Pareto optimality.

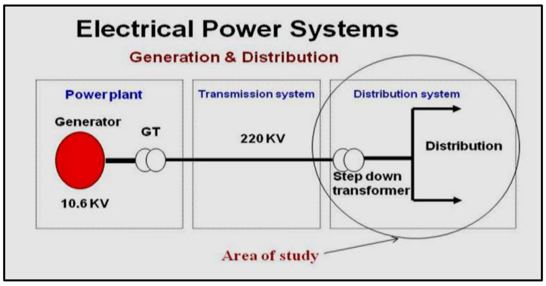

Figure1. Simplified diagram of electricity distribution systems starting from generation stations to consumers

The main task of network planning is to make studies for establishing new substations or extensions for existing substations in order to fulfill the demands of consumers. The national grid of Egypt includes medium voltage networks (11 kV & 22 kV) with primary distribution networks (33 kV & 66 kV). In order to make a successful study and design of MV networks, the following steps must are usually done:

1. Analysis of the Existing Network and Study of load forecast.
2. Study of voltage drop, overloads and power losses level.
3. Application of computer program to construct a strategy to face and solve all problems in the MV network.
4. Performance of economical calculations.

Network reconfiguration allows transfer of loads from heavily loaded feeders to lightly loaded ones. Such a transfer is effective not only in terms of altering level of loads on the feeders being switched, but also in improving the voltage profile along the feeders and reducing the overall system loads. Generally, a balanced system has smaller worst voltage drops and energy losses. As a result, a utility can produce power with higher quality and lower electricity price.

Due to analysis of the existing network, some urgent works are to be done to overcome the existing network problems, especially overload and voltage drops. The load-forecast study leads to the key features of the studied strategies, which deal with cable loading. The duration of the study is ten years. This period is a compromise between the better global economic optimization provided by a longer term master plan, and the accuracy of available data, and load forecast model. The planning study for real city zone, considering three different types of loads, is performed as follows:

Urban area

A careful study to classify this area into three zones; one having a big university and health center, second one for habitation, the third one having small industries.

Extension area

This area includes the recent developed areas around the inner urban zone described above.

The reconfiguration algorithm directly constructs an optimal solution considering minimum overloads and losses. The unbalanced loads problems for a radial type distribution system are solved by the proposed method.

RECONFIGURATION OF DISTRIBUTION NETWORK AS MULTICRITERIA PROBLEM

The reconfiguration issue represents a multi-criteria optimization problem, where the solution is chosen after the evaluation of a group of indices. Genetic Algorithms

(GA) [1] are optimization search procedures which have gained a great deal of interest over the past decade. GA search for the global optimum at different zones in the search space at once, and not like the other optimization techniques where any of them works with only a single point and depends on the objective function derivatives. They are particularly effective for combinatorial optimization problems with large and complex search spaces. The search of any GA starts with a random generation of a population of strings. Each string is divided into a number of substrings equal to the number of the problem variables. Each substring consists of a number of genes to present one of the variables in a certain coding system. Figure 1 shows the basic flow diagram of a genetic algorithm.

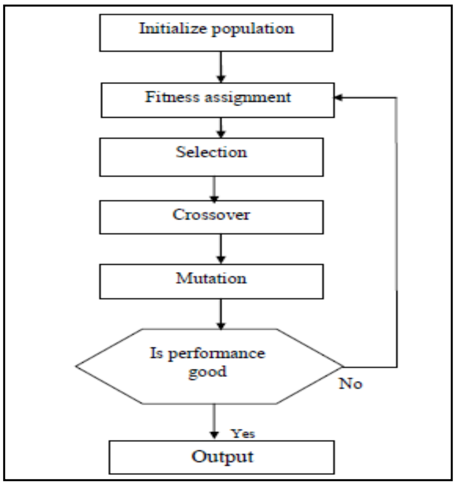

Figure 2.Basic structure of genetic algorithm

MULTI-OBJECTIVE EVOLUTIONARY ALGORITHMS

Multi-objective optimization methods, deal with finding optimal solutions to problems having multiple objectives [2]. So, in this type of problems the researcher is never satisfied by finding one solution that is optimum with respect to a single criterion. The concept is that the solution to a multi-objective optimization problem is normally not a single value, but instead, a set of values also called the "Pareto set". Let us illustrate the Pareto optimal solution with the time & space complexity of an algorithm shown in the figure 2.

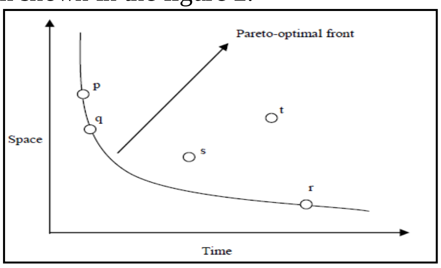

Figure 2. Pareto optimal solutions

In this problem we have to minimize both times as well as space complexity. The point 'p' represents a solution, which has a minimal time, but the space complexity is high. On the other hand, the point 'r' represents a solution with high time complexity but minimum space complexity. Considering both objectives, no solution is optimal. So in this case we can't say that solution 'p' is better than 'r'. In fact, there exist, many such solutions like 'q' that also belong to the Pareto optimal set, and one that sort, the solution according to the performance metric considering both objectives. All the solutions, on the curve, are known as Pareto-optimal solutions. From figure 2 it is clear that there exist, solutions, which do not belong to the Pareto optimal set, such as a solution like 't'. The reason why 't' does not belong to Pareto optimal set is obvious. If we compare 't' with solution 'q', 't' is not better than 'q' with respect to any of the objectives. So we can say that 't' is a dominated solution or inferior solution. Now we are clear about the optimality concept of multi-criterion. Based on the above discussions, we first define conditions for a solution to become dominated solution or inferior solution. Let us consider a problem having "m" objectives:

Say f_i *, i = 1,2,3,....., m and m >1*

Any two solutions $u^{(1)}$ and $u^{(2)}$ (having 'decision variables each) can have one of two possibilities-one dominates the other or non dominates the other. A solution $u^{(1)}$ is said to dominate the other solution $u^{(2)}$, if the following conditions are true:

1. The solution $u^{(1)}$ is no worse (say the operator denotes worse and denotes better) than $u^{(2)}$ in all objectives, or

$$fi\,(u^{(1)}) \geq fi\,(u^{(2)}),\ \ i = 1,2,3....,m.$$

2.The solution $u^{(1)}$ is strictly better than $u^{(2)}$ in at least one objective, or

$$fi\,(u\,(1)) > fi\,(u\,(2))\ \text{for at least one, } i\ \{1,2,3,..\ ,m\}.$$

If any of the above condition is violated, the solution $u^{(1)}$ does not dominate the solution $u^{(2)}$. If $u^{(1)}$ dominates the solution $u^{(2)}$, then we can also say that $u^{(2)}$ is dominated by $u^{(1)}$, or $u^{(1)}$ is non-dominated by $u^{(2)}$ or simply between the two solutions, $u^{(1)}$ is the non-dominated solution [2]. The following definitions ensure whether a set of solutions belongs to a local or global Pareto-optimal set:

Local Pareto-optimal set

If for every member u in a set S, ∃ no solution v satisfying $||u - v||_{\infty} \leq \varepsilon$, where ε is a small positive number, which dominates any member in the set S, then the solutions belonging to the set S constitute a local Pareto-optimal set. The definition says that if we perturbing the solution u in a small amount then the resultant solution v dominates any member of that set, then the set is called local Pareto optimal set.

Global Pareto-optimal set

If no solution exists in the search space which dominates any member in the set S, then the solutions belonging to the set S constitute a global Pareto-optimal set.

DEVELOPMENT OF GA FOR RECONFIGURATION OF DISTRIBUTION SYSTEMS

In both normal and emergency operation of a distribution system, decreasing overloading is usually achieved by reconfiguring the distribution feeders and redistributing the load currents among feeders and transformers. The selection of an optimum configuration among discrete numerous switching options requires solution of a complicated combinatorial optimization problem which cannot be solved without making approximations. GA has been recently proven as an effective tool for solving combinatorial optimization type problems**.**

Genetic mode

GA is derivative-free stochastic optimization method based loosely on the concepts of natural selection and evolutionary processes. The characteristics of GA used here are as the following:

Size of population

Choosing the size of population is the first step the programmer has to do. To increase the probability of finding an optimum solution, a large size of population has to be used, but this also affects the speed of computation. Besides large population, means large number of computations that decreases the power of GA.

Codification of chromosomes

In this case, the representation by means of strings of bits was chosen. Each gene j of the chromosome can store a "0" which indicates the absence of the corresponding line or "1" that indicates the presence of the line. This means that the chromosome is considered as a network reconfiguration. Another restriction is imposed on the sum of all genes performed on a certain chromosome. In addition, this configuration must be radial which means that it does not contain any closed loop [3].

Fitness functions

In the distribution system planning, engineers consider one or more of the following three objectives, which are used, in the proposed GA [2], and they are described as follows:

$$S_j^u = \sqrt{\tfrac{1}{3}\sum_{p=a,b,c} |\overline{S}_j^p - \overline{S}_j^o|^2} \qquad (1)$$

Three complex powers expressed by $S_j^a, \overline{S}_j^b, \overline{S}_j^c$, for individual feeder loading. The superscripts a, b and c stand for the corresponding phases, and j denotes the specified order of the feeder segment. The unbalance of these three complex powers can be evaluated as in equation (1). In which, the $\overline{S}_j^o$ stands for an ideal loading per phase as follows:

$$\overline{S}_j^o = (\overline{S}_j^a + \overline{S}_j^b + \overline{S}_j^c) / 3 \qquad (2)$$

Average voltage drop

Reducing the voltage drop and compressing the voltage spread are also important objectives to be achieved by distribution engineers. The average voltage drop can be evaluated as follows:

$$AV_d = \tfrac{1}{n}\sum_{k=1}^{n} VD_k \ , \qquad (3)$$

Where, n is the total number of load points of the objective feeder, and

$$VD_k = \tfrac{1}{3}\sum_{p=a,b,c} |\frac{V_{rated} - V_k^p}{V_{rated}}| x100\% \qquad (4)$$

In which V_{rated} represents the rated phase voltage, V_K^p denotes the magnitude of the phase voltage of phase "p" at load point k, and VD_k denotes the average of the three phases voltage drops at load point k.

Total line losses (TLL)

Decreasing system losses and improving system operation efficiency are usually one of the major objectives of a power utility. Hence, minimization of line losses is also the objective function of the proposed approach. The transmission losses can be expressed as:

$$TL_\ell = \sum_{j=1}^{m}\sum_{p=a,b,c} (I_j^p)^2 . r_j^p + (I_j^{ne})^2 . r_j^{ne} \qquad (4)$$

Where: I_j^p and r_j^p are the current and resistance of phase p of the jgth feeder segment, respectively. The last term is included for the line losses in the neutral wire of the jth branch segment, which was not included in the problem formulation given in [3].

PRESENTATION

The model of distribution system shown in fig. 4 is tested by the proposed method. This system includes one substation, and four distribution boards. The reconfiguration problem attempts to determine the states of the switches for minimizing the effects caused from the unbalance operation.

SOFTWARE USED FOR MEDIUM VOLTAGE NETWORK STUDIES

The "PRAO" program is used for medium voltage distribution network studies. Its application environment is, anticipation, optimization, economic overview, dynamic time management and user-friendly with local integration.
"PRAO" takes into account the dynamic evolution of the network over time, whether it is for the medium or the short term. Network development decisions are facilitated by highly efficient multi-criterion optimization algorithms, together with investment considerations [4].

Case study

Sample of distribution network, shown in fig. 4, is tested by the proposed method. This system includes one substation, four distribution boards, The network is fed from 66/11 kV substation, and contains 11 feeders; all fed from the main bus bar of the 11 kV distribution board, which in turn is fed from the main substation via four cables of cross section AL (3x240) mm2. Strategy studies, this strategy have been based on a technoeconomic study considering the total present values of the different equipment. Over the duration of the master plan period, all the studies consider all the regulations of the overloads, voltage drops and power losses in normal and emergency conditions, as described in the following table1.

Table 1. The standard values

Situation	Normal	Emergency
Load	1Amper (A) /mm2 for aluminum cables ,	A/mm2 for aluminum cables ,
	1.5 A/mm2 for overhead lines	1.5 A/mm2 for overhead lines ,
	2A/mm2 for copper cables.	2 A/mm2 for copper cables.
Voltage drop	3%for each kiosk or MV customer	6%for each kiosk or MV customer
Overloads	50%for each kiosk or MV customer	80%for each kiosk or MV customer

The calculations of the normal and emergency where carried out using PRAO software..

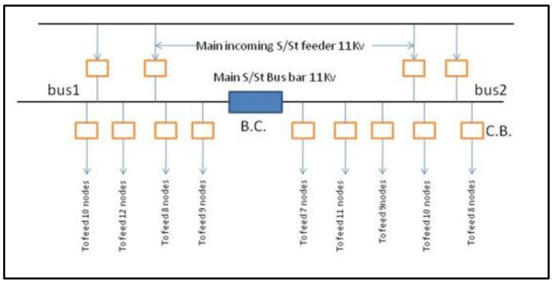

Figure 3. Scheme for sample network structure of the one of distribution board testing system

The sample network is formed of 71 nodes, two sections and 9 outgoing & 4 incoming feeders.

ECONOMICAL CALCULATIONS

Costs included in the present value calculations will be the investment costs based on a general normative average according to their MV supply cost.

Present value calculation for strategy

The following table 2, describes for each year the components of the total present value of the strategy.

Table 2. Total present value of the strategy

Year	Cost of Work in thousands L.E
2009	7156.5
2010	572
2011	2198
2012	402
2013	368
2014	1313.5
2015	376.5
2016	368
2017	368
2020	249
Total	13371.5

The total present value for this strategy is 13.3715 million Egyptian pounds.

RESULTS AND DISCUSSION

This case study represents how to perform management method for MV distribution networks, through analysis of the existing network to know the weak points and make solution to solve the problems, which face the network through strategy. PRAO program helps how to make master plan of the MV network, and how to face increasing of loads in the future. Since the Table 3,. Repesent the network optimal configuration using the proposed GA.

Table 3. The network optimal configuration when the genetic program is applied.

Situation	Before reconfiguration	After reconfiguration
Total powered load	69579.9 kVA	69579.9 kVA
overload	22097.3 kVA	5484.6 kVA
Voltage drop	9.23 %	4.13 %
Power losses	3175.1 kW	1454.2 kW

CONCLUSIONS

This paper deals with planning of medium voltage distribution network which can be divided into substations, distribution boards, conductors and kiosks. Studies of the factors affecting the MV distribution network have been presented. The magnitude of energy dissipation or the unavoidable component depends largely on the system configuration, pattern of loading of distribution conductors, magnitude and types of loads, characteristics of equipments etc. In this paper, there is a formulation of the feeder reconfiguration to reduce voltage drop and balance the load of distribution network under normal operating conditions. The calculation of the voltage drop, overload and technical losses in the sample network was calculated using multi criterion algorithm. Multi criterion algorithm has been used for the optimization of the electrical network. This algorithm is based on reconfiguration of the system under study, while observing the over load and voltage drop combined with system loss to reach the optimum configuration for the system. Results of the paper show that the multi criterion algorithm has succeeded to reduce voltage drop, decrease overload and technical loss for all sample networks of the system to reach the acceptable limit.

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