Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 4 [9] August 2015: 115-120

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE **OPEN ACCESS**

Reconfiguration Optimization for Loss Reduction in Distribution Networks using Hybrid PSO algorithm and Fuzzy logic

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ABSTRACT
Voltage drop, multiple power outages, load imbalance and high losses are major problems appeared in distribution networks. Reconfiguration is the easiest and least costly solution to overcome the aforementioned challenges without any need to install additional equipment in the network. Reconfiguration can be defined as imposing changes to the topology of the distribution network by appropriate closing and opening of the network switches. Minimization of losses in a distribution network can be identified as the main objective of the reconfiguration. In this paper, a new evolutionary approach based on a hybrid fuzzy- particle swarm optimization (PSO) hybrid algorithm is proposed to solve the problem of the distribution networks reconfiguration. In this paper, results obtained using the proposed method, are compared with other methods. The obtained results indicate that use of the fuzzy system to adjust PSO parameters (i.e. C1, C2, W) enhances the performance of the reconfiguration algorithm, in terms of selection of the appropriate switches, and faster convergence of the PSO algorithm.
Keywords: *Reconfiguration Algorithms, PSO -Fuzzy Logic, Distribution networks, Losses reduction*

Received 11.05.2014 Revised 13.05.2014 Accepted 22.05.2015

INTRODUCTION

Distribution networks transfer energy task from the distribution centres to serve the consumers. These networks have generally radial form with many branches. Hence, the amount of electricity losses in these networks is considerably high. Based on the published researches, about 13 percent of the generated electricity is dissipated in the distribution networks. The power stations are wasted in path production to consumption. Loss of the System-levels power exists, including generation, transmission, distribution which is 75 percent of losses occurring In the distribution system [1]. Feeders stemming from original substations supply different types of loads, including residential, commercial, industrial, agricultural, and lighting loads. The profile of loads changes on daily and seasonal basis. The spatial and temporal variations in load results in changes in load profiles from feeder to feeder. Moreover, there will be unbalanced loads on the feeders. A remedy to this problem is to change some parts of the distribution system (i.e. reconfiguration) to transfer loads from one feeder to the other feeders such that the radial structure of the network is maintained and the network is better utilized. Network reconfiguration can also adjust the load between substations, reduce system losses and improve profiles of the switches conditions [2-4].

Particle Swarm Optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity.

Each particle's movement is influenced by its local best known position but, is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions.

PSO is originally attributed to Kennedy, Eberhart and Shi and was first intended for simulating social behavior, as a stylized representation of the movement of organisms in a bird flock or fish school. The algorithm was simplified and it was observed to be performing optimization.

Fuzzy-PSO hybrid algorithm

The proposed FPSO algorithm is composed of two parts, namely a fuzzy logic system and PSO algorithm. The fuzzy logic system consists of three input variables, D1, D2, NCBPE, and three output variables, W, C1, C2.The variables range, fuzzy functions and required Rules must be defined for the fuzzy system. The inputs of the fuzzy system are generated by the PSO algorithm and outputs of the fuzzy system are used as the input parameters to PSO algorithm.

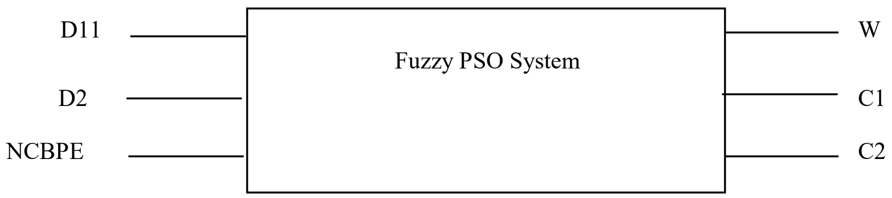

Figure.1.fuzzy inference system FPSO

D1=|p_best-x| . (1)

D2=|g_best-x| . (2)

NCBPE= CBPE- $CBPE_{min}$/ $CBPE_{max}$- CBPE . (3)

Where, D1 isthe particle distance to the best local position, D2 is particle distance to the best global position experience, CBPE is the fitness of the current position, $CBPE_{min}$ indicates the best fitness up to current iteration ,$CBPE_{max}$ denotes the worst fitness up to current iteration. Moreover, NCBPE is the normalized value of the current position with respect to the best and worst fitness value of the particle. Selection of appropriate fuzzy rules has a significant impact on the results. The fuzzy rules used in the system are presented in table below.

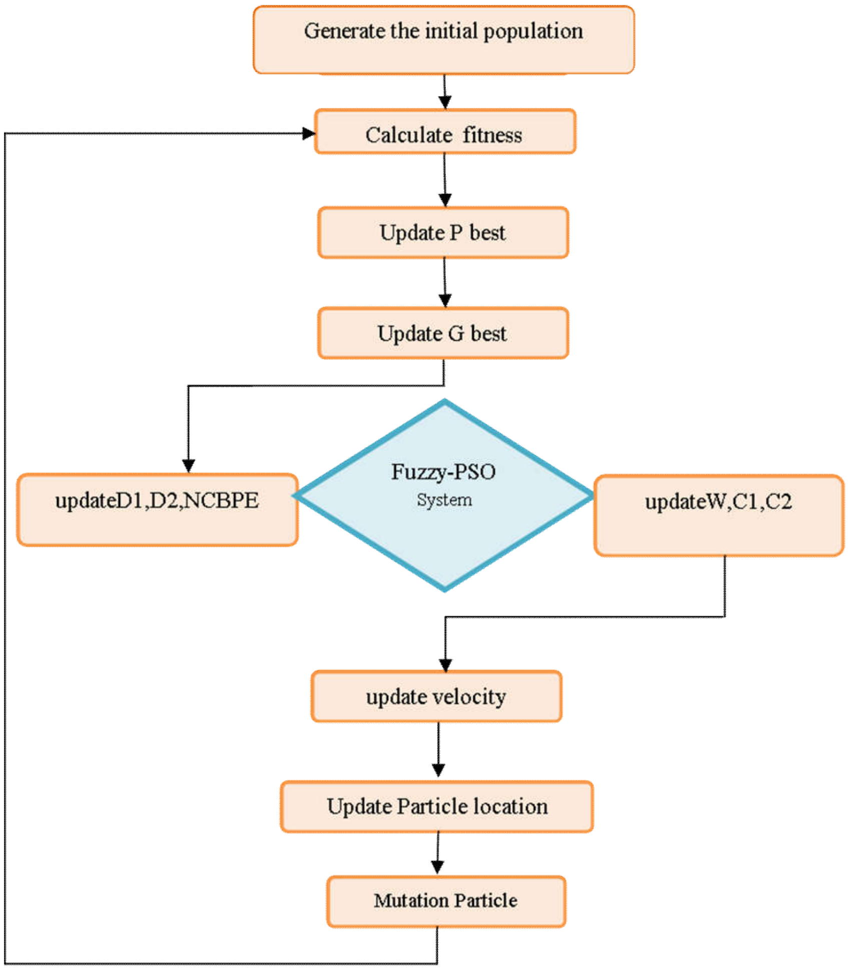

Figure.2. Flowchart of the hybrid algorithm Fuzzy-PSO.

Table 1. The number of fuzzy rules Fuzzy-PSO algorithm

Rules	Input	Output
	D1 D2 NCBPE	W C1 C2
1	H HH	H L L
2	L LL	LHH
3	L L M	MMM
4	L L H	H L L

Constraint on the fitness function

It is clear that all the positions produced by the PSO may not correspond to a radial topology.

Hence, a constraint must be considered to ensure radial topology of the reconfigured distribution network.

In a radial network all of distribution substations are feeding the network and there must be no closed path or loop between the distribution substations.

This can be checked by help of a theorem in the graph theory. If one-by-one elimination of the first-order nodes (i.e. nodes with only one branch) of a tree leads to the elimination of the whole tree, it can be concluded that the tree represents a radial network.

Other network constraints include maximum allowable voltage drop and maximum current flowing through the lines.

Determining the fitness functions

The fitness function is the sum of the network losses, as stated below,

$$F = \sum_{i=1} r_i I_i^2 \, . \qquad (4)$$

Fuzzy Logic

Step One

Define the control objectives and criteria.

Consider question like:

What is trying to be controlled?

What has to be done to control the system?

What kind of response is needed?1

What are the possible (probable) system failure modes?

Step Two

Determine input and output relationships

Determine the least number of variables for inputs to the fuzzy logic system

Step Three

Break down the control problem into a series of IF X AND Y, THEN Z rules based on the fuzzy logic rules.

These IF X AND Y, THEN Z rules should define the desired system output response for the given systems input conditions.

Step Four

Create a fuzzy logic membership function that defines the meaning or values of the input and output terms used in the rules

Step Five

After the membership functions are created, program everything then into the fuzzy logic system

Step Six

Finally, test the system, evaluate results and make the necessary adjustments until a desired result is obtain

The above steps are summarized into three main stages

Fuzzification: Membership functions used to graphically describe a situation

Evaluation of Rules: Application of the fuzzy logic rules

Diffuzification: Obtaining the crisp results.

Algorithm PSO

Particle Swarm Optimization is an approach to problems whose solutions can be represented as a point in an n-dimensional solution space. A number of *particles* are randomly set into motion through this space.a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is.. In PSO, each single solution is a "bird" in the search

space. We call it "particle". All of particles have fitness values which are evaluated by the fitness function to be optimized, and have velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles. . In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called p best. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called g best. When a particle takes part of the population as its topological neighbors, the best value is a local best and is called l best.
After finding the two best values, the particle updates its velocity and positions.
V[] is the particle velocity, present [] is the current particle (solution). P best[] and g best [] are defined as stated before. Rand () is a random number between (0,1). C1, C2, W are learning factors.

Simulation
The proposed method is evaluated using a distribution network with 69 buses and 5 rings. There are several open switches in the basic network configuration, with the following indices, [69 70 71 72 73].
The total network load is 19/380 kW and Loss
The initial configuration is 224/426kW.

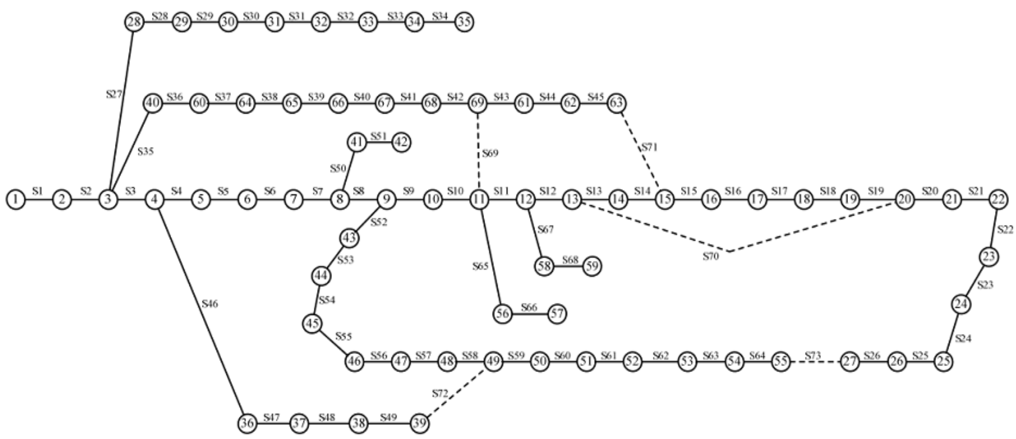

Figure.3. 69 bus network.

The fuzzy system parameters are as follow: Linguistic variables range is set to [0, 1] and triangular output membership functions are employed while Gaussian and Sigmund membership functions are used for the inputs. Each variable includes high, medium and low membership functions. Finally, the fuzzy inference mechanism is of Mamdani type. Parameters of the PSO algorithm are as follow: Number of particles=50, The number of iterations = 100, Number of dimensions=5C1=C2=[0 2], alpha=0.05,W=[0 1.5]. Moreover, the best value for [C1, C2, W] is [1.57,1.57,1.02].the proposed method is implemented in MATLAB on computer with Intel CORE i5, 2GB Graphics NVIDIA GEFORCE, 6 GB RAM, 3 MB of cache and Windows 8.1, 64-bit.Fuzzy and PSO hybrid algorithm has converged to the solution of Table 2 after 20 iterations.

Table 2. Number of open keysTo reduce.

Number of Answer	Number of Keys
1	69-70-14-58-61
2	70-14-57-69-61
3	55-14-70-61-69
4	14-56-70-69-61

After opening of the selected switches, the new configuration loss is equal to 99/519 KW. The new configuration has reduced network losses by 55/65 percent.

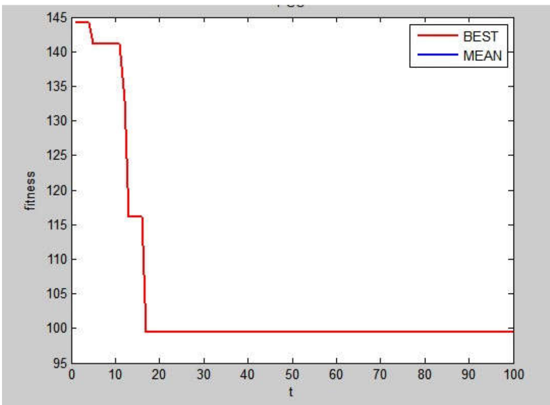

Figure.4. Displaying graphs of network losses.

EVALUATION OF RESULTS

According to Table 3 of, the loss reduction by the proposed algorithm is lower than the other algorithms. In Figure 5 it is seen that the proposed algorithm converges to the best global solution faster than the PSO and GA. On the other hand, while the SLFA algorithm converges faster than the proposed algorithm, but the achieved reduction in losses by the SLFA is smaller compared to the proposed method. Obviously, loss Reduction is a more important factor compared to the rate of convergence.
By comparison of the PSO algorithm with the proposed algorithm it can be seen that the fuzzy systems has a significant impact on the performance of the algorithm. In fact, the fuzzy system eliminates the main problem of the PSO algorithm, i.e. falling into the trap of the local minima and slow convergence rate.

Table 3. The amount of loss reduction in algorithms**.**

Algorithm	loss reduction (MW)	loss reduction percent
GA	205/32	8/513
PSO	205/32	8/513
SLFA	205/32	8/513
LIU	102/6	54/283
ZHANG	102/1	54/506
Fuzzy-PSO	99/518	55/656

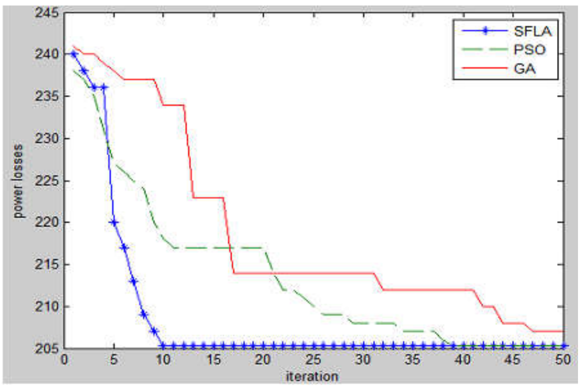

Figure.5. Comparison of loss reduction obtained by different algorithms.

CONCLUSION AND FUTURE WORKS

In this paper, a reconfiguration approach based on a fuzzy-PSO hybrid algorithm was developed to reduce distribution network losses. In the proposed hybrid approach, the fuzzy logic system prevents PSO from getting stuck into local minima and improves the convergence rate of the PSO algorithm. The proposed algorithm was compared with other algorithms, and it was shown through simulation that the proposed approach can achieve lower losses in the distribution network.

Fuzzy logic is a best approach for nonlinear functions in the PSO. For the future researches, the fuzzy logic can be used a new non-linear functions for inertia factor and acceleration coefficients in the PSO algorithm. The decision variables for such fuzzy systems may be selected as particle current speed and position, C1 and C2.

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CITATION OF THIS ARTICLE

Mohadeseh R, Hamid T, Anise R· Reconfiguration Optimization for Loss Reduction in Distribution Networks using Hybrid PSO algorithm and Fuzzy logic. Bull. Env. Pharmacol. Life Sci., Vol 4 [9] August 2015: 115-120

