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Application of Evolutional Algorithms for Productivity Improvement and Reduction of Active Power Losses in Radial Distribution System

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Abstract: Power losses in distribution system have become the most concerned issue in power losses analysis in any power system. In the effort of reducing power losses within distribution system, reactive power compensation has become increasingly important as it affects the operational, economical and quality of service for electric power systems. This paper presents a new method for determining capacitor placement in radial distribution systems. The capacitor placement problem consist of finding size & places to install capacitor bank in an electrical distribution network aiming to reduce losses and voltage profile Improvement due to the compensation of the reactive component of power flow.
The capacitor placement is hard to solve in sense of global optimization due to the high non linear and mixed integer problem. To solve the problem efficiently, this paper by Genetic Algorithm (GA) and Colonal Selection Algorithm (CSA) that is one of the efficient optimization methods.

Key-word: Capacitor placement, Genetic Algorithm, Colonal Selection Algorithm, Back/Forward Sweep, Loss Reduction.

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1 Introduction

Capacitors are often installed in distribution system for reactive power compensation to carry out power and energy loss reduction, voltage regulation, system security improvement and system capacity release. Economic benefits of the capacitor depends mainly on where and how many capacities of the capacitor are installed and proper control schemes of the capacitors at different load levels in the distribution system [1].

A variety of methods have been devoted to solving the capacitor placement problem. A capacitor allocation techniques can be found in [2]. Among various approaches, the metaheuristics play a relevant role, since exact optimization methods are not suitable for tacking real world instances. Focusing only on metaheuristic methods, [3-6] propose different methods for capacitor placement problem.

This article presents a new approach base on a Genetic Algorithm (GA) & Colonal Selection Algorithm (CSA) for solving the capacitor placement problem. In this paper presents a very fast and simple power flow problem for solving the capacitor placement. The main contribution of this study is combination of GA & CSA. To demonstrate the effectiveness of proposed algorithm, this method is applied to a real radial distribution feeder. In comparison with conventional power flow method in terms of solution accuracy and computational time.

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2 Problem Formulations

2.1. Objective function

The objective function of the problem can be expressed as follows to minimize the capacitor investment cost and system energy loss and voltages at different buses within the limits.:

$$Min\ f(i,c) = \sum_{i=1}^{I} C\,(i,Qc) + P_{loss}(i,Qc)$$

Qc : discrete variables, for fixed typed capacitor:In this formulation, sizing vector whose components are multiples of the standard size of one capacitor bank. $C_i(i,Qc)$ represent the investment cost associated with the capacitor installed at node *i*. P_{loss} is the power loss.

2.2. Evaluation of fitness function

The evaluation of fitness function is a procedure to determine the fitness of each string in the population. Since the GA & CSA proceeds in the direction of evolving best-fit strings and the fitness value is the

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only information available to the GA & CSA, the performance of the algorithm is highly sensitive to the fitness values. The fitness function F, which has been chosen in this problem, is

$$F = \frac{1}{f(i,c)}$$

3 Proposed Algorithm

3.1. Implementation of CSA

Clonal Selection principle is a form of natural selection [3] and it describe the essential features which contain adequate diversity, discrimination of self and non-self and long-lasting immunologic memory. The main idea of clonal selection theory lies in that the antibodies can selectively react to the antigens, which are the native production and spread on the cell surface in the form of peptides. When exposed to antigens, the immune cells that recognize and eliminate the antigens will be selected and arouse an effective response against them. The reaction leads to cell proliferating clonally and the colony has the same antibodies. Consequently, the process of clonal selection actually consists of three main steps:

Clone:descend a group of identical cells from a single common ancestor through asexual propagation. Mutation: gain higher affinity mainly through hypermutation [4]. Selection: select some excellent individuals from the sub-population generated by clonal proliferation.

Assuming the objective function and restraining conditions of optimization are the antigens invading the body and candidate solutions are the antibodies recognizing antigens, then the process of optimization can be considered as the reaction between antigens and antibodies, and the affinity between the antigens and the antibodies are the matching degree between objective function and solutions.

3.2. Implementation of GA

In artificial intelligence, an Evolutionary Algorithm (EA) is a subset of Evolutionary Computation that involves combinatorial optimization problems. GA's are generalized search algorithms based on the mechanics of natural genetics[13]. GA maintains a population of individuals that represent the candidate solutions to the given problem. Eachindividual in the population is evaluated to give some measure to its fitness to the problem from the objectivefunction. Genetic Algorithms combine solution evaluation with stochastic operators namely, selection, crossoverand mutation to obtain optimality.

3.3. Load flow method

In order to evaluate the power distribution network and examine the effectiveness of possible changes on system in network programing state, it is necessary to perform power flow analysis on the network which is probably the most important of all network calculations.

3.3.1 Backward Forward Sweep method

The methods proposed for solving distribution power flow analysis are essentially classified into three categories: direct methods, backward/forward sweep methods and Newton-Raphson (NR) methods. In this paper we utilize the back/forward sweep method which is simple, flexible, reliable, and didn't need Jacobian matrix and its inverse and have high convergence speed.Study of power flow system is usually performed to achieve the following goals:

a) Sufficient Active and reactive power flow in network branches.
b) To avoid overloading in different sections.
c) Effect of adding new parts to the system under study.
d) To analysethe loss in different section at the critical situation.
e) The optimal power flow analysis and assignment.
f) Optimization of system losses.

The Back/Forward Sweep algorithm is as below:

First, the initial voltage of all buses is consider to be 1 ∢0. With the known primary load of each line, the current of last bus is calculated as below:

$$s_n = V_n I_n^* \Rightarrow I_n^* = \frac{s_n^*}{v_n^*} = \frac{p_n^* - JQ_n^*}{V_n^*}$$

In each iteration, new voltage and load flow is calculated.New voltage of each bus is calculated using *kvl* law and by starting from first bus.

Having new voltages, new current of each line is obtained utilizing the last bus.This process will continue until the maximum total voltage difference of all buses is greater than the pre-specified value [7,8][7, 10]. The flowchart of proposed Back/Forward Sweep method is shown in Fig (1).

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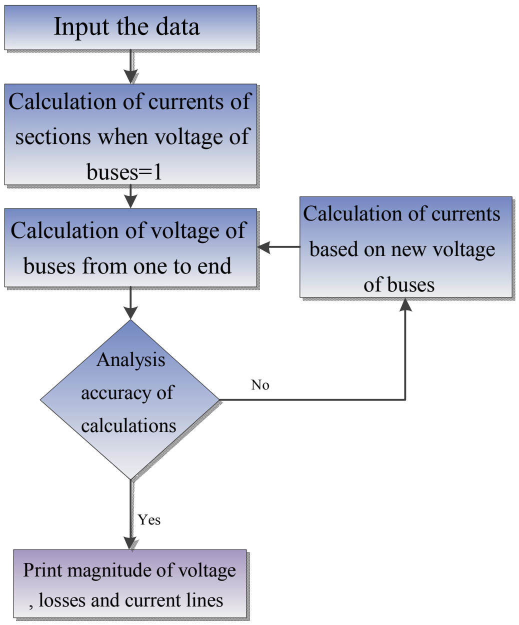

Fig Fig.1 : Flowchart Back/Forward Sweep method

4 Problem Solution

In order to test the proposed algorithm, a real radial distribution network has been considered, Figure 2 and Table 1 show the single line diagram and specifications of test network, respectively.

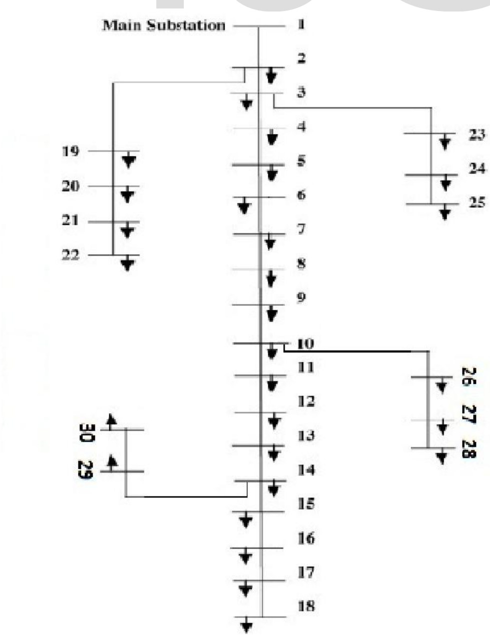

Fig.2 Test network single line diagram

A number of tests on the performance of the proposed algorithm have been carried to determine the most suitable GA & CSA parameters setting.

Table 1: Specification of test network

power		Impedance of	Bus
KW	KVAR	Section	Number
0	0	…	1
2.7	0.9	0.016+j0.039	2
2.7	0.9	0.015+j0.04	3
7.2	2.7	0.015+j0.038	4
16.2	6.3	0.017+j0.041	5
58.5	27	0.017+j0.041	6
7.2	2.7	0.015+j0.039	7
18.9	8.1	0.013+j0.037	8
7.2	2.7	0.014+j0.04	9
24.3	10.8	0.017+j0.042	10
0	0	0.015+j0.039	11
12.6	5.4	0.016+j0.041	12
18	7.2	0.016+j0.041	13
5.4	1.8	0.015+j0.038	14
8.1	3.6	0.015+j0.038	15
5.4	1.8	0.016+j0.041	16
10.8	4.5	0.013+j0.044	17
15.3	6.3	0.015+j0.039	18
2.7	0.9	0.012+j0.035	19
12.6	4.5	0.014+j0.039	20
20.7	9	0.015+j0.041	21
7.2	2.7	0.016+j0.041	22
10.8	4.5	0.016+j0.041	23
10.8	1.8	0.016+j0.041	24
10.8	1.8	0.016+j0.041	25
10.8	4.5	0.016+j0.041	26
7.2	1.8	0.016+j0.041	27
10.8	4.5	0.016+j0.041	28
7.2	4.5	0.016+j0.041	29
10.8	4.5	0.016+j0.041	30

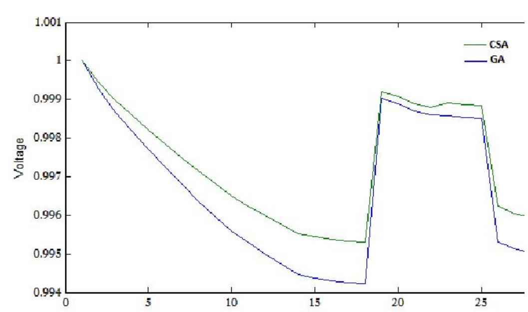

Fig.3: Voltage profiles of system for two Methods

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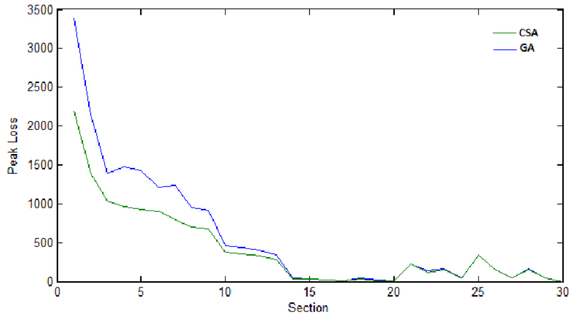

Fig.4: power loss profiles in each branchs of systems for two Methods

Table 2: Execution time and number of Iteration

Feeder	GA Method		CSA Method	
	Time (sec)	Iteration	Time (sec)	Iteration
30 bus Network test	0.0165	3	0.00565	3

5 Cost Analysis

For economic evaluating of the proposed algorithm, the following equation were considered for the economic gain:

$$Annual\ Gain = 8760 \times kwh.cost \times \Delta P_{loss}$$

Where:

Annual Gain: the annual economic gain with using the capacitors regard to losses reduction for one year.

8760: the conversion factor of power losses to energy losses.

Kwh.cost: the cost of energy.

ΔP_{loss}: power losses reduction regard to use of capacitors.

$$Annual\ Cost: ((\alpha.CapCost)/(1-(1/(1+i)^{\beta}))$$

Where:

Annual Cost: the total cost of capacitors and their accessories for one year. α: Investment period, β: Interest rate. According to above relations, the fitness function can be formulated as:

$$Fitness = Annual\ Gain - Annual\ Cost$$

In this study for the example network and with considering of the cost in *IRAN*, for the planning study 20 years long and interest rate 20% , inflation rate 25% , kwh. cost = 200 Rials, the reduction cost of investment cost of losses for 5 years was equal to cost of investments and the fitness will be 28550000 Rials for 20 years period.

Table 4: cost & size capacitors

(a)

method	GA
Location	3 4 15 26 27 22 30
Capacitor size (kvar)	450 600 750 900 1050 1200 1350
Capacitor cost (Toman/kvar)	0.253 0.28 0.276 0.189 0.238 0.1760.217

(b)

method	CSA
Location	3 8 10 16 22 25 28
Capacitor size (kvar)	300 300 450 600 750 900 1050 1200 1200
Capacitor cost (Toman/kvar)	0.36 0.36 0.253 0.28 0.276 0.189 0.238 0.1760. 1760

These tables 4 show the CSA algorithm is powerful for allocation and sizing the capacitor bank in the test network.

6 Conclusion

In this paper, implementation of GA to the optimal placement of capacitor bank has been illustrated. The effectiveness of the used power flow method to solve the capacitor placement problem has been demonstrated through the numerical example. The result showed the GA is a proper optimization method for optimal placement of capacitors bank iN radial distribution network. Furthermore, It was showed the used power flow method in capacitor placement problem is better than conventional power flow method in terms of solution quality and consumed time. The economic study showed the investments costs will be compensated in a few years by reduction costs of losses

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