International Journal on "Technical and Physical Problems of Engineering" (IJTPE)
Published by International Organization of IOTPE
ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2014 | Issue 18 | Volume 6 | Number 1 | Pages 131-134

INTELLIGENT RECONFIGURATION OF DISTRIBUTION NETWORKS VIA HARMONY SEARCH ALGORITHM

M. Habibi [1] M. Kazemi [2]

1. Department of Computer Engineering, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran
m.habibi60@gmail.com
2. Computer Engineering Department, Sharif University of Technology, Tehran, Iran, mkazemi@alum.sharif.edu

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:

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

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:

$$V^{\min} \le V_b \le V^{\max} \quad , \quad b = 1,\ldots,N_B \tag{2}$$

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:

$$-I_l^{\max} \le I_l \le I_l^{\max} \tag{3}$$

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 $S = [s_1, s_2, \ldots, s_N]$ 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. $x' = (x'_1, x'_2, \ldots, x'_D)$ 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- Improvise 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.

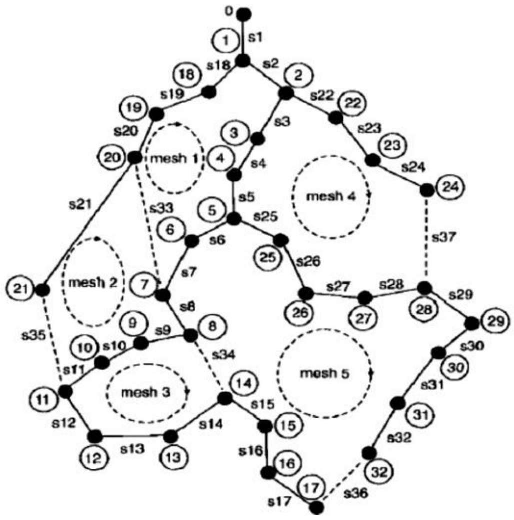

Figure 1. Schematic of 33-bus distribution network [17]

A. Loss Reduction

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

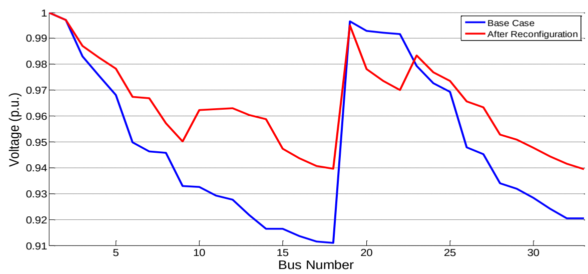

Figure 2. Voltage profile of the system before and after reconfiguration

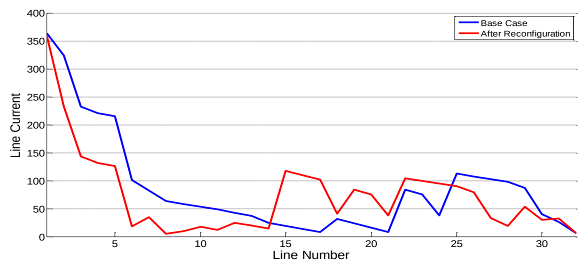

Figure 3. Line current of feeders of the system before and after reconfiguration

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.

ACKNOWLEDGEMENTS

The authors wish to thank from the Islamic Azad University for supporting the projects. This research was supported by Kermanshah Branch, Islamic Azad University, Kermanshah, Iran.

REFERENCES

[1] A. Merlin, H. Back, "Search for a Minimum-Loss Operating Spanning Tree Configuration for an Urban Power Distribution System", 5th Power Systems Comp Conf., 1-5 Sept. 1975.

[2] D. Shirmohammadi, H.W. Hong, "Reconfiguration of Electric Distribution Networks for Resistive Line Losses Reduction", IEEE Transactions on Power Delivery, Vol. 4, pp. 1492-1498, 1989.

[3] S.K. Goswami, S.K. Basu, "A New Algorithm for the Reconfiguration of Distribution Feeders for Loss Minimization", IEEE Trans. Power Deliv., Vol. 7, No. 3, pp. 1484-1491, 1992.

[4] V. Glaomocanin, "Optimal Loss Reduction of Distribution Networks", IEEE Trans. Power Syst., Vol. 5, No. 3, pp. 774-781, 1990.

[5] K. Nara, A. Shiose, M. Kitagawa, T. Ishihara, "Implementation of Genetic Algorithm for Distribution Systems Loss Minimum Reconfiguration", IEEE Transactions on Power Systems, Vol. 7, pp. 1044-1051, 1992.

[6] J.Z. Zhu, "Optimal Reconfiguration of Electrical Distribution Network Using the Refined Genetic Algorithm", Electric Power Systems Research, Vol. 62, pp. 37-42, 2002.

[7] H.D. Chiang, R. Jean Jumeau, "Optimal Network Reconfigurations in Distribution Systems I", A New Formulation and a Solution Methodology, IEEE Transactions on Power Delivery, Vol. 5, pp. 1902-1909 1990.

[8] T. Tanabe, T. Funabashi, K. Nara, Y. Mishima, R. Yokoyama, "A Loss Minimum Reconfiguration Algorithm of Distribution Systems under Three-Phase Unbalanced Condition", IEEE Power and Energy Society General Meeting, Conversion and Delivery of Electrical Energy in the 21st Century, pp. 1-4, 2008.

[9] J. Olamaei, T. Niknam, G. Gharehpetian, "Application of Particle Swarm Optimization for Distribution Feeder Reconfiguration Considering Distributed Generators", Applied Mathematics and Computation, Vol. 201, pp. 575-586, 2008.
[10] M.H. Hemmatpour, M. Mohammadian, "Incorporating SVC Planning to Reconfiguration Based on Voltage Security Margin", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 10, Vol. 4, No. 1, pp. 1-10, Mar. 2012.
[11] K.S. Lee, Z.W. Geem, "A New Meta-Heuristic Algorithm for Continues Engineering Optimization - Harmony Search Theory and Practice", Comput. Meth. Appl. Mech. Eng., Vol. 194, pp. 3902-3933, 2004.
[12] K.S. Lee, Z.W. Geem, "A New Structural Optimization Method Based on the Harmony Search Algorithm", Computers and Structures, Vol. 82, pp. 781-798, 2004.
[13] M. Afkousi Paqaleh, S.H. Hosseini, "Transmission Constrained Energy and Reserve Dispatch by Harmony Search Algorithm", IEEE General Meeting, Canada, 2009.
[14] N. Amjady, O. Abedinia, H.A. Shayanfar, A. Ghasemi, "Market Optimization Using Fuzzy Based Multiobjective Harmony Search Algorithm", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 12, Vol. 4, No. 3, pp. 9-15, September 2012.
[15] K. Nekooei, M.M. Farsangi, H. Nezamabadipour, "An Improved Harmony Search Approach to Economic Dispatch", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 8, Vol. 3, No. 3, pp. 25-31, September 2011.
[16] M.H. Shariatkhah, M.R. Haghifam, J. Salehi, A. Moser, "Duration Based Reconfiguration of Electric Distribution Networks Using Dynamic Programming and Harmony Search Algorithm", International Journal of Electrical Power & Energy Systems, Vol. 41, Issue 1, pp. 1-10, October 2012.
[17] W. Lin, H. Chin, "A New Approach for Distribution Feeder Reconfiguration for Loss Reduction and Service Restoration", IEEE Transactions on Power Delivery, Vol. 13, No. 3, pp. 870-875, July 1998.
[18] Y. Wu, C. Lee, L. Liu, S. Tsai, "Study of Reconfiguration for the Distribution System with Distributed Generators", IEEE Trans. Power Delivery, Vol. 25, No. 3, pp. 1678-1685, July 2010.
[19] J.H. Choi, J.C. Kim, S. Moon, "Integration Operation of Dispersed Generations to Automated Distribution Networks for Network Reconfiguration", IEEE Power Technology Engineering Conf., Vol. 4, pp. 2363-2367, Bologna, Italy, 2003.
[20] G.K. Viswanadha Raju, P.R. Bijwe, "Efficient Reconfiguration of Balanced and Unbalanced Distribution Systems for Loss Minimization", IET Gener. Transm. Distrib., Vol. 2, No. 1, pp. 7-12, 2008.

BIOGRAPHIES

Maryam Habibi was born in Kermanshah, Iran in 1981. She received B.Sc. degree in Computer Software Engineering from Razi University, Kermanshah, Iran in 2004 and M.Sc. degree in Artificial Intelligence from Science and Research Branch, Islamic Azad University, Tehran, Iran in 2008. Since 2008, she has been a Lecturer at the Computer Engineering Department, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran. She is a Faculty Member of the Computer Engineering Department at the same university.

Mohsen Kazemi received the B.Sc. degree in Computer Engineering from Shahid Bahonar University, Kerman, Iran, in 2008. He received the M.Sc. degree in Computer Engineering from Sharif University of Technology, Tehran, Iran, in 2011. His research interests include optimization, bioelectric, embedded systems, cognitive radio, and wireless sensor networks.