UTILIZATION OF PSO WITH PARALLEL OPERATIONS FOR OPTIMIZATION OF MV NETWORK COMPENZATION

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ABSTRACT

This article deals with possibilities of determining optimal distribution of capacitors by particle swarm optimization (PSO) with parallel operations used in shunt compensation of medium voltage (MV) distribution network. The goal is to find such a parameter setup which leads to minimum price, minimum level of the total power losses, price of capacitors and maintenance expenses while respecting given limitations.

1. INTRODUCTION

One of the important aims of distribution companies is the operational cost reduction. One of the ways how to do it is decreasing of power losses in the power network using parallel compensation. The optimization of shunt compensation distribution is multicriterial combinatorial problem extremely problematic or impossible to be evaluated by a continuous criteria function. The modern global optimization method can be used to overcome these limitations.

The chosen method is called Particle Swarm Optimization which was improved by parallel operations. The application of PSO has been created using Matlab programming language. The program looks for an optimal distribution of capacitors of parallel compensation in the power network. The distribution of capacitors should lead to the solution providing the lowest power losses and minimum capital and operational costs. This optimization fulfills the requirement that the value of capacitors can be changed and the system also has to take into account all given limitations.

PSO technique was discovered by studying the social behavior of bees. These phenomena can also be observed on the insect colonies or on the fish or bird swarm. The method belongs to the same group of global evolutionary optimization methods as genetic algorithms (GA). It is applicable to solving number of problems where local methods fail or their usage is inefficient, like in this case. The main reason, why the algorithm performs well in these cases, is the usage of fitness function as evaluation system. The fitness function has low 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 parameter setup.

2. PSO AND IMPLEMINTATION

The simplified principle of PSO can be described in the following way. Each potential solution is called particle. This particle flies through the N-dimensional space of solutions. Particle randomly decides to move to the best position of all or to its own best position, but it has to respect its current direction and speed of movement – velocity. Each particle holds information about its own position, velocity and the position with the best fitness function it ever has flown through.

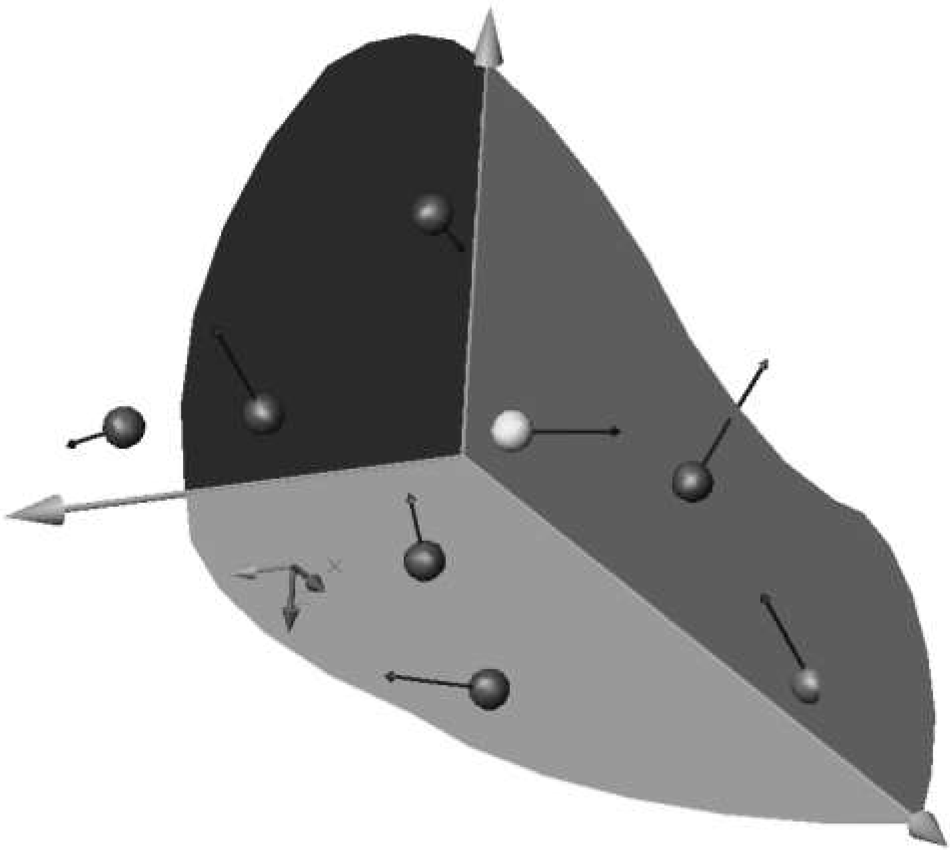

Figure 1: 3D illustration of PSO – balls represent positions and arrows are their vectors of velocity, the white particle is optimal solution.

The position here represents one potential solution, velocity shows the trend of this particle and both are presented by a vector in the program implementation. The particles were coded by natural numbers. The position of each element in the vector space corresponds to the number of the node in which shunt capacitor should be placed and value designates the capacitor type. The whole set of the particles at one single run is called the population. The subset made of newly born particles is called the generation.

First generation of particles is produced with random position and velocity. Particles' velocity is checked to be in the limits. Top speed can be different for each unit of velocity vector. If velocity component exceeds the maximum allowed value then it is set to the top value. After this correction, solution is evaluated with fitness function. The lower the fitness function value means the better solution. Solutions are sorted with respect to their fitness functions. First cycle ends after the creation of the new velocity vector and the calculation of the new position of the particular particle.

New vector of velocity is calculated by this formula:

$$\vec{v} = \vec{v}_0 + c_1 \cdot n_1 \cdot (\vec{p}_{best} - \vec{p}_{pos}) + c_2 \cdot n_2 \cdot (\vec{g}_{best} - \vec{p}_{pos}) \quad (1)$$

Where $\vec{v}$ denotes new vector of velocity, $\vec{v}_0$ is original vector of velocity, c_1 and c_2 are constants which are set to balance of differences of positions, n_1 and n_2 are random variables, $\vec{p}_{best}$ is the best position of particle, $\vec{p}_{pos}$ is actual position of particle and $\vec{g}_{best}$ is the best position of all particles.

New position is determined by this formula:

$$\vec{p}_{posn} = \vec{p}_{pos} + \vec{v} \quad (2)$$

2.1. BORDER

Each particle should be kept in confined 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 returns 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. Bouncing back to the allowed space can be perfect or non perfect. Regarding non perfect bounce, it is possible for the particle to end up in a random position. Concerning the fourth case, the particle can fly through forbidden area back to the allowed space, but on the other side of allowed space. This approach can be used in case of small limited space.

2.2. PARALLEL OPERATION

One of the advantages of PSO utilization is the possibility to introduce parallel operations with mutual coupling which enables searching in a larger area of feasible solutions and thereby finding the optimum solution faster. Parallel operation means that instead of a single branch of evolution several branches are created. These branches influence each other during the evolution only after a given number of generations when the temporary best solution of all the branches is transferred to the other branches. Thus the evolution of the branches is independent, but they can also use the results of the other branches. This modification limits a possible deadlock of the algorithm in the local minimum.

3. DISTRIBUTION NETWORK COMPENSATION

The reason for using power-factor compensation in electrical power networks is to increase bus voltages and at the same time to decrease network power losses. The cost of compensating capacitors is not negligible and it is important to find their optimum distribution in the network.

The application was tested on a middle voltage overhead power network [2]. The matrix of capacitors employed 13 types of capacitors and one position for a situation where there is no compensation connected to the bus. A 30-bus radial network with 15 take-offs is considered leading to 24.10^{33} combinations of distribution capacitors. The network load changed discretely with time and the load curve was described by 4 level steps. It was supposed that the requirements concerning a suitable solution were as follows:

- Bus voltage drop cannot exceed a given value.

- Purchase price of capacitors and cost of network losses should be as low as possible.
- Maximum and minimum permitted values of power factor at the supply points have to be within the limits.

The compared results, achieved by basic setup (without parallel operation), involve 700 generations with 40 particles per generation and it was started 4 different times. The setup with parallel operation was the same but 5 parallel branches were used in computation. The best solution, acquired by parallel operations, was found after 3 minutes and 59 seconds of computation, at the computer with processor Pentium 4 3.06 GHz, in the 380th generation. The power losses were decreased by about 9.5 % on average and power factors at the feeder were not exceeding the value of 0.98 which was one of computation conditions as a protection from overcompensation. The improvement of network parameters (for best solution with parallel operation) can be seen in Tab.1. To illustration of the trend of the algorithms (with and without parallel branches) is shown in Figure. 3.

Losses	Time (h)	6:00~9:00	9:00~16:00	16:00~23:00	23:00~6:00
before compenzation	MW	0,205	0,310	0,315	0,244
after compenzation	MW	0,183	0,283	0,288	0,220
Loss decrease after compenzation	%	10,7	8,7	8,6	9,8
cos φ before compenzation	-	0,9038	0,9031	0,9034	0,9009
cos φ after compenzation	-	0,9563	0,9469	0,9474	0,9502

Table 1: Values of power factor and power losses for the best solution without parallel operation

4. CONCLUSION

PSO is a stochastic optimization method which is used to find the minimal financial cost regarding power losses, minimal acquisition and operational cost of nested capacitors, all under given certain limitations. This algorithm was improved using parallel evolution branches for the purpose of accelerating the process of optimization. The benefit of this enhancement can be seen in Figure 3 where it is clear that the solution obtained by using parallel operations provided better results than the system based on the non-parallel procedure.

One of the main disadvantages of this method is its stochastic behavior, i.e. it is not possible to find a one way to the global optimum. On the other hand, the algorithm is a general robustness, very simple and very efficient. Compared to classic methods, the solution based on PSO provides better results in a shorter time.

The implementation of PSO has been done in Matlab programming language. Its practical applicability is demonstrated on an example of a 22 kV overhead distribution network. A possible application of the described method could be especially in industrial networks to fulfill the loss limitations due to the reactive currents and to improve voltage level at network buses.

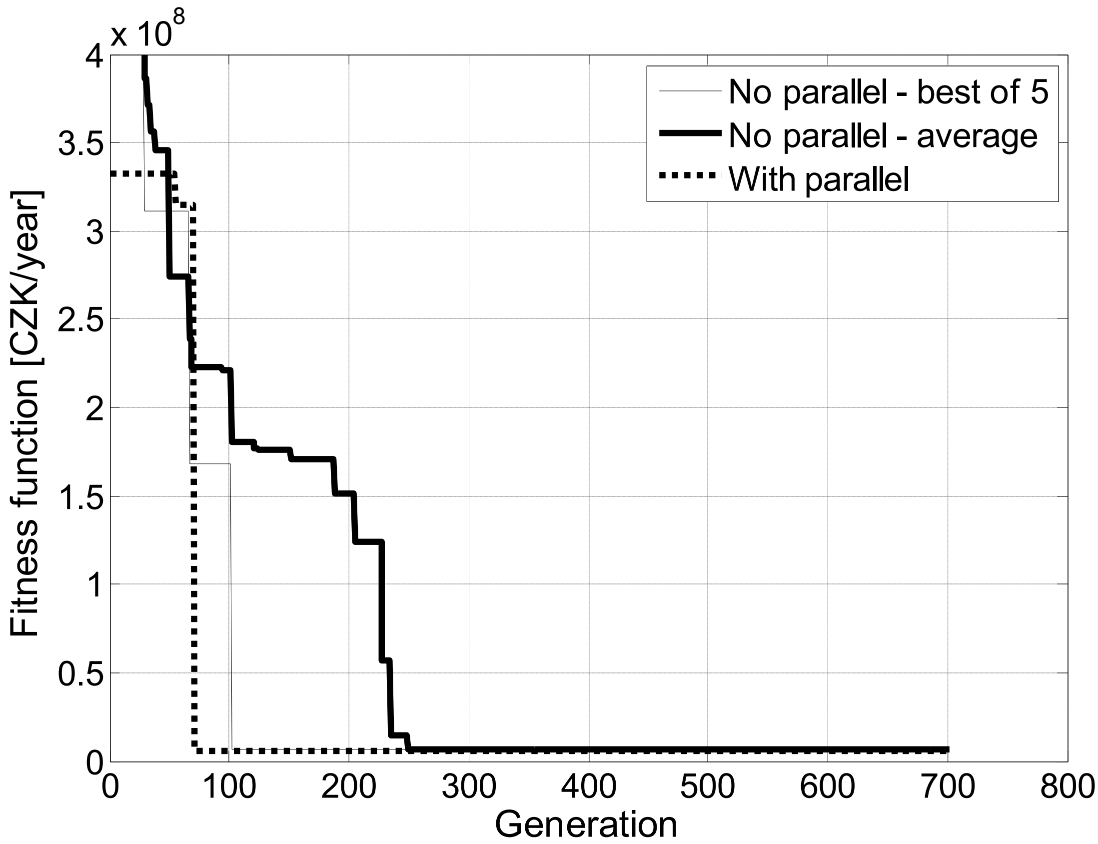

Figure 2: Fitness function with (dotted line) and without (full line) parallel operations

ACKNOWLEDGMENTS

This paper was made with project MSM0021630516 support of The Ministry of Education, Youth and Sports of The Czech Republic.

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