OPTIMIZATION OF PARALLEL COMPENSATION IN DISTRIBUTION NETWORK WITH PSO

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ABSTRACT

This paper describes a possible application of Hybrid Particle Swarm Optimization (HPSO) method for solving the optimum distribution of capacitors used for the parallel compensation in a distribution network. The aim is to find such distribution of capacitors leading to minimum costs of network losses and costs of acquisition and operation of capacitors while respecting given limitations. Its functionality is shown on an example of a power network.

1 INTRODUCTION

This program uses a new type of optimization algorithm called hybrid particle swarm optimization (HPSO) for solving the optimization of distribution of capacitors of parallel compensation in a distribution network. The application of HPSO has been worked out using Matlab programming language. Primary objective the program was its universal application to various kinds of networks, loads and feeders. The main criteria for finding the distribution of capacitors are following:

1. Bus voltage drop cannot exceed a given value
2. Cost of acquisition of capacitors and costs of network losses should be as low as possible.

The HPSO algorithm that is based on the method of Particle Swarms Optimization (PSO), but it incorporates also certain principles genetic algorithms (GA). This method belongs – together with genetic algorithms and PSO – to the evolution algorithms and to the methods of global optimalization. HPSO disposes of its common components, such as system of population initialization, searching optimum through generation updating and evaluation system using a fitness function. The advantage of the incorporation of the fitness function leads to lower requirements on the criterial function. It does not have to be differentiable nor even continuous. The only requirement concerning the criterial function is that it must be evaluable for each input parameters setup.

The main difference between HPSO and PSO consists in separating the algorithm into two parts: a searching one and an optimizing one. Another important difference is that includes the evolution crossover operator, not used in standard PSO.

The simplified principle of HPSO can be described the following way. Each potential solution is called particle. This particle flies through the N-dimensional space of solution. Each solution that has been flown by a particle is tested. If the solution has extraordinary qualities, it is saved among elite individuals. Then the second phase follows where the elite individuals are crossed with each other. This leads to avoiding the deadlock of the algorithm in the local minimum and at the same time the continuation of the evolution of new individuals is assured.

HPSO optimization method has not been so far used to power engineering, therefore the described application represents a novel approach.

2 HPSO

This algorithm was used as core optimization program. The HPSO on based on the PSO and evolution operator crossover. Principle of HPSO is flying particle through the problem space, when the best solutions are copied between elite individuals. Each particle is determined by actual position presented by potential solution, and the velocity. In the second part elite individuals are crossed with itself and new potential better solutions are created. The solution generated by PSO is called particle then PSO results used by GA and are called individuals.

First generation of particles is generated with random position and velocity. Each position represents one solution. Particle's velocity is checked to be in the limits. Top speed can be for each unit of velocity different. If velocity component overcome allowed value then it is set to the top value. After this correction, solution is evaluated with fitness function. The lower fitness value then better the solution is. Solutions are sorted with respect his fitness function. Then the group of elite individuals is created where the solutions are copied from PSO part. In the second part will describe their edits. First cycle end after the creation of the new velocity vector and the calculation of the new position of particle. New vector of velocity is calculated by this formula:

$$\overline{v_k} = \overline{v_k} + c \cdot \left(\overline{pos_k} - \overline{pos_n} \right) \qquad (1)$$

Where is v_k vector of velocity *k-th* particle

c is constant which set to ballance of divergence of positions

pos_k is actual position *k-th* particle

pos_n is actual position *n-th* particle which in random access.

New position will be assigned by this formula:

$$\overline{pos_k} = \overline{pos_k} + \overline{v_k} \qquad (2)$$

In the next generation, there are same changes so the first generation. At first actual positions are evaluated and new positions as described in first part are recreated. The actual positions are copied to the group of elite individuals, when are save information form before generation. Expect actual position its save their fitness function. It make possible sorted all individuals in elite group. The more qualitative the solution is, the higher position it has among the others. Now can applying procedure which inspired genetic algorithm – decimation. In decimation is saved only better half of population of individuals. This brutal but simple method it can be easer crease total quality of population.

For acceleration of convergency there are two components. First one have model in GA again it is the crossover operator. Crossover operator is working on this way. At first it randomly chooses quaternion form elite group. Next time is tournament - two individuals are competition of parent position. The winner is solution with lower fitness function. When the both parents are chosen then are created new solutions with one point crossing. Size of new created group children is restricted to the size of elite group. Children are evaluated and assigned to elite group, which is again sorted and decimated to the original size of elite group. Second component for convergency acceleration is insert best solution to one particle. It is returned to original PSO. This step was ending whole cycle.

The whole cycle is repeated for every number of the generation. In the bad case the elite group can be flood with the only one solution. The opposite of this bad case is here safety lock in shape intelligent sort of solution. If the algorithm founds in the group two equivalent individuals then another individual is sent to the last position in group. The free position is given next individual. This process ensure that at the top position then will be each individual only one.

3 PSO CONSTRAINTS

Each particle should be kept in limited space corresponding to the parameter limitations. This problem is solved in this program by one of four methods. In the first case the particle arriving to the forbidden area is returned to its previous position. In the second case the particle is held on the border. In the third case the particle is bounced back to the allowed space. Bounces back to the allowed space can be perfect or non perfect. In non perfect bounce it is able bounce return to random position. In fourth case particle can fly through forbidden range back to the allowed space, but on his besides. This case can be used in case of small limited space.

4 HPSO PROGRAM

The application of HPSO has been worked out in Matlab programming language. Program construction was designed as a modular structure to protect program from the other users mistakes. Program has simple graphic terminal output is able to export data output to Microsoft Excel.

Its practical applicability will be demonstrated on an example of a 22 kV overhead distribution network. This radial network has 30 branches and 15 loads. These loads have a various value for different time interval. Figure 1 shows behavior of the fitness function of the best individual over the course of generations. In this case, the obtained optimum led to increasing the power factor at the supply point from 0.900 to 0.996. The economic return to investment and service of capacitors was been calculated to 5 years. The scheme of the best solution is on Fig. 2. Power factor depending to the time and power losses are shown in table Tab. 1.

During next 25 year of technical life time of capacitors this is able to save about 37 millions CZK compared to the actual situation. Calculation spent 8 minutes when program tested 99 100 solutions from 10^{30} possible solutions.

Power Losses	Time	6~9	9~16	16~23	23~6
before compenzation	MW	1,006	1,520	1,543	1,194
after compenzation	MW	0,876	1,334	1,358	1,037
lower losses after compenzation	%	15,3	16,1	13,9	15,4
cos φ before compenzation	-	0,9026	0,9025	0,9020	0,8997
cos φ after compenzation	-	0,9999	0,9967	0,9969	0,9994

Tab. 1: *Values of power factor and power losses for the best solution*

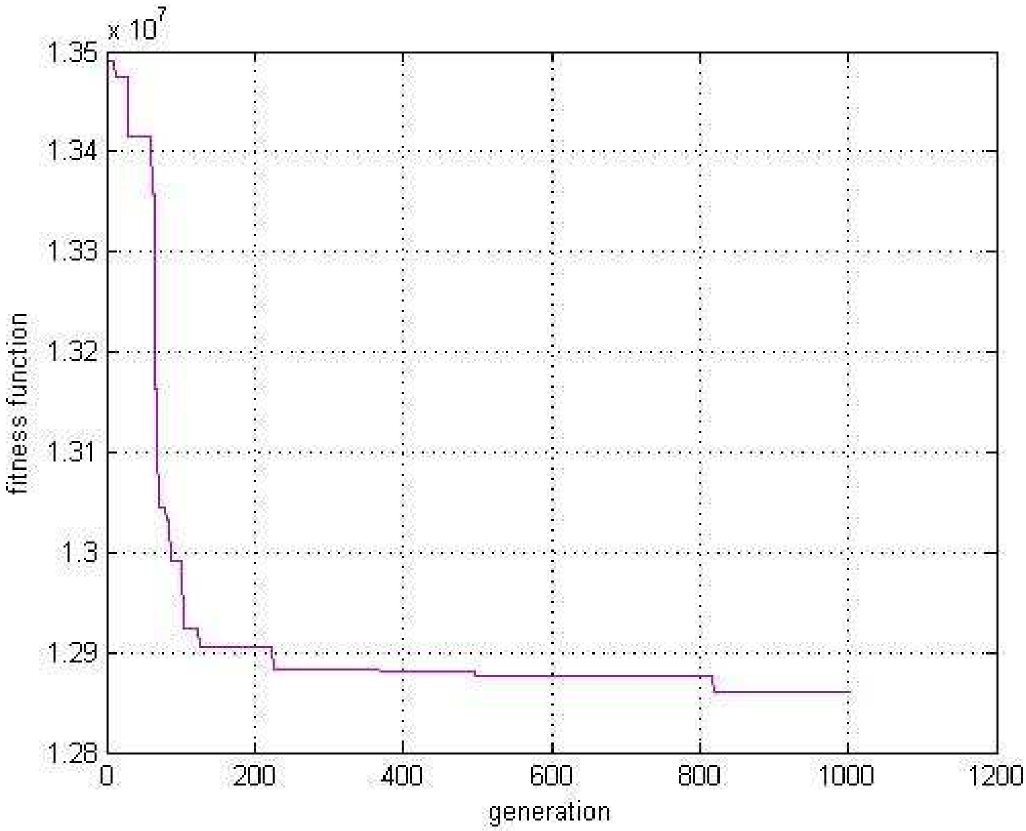

Fig. 1: *Growing of fitness function*

5 CONCLUSION

This program using algorithm HSO is shown as superior and universal tool for solving optimization dislocation of capacitors of parallel compensation in distribution network. This algorithm profiting from the qualities of both PSO and GA has big potential to develop into successful in the domain of global optimization algorithms. From its parents it takes advantages etc. robustness, flexibility and low demands to the criterion function. On the other hand it has also several disadvantages as stochastic behavior resulting from the searching method.

As a possible application of the method is concerned, it could be used especially in industrial networks where there is a need to limit losses due to the reactive currents and to improve voltage level at network buses. If the exponential growth of solutions is considered with every bus and that the position and magnitude of loads changing with time, than starting from a certain number of buses causes the impossibility of the effective use of classical methods. Solution of this combinatorial problem with HPSO was found to be reached more quickly comfortable results to the classical method.

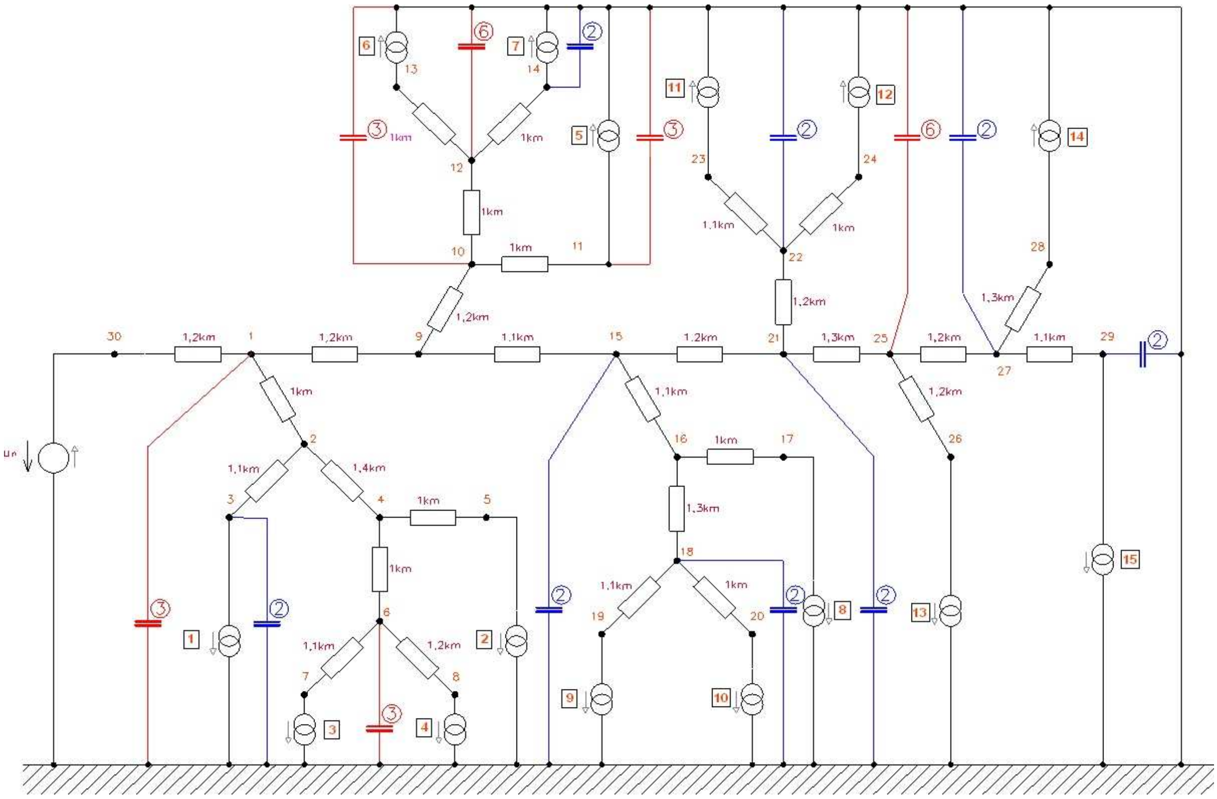

Fig. 2: *Schematic diagram of network*

REFERENCES

[1] Xiaohui, H.: Particle Swarm Optimization, 2003,

http://www.swarmintelligence.org/index.php

[2] Barati, H., Haghjoo, F., Yarali, A.: Application of Genetic Algorithm (Corrected) for Optimum Size and Location of Shunt Capacitors on Radial Distribution System from Customers Point of View as well as that Electric Utilities, 17th International Conference on Electricity Distribution, Barcelona, 12-15 May 2003

[3] Moloh, J.: Electric Power System Applications of Optimization, ISBN 0-8247-9105-3

[4] Mařík, V. a kol.: Umělá inteligence 3, Academia Praha, ISBN 80-200-0472-6

[5] Vybíral, D.: Optimalizace energetické distribuční sítě, Diplomová práce FEI VUT v Brně 1999