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PRIORITIZATION OF DISTRIBUTION NETWORK AREAS IN SANANDAJ CIYT (IRAN) TO INSTALL DG USING AHP ALGORITHM

M.A. Harighi [1] S. Soleymani [2] F. Faghihi [3] B. Mozafari [4]

Department of Power Electric, Faculty of engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
aminharighi@yahoo.com, s.soleymani@srbiau.ac.ir, faramarz_faghihi@hotmail.com, mozafari_babak@yahoo.com

Abstract- Reconfiguration in power systems leads to entry of distributed generation. According to specifications, operating conditions and placement, DG units play an important role in distribution networks. High costs of network development and consequently energy loss and also the quality requirement of distribution network such as voltage sag, unbalance, etc. using DG resources to be considered. Small generation units located close to or in the load centers. One of the most important tasks for electric companies is to supply safe and appropriate electricity to the costumers. In this paper, the prioritization of seven urban areas has been done to install distributed generation using AHP algorithm. Power quality and load growth are the criterion of prioritization. In this study economic factors for DG placement have not been considered. Results are tested on a real medium voltage grid by Digsilent software to verify the efficiency of distributed generation. The results show that DG permits an increase in power transfer capacity, maximum loading line and load voltage, also reduce power losses.

Keywords: Analytic Hierarchical Process (AHP), Load Flow and Growth, Power Quality, Distributed Generation (DG), Medium Voltage (MV), Low Voltage (LV), Geographic Information Systems (GIS).

I. INTRODUCTION

One of the main goals in locating distributed generation in a distributed system is to reduce the total losses of the system. Also, by considering some practical limitations and constraints such as heat line, voltage per bus, maximum return power, the level of short circuit, etc., different optimization algorithms have been proposed for optimal allocation of distributed generation in the literature [1]. In fact, we can seek the object of reducing power dissipation from both economic and electrical perspectives. In some ways, the intelligent algorithms are used based on sensitivity indices for comparison. And this index is obtained from the place of DG by conventional power flow equations [2]. In other situations, the problems of choosing the size and optimal place of DG are investigated based on power loss sensitivities and Kalman Filter Algorithms (CFA) [3]. In some other cases, a method is provided to select size and the place of DG units based on improvement of voltage stability limit [4].

In one of the methods, with two GA and PSO algorithms and by considering the function based on parameters of short circuit and required protective equipment, different issues such as active power loss, system reactive, voltage profile, line loading and network capacity are compared to optimize and instant locating of distributed generation units, commercial loads and residential and industrial loads and mixed situations [5].

With newer technologies, by using a fuzzy algorithm and by considering the multi-objective function of system loss, system loading due to the profitability of the power system has been debated [6]. In more optimum methods, candidate sites are prioritized to install DG units, by the effective amount of power losses reduction [7]. In recent methods, for mixed optimal locating of DG, technical factors have been considered such as minimizing line losses and reducing voltage sag and economic factors (the cost of installation and maintenance of DG).

Moreover, different algorithms with different abilities have been used in DG placement. Each of them is used for specific purposes such as cost reduction, voltage modification, etc. The proposed method in this paper is using AHP.

II. INTRODUCING THE STUDIED AREA

Increasing electricity demand on one hand, impossibility network development in some urban areas and existence full load MV lines on the other hand, tend to use of distributed generation increased. Sanandaj area is 3033 square kilometers. Energy losses about 11.1% and synchronous maximum load is equal to 110 MW at the end of 2013. Figure 1 shows the selected region on GIS map. These areas include Baharan housing, Zagros town, Degaran town, Naisar, Enghelab square, Azadi square, Keshavarz town.

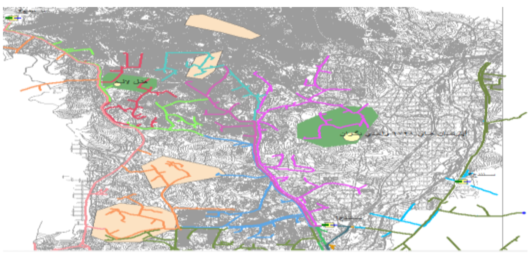

Figure 1. Candidate sites [10]

III. HIERARCHY PROCESS

One of the most comprehensive systems for decision making that consider quantitative and qualitative multiple measures is AHP. This process involved different options for decision-making and it has the possibility of sensitivity analysis on the criteria and sub criteria. Furthermore, it is based on pair comparison that facilitates judgment and calculations. Also, the degree of compatibility and incompatibility show that there are superior benefits of this method of multi-criteria decision making. In this method, criteria are compared pairwise and in a matrix of pairwise comparison. In other words, the numbers of paired comparison matrix show the preference of one criterion to another [2]. In Figure 2, the analytic hierarchical tree of paper is shown.

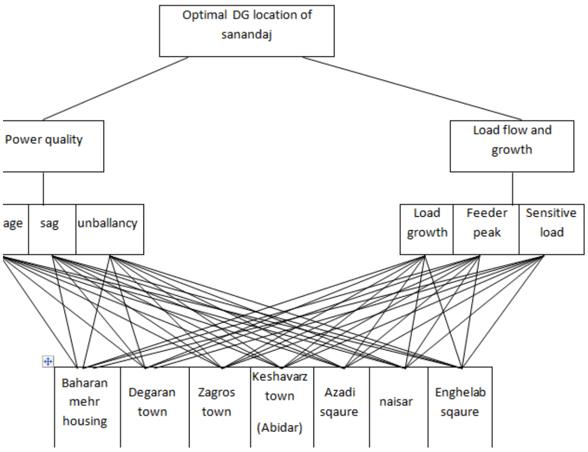

Figure 2. Hierarchical tree of problem [2]

A. Hierarchy Structure

Hierarchical tree is composed of three main steps which include: creating a hierarchical structure, priority analysis and confirming system compatibility. First, decision-maker should construct the decision making issue in multiple levels. Then, decision-maker should conduct comparisons based on scientific-empirical knowledge. When the comparisons are performed by using subjective judgments, it is possible that inconsistency occurs some here among decision-making. If the inconsistency rate is greater than 0.1, decision-maker should review their comparisons. After confirming the compatibility of comparisons, we can combine judgments and detect the preference of areas and standards. According to power industry standard in Iran, in Table 1 standard voltage range is presented.

Table 1. Standard voltage range

High	Low	Voltage Level
420	360	400
241	207	220

According to NEMA definition, voltage unbalance in percent is:

$$U\% = \frac{D_{\max}}{V_{L_{av}}} \tag{1}$$

which $D_{\max}$ is maximum deviation from mean of effective supply of voltage lines, $V_{L_{av}}$ is the mean of effective supply of voltage lines. According to power industry standard of Iran, the amount of allowable voltage unbalance for voltage level of 400 volts is 2 percent.

IV. CRITERIA AND SUB-CRITERIA OF PROBLEM

A. Power Quality

The proposed method for comparing regions is done from the viewpoint of voltage sag. First by the background of referring the customers of seven selected areas of the city and then it is done based on voltage sampling. Comparison sites was done from the viewpoint voltage unbalance by two methods: Current unbalance of distribution substation in regions and voltage sampling. Table 2 shows the amount of current unbalance and maximum loading on distribution substation situated in Enghelab square. In figure 3 illustrates the distribution substations with minimum current unbalance in Degaran town.

Table 2. Distribution substations of Enghelab square [10]

Substation Name	Capacity (KVA)	Maximum Loading (%)	Current Unbalance (%)
Sarhang mosque	630	31	4
Enghelab square	500	53	8
Hami passage	800	82.5	30
Stad	1250	27	15
Mardokh bridge	800	65.5	25
Ghale 4 lan	800	33	5

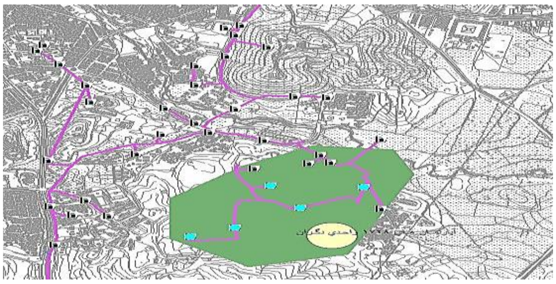

Figure 3. Unbalanced substations in Degaran town [10]

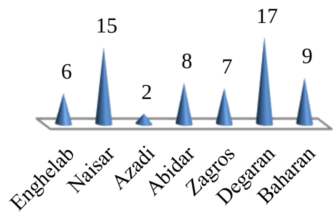

Figure 4. Comparison power outage, 2013 [10]

By using GIS software, overloaded and unbalanced substations are identified. Figure 3 shows unbalanced substations in Degaran town. Figure 4 presented the number of power outages of MV lines on areas. Degaran town with 17 times outage is in first place and Azadi Square with two times outage is in last place. This chart is used for paired comparison from the viewpoint of power outage sub-criteria.

B. Load Flow and Growth Criteria

This criteria can be investigated in two stages:
-Prediction of future loads in each region.
-Load growth of MV line

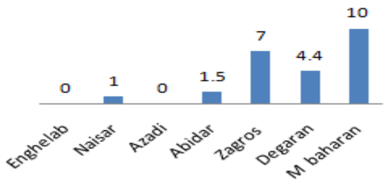

Figure 5. Future loads in MW [10]

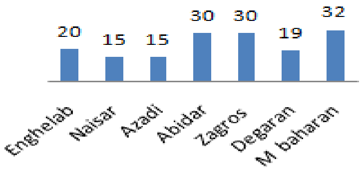

Figure 6. Load growth of MV line in percent [10]

One of the methods to determine the load growth of line in selected areas is new applicants in each area. Figure 5 shows that Azadi and Enghelab squares don't have new load and Baharan housing need to 10 MW power in the future. Bahran housing has the maximum growth rate of 32% and Naisar has the minimum growth rate of 15%. Figure 6 shows that Baharan housing based on load growth criteria is in the first place.

Pairwise comparison matrix of power quality and load flow-growth is according to Table 4. It is assumed that power quality is more important than load flow and growth. Matrices of pairwise comparisons of power quality sub-criteria and load flow-growth sub-criteria is in tables 5 and 6. In power quality criteria, outage is the most important factor and voltage sag more important than voltage unbalance. In load flow-growth criteria load sensitive sub-criteria is more important than load growth. Commercial loads more sensitive than residential loads are considered. Most commercial loads located in Azadi and Enghelab areas. Maximum loading line also more important than load growth.

After completing the matrix of pairwise comparisons, according to all sub-criteria and by using collected information Expert Choice software was used to analyze the multi-criteria analysis problems. It will provide preferences and final weight of regions by charts and appropriate graphs.

Table 3. Matrix of pairwise comparisons criteria

	Power Quality	Load Flow and Growth
Power Quality	1	4
Load Flow and Growth		1

Table 4. Matrix of power quality sub-criteria

	Sag	Unbalance	Outage
Sag	1	4	4
Unbalance		1	5
Outage			1

Table 5. Matrix of load flow and growth sub-criteria

	Load Sensitive	Maximum loading of MV Line	Load Growth
Load Sensitive	1	3	4
Maximum loading of MV Line		1	3
Load Growth			1

C. The Weight Results and Final Preferences of Places

Figures 7 to 10 show the weight of each area based on power quality criteria and their sub-criteria. Figure 7 shows that Naisar and Degaran respectively with weights of 0.362 and 0.236 have the highest voltage sag. Figure8 shows that Naisar and Azadi square respectively, with a weight of 0.364 and 0.233 have the highest voltage unbalance. Naisar and Degaran in Figure 9, respectively, with weights of 0.295 and 0.273 have the highest power outage. Since the medium voltage network in Azadi square is a ground cable, it has the lowest power outage with a weight of 0.041. There are power quality problems in Naisar. So Naisar has the maximum weight (Figure 10). Azadi square with numerous transformers has the minimum weight. Baharan housing is in last place than other options due to appropriate power quality from the view of voltage unbalance and voltage sag. Figure 11 shows the final weight of options based on load flow and growth criteria. Enghelab and Azadi square respectively with weights of 0.213 and 0.207 have the highest load growth. Keshavarz town or Abidar has the minimum weight (0.089).

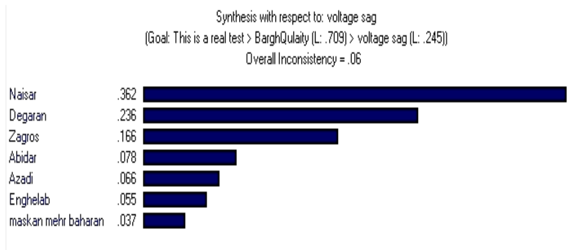

Figure7. Final weight of areas- voltage sag.

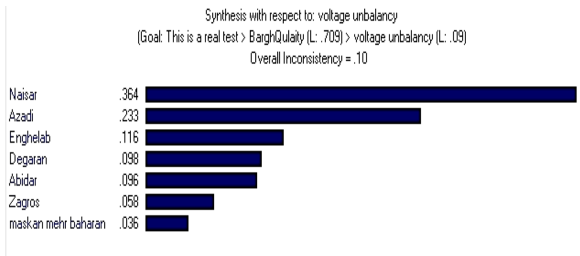

Figure 8. Final weight of areas - voltage unbalance

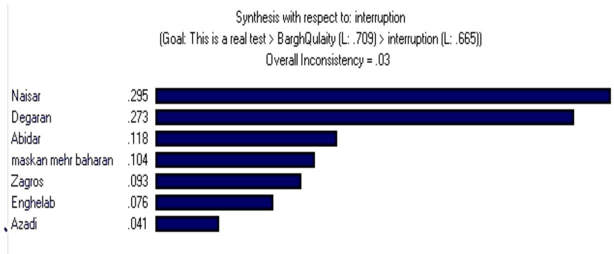

Figure 9. Final weight of areas - power outage

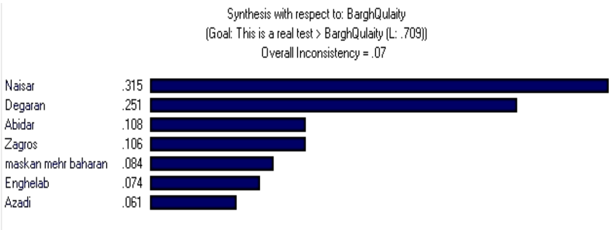

Figure 10. Final weight of areas - power quality criteria

In the following, sensitivity are presented in figures 12 and 13. In these charts, criteria are shown on the horizontal axis and options have been shown on the vertical axis. The option's line intersects with vertical lines related to criteria, it shows the weight of each option about the criteria. The criteria's priorities are shown by vertical lines. The overall weight of each area is visible on the right vertical axis.

In Figure 14, the final priority and weight of places are offered. Naisar with a weight of 0.266 and the Degaran town with a weight of 0.21 are in first and second places and Baharan housing with a weight of 0.095 has the minimum weight.

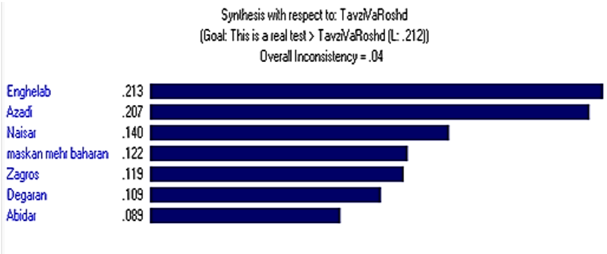

Figure 11. Final weight of areas - load flow - growth criteria

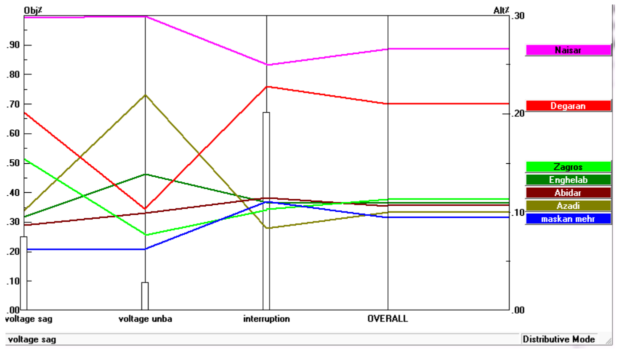

Figure 12. Sensitivity based on power quality

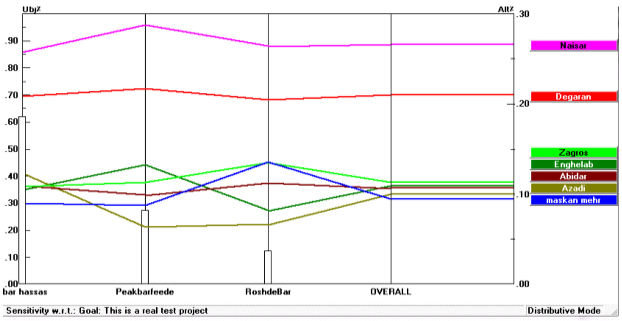

Figure 13. Sensitivity based on load flow and growth

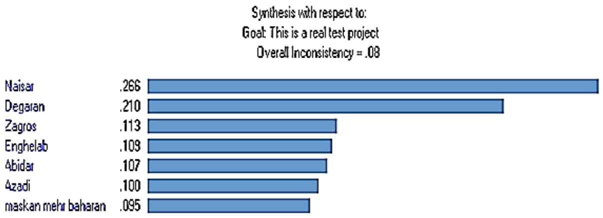

Figure 14. Final priority of areas

V. SIMULATION OF SAMPLE AND ACTUAL LINE WITH DIGSILENT SOFTWARE AND INVESTIGATING THE EFFECT OF DG

According to the single line diagram in Figure 15, a 1.2 MW DG unit is simulated in Abidar MV line. Loads data is shown in Table 6. The effect of DG for increasing of distribution line capacity and reducing line losses and improving the voltage profile of load points are shown in two Tables 7 and 8.

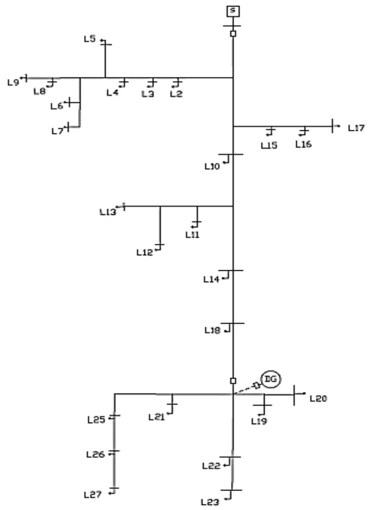

Figure 15. Single-Line diagram of Abidar MV line

Table 6. Load in kilowatt and number of end use Abidar line

Point	Load (KW)	Number of End Use
2	118	178
3	67	3
4	124	201
5	275	429
6	314	528
7	325	442
8	112	140
9	94	101
10	110	32
11	106	122
12	266	230
13	102	1
14	35	2
15	287	475
16	120	148
17	69	3
18	110	130
19	59	92
20	89	139
21	65	81
22	173	3
23	280	370
25	59	37
26	42	24
27	40	24
Total	3445	3935

Table 7. Variations of voltage after and before DG placement

Load Points	Voltage With DG	Voltage Without DG
19	393	388
20	393	388
21	394	388
22	394	388
23	394	388
25	393	387
26	392	386
27	392	386

Table 8. Results of line losses

	With DG	Without DG
Power Input (KW)	2669	3525
Power Loss (KW)	64	80

VI. CONCLUSION

In this paper AHP algorithm for DG placement in distribution network is used. Power quality and load flow and load growth are the main criteria for decision making. Each criteria has three sub-criteria. Criteria and sub-criteria and urban areas are compared separately. Decision-maker is electric company. According to power utility the importance of power quality is more than load flow and growth criteria. Naisar with numerous outages, and unauthorized junctions is in first priority of DG installation. Length line of low voltage network is long there. There are many unbalanced distribution substations in Naisar. But Baharan housing is placed at the last priority, because there voltage profile is satisfactory. Substations located close to load centers.

Length of LV line is short there. If load flow and growth criteria was more important than power quality, fundamental changes were created in priorities. In this case, the electricity supply of Baharan housing seemed necessary. Finally, the results of simulation show that DG allocation improve the voltage profile, decrease power losses and increase power transfer capacity. In some cases, perhaps renewable DG uncertainty increases power outage and thus power quality not only gets better but also gets worse. So we can tell that DG often improve the voltage quality. For future research, DG installation is recommended on low voltage network.

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BIOGRAPHIES

Mohammad Amin Harighi was born in Sanandaj, Iran, 1975. He received the B.Sc. degree in Electrical Power Engineering from Shahid Rajaei University, Tehran, Iran in 2001 and M.Sc. degree in Electrical Power Engineering from Science and Research Branch, Islamic Azad University, Tehran, Iran in 2014. His research interests are in distributed generation on distribution grid and renewable energy.

Soodabeh Soleymani received the B.Sc. degree in Electronic Engineering in 2000, the M.Sc. and Ph.D. degrees in Electrical Engineering in 2002 and 2007, respectively all from Sharif University of Technology, Tehran, Iran. She is the Faculty Member of Science and Research Branch, Islamic Azad University, Tehran, Iran. Her research interests are power system operation and planning.

Faramarz Faghihi received the B.Sc. degree in Electrical Engineering from University of Tehran, Iran, in 2000, the M.Sc. in Communication Engineering from Imam Hossein University, Tehran, Iran, in 2002, and the Ph.D. degree in Current Injection Transformer Optimization from Iran University of Science and Technology, Tehran, Iran in 2008. He is the Faculty Member of Science and Research Branch, Islamic Azad University, Tehran, Iran. His research interests are EMC, transformers designing and operation, renewable energy and superconductors.

Babak Mozafari received his M.Sc. and Ph.D. degrees from the Electrical Engineering Department of Sharif University of Technology, Tehran, Iran in 2002 and 2006, respectively. Presently, he is an Assistant Professor in the Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran. His research interests are in restructured power system operation and control.