

INTELLIGENT RECONFIGURATION OF DISTRIBUTION NETWORKS VIA HARMONY SEARCH ALGORITHM

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Abstract- This paper proposes a novel method for reconfiguration of distribution network. The proposed method is based on a hybrid Harmony Search Algorithm (HSA) and Graph theory. The objective function of the optimization problem is loss reduction. The proposed method has been conducted on 33-bus test distribution network. Two different case studies are investigated in this paper. In the first one loss reduction is the objective while the number of switching is not considered as a constraint; while in the second one number of switching is added as a constraint to the optimization problem and its effect on loss reduction is analyzed. The obtained results show the effectiveness of proposed method in finding the optimum configuration. The results also demonstrate that proposed hybrid method is capable of finding the best solution.

Keywords: Reconfiguration, Loss Reduction, Harmony Search Algorithm, Graph Theory.

I. INTRODUCTION

Merlin and Back first proposed the idea of distribution network reconfiguration in 1975 [1]. In their approach, a linear model for distribution network reconfiguration was presented and discrete branch and bound method was employed to solve the reconfiguration problem. Based upon their method, all normally open switches are initially considered to be closed; then switches, which lead to most loss reduction are opened. Having a considerable impact on the operation and costs of the distribution network, reconfiguration has been subject of many research studies. In [2] Shirmohammadi extended Merlin Beck's method and proposed an iterative solution.

In his method at first all switches are considered to be closed, then a load flow is performed in the created meshed network, using the load flow results switch with minimum current flow across are opened, this procedure is repeated until determining the new radial configuration. Reference [3] presents an algorithm based upon the optimal flow pattern of a single loop created by closing a normally open switch, and then the switch with minimum current is opened. This procedure is performed for all loops to achieve the optimal configuration.

A quadratic programming technique is utilized in [4] to solve the reconfiguration problem of distribution network. Being a very complicated optimization problem, reconfiguration problem attracts researches to implement evolutionary algorithms to solve this problem. Most of the heuristic algorithms have been used to determine the optimal solution of the reconfiguration problem, including, Genetic Algorithm [5-6], Simulated Annealing [7], Tabu Search [8], Particle Swarm Optimization [9]. In [10] the problem of optimal reconfiguration in the presence of SVC is discussed.

In this paper, a network reconfiguration approach based on Harmony Search Algorithm (HSA) [11-13] and Graph theory for balanced and unbalanced radial distribution networks is proposed for energy loss reduction. HSA has been successfully applied to solve complicated optimization problems in the realm of power system [14-15]. The objective function is loss reduction. The proposed method has been conducted on 33-bus balanced distribution network and the 25-bus unbalanced distribution system. The results are compared with those reported in the literature. The obtained results demonstrate the effectiveness of the proposed scheme.

II. PROPOSED ALGORITHM

In this section of the paper, the proposed method based on hybrid HSA and Graph theory is discussed. In the first subsection the problem formulation is presented and then application of the proposed method to the reconfiguration problem is explained.

A. Problem Formulation

Objective function (loss minimization) of the network reconfiguration problem can be formulated as follows:

$$\text{minimize real power loss} = \min \sum_{l=1}^{N_L} I_l^2 R_l \quad (1)$$

where, I_l is the current across line l , R_l is the resistance of branch b and N_L is the total number of lines (branches) in the distribution network. The optimization problem is subjected to the following constraints:

A. 1. Voltage Constraint

Voltage magnitude at each node of the system must lie within their permissible ranges in order to maintain power quality:

$$V^{\min} \leq V_b \leq V^{\max}, \quad b=1, \dots, N_B \quad (2)$$

where, b indicates the bus number, V^{\min} and V^{\max} are minimum and maximum voltage limit and N_B is the number of buses.

A.2. Current Constraint

Current magnitude of each branch of the network must be within their permissible ranges in order to avoid thermal or physical violation of branches:

$$-I_l^{\max} \leq I_l \leq I_l^{\max} \quad (3)$$

B. Proposed Method

The proposed method is a hybrid approach based on HSA and Graph theory. The optimization tool aims at optimal reconfiguration determination of distribution networks. Objective function is considered to be loss reduction. Traditionally, in most of reconfiguration approaches, a matrix of all system switches status represented a configuration of network, in which D denotes total number of switches and s can be 0 or 1, as open and close switches, respectively [16].

In order to overcome complexity of the optimization process and avoiding the creation of many unfeasible configuration and to decrease the computational costs of the optimization problem, in this study a novel method is adopted. Based on this method a matrix of normally opened switches $S = [s_1, s_2, \dots, s_N]$ to denote a configuration, in which N denotes the number of loops in the network, is utilized. On the other hand, graph theory is implemented to check each solution generated by the HSA to see if it represents a tree or not.

If the generated solution is representative of a radial distribution network that solution is accepted, otherwise it is replaced by another randomly generated solution. Steps in finding the optimal configuration using proposed method is as follows:

- 1- Initialize the optimization problem and algorithm parameters. In this step the optimization problem, objective function and constraints are specified. $x' = (x'_1, x'_2, \dots, x'_D)$ is a candidate solution consists of D decision variables. Moreover, HSA parameters are specified in this step.
- 2- Initialize the harmony memory (HM). In this step, the harmony memory matrix, is filled with as many randomly generated solution vectors as HMS.
- 3- In order to calculate loss for each solution, a backward-forward load flow method is implemented to calculate bus voltages and line currents and therefore losses of the network.
- 4- Improve a new harmony from the HM. A new harmony vector is generated from the HM based on memory considerations, pitch adjustments, and randomization.
- 5- In this step HM is updated. Initial and generated HM vectors are compared in term of the value of the objective

function (here, losses) and new HM will include best harmony vectors of the both initial and newly generated HM vectors.

6- Steps 4 and 5 are repeated until the termination criteria are satisfied.

III. SIMULATION RESULTS

The proposed hybrid method based on HSA and Graph theory is tested on 33-bus distribution test system that has been highly used as the benchmark in literatures [17-18]. The load and branch data of the 33-bus test system are taken from [17]. Furthermore, the base voltage and power of 33-bus test system are 12.66 KV and 1 MVA, respectively. This system consists of one source transformer, 32-bus, and 5 tie switches.

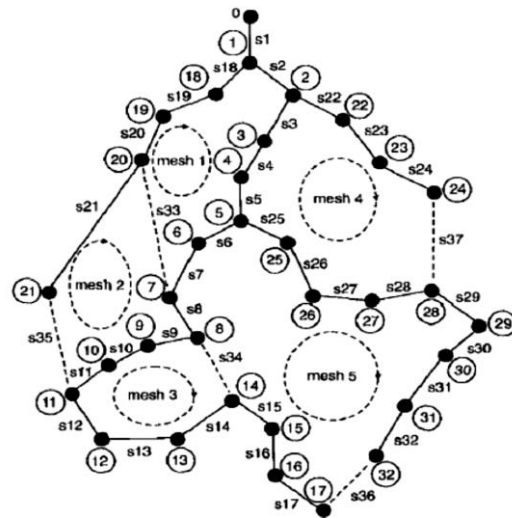


Figure 1. Schematic of 33-bus distribution network [17]

A. Loss Reduction

In this sub-section the proposed algorithm is performed to minimize the losses of the network.

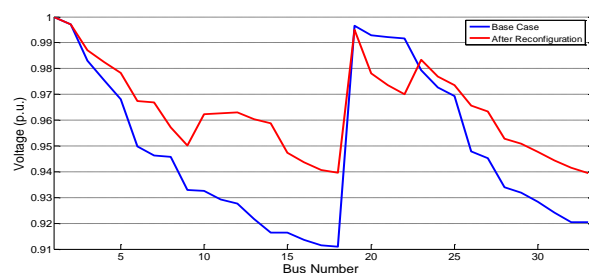


Figure 2. Voltage profile of the system before and after reconfiguration

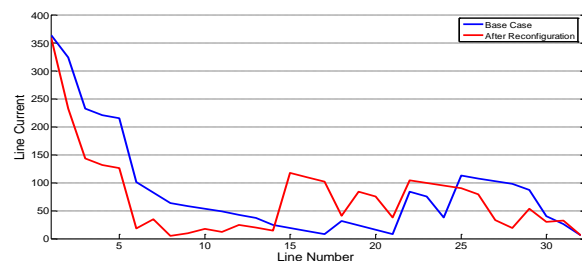


Figure 3. Line current of feeders of the system before and after reconfiguration

Table 1. The best result of the proposed hybrid method for 33-bus balanced test system in comparison with other methods

Method	Open Switches	Loss (kW)	Loss Reduction (%)
Base Case	33,34,35,36,37	199.3	0
AS [18]	6,9,14,26,31	153.18	23.141
ACS [18]	7,9,14,28,32	137	31.259
GA [19]	7,9,14,28,32	137	31.259
Efficient Method [20]	7,9,14,32,37	139.55	29.979
Proposed Method	7,9,14,32,37	138.724	30.394

Table 1 is the results of the proposed Hybrid HSA and Graph theory for the 33-bus test system in comparison with other methods reported in the literature. As the results demonstrate the proposed method can find the optimal solution that yield considerable loss reduction while the number of switching is lower those with better solution. The obtained results indicate that the tie switches number 33-36 should be closed and switches number 7, 9, 14, 32 should be opened while the status of the tie switch number 37 remain unchanged.

Having a great impact on losses of the system, reconfiguration can effectively reduce the losses of the distribution network, as demonstrated by the optimal solution, which render about 31% decrease in the losses. In order to investigate the impact of reconfiguration on voltage profile of the distribution network, voltage profile for the base case is compared with those of the optimal solution. This point is depicted in Figure 2. As can be seen in this figure, the voltage profile of the 33-bus system has improved considerably, especially at buses 18 and 30-33. Shown in Figure 3 is the change in line current of feeders of the network before and after reconfiguration.

B. Minimum Switching

Now, that the effectiveness of the proposed method in dealing with the optimization of the reconfiguration problem, the proposed approach is used with the constraint of minimum switching. Since switching in the distribution network impose extra costs and there is a need for switch replacement after a defined number of switching, this sub-section investigates the impact of limiting the number of switching on the loss reduction of the network. Table 2 shows the results of reconfiguration of the 33-bus network while restricting the number of switching.

Table 2. Impact of number of switching on loss reduction

No. of Switching	Open Switches	Loss (kW)
Base Case	33,34,35,36,37	199.3
4	7,11,34,36,37	141.261
6	7,9,14,36,37	139.681
8 & 10	7,9,14,32,37	138.724

As shown Table 2, with restricting, the number of switching the losses of the system increases. With limiting the number of switching to 8 and 10 the result will be the same and as the best result. The losses increase less than 1 percent with limiting the number of switching to 6. The change is more considerable when the number of switching is limited to 4 switching. It should be noted that since for switch change, one switch should be opened and another one should be closed, thus the number of switching would always be an even number.

IV. CONCLUSIONS

A novel reconfiguration approach based on a hybrid HSA and Graph theory has been proposed in this paper. Like other studies in this field, the objective function of the optimization problem has been considered as loss reduction. The proposed method is conducted on 33-bus test distribution network. The obtained results demonstrate the effectiveness of the proposed method and its capability in finding the optimum configuration.

Voltage profile has also been provided that show considerable improvement by the proper reconfiguration. It was also shown that losses of the system can decrease significantly by applying an appropriate configuration. In comparison with other heuristic approached provided in the literature, the proposed method demonstrates its advantages in finding the optimal solution.

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BIOGRAPHIES



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