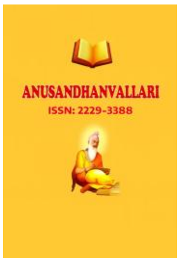

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Cost Effective Power Trading with Optimal Power Loss in Power System Distribution

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Abstract

This paper presents SPSO algorithm to study distribution system reconfiguration for power trading. The objective is to have cost effective power trading by minimizing power loss. The SPSO IS also set up, in which modifications are made to the standard PSO. The proposed method is applied to a 33-bus distribution network.

Keywords: network reconfiguration, power trading, SPSO,

Introduction:

Distribution system analysis is more complex due to uncertainty of load on different feeders which continuously changes. We have to change the system configuration continuously to minimize the distribution loss for different types of loads. This requires reconfiguration of the network from time to time as load changes. Network reconfiguration is the process of changing the open/closed status of sectionalizes and ties switches. The objective of network reconfiguration is to reduce system losses and to facilitate cost effective power trading. Network reconfiguration is a complex combinatorial non differentiable constrained optimization problem. Different researchers proposed different methods for network reconfiguration. The search space consists of finding the best possible trees, that satisfy the constraint and minimize the objective function, among all feasible trees. Of course, we get the solution by examining all feasible spanning trees, but the task would be computationally formidable for practical modern systems. Therefore, it is of utmost importance to develop an efficient search method. In this paper, we apply SPSO based search scheme to find the best possible state of the network for the given objective function.

Especially with the development of remote-control capability to the switches, reconfiguration becomes an integral part of distribution network management. The operational problem of network reconfiguration is well documented in different papers. the earliest solution scheme developed uses branch and bound techniques to determine network configuration {1-2]. [1-2]. A. merlyn (1) was the first to developed the branch and bound technique. The algorithm starts with a meshed configuration obtained by closing all tie switches then successively opening the switches to remove the loops. On the other hand, Civanlar et al. [2] simultaneously opening and closing of a pair of switches to maintain radial configuration.Thus, the processensures that the radial constraint always preserved. These methods mostly give a local optimal solution, as the search space does not consist of all the possible trees.The search method provided by baran [3] has improved characteristics but it is time consuming and normally converge to a local minimum.

Literatures [4-6] providespioneering work on the development heuristic methods with branch exchange and optimal power flow.Shirmohammadi D.[5] presented a switch exchange criterion to select the best possible switch in a particular step. Although the main advantage of these methods is simplicity, their search space is limited.

Modern researchuseartificial intelligence (AI) based evolutionary algorithm [7]-[10], likeHarmony search (HA), simulated annealing (SA), genetic algorithm (GA), particle swarm optimization, immune algorithm (IA) etc. R.S. Rao*et al* [9] presented the solution of problem in reconfiguration of Distribution network in presence of Distributed generation using Harmony search algorithm with an objective of minimizing real power loss in different types of load conditions. Y. Y. Hong *et al* [10] presented minimization of megawatt losses using method based genetic algorithm to determine network configuration taking both normal condition and contingencies into account. F.R. Alonso [7] applied the artificial immune algorithm for multiobjective reconfiguration. These algorithms able to provide global optimal result. In recent years, these algorithms have improved the computational efficiency of DNR problem.

Kennedy J. and Eberhart R. C. [16] in 1995 proposed PSO algorithm, inspired by the social behavior of bird flocking. The features of PSO include parallel computing, high calculation efficiency, and good robustness. Since then, it has been applied to a number of complex optimization problems from different branch of science and engineering.Among others, it includes application to distribution system reconfiguration [11]-[15]. T. M. Khalil et al [11] explained the working principles of Selective particle swarm optimization and applied the technique on capacitor sizing to select the best size of capacitor among a set of capacitors.

The paper presents a SPSO based analysis of distribution system for reconfiguration and loss minimization. The SPSO method is computationally attractive and efficient. The proposed solution method can also be used for cost effective power trading to reduce the overall cost of power to the consumers. Test results demonstrate the comparative performance of the proposed method with existing methods.

Problem formulation:

The network reconfiguration problem corresponds to that of a minimal spanning tree problem of graph representing the network topology. The problem is basically a combinatorial optimization problem and the search space consists of all possible spanning trees.Given a graph, find a spanning tree such that the objective function is minimized while the following constraints are satisfied:

(i) voltage constraints, (ii) capacity constraints of lines/transformers.

The loads are represented as constant power sinks given by $S_L=P_L+jQ_L$. The lines are represented by constant impedance lumped parameters given by $Z=R_L+jX_L$. The power flow equations of a radial distribution network consist of a set of recursive branch equations voltage magnitude, real and reactive power. Each branch has a sending end and receiving end. The recursive branch equations represent the receiving end branch values in terms of sending end values. Thus, if P_1, Q_1, V_1 at the root node is known or can be estimated then the values at other nodes can be calculated by applying the above branch equations successively by forward updating process.

$$P_{k+1} = P_k - P_{Loss\,(k)} - P_{Lk+1}$$
$$Q_{k+1} = Q_k - Q_{Loss\,(k)} - Q_{Lk+1}$$

Where, P_k = Real power flow in kth branch

Q_k=Reactive power flow in kth branch

$$|V_{k+1}|^2 = |V_k|^2 + \frac{R_k^{\,2} + X_k^2}{V_k^2} \times \left(P_k^2 + Q_k^2\right) - 2 \times \left(R_k \times P_k + X_k \times Q_k\right)$$

Where, V_k= Voltage drop in Kth bus

V_{k+1}= Voltage drop in K+1th bus

The branch equations of distribution load flow can also be written in backward too i.e. by using receiving end quantities of the branch, we can express the sending end quantities with the help of the following equations. This process of finding the sending end quantities from receiving end quantities is known as backward updating. Just like forward update, a backward update proceeds in the backward direction calculating the quantities at the receiving end of each branch by applying successively the equation.The backward process will end at the root node (node 1) and provide the updated estimate of the injected power into the system P1 & Q1. By applying forward and backward update process successively we can obtain the load flow of the distribution system.Having the load flow solution, the power loss can be expressed in terms of system variables to formulate the objective function as:

Ploss(k, k+1)=Real power loss in branch between Kth and (K+1)th bus

Qloss(k, k+1)=Reactive power loss in branch between Kth and (K+1)th bus

$$P_{Loss(k,k+1)} = R_k \times \frac{P_k^2 + Q_k^2}{|V_k|^2}$$
$$Q_{Loss(k,k+1)} = X_k \times \frac{P_k^2 + Q_k^2}{|V_k|^2}$$

The objective function is

Minimise$P_{T,Loss} = \sum_{k=1}^{n} P_{loss}(k, k+1)$

Overview of SPSO:

In the basic PSO the search space is a real-valued space, where the search space in the binary PSO is a set of *0's* and *1's,* but in the SPSO the search space is a set of selected values. In the SPSO the search space may be different from one dimension to another. For each dimension (for example, *d*-dimension) the search space (*Sd*) is a set of *dn*values (*Sd = [sd1, sd2 ... sdn]*), where *dn*is the number of the selected values in the dimension *d*. Similar to the basic PSO and binary PSO, in SPSO the fitness function *F* and the dimensions must be defined [22]. But the difference here is that function *F* maps at each dimension *d* from *dn*values which represent the selective space *Sd*. By other words, the position of each particle has been changed from being a point in real-valued or binary space to be a point in a selective space.

The velocity update is given as

$$sigmoid(v_{id}^{k+1}) = dn\frac{1}{1+e^{-v_{id}^{k+1}}}$$

And the particle position is updated using below equation

$$x_{id}^{k+1} = \begin{cases} sd_1, if, sigmoid(v_{id}^{k+1}) \langle 1 \\ sd_2, if, sigmoid(v_{id}^{k+1}) \langle 2 \\ sd_3, if, sigmoid(v_{id}^{k+1}) \langle 3 \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ sd_n, if, sigmoid(v_{id}^{k+1}) \leq dn \\ . \end{cases}$$

Where, *sd1, sd2, sd3,….,sdn*are the selected values in the dimension *d*. Velocity values are restricted to some minimum and maximum values [*Velmin* , *Velmax*]

$$v_{id}^{k+1} = \begin{cases} v_{\max}, if, v_{id}^{k+1} \rangle v_{\max} \\ v_{id}^{k+1}, if, \left|v_{id}^{k+1}\right| \leq v_{\max} \\ v_{\min}, if, v_{id}^{k+1} \langle v_{\min} \end{cases}$$

The solving DNR problem by SPSO can be divided to three steps:

A) Specifying the number of dimensions;
B) Finding the search space for each dimension;
C) Using SPSO to select the optimal solution from the search spaces.

A. Specifying the Number of Dimensions:

Distribution network is designed as multi loop circuits but it runs in open loop to assure the network in the form of a tree. To specify the number of dimensions for DNR problem, all tieswitches must be closed. It will give the number of loops. The number of dimensions equals the number of loops.

B. Finding the Search Space for Each Dimension:

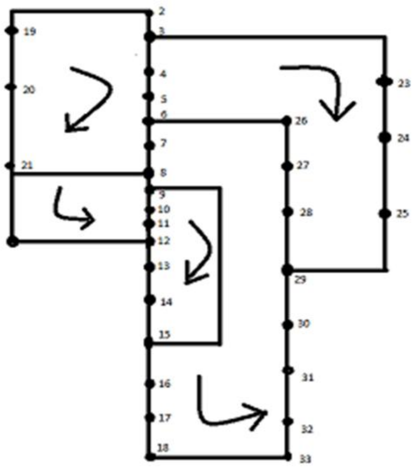
step 1: The system shown in Fig. 1 has 17 brunches, 15 sections and 2 tie switches.
step 2: Closing the tie switches will form 2 loops.

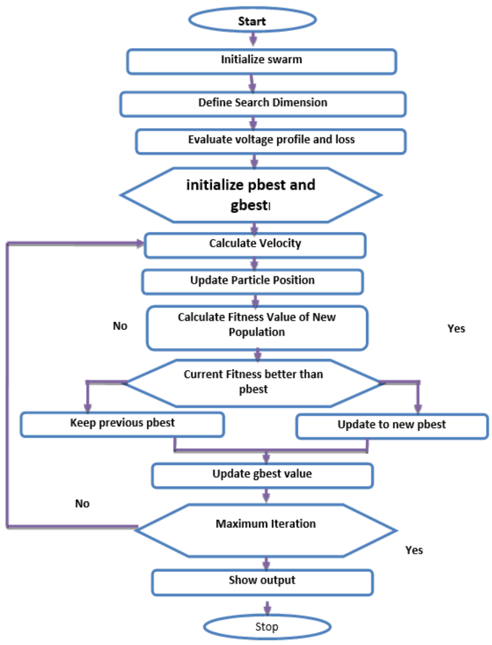
step 3: Accordingly, the branches which don't belong to any loop will not represented in the search spaces, and therefore in optimization algorithm the test system shown in Fig 4.2 (a) can be simplified to Fig. 4.2 (b).

step 4: The number of dimensions is equal to the number of loops so in this case we have two dimensions.

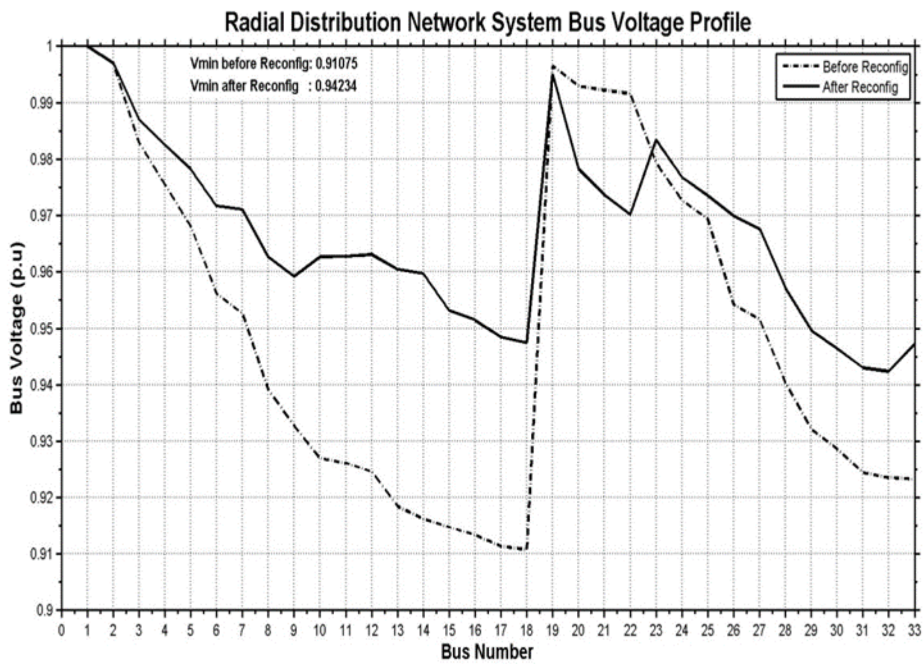
step 5: The search space for each dimension will be the branches which belong to the loop represented by this dimension. In this case d1 = [2, 3, 4, 5, 6, 7, 18, 20, 19], d2 = [8, 9, 10, 11, 21], d3=[3, 4, 5, 25, 26, 27, 28, 22, 23, 24], d4=[6, 7, 8, 25, 26, 27, 28, 29, 30, 31, 32, 15, 16, 17], d5=[9, 10, 11, 12, 13, 14]

step 6: Branches belong to the two or more loops and two or more dimensions, should be appearing in only one dimension, this will be done randomly.





RESULT ANALYSIS:



SCENARIOS	TIE SWITCHES	POWER LOSS (KW)	MINIMUM VOLTAGE (V)	MINIMUM VOLTAGE AT BUS NO.
Base case network	**33,34,35,36,37**	**208.4592**	**0.91075**	**18**
Reconfigured (Hit and trial)	**14, 20, 21, 28, 30**	**161.70**	**0.9201**	**13**
Reconfigured network(SPSO)	**7,11,32,34,37**	**138.44**	**0.94047**	**33**

Conclusion:

The result demonstrates the ability of SPSO algorithm to find an optimal configuration for the network. The search process able to handle the constraint s effectively during programme simulation. The ranking of a feasible combination of switches are done on the basis of estimated power flows. The candidate solution which provides the information about the status of the switches used to find the losses and saving in cost during power trading. The fact that the branches which don't belong to any loop is not represented in the search spaces, and therefore in optimization algorithm, increases the computational efficiency. Creation of number of unfeasible solutions violating radial constraint is also limited improving the performance.

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