Reconfiguration of Active Distribution Networks in order to Reduce the Cost of Operation

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ABSTRACT
The development and installation of Distributed Generators (DGs) in distribution power networks turned these networks from a passive into active ones in power systems. Proper management and control of these resources can help to improve power quality, and increase security and effectiveness of power networks. The power management of DGs considering their operating cost along with reconfiguration of distribution network can reduce the cost of operation, including cost of energy losses, cost of power purchasing from the upstream network and cost of power generation by dispatchable DGs. In this study a new method is presented for daily reconfiguration of distribution network in presence of dispatchable DGs and renewable DGs in order to reduce the total operating cost of distribution companies. Dynamic modeling of renewable DGs based on uncertainty of their output, switching costs and varying load are considered in this paper. Finally, the method has been tested in three stages on 16-Bus IEEE to demonstrate the effectiveness of proposed method.

KEYWORDS: Active Distribution Networks, Reconfiguration of Distribution Networks, Power Management, Network Operation Cost, Cost of Switching.

1. INTRODUCTION

Typically, most of the distribution systems are designed as ring/loop networks but because of the complexity in operation, protection topology and prevention of high short circuit level, electrical distribution systems usually operate in radial configuration. However, the radial distribution systems have major problems that it can be pointed to significant energy loss. There are various strategies for reducing loss in distribution networks such as: capacitor placement in distribution systems, use of distributed generators, substitution cross section of conductors, changes of the voltage level and reconfiguration of distribution feeders. Many of these methods are very expensive and need installing new instruments in the network; also this operation might create new faults and other problems like the complexity of the network protection [1]. One of the inexpensive methods to reduce the losses is reconfiguration of distribution networks. In distribution networks, there are some switches to manage the network structure. Network switches are divided into normally open (tie switches) and normally closed (sectionalizing switches) [1]. These switches are used for protection and management of network configuration. Generally, reconfiguration is the changes in the status of the existent switches in networks and changes the path of the power flow. The objective of reconfiguration is usually a reduction in loss, an increase in reliability indices, a decrease in switching number, and a reduction in customer energy not supplied or a reduction in the system operating cost [1]. The methods of reconfiguration can be broadly classified into four categories: heuristics, expert systems, meta-heuristic, and mathematical programming [2].

Marilyn and Back presented the idea of distribution network reconfiguration for the first time in 1975 [3]. He presented a linear model for distribution network reconfiguration and solved it by using discrete branch and bound method. In this method, initially all normally open switches are considered to be closed and subsequently normally closed switches which lead to loss reduction are opened. In 1988, Civanlar and colleagues presented another method of reconfiguration for power loss reduction [4]. In this paper one proper normally open switch is selected and is assumed to be closed, then in the obtained loop, normally closed switches are opened respectively to find critical switch which leads to the most power loss reduction. In 1989, Shirmohammadi and Hong with extending Merilyn and Back's method offered an ingenious method [5]. In this method first all normally open switches are closed and using load flow in created meshed network, switch which minimum current flow across is opened, this procedure is repeated until new radial configurations are found. In [6] branch exchange method has been implemented for distribution network reconfiguration. Graph theory is used for solving the reconfiguration problem in [7]. In this method distribution network is considered as a graph and each sub graph of the main graph which has a tree structure can be considered as a network configuration. With expanding artificial intelligence techniques, new methods have been implemented for reconfiguration of distribution network. For instance, in [8] simulated annealing method has been used for solving reconfiguration problem. Ref. [9] is one of the papers in which the genetic algorithm (GA) has been implemented for reconfiguration of distribution networks. Also, in [10] particle swarm optimization (PSO) method has been implemented for reconfiguration problem. In [11] a new hybrid evolutionary (EA) algorithm based on the combination of the honey bee mating optimization (HBMO) and the Discrete Particle Swarm Optimization (DPSO), called DPSO–HBMO, is implemented to solve a multi objective and non-differentiable distribution feeder reconfiguration problem. Ref. [12] introduces an ant colony search algorithm (ACSA) to solve the optimal network reconfiguration problem for power loss reduction. In [13] new method for multi-objective reconfiguration of distribution system based on the novel Intelligent Water Drops (IWD) algorithm in order to mitigate losses, improve the voltage profile and equalize the feeder load balancing, is presented. Ref. [14] proposes a new methodology for the dynamic reconfiguration of the distribution network which is based on the Lagrange relaxation approach. The aim of this paper is to determine the optimal configurations of the distribution network over the specified time interval. The objective is to minimize the active power losses. Finally, Ref. [15] introduces an executable reconfiguration method in real distribution networks considering operation and coordination of protective devices of the network. The objective of this paper is to attain an optimal configuration with minimum active power loss and voltage deviation while protection system functions properly.

Problems such as the increasing number of consumers in electricity networks (rapid load growth), environmental pollution, global warming and depletion of fossil fuel resources tendency toward using distributed generators (DGs) have increased. With Employing distributed generators in distribution networks, possibility of electricity production will be created at the utilization location and need to the long transmission lines is reduced. By the presence of distributed generators (DGs), distribution networks are changed from a passive network (only loads are connected to it) into an active network (loads and DGs are connected to it). Hence, the active distribution network is a new solution to the flexible utilization of distributed energy resources to suit the characteristics of the distribution network [16]. The important advantages of active distribution networks are rapid change of demands and generation, electric power service provided by distributed participants, bidirectional energy flow and etc.

Nowadays, due to the development of distributed generators and their presence in the distribution networks; studies focus on reconfiguration of distribution feeders with DGs. For example, in ref. [2] genetic algorithm (GA) has been implemented for reconfiguration problem in the presence of different types of distributed generators sources. Loss reduction is the objective of this article. In [17] an ant colony algorithm is used to determine the optimal configuration of the network in the presence of DGs. In [18] PSO algorithm is used to determine the optimal configuration in the presence of dispatchable DGs and non-dispatchable DGs. Also, In Ref. [19] the problem of simultaneous network reconfiguration, optimal DG units and fixed/switched capacitor banks allocation considering different load levels is developed. The objective function of this article encompasses the total cost of power loss, the investment and operation costs of DG units, the installation cost of fixed/switched capacitor banks and cost of purchased active power demand from upstream network.

In this paper, a new method is presented for daily reconfiguration of distribution network in presence of dispatchable DGs and renewable DGs in order to reduce the total operating cost of distribution companies. Modeling of Renewable DGs based on uncertainty of their output, considering switching costs, dynamic modeling in reconfiguration with considering varying load are considered in this study. Finally, the method has been tested in three stages on 16-Bus IEEE to demonstrate the effectiveness of proposed method.

2. THE PROPOSED METHOD FOR POWER MANAGEMENT WITH RECONFIGURATION IN ORDER TO REDUCE THE COST OF OPERATION

By the presence and installation different types of distributed generators, distribution network is changed from a passive network into an active network. Proper management and control of these resources can help to increase power quality, security and effectiveness of power networks. The power management of distributed generators (DGs) considering their operating costs along with reconfiguration of distribution networks can reduce the costs of operation such as cost of power losses, cost of power purchasing and etc. In this section at first the steps of proposed method for power management with reconfiguration in order to reduce the operating cost is presented.

This method is described as follows:

Step 1) Read the input data, including network configuration, line impedance, position and status of N.O / N.C switches, and capacity of the equipment.

Read the load data with assuming it fixed, over a period of Δt.

Read the dispatchable DGs data, including capacity and cost function of units.

Read the renewable DGs data, including probability distribution function according to hour, day and season.

Read the switching costs for distribution network switches.

Step 2) Determine all feasible radial configurations with respect to various operational constraints of the system.

Step 3) Calculate the output power of renewable DGs (wind turbines and photovoltaic) taking into consideration the uncertainty of their output during the 24-hour and according to the probability distribution function.

Step 4) Calculate the costs of power generation by upstream network, dispatchable DGs and power loss for all feasible radial configurations obtained from step 2.

Step 5) Calculate the total operating costs including the costs of power generation and power loss obtained from step 4 and the switching costs for all feasible radial configurations.

Step 6) Compare the costs obtained from step 5, for all feasible radial configurations and determine the minimum operating cost.

Step 7) Finally, determine the optimal configuration with minimum operating cost along with planning of power generation by upstream network and dispatchable DGs.

In the following of this section full explanation of each step will be discussed.

2.1. The proposed method for determination of feasible radial configurations of network

In the original configuration of a distribution network there are some normally open and some normally closed switches. By opening and closing these switches, the path of the power flow in the distribution system can be changed in a way that system loss reduces. As mentioned, electrical distribution systems usually operate in radial configuration. For this reason, the configuration of system after reconfiguration must be maintained radial and at the same time all the loads must be fed and not isolated.

The first step to solve reconfiguration problem is representation of the network structure with a comprehensive code for computer. To show the status of "N" switches in a distribution feeder, a string of "N" bit can be used. For each switch, "1" shows that its status is closed and "0" shows it is open. For example, in the feeders shown in Figure 1 the mentioned code is (1111011110).

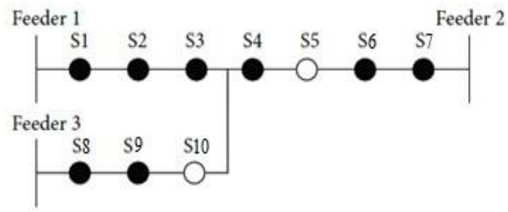

Fig. 1. The typical network to explain binary code generation.

If the statuses of switches change, their string code will change too. Then reconfiguration problem is a binary issue, because all states of the network are combinations of "0" and "1" [20]. For a distribution network with N switches there are 2^N possible codes which all of them are not necessarily feasible. There are different ways to determine feasible states. Three ways of them will be introduced in the following that everyone has advantages and disadvantages.

The First Method: Generate a random binary code and restructure the network by it. If all buses are fed just from one side, this code is feasible and should be saved; otherwise, it is not. The speed of this method is low.

The Second Method: The desired codes can be generated manually, for example, by Microsoft Office Excel and then saved in a database. This way is not automatic but is very fast.

The Third Method: Figure 2 explains this method. Here the network has three feeders and it is obvious that there must not be any closed loop between them, and all buses must be fed too. So all connection ways between feeders should be found and every network code must have just one 0. If there are more, that code is infeasible. The other important limitation is that switches of end loads or feeders should be 1. To understand this method, see Figure 2. Connection ways between feeders include down branch (codes 13, 14, 26, 25, and 23), left branch (codes 12, 15, 19, and 18), and right branch (codes 17, 21 and 24). In every three codes, there should be just one 0 to meet network structure feasibility. All feasible states of the network are equal to multiplication of the number of all collected codes. For example, in Figure 2 the number of feasible codes is 60; this number is gotten from the multiplication of five down branch codes by four left branch codes by three right branch codes. This method is harder but it is very fast and reliable. One more advantage of the proposed method is that it guarantees fast convergence because answer space will reduce significantly. For example, in Figure 2 feasible states are equal to 60 (as already mentioned), but all states are equal to 216 (=65536); then answer space is about 0.09% of the search space. Flowchart of Figure 3 will explain this method.

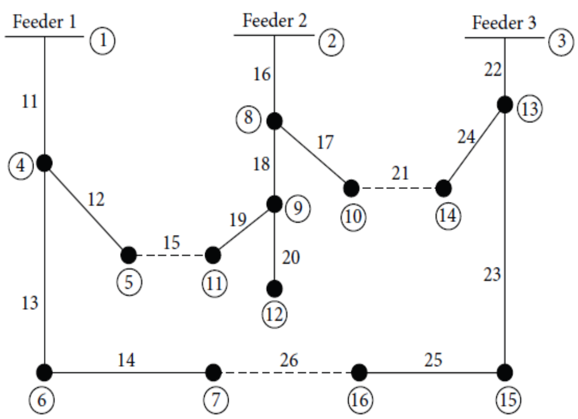

Fig. 2. The 3-feeder distribution network.

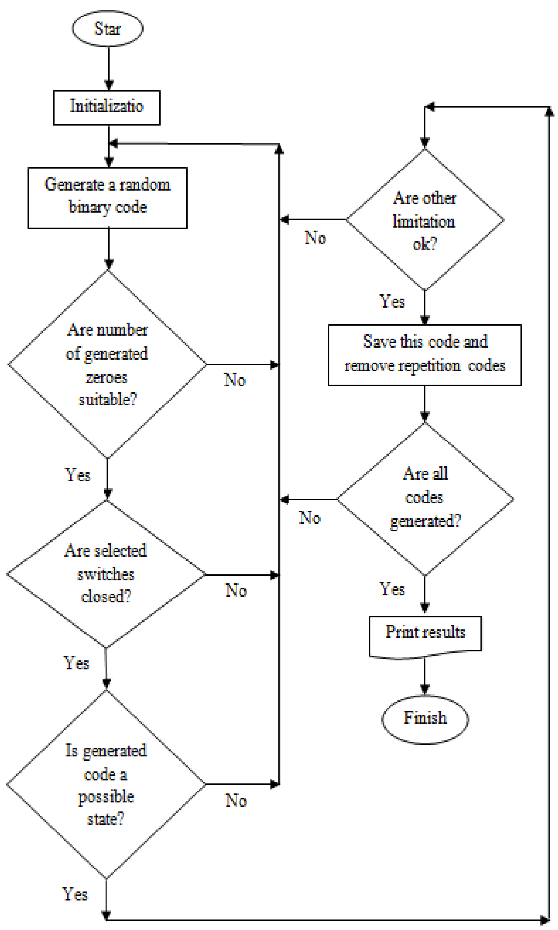

Fig. 3. Flowchart of third method.

2.2. Calculate the output power of renewable DGs taking into consideration the uncertainty of their output

Determining the output power of renewable DGs is essential for system studies in presence of these resources. But because of the lack of accurate prediction of wind speed and solar irradiance in the specific time periods, power generation by wind and solar turbines is faced with uncertainty.

According to the probability distribution of predicted wind speed and probability distribution of solar irradiance; the output power of these units can be achieved. In this section complete description of uncertainty modeling of wind and solar power is provided.

In references [21] and [22] it is shown that the wind speed and solar irradiance for each hour of the day are modeled by Weibull and Beta probability density functions (PDFs), respectively.

To calculate the probability of wind speed and solar irradiance during any specific hour, equations (1) and (2) are used:

$$P_v\{G_w\} = \int_{v_{w1}}^{v_{w2}} f_r(v)dv \tag{1}$$

$$P_s\{G_y\} = \int_{s_{y1}}^{s_{y2}} f_b(s)ds \tag{2}$$

Where $f_b(s), f_r(v)$ are Beta distribution function of s and Weibull distribution function of v, respectively; v_{w1}, v_{w2} and s_{y1}, s_{y2} are the beginning and end of the period, respectively.

Equations (3) and (4) show the output power of wind turbine and solar power plant, respectively.

$$P_{out}(v) = \begin{Bmatrix} 0 & ,0 \le v_{aw} \le v_{ci} \\ P_{rated} * \dfrac{v_{aw} - v_{ci}}{v_r - v_{ci}} & ,v_{ci} \le v_{aw} \le v_r \\ P_{rated} & ,v_r \le v_{aw} \le v_{co} \\ 0 & ,v_{co} \le v_{aw} \end{Bmatrix} \tag{3}$$

Where v_{co}, v_r, v_{ci} are cut-off speed, rated speed and cut-in speed of the wind turbine, respectively; v_{aw} is average wind speed of each interval and P_{rated} is rated power of wind turbine.

$$P_{out}(s) = \begin{Bmatrix} P_{rated} * \dfrac{s}{s_r} & ,s \le s_r \\ P_{rated} & ,s \ge s_r \end{Bmatrix} \tag{4}$$

Where s is solar irradiance; P_{rated} is rated power of solar power plant and s_r is solar irradiance in rated power.

Finally, the average power of each wind turbine and solar cells is obtained from equations (5) and (6), respectively.

$$P_{av} = \sum_{v_{ci}}^{v_{co}} P_{out}(v) \times P_v\{G_w\} \quad (5)$$

$$P_{av} = \sum_{s_{y1}}^{s_{y2}} P_{out}(s) \times P_s\{G_y\} \quad (6)$$

Notably, renewable DGs are modeled as negative PQ nodes in studies. So in this article, the average output power of each DG (Equation (5 and 6)) is considered as negative load in the load flow calculation.

2.3. Calculate the cost of power generation by upstream network and dispatchable DGs

Dispatchable DGs refers to sources of electricity that the output power of them can be controlled by the operator. These resources unlike conventional thermal power plants and renewable DGs can be turned on or off, or can adjust their power output accordingly to an order. The most common dispatchable power plants are diesel generators, natural gas and biomass.

In order to plan the output power of dispatchable DGs and evaluate their impact on distribution networks, an optimal power flow (OPF) is performed to minimize the total cost of generation by the distributed generators. In the following of this section full explanation of OPF formulization is presented [23].

As mentioned, an optimal power flow (OPF) is performed to minimize the total generation cost of the active power generated by the distributed generators and the grid supply (upstream network). Equation (7) shows the objective function of OPF for dispatchable DGs and upstream network that is considered as a source of power generation:

$$Minmize\ \ Z = \sum_{n=1}^{Ng} f_n(P_n) \quad (7)$$

The fuel cost functions of generation units can be presented as quadratic functions:

$$f_n(P_n) = a_n P_n^2 + b_n P_n + c_n \quad (8)$$

Where Z is total fuel cost of generating units; f_n is cost function of unit n; P_n is active power generation of unit n (MW); N_g is number of generating units and a_n, b_n, c_n are cost coefficients of unit n.

The objective function in (7) is subject to the following constraints.

Bus voltage limits:

$$V^{min} \le V_i \le V^{max} \quad (9)$$

Active power generation limits:

$$P_n^{min} \le P_i \le P_n^{max} \quad (10)$$

Reactive power generation limits:

$$Q_n^{min} \le Q_i \le Q_n^{max} \quad (11)$$

Where P_n^{min}, P_n^{max} are minimum and maximum active powers of unit n, respectively and Q_n^{min}, Q_n^{max} are minimum and maximum reactive powers of unit n, respectively.

3. CASE STUDY

In order to demonstrate the validity, effectiveness and efficiency of the suggested method, this method has been tested on IEEE 16-Bus test system [24]. In Figure 2 the single-line diagram of 16 bus system is presented. The rated voltage of network is 23kV. The branches that are shown by dash-points (15, 21 and 26) in Figure 2; are open switches. Load profile of a distribution feeder in Iran has been used in this paper. This load includes three different types; commercial (C), residential (R) and industrial (I) (see Figure 4).

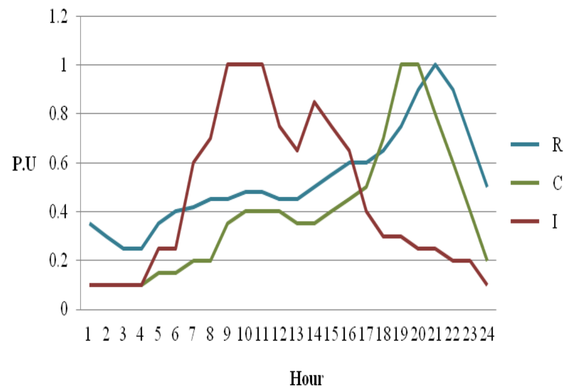

Fig. 4. Daily load profile of network.

In the following; results of daily reconfiguration in three different scenarios are presented.

3.1. Reconfiguration of distribution network without DGs

In this section of article, results of the reconfiguration of passive distribution network (without DGs) are presented. The objective function of this scenario is minimizing the total costs of energy loss and switching for each hour of the day. The objective function can be described as follows:

$$MinumizeF = cost_{Loss} + cost_{sw} \tag{14}$$

Where F is objective function; $Cost_{Loss}$ is the cost of energy losses; and $Cost_{SW}$ is the cost of switching operation.

Table 1 shows the results of this stage.

Furthermore, the cost of any switching is assumed $0.1 (10 Cent).

Table 1. Reconfiguration of 16-bus network without DGs.

Hour	Loss cost ($)	Opened Switches	No. of Switching	Total Cost ($)
1	8.984	17,19,26	0	8.984
2	7.096	17,19,26	0	7.096
3	5.424	17,19,26	0	5.424
4	5.424	17,19,26	0	5.424
5	11.384	17,19,26	0	11.484
6	16.376	17,19,26	0	16.376
7	29.592	17,19,26	0	29.792
8	28.525	19,21,26	2	28.625
9	47.766	19,21,26	0	47.766
10	53.730	19,21,26	0	53.730
11	53.730	19,21,26	0	53.730
12	51.812	17,19,26	2	52.012
13	50.373	14,17,19	2	50.573
14	66.807	14,17,19	0	66.807
15	72.216	14,17,19	0	72.216
16	78.381	14,17,19	0	78.381
17	72.930	17,19,26	2	73.130
18	97.517	17,19,26	0	97.517
19	146.403	17,19,26	0	146.403
20	153.504	17,19,26	0	153.504
21	143.000	17,19,26	0	143.000
22	103.760	17,19,25	2	103.960
23	45.528	17,19,26	2	45.725
24	17.733	17,19,26	0	17.733

According to the second column of Table 1; the total loss cost of network is $1367.995. The Fourth column of the table shows the number of switching operations. It is obvious that number of switching operations during the 24-hour is equal to 12 and the total cost of switching is $1.2 (120 Cent). Finally, the last column of table represents the total costs of energy losses and switching for a day which this cost is equal to $1369.195.

According to the load profile of a distribution feeder in Iran, requirement power of loads in a day is 322.873 MW that the cost of power purchasing from upstream network based on cost of electricity is $26024.71.

Eventually, the total operating cost of Distribution Company in a day that includes the total costs of power purchasing from upstream network and switching is equal to $27394.002.

3.2. Reconfiguration of distribution network with renewable DGs

For simulation of second stage; the output power of renewable DGs has been used for a period of 24-hour. In this article; it is assumed that wind turbine with capacity of 500 kW is located at bus 9 and photovoltaic system with capacity of 200 kW is located at bus 5. The output power of the wind turbine and photovoltaic system is calculated according to the equations mentioned in previous section. The output power of these units is shown in Figure 5 and 6.

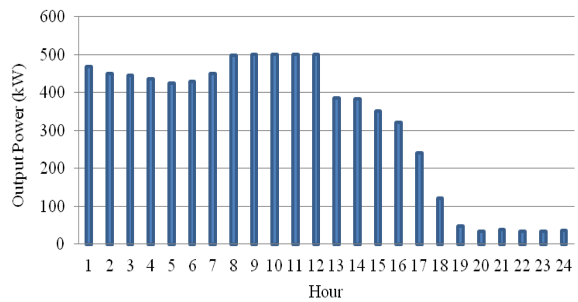

Fig. 5. Output power of wind turbine.

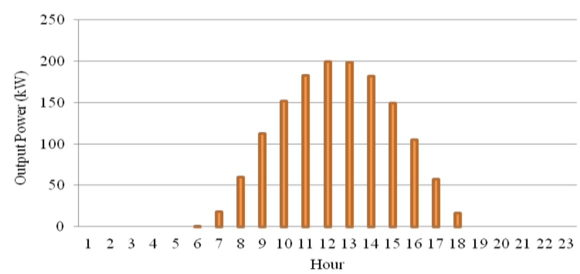

Fig. 6. Output power of photovoltaic system.

The objective function of this scenario like first scenario is minimizing the total costs of energy losses and switching for each hour of the day.

Table 2 shows the results of this scenario. Furthermore, the cost of any switching is assumed $0.1 (10 Cent).

According to the second column of Table 2, the total loss cost of network is equal to $1312.926. By comparing pervious stage with this stage, the loss cost is reduced by $55.069 and %4.1. Also, the Fourth column of the table shows the number of switching operations. It is obvious that number of switching operations during the 24-hour is equal to 12 and the total cost of switching is $1.2 (120 Cent). Finally, the last column of table represents the total costs of energy losses and switching for a day which this cost is $1314.126. This value is reduced $55.166 in compared with the first stage.

According to the load profile of a distribution feeder in Iran, requirement power of loads in a day is 322.873 MW that according to Figure 5 and 6, 7.632 MW is provided by wind turbine and 1.437 MW is provided by photovoltaic system. Thus, 313.8062 MW power is purchased from upstream network. Cost of power purchasing from upstream network based on cost of electricity is $25319.17 that is reduced $705.54 in compared with the first stage.

Eventually, the total operating cost of Distribution Company in a day that includes the total costs of power purchasing from upstream network and switching is equal to $26633.296. This cost is reduced $760.706 and %2.78 compared to first scenario.

Table 2. Reconfiguration of 16-bus network with renewable DGs.

Hour	Loss cost ($)	Opened Switches	No. of Switching	Total Cost ($)
1	7.704	17,19,26	0	7.704
2	5.996	17,19,26	0	5.996
3	4.480	17,19,26	0	4.480
4	4.497	17,19,26	0	4.497
5	9.832	17,19,26	0	9.832
6	14.281	17,19,26	0	14.281
7	27.090	17,19,26	0	27.090
8	25.860	19,21,26	2	26.060
9	43.782	19,21,26	0	43.782
10	49.434	19,21,26	0	49. 434
11	49.350	19,21,26	0	49.350
12	46.991	17,19,26	2	47.192
13	46.521	14,17,19	2	46.721
14	62.397	14,17,19	0	62.397
15	67.995	14,17,19	0	67.995
16	74.385	14,17,19	0	74.385
17	69.836	17,19,26	2	70.036
18	95.664	17,19,26	0	95.664
19	145.500	17,19,26	0	145.500
20	152.829	17,19,26	0	152.829
21	142.330	17,19,26	0	142.330
22	103.320	17,19,25	2	103.520
23	45.268	17,19,26	2	45.468
24	17.584	17,19,26	0	17.584

3.3. Reconfiguration of distribution network with renewable and dispatchable DGs

In this section, daily reconfiguration of network is discussed in the presence of renewable and dispatchable DGs simultaneously. In addition to wind turbine and photovoltaic systems at buses 9 and 5, one dispatchable unit with a nominal capacity of 1 MW is located at bus 12.

In this case, dispatchable DG like wind turbine and photovoltaic system, has the task of providing the requirement power of loads; But these kinds of units are different with renewable DGs. The output power of dispatchable DG is not known in advance and proper planning must be done to determine the power output.

In order to plan power generation by DG and upstream network, the optimal power flow (OPF) based on PSO optimizing algorithm is used in MATLAB. It should be noted that in this study cost coefficients of DG are 0.008, 45 and 78; respectively.

The objective function of this scenario is minimizing the total costs of power generation, energy losses and switching for each hour of the day. The objective function can be described as follows:

$$Minimize F = Cost_{Loss} + Cost_{SW} + Cost_{OPF} \quad (15)$$

Where F is objective function; $Cost_{Loss}$ is the cost of energy losses, $Cost_{SW}$ is the cost of switching operation; and $Cost_{OPF}$ is power generation cost.

Table 3 shows the results of this stage.

Furthermore, the cost of one switching is assumed $0.1 (10 Cent).

According to the second column of Table 3, the total loss cost of network is $167.515 which this value is decreased greatly compared to two previous stages. According to the third column of the table; power generation cost by upstream network and dispatchable DG (cost of OPF) is $17781.8998. Fourth column of the table shows the number of switching operations. It is obvious that number of switching operations during the 24-hour is equal to 12 and the total cost of switching is $1.2 (120 Cent). Finally, the last column of table represents the total costs of power generation, energy loss and switching for a day which this cost is $17948.7877.

According to the load profile of a distribution feeder in Iran, requirement power of loads in a day is 322.873 MW that 9.069 MW is provided by renewable units and 22.072 MW is provided by dispatchable unit. Thus, 290.2292 MW power is purchased from upstream network. Cost of power purchasing from upstream network based on cost of electricity is $23420.316 that is reduced $2604.394 (%10) compared to the first stage and is reduced $1898.854 (%7.4) compared to the second stage.

Eventually, the total operating cost of Distribution Company in a day that includes the total costs of power purchasing from upstream network, power generation by unit and switching is equal to $24664.1684. This cost is reduced $2729.8336 (%9.96) compared to first scenario and is reduced $1969.1276 (%7.4) compared to the second scenario.

Therefore, as shown in Figure 7, the presence of different types of distributed generators (DGs) along with reconfiguration in distribution networks reduces the cost of operation significantly.

Table 3. Reconfiguration of 16-bus network with renewable and dispatchable DGs.

Hour	Loss cost ($)	OPF cost ($)	Opened Switches	No. of Switching	Total Cost ($)
1	0.432	407.814	12,14,17	0	408.248
2	0.368	380.011	12,14,17	0	380.380
3	0.312	351.643	12,14,17	0	351.955
4	0.312	352.093	12,14,17	0	352.405
5	0.7922	477.072	12,14,17	0	477.867
6	0.848	505.450	12,14,17	0	506.295
7	2.304	644.890	12,14,17	0	647.195
8	1.812	644.239	12,14,24	2	646.252
9	5.346	862.450	12,14,24	0	867.796
10	7.524	880.866	12,14,24	0	888.390
11	7.446	880.857	12,14,24	0	888.303
12	5.368	778.406	12,14,17	2	783.974
13	5.202	732.131	12,14,21	2	737.533
14	9.9	822.375	12,14,21	0	832.275
15	10.81	842.199	12,14,21	0	853.100
16	11.43	862.578	12,14,21	0	874.008
17	11.6	819.293	12,14,17	2	822.093
18	15.3	894.142	12,14,17	0	909.441
19	16.02	1076.137	12,14,17	0	1092.157
20	18.9	1145.443	12,14,17	0	1164.343
21	15.04	1122.295	12,14,17	0	1137.334
22	12.96	969.417	12,17,26	2	982.577
23	6.44	776.893	12,14,17	2	783.532
24	1.05	553.202	12,14,17	0	561.330

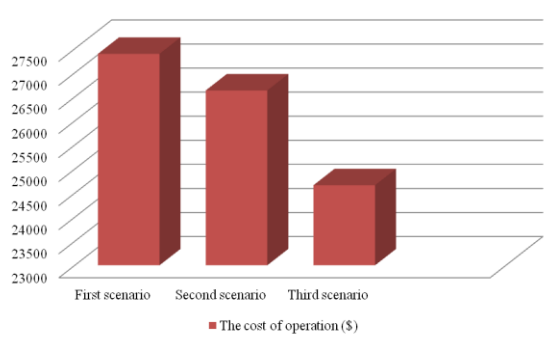

Fig. 7. Comparison of operating cost for three scenarios.

4. CONCLUSION

In this paper a novel method has been presented for daily reconfiguration of distribution network in presence of dispatchable DGs and renewable DGs in order to reduce the total operating cost of distribution companies. At first, a new method is presented for determination of all feasible radial configurations of network. Then, modeling of renewable DGs based on uncertainty of their output and power management of dispatchable DGs is discussed. Finally, the method has been tested on 16-Bus IEEE in three different stages.

Results demonstrate that power management of distributed generators (DGs) according to their operating costs along with reconfiguration of distribution networks can improve system performance and can reduce the costs of operation such as cost of power loss, cost of power purchasing and etc.

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