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A New Method of Distribution Marginal Price Calculation in Distribution Networks by Considering the Effect of Distributed Generations Location on Network Loss

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Abstract- *The determination of practical and coherent policy to pin down the price in restructured distribution networks should be considered as a momentous topic. The present paper introduces a new method of distribution marginal price (DMP) calculation. The main aim of this paper is to evaluate the DMP for both producers and consumers separately. For this purpose, the first part of the procedure emphasizes a price by which the producers should sell their power. To meet this target, the share of each node plays a significant role in the total active loss of the network. The producers will make a substantial profit when their efficiency leads to decreasing the share of the node that is associated with the total loss. In the second part of the procedure, DMP is computed for the consumers. In this part, based on the distribution system operator's decision about the obtained profit allocated to the consumers, their payment has been reduced. This method has been applied to the 33-Bus Distribution System. The results demonstrate the characteristic of the method which tends to encourage the distributed units to increase their output powers. This is the reason why the penetration of these units in the networks is an opportunity for consumers from an economic aspect in such a way that merchandising surplus (MS) becomes zero.*

Keyword: Distribution marginal price, Distribution network, Power active loss, Distributed generation, Consumer.

1. INTRODUCTION

Nowadays the penetration of distributed generations (DGs) into the structure of distribution networks is undeniable due to their advantages for these networks from different aspects. From the technical aspect, they have an efficiency impact on reducing the loss of the networks [1], power quality improvement [2], voltage stability [3], load shedding problem [4] and reliability improvement [5]. From the financial point of view, they help reduce the costs that the consumers should pay because of their energy consumption as well as those required for construction and expansion of the distribution systems. The majority of studies on the distribution networks have been restricted to specifying the optimum size and location of the DGs on account of their technical outcome. The optimum size and location of DGs have been determined in [6-8] with the purpose of reducing the network loss. The optimal place for DG installation has been specified in [9] based on the improvement in voltage

and reduction in network loss. In [10-11], the reliability of the network is an important issue to pinpoint the best location for DGs. The optimal size and location of DGs have been specified in [12] in order to minimize the energy loss. The placement of DG has been done in [13] by considering the reduction in network loss, the improvement in voltage, and the reliability of the network as the targets of this study. Besides all the technical issues, a significant motivation for penetration of distributed generations into the network acts as the economic issues. Reduction in the consumers' payment can be one of the economic effects of DG's insight on the network. To analyse the economic problem, it is required to consider two important issues. First, the DG owners should be motivated to invest in the network. Second, the DG's impact on the network should be demonstrated by decrementing consumers' payment for energy; hence, it is necessary to have an appropriate framework for pricing the distribution system in order to achieve two main targets: to encourage the DG owners to participate in the network and to diminish the consumers' payment. The insight of DG in the distribution networks helps the networks become similar to transmission networks; thus, this restructuring can contribute to developing economic

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policies that exist in the transmission networks, in the radial networks. One of these policies is nodal pricing which can produce an efficient result [14].

The most notable method to calculate the price in each node is the Locational Marginal Price (LMP) which has been employed a lot in the papers [15-18]. LMP at each node can be defined as an optimal cost to convey an increment of energy to that node in a way that all the generation and security constraints are followed [19]. The cost of energy, congestion, and the loss are the components of the LMP in transmission systems [16-17]. In view of the fact that the voltage level is low and the resistance to inductance ratio is high in distribution networks, there is a difference between LMP in this network and that in transmission networks; thus, it can be more intelligible to use Distribution Marginal Price (DMP) instead of LMP in the radial systems.

The major subject discussed in the distribution systems is the network losses. It can be the backbone of the DMP calculation in the distribution network, but congestion cost can be negligible in the distribution system by reason of network main features.

The network losses play an important role in the distribution system; therefore, finding a fair method to allocate the losses of the network to each participant is momentous. Numerous works have been done around loss allocation problem in order to specify the share of each node in the total network losses [20-24].

Only recently, a few works have been conducted to analyze the LMP on the distribution networks. In [14] for the first time, this topic has been brought up; moreover, in [25], to calculate the LMP, a method has been expressed based on the marginal loss. The main disadvantage of this paper is its non-zero MS which is uncontrollable, and DSO fails to control the benefit of the DG units. MS is defined as the benefit deviation of the distribution company (DISCO’s). The MS produced should be manageable and, by reason of the impact of DG on the network loss reduction, it should be assigned to DGs instead of remaining for DISCO. The authors in [26] with the help of the cost allocation method in [25] have determined the optimal place for DGs. The LMP has been reckoned according to the amount of the reduced loss in [27] and the DG owners are contributed in the amount of loss shares. In [28] based on the reduced amount of loss and emission, the LMP has been determined at each DG bus; furthermore, finally, in [29], by considering the uncertainty in the market price and load in the distribution networks, the stochastic LMP in distribution networks has been calculated based on the method in [28]. In [27-28] iterative approach is employed in order to calculate LMP at each DG bus. The calculation of LMP by the iterative method has been proposed for the first time in [30] and the effectiveness of the proposed method has been illustrated in that paper. In [27-29], the share of each DG in the reduced active loss and emission has been specified, using game theory; however, this method cannot be compatible with the distribution network when the number of DGs increases [31].

As mentioned above, one of the indispensable purposes of DGs’ insight into the distribution systems is to reduce the cost for consumers. However, this issue has not been taken into account in the previous studies.

In this paper, a new method for computing the DMP has been presented, emphasizing the location impact of DG on DMP calculation. The key characteristic of this method is to consider both DG owners and consumers simultaneously. This method recommends that the DG owners sell their production with the price which is more than the reference bus price; additionally, it makes the consumers pay for their consumption in the price which is less than the reference bus price. In point of fact, this method has been divided into finding the DMP for DG owners and the consumers in a way that operates the network in the optimal manner and the MS becomes zero.

The contributions of the present paper can be categorized as follows:

- DMP is calculated for both consumers and DGs.
- The benefits of the DGs from the economic outlook have been specified for the consumers.
- The MS produced becomes zero.
- The participants’ location impact on their electricity price has been demonstrated.
- The ability of the DSO to handle the profit obtained among network participants has been indicated.

This paper is organized as follows. Section 2 is categorized in two subsections: in the first part, the contribution of each node in the network loss is determined, and then in the second part, the method recommended for computing DMP is presented. The simulation and the results are discussed in section 3, and section 4 presents the conclusion.

2. RECOMMENDED METHOD FOR DMP CALCULATION

In this section, a novel method for the calculation of DMP is introduced which is based on the location impact of DGs on the network loss. As adverted above, one of the clearest reasons for the penetration of DGs into the distribution networks is to diminish the consumers' payment; hence, it is required to have an appropriate cost allocation method in the network. It is also essential to persuade the producers to invest in the network; thus, the distribution companies (DISCOs) should recommend the favorable price to producers to sell their products. The procedure utilized in this paper covers all the above-mentioned targets. Prior to defining a new structure for the calculation of DMP, it is necessary to discuss the losses in the distribution networks, which play an important role in evaluating DMP in the distribution networks.

2.1. Loss Allocation

In restructured distribution networks, the participants connected to different buses are responsible for paying the costs related to the network loss. Accordingly, the DG owners have to act in such a way that their productivity is beneficial to reducing losses. From now on, it is by the high priority that the contribution of the node to the network loss will be determined.

For example, in a simplified distribution network shown in Fig. 1, crossing the current from the ith branch leads to loss in that branch. This fact results from preparing power for the loads located beyond the ith branch; accordingly, the loss of this branch should be allocated between the loads. This procedure must be employed for all branches, and the portion of each node in the loss of each branch of network should be computed.

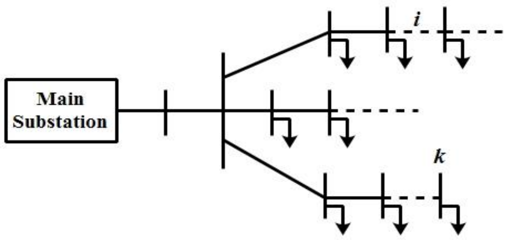

Fig. 1. Simplified distribution network

The losses in the ith branch can be calculated as follows:

$$loss_{branch} = V_{line,i} I^{*}_{line,i} \quad (1)$$

Where $loss_{branch}$ refers to the losses of i^{th} branch and $V_{line,i}$ and $I_{line,i}$ refer to the voltage drop and line current separately.

The contribution of the k^{th} bus in the network losses is expressed as follows:

$$ls_k = \sum_{i=1}^{Nl} ls_{k,i} \quad (2)$$

Where Nl is the number of branch in the network and $ls_{k,i}$ indicates the allocated losses to the k^{th} bus from the i^{th} branch.

It is clear that the share of the k^{th} bus in the network losses is equal to the sum of its portion in each branch losses which is located before it. In addition, sum of the current of buses which are located beyond the i^{th} branch form its current and can be written as follows:

$$I_{line,i} = \sum_{k \in S_i} I_k \quad (3)$$

Where S_i refers to the coalition of buses which are located beyond i^{th} branch.

Furthermore, the loss share of the k^{th} bus from the i^{th} branch losses can be obtained as follows [21]:

$$ls_{k,i} = V_{line,i} I^{*}_{k} \quad (4)$$

Where I_k indicates the current injected to the k^{th} bus.

This approach can be used for all branches and in each one, the share of each bus is specified, then the total network losses can be obtained from the sum of the each node's losses.

$$Totalloss = \sum_{k=1}^{Nb}\sum_{i=1}^{Nl} ls_{k,i} \quad (5)$$

Where Nb indicates the number of buses in the network.

The active loss share of the bus can be obtained from the real part of ls_k in (2) as follows:

$$P_{loss,k} = real\{ls_k\} \quad (6)$$

Finally, total active power loss of network is equal to:

$$Active_{loss} = \sum_{k=1}^{Nb} P_{loss,k} \quad (7)$$

It should be considered that, as a reason of analyzing the impact of DG's location on the network loss and pricing, it can be necessary that the contribution of the each node in the active loss of the network is specified. It cannot be useful to specify the loss share of the DG and load in each node separately, whereas the effect of each one's contribution in the loss share of the node which are connected, is determinative.

2.2. Formulation of DMP

The DMP calculation is divided into two parts. In the first part, the DMP is computed for DG owners, then in the second part, it is calculated for the consumers. It is found that in this method, the merchandising surplus (MS) is equal to zero.

The primary objective of this method is to demonstrate that the costs, which the consumers should pay in today's modern distribution system should fall in the presence of DGs in the network. Another important target of this method is to convince the producers to participate in the system actively. In order to control the system completely by DISCOs and participate in the power market efficiently, the amount of DG's generation should be specified.

Through this payment method, for determining the DGs net generation power, an iterative approach is selected.

At each iteration, after estimating the optimum generated active power of each DG, AC power flow by considering the new power of the DGs and network data is performed. Backward Forward (BF) approach is used for performing the AC power flow.

Based on the BF approach, for each network branch following equation can be written:

$$V_{sen,i} - V_{rec,i} = Z_{line,i} I_{line,i} \tag{8}$$

Where indices *sen* and *rec* refer to the sending and receiving nodes of the i^{th} branch. Z_{line} indicates the i^{th} branch impedance.

Each DG should follow the system's limitation such as voltage and current constraints. Hence, the voltage constraint is expressed as follows:

$$V_{min} \le V_k \le V_{max} \tag{9}$$

Where indices V_{min} and V_{max} refer to the minimum and maximum allowable magnitude of voltage in each node. The current constraint is written as follows:

$$I_{line,i} \le I_{line,max} \tag{10}$$

Where $I_{line,max}$ refers to the maximum allowable magnitude of current passing from each branch.
To state the proposed approach, first, it is assumed that there are no DGs in the network, and then in the second part, DG units are installed in the network.

In the first step, the price of electricity in each network bus is assumed equal to the slack bus price before DG installation. Thus, the paid cost by the consumers in the kth bus can be expressed as follows:

$$cost_k = \left(p_{load_k} + p_{loss_k}\right) \times \gamma_{ref} \tag{11}$$

Where p_{load_k} and p_{loss_k} indicate the active power consumption and the active loss share of the k^{th} node respectively. γ_{ref} is the price of reference bus.

In the second step, DGs are installed in the network. The DG owners need to maximize their income, according to the determined DMP. Therefore, the benefit obtained for the DG owners will be maximized if:

$$\frac{\partial Cost_{func.,j}}{\partial P_{DG_j}} = DMP_1^j \tag{12}$$

Where DMP_1^j refers to the proposed price for the j^{th} DG owner.

The cost function of the jth DG can be defined as follows:

$$Cost_{func.,j} = \alpha_{1j} P_{DG_j}^2 + \alpha_{2j} P_{DG_j} + \alpha_{3j} \tag{13}$$

The profit resulting from the DGs installation in the network is expressed as follows:

$$\Psi = \left(Active_{loss_{before}} - Active_{loss_{after}}\right) \times \gamma_{ref} \tag{14}$$

Where indices $after$ and $before$ refer to the state with and without DG installation respectively. Ψ refers to the profit obtained from DG installation.

With regard to the authority of the DG owners on determining their unit place, in order to modelling the DGs location impact on the price, which is proposed for them, following equation is used.

$$\varphi_{DG_j} = \left(\frac{p_{loss_{before,k\,j}} - p_{loss_{after,k\,j}}}{p_{loss_{before,k\,j}}} \right) \tag{15}$$

Where, indices k and j refer to the k^{th} node on which the j^{th} DG located.

Distribution system operator (DSO) by taking into accounts two major targets; persuasion of the DG owners and explanation of the DGs effect on the consumers' payment should allocate the obtained profit among the network participants.

Contribution of each DG from the obtained profit can be calculated as follows:

$$\beta_{DG_j} = \frac{\varphi_{DG_j}}{\sum_{j=1}^{N_{DG}} \varphi_{DG_j}} (\omega_1 \Psi) \tag{16}$$

Where, β refers to the benefit obtained for the j^{th} DG and ω_1 refers to the percentage of the obtained profit which is assigned to the DGs based on the DSO's decision.

According to the output power of DG units and the allocated profit to them, the change of DMP for each unit can be obtained as follows:

$$\Delta DMP_1^j = \left(\frac{\beta_{DG_j}}{P_{DG_j}} \right) \tag{17}$$

Where, indices 1 refers to the calculated DMP for each DG owner.

Finally the nodal price for each DG unit can be determined as follows:

$$DMP_1^j = \gamma_{ref} + \Delta DMP_1^j \quad (18)$$

The process of nodal pricing calculation will be ended, when the difference between the generated powers of the each DG in two iterations can be neglected. Thus, the stop criteria is defined as follows:

$$\left(P_{DG_j}^{l+1} - P_{DG_j}^{l}\right) \le \varepsilon \quad (19)$$

Where, indices l refers to the iteration number and P shows the generated power of the j^{th} DG.

The other part of the proposed method is to specify the DMP for consumers. With the respect to the DSO's decision about the amount of the allocated profit to the consumers, the allocated profit should be subtracted from their payment. Therefore, a new payment cost for the consumers in kth bus can be computed as follows:

$$cost_{new,k} = \left(p_{load_k} + p_{loss_k}\right) \times \gamma_{ref} - Cdev_k\left(\omega_2 \Psi\right) \quad (20)$$

Where, $Cdev$ is a weighting factor to show how the obtained profit is distributed for each node and can be calculated as follows:

$$Cdev_k = \frac{p_{loss_{before,k}} - p_{loss_{after,k}}}{Active_{loss_{before}} - Active_{loss_{after}}} \quad (21)$$

and ω_2 refers to the percentage of the profit which is assigned to the consumers based on the DSO's decision. Finally, the DMP for consumers in each node can be evaluated as follows:

$$DMP_2^k = \frac{cost_{new,k}}{p_{load_k} + p_{loss_k}} \quad (22)$$

Where, indices 2 refers to the calculated DMP for the network consumers and p_{load_k} refers to the active power, which has been consumed in the k^{th} node.

The amount of merchandising surplus (MS) can be calculated as follows:

$$MS = \left(\sum_{k=1}^{Nb} cost_k\right) - \left(cost_{up}\right) - \left(\sum_{j=1}^{N_{DG}} Income_{DG_j}\right) \quad (23)$$

Where, $cost_k$ determines the paid cost by the consumers, which are connected on k^{th} node, $cost_{up}$ is the cost that should be paid for upstream network and $Income_{DG_j}$ is the revenue of the j^{th} DG owner and can be computed as follows:

$$Income_{DG_j} = P_{DG_j} \times DMP_1^j \quad (24)$$

In the restructured distribution network, there are two ways for providing the network energy; buying energy from the DG owners or providing it from the upstream network.

The cost should be paid for the upstream network can be calculated as follows:

$$cost_{up} = \gamma_{ref}\left(\sum_{k=1}^{Nb} p_{load,k} - \sum_{j=1}^{N_{DG}} p_{DG} + Active_{loss,after}\right) \quad (25)$$

It can be concluded that when:

$$\omega_1 + \omega_2 = 1 \quad (26)$$

The MS equals to the zero and it is the other feature of the proposed method.

Fig. 2 shows the flowchart of DMP calculation for the DGs and consumers.

3. SIMULATION AND RESULTS

In this section, the proposed method for DMP calculation is implemented into the structure of network cost allocation, and the results are obtained. The 33-node radial distribution system is considered for simulation, which is shown in Fig. 3. The network data are available in the appendix. As discussed in the previous sections, the DMP determination is divided into two parts. The first part determines the proposed price for DG companies, and in the second part, the DMP is calculated for the consumers

The results obtained are discussed in three cases:

CASE 1:

The impact of the DG's maximum capacity of generation on the DMP calculation for consumers and producers has been demonstrated.

CASE 2:

The impact of the location of DG on the DMP has been found.

CASE 3:

The impact of the slack bus price on the DMP calculated for the consumers and producers has been presented.

Three DG units are employed in this simulation, and their cost function coefficients are shown in Table 1 [27].

Table 1. DG's Cost function's coefficients [27]

DG unit No.	α_1($/MW²)	α_2($/MW)	α_3($)
1	5.8 ×10⁻⁶	21	0
2	5.3 ×10⁻⁶	20	0
3	5×10⁻⁶	20	0

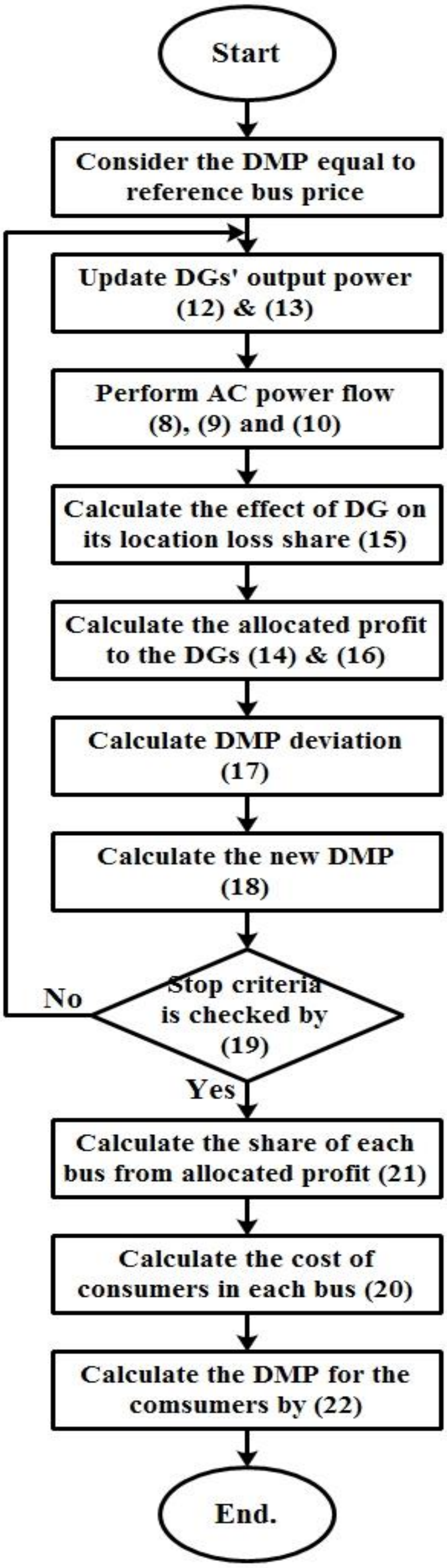

Fig. 2. Flowchart of DMP calculation for the DG and consumers

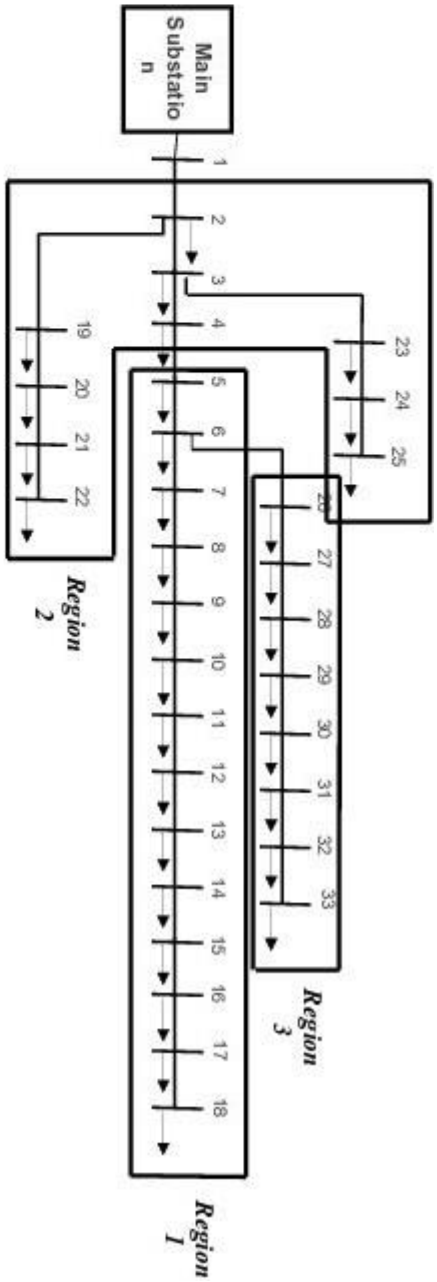

Fig. 3. 33-Bus radial distribution system

As it is indicated in Fig. 3, the test distribution network has been divided into three regions. One of the priorities of DG owners to select the place in each region can be the place where its contribution to the active power loss of the network is more than the others. Figure 4 depicts the loss share of each node before DG installation on the network. This figure illustrates that for region 1 at node 8, region 2 at node 25, and region 3 at node 30, the loss share is more than that of the other nodes. Therefore, these nodes can be a suitable place for the DG installation.

CASE 1: Table 2 presents the DMP for each DG and load, which is connected to the particular buses in three different scenarios for the DG's maximum capacity of generation. The DMP is calculated for each DG and consumer when the price of the reference bus is equal to 40 ($); in addition, based on the DSO's decision, the share of the DGs and loads from the profit obtained is the same ($\omega_1 = \omega_2 = 0.5$).

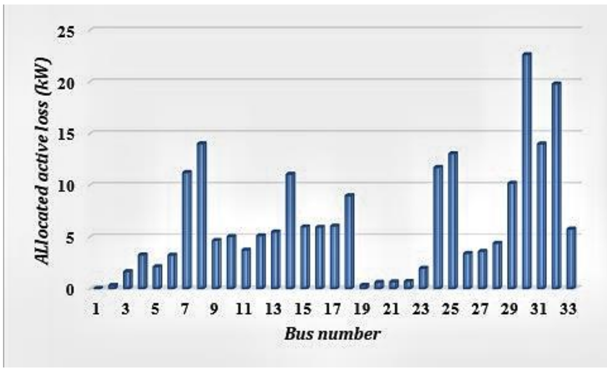

Fig. 4. Allocated active loss (kW) before DG installation

Table 2. Calculated DMP for the DG and consumer in different scenarios of max capacity of DG

Capacity Of each DG (MW)	DMP at node 8 ($/MWhr)		DMP at node 25 ($/MWhr)		DMP at node 31 ($/MWhr)	
	DG	Load	DG	Load	DG	Load
0.5	41.94	37.53	41.03	39.40	41.02	37.98
1	41.41	37.34	40.67	39.41	40.53	38.44
2	40.05	42.53	40.04	41.03	40.07	45.20

Based on this table, it can be concluded that for the network, the maximum demand of which is 3.7 MW, it cannot be profitable for the consumers and DGs when the sum of the output power of the DGs becomes more than the total demand. Hence, the maximum generation capacity of the DG should be adjusted in a way that it becomes relevant to the network demand. Table 2 indicates that when the maximum generating capacity of DG is 2 MW, it can have a negative effect on the DMP for the consumers.

CASE 2: In this case, for each region, three candidate nodes for DG installation have been considered. The property of these nodes, in comparison with the others, is their loss share which is more than that of the others. Table 3 depicts the DMP calculated for the DG and load which are connected to the same node in three different locations.

Table 3. Calculated DMP for the DG and consumer in different locations ($/MWhr)

DG and consumers	DMP at location1 [8,25,31]	DMP at location 2 [7,24,32]	DMP at location 3 [14,4,31]
DG1	41.94	41.53	41.52
DG2	41.03	40.81	41.49
DG3	41.02	41.31	41.26
Consumer1	37.53	37.97	35.60
Consumer2	39.40	39.44	38.65
Consumer3	37.98	37.17	36.31
Total profit ($)	3.987	3.611	4.291

As it is shown, when DGs are placed at location 3, the total profit is more than that of the other locations, which can lead to increasing the DMP for the DG owners and reducing it for the consumers. Therefore, the selection of the appropriate place for the DG installation is momentous from three different aspects. According to the results obtained, the place for the DG can be selected by the DSO recommendation, the consumers' requirement, or the DG owners' authority by considering the network limitations.

CASE 3: In this case, with regard to the different prices of the reference bus, the DMP and the profit obtained for each DG unit are calculated and shown in Table 4.

Table 4. Calculated DMP and obtained profit for DGs in different scenarios of ref Bus Price

DG No.		Ref bus price ($/MWhr)			
		20	30	40	50
DG1	DMP ($/MWhr)	20	31.14	41.52	51.90
	Profit ($)	0	5.07	10.26	15.45
DG2	DMP ($/MWhr)	20	31.12	41.49	51.87
	Profit ($)	0	5.56	10.74	15.93
DG3	DMP ($/MWhr)	20	30.94	41.26	51.58
	Profit ($)	0	5.47	10.63	15.79

This table shows that the appreciation of price in the reference bus results in increasing the profit remained for the DG. On the other hand, when the price of the reference bus is 20 ($), all the DG units prefer to generate no power due to the fact that their second coefficient of the cost function is bigger than or equal to the reference bus price; moreover, it cannot be economic for them to generate the active power.

The other characteristic of the proposed method is that MS becomes zero. Table 5 represents the consumers' payment and the expenditure on the upstream network and DG owners in two different DSO's decisions to allocate the profit to the participants.

It can be observed that the sum of the cost paid for the upstream network and DG owners is equal to the consumers' payment; accordingly, the MS cannot be the production of the proposed method.

The DMP for each DG unit has been calculated by three different methods, and the results are illustrated in Table 6.

This table indicates that the DMP calculated in the proposed method is higher than that in other methods. Thus, this can lead to encouraging DG owners to invest more in the distribution networks. In addition, Table 6 presents the MS produced in each method. It can be observed that in contrast to the proposed method, MS is produced in uniform and marginal loss methods.

Table 5. The consumers' payment, expenditure to the upstream and DG owners in two different DSO's decision

		Ref bus price ($/MWhr)		
		30	40	50
Cost of Upstream ($)		69.513	92.684	115.85
ω_1 = 0.5, ω_2= 0.5	Consumers Payment ($)	116.12	154.83	193.53
	DG Revenue ($)	46.609	62.145	77.681
ω_1 = 0.7, ω_2 = 0.3	Consumers Payment ($)	116.78	155.68	194.61
	DG Revenue ($)	47.252	63.003	78.754

Table 6. Calculated DMP for the DG unit and produced MS in different DMP methods

DMP Method	DG number, Produced MS	Ref bus price ($/MWhr), DMP ($/MWhr)			
		20	30	40	50
Uniform	1	20	30	40	50
Marginal loss		20	31.4099	41.8798	52.3598
Proposed		20	32.2899	43.0532	53.8165
Uniform	2	20	30	40	50
Marginal loss		20	30.4027	40.5369	50.6712
Proposed		20	32.2480	42.9973	53.7467
Uniform	3	20	30	40	50
Marginal loss		20	31.4010	41.8680	52.3350
Proposed		20	31.8987	42.5317	53.1646
Uniform	MS	0	3.2501	4.3335	5.4169
Marginal loss		0	1.6434	2.1911	2.7389
Proposed		0	0	0	0

Finally, the presence of the DGs in the network not only reduces the consumer's payment that is connected to the DG's node, but also it can reduce the consumers' payment connected to the other nodes. Table 7 demonstrates the consumers' price and payment cost in each node with and without DG installation in the network. It should be mentioned that the results are obtained in this condition: $(\omega_1 = 0.2,\ \omega_2 = 0.8)$, and the reference bus price is equal to 40 ($). However, it cannot be neglected that the impact of the DG on the reduction of the consumers' payment cost located at DG nodes, compared to other nodes, is more significant.

Table 7. Consumer's price and payment with and without DGs installation

Bus NO.	Price without DG ($/MWhr)	Price with DG ($/MWhr)	Cost without DG ($)	Cost with DG ($)
1	40	40	0	0
2	40	39.9781	4.0125	4.0103
3	40	39.8448	3.6653	3.6511
4	40	37.8404	4.9302	4.6640
5	40	39.6828	2.4842	2.4645
6	40	39.5004	2.5294	2.4978
7	40	39.5639	8.4491	8.3570
8	40	39.4209	8.5606	8.4367
9	40	39.2357	2.5862	2.5368
10	40	39.1372	2.6015	2.5454
11	40	39.3462	1.9490	1.9171
12	40	39.2515	2.6045	2.5558
13	40	39.1757	2.6191	2.5651
14	40	32.9715	5.2424	4.3212
15	40	38.7596	2.6384	2.5566
16	40	38.9141	2.6372	2.5656
17	40	38.9107	2.6417	2.5698
18	40	39.0154	3.9593	3.8618
19	40	39.9759	3.6128	3.6106
20	40	39.9758	3.6239	3.6217
21	40	39.9757	3.6259	3.6237
22	40	39.9757	3.6277	3.6255
23	40	39.8532	3.6783	3.6648
24	40	39.8441	17.268	17.201
25	40	39.8429	17.321	17.253
26	40	39.5066	2.5358	2.5045
27	40	39.4776	2.5437	2.5104
28	40	39.3463	2.5752	2.5331
29	40	39.3937	5.2074	5.1284
30	40	40.5977	8.9051	9.0382
31	40	34.1071	6.5597	5.5933
32	40	39.2205	9.1916	9.0125
33	40	39.3410	2.6302	2.5869

The benefits of DGs from technical perspectives are as important as their benefits from economic outlook. Fig. 5 shows network voltage profile before and after DGs installation.

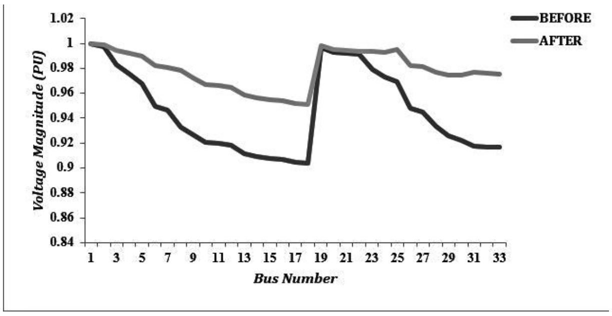

Fig. 5. Network voltage profile before and after DG installation

As shown in Fig. 5, voltage profile has improved after DG installation. In consequence of the DGs presence in the network, the current passing along the network branches is decreased. Therefore, the voltage magnitude improves at the consumer's side. The network active power loss in three different scenarios for DG's location and befor installation is illustrated in Fig. 6.

As shown in Fig. 6, the network active loss is diminished after DG installation as a reason of reduction in the power provided by the upstream network.

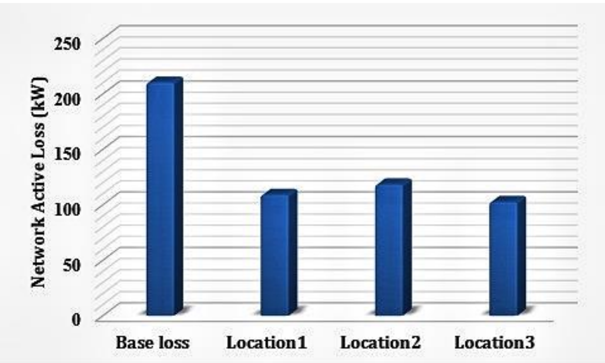

Fig. 6. Network active power loss in different scenarios for DG's location

4. CONCLUSIONS

To sum up the results, it can be concluded that in restructured distribution network, the presence of distributed generation in distribution networks is an incontrovertible account of their positive effect on both technical and economic aspects of these networks. From an economic perspectives, the presence of DGs can help reduce consumers' payments. Therefore, to attain this objective, it is essential to have a logical cost-allocation method in order to specify the share of each participant in the network cost. The proposed new method of DMP calculation, which is based on the impact of DG's location on the network loss, offers a reasonable price determination for the producers and then encourages them to enter the network. In addition, the main concern of this method is to provide a price lower than the reference bus price for the consumers to convince them why the penetration of DGs in distribution networks is advisable from a financial outlook. With the help of this method, DISCOs can estimate the outputs of DGs; hence, they can take part in the market in an effective manner. Finally, it can be notified that in the method recommended, the merchandized surplus ie equal to zero.

APPENDIX

Table 8 shows 33-bus distribution network data.

Table 8. 33-Bus distribution network data

Line	From node	To node	R (Ω)	X (Ω)	P (kW)	Q (kVAr)
1	1	2	0.0922	0.0477	100	60
2	2	3	0.4930	0.2511	90	40
3	3	4	0.3660	0.1864	120	80
4	4	5	0.3811	0.1941	60	30
5	5	6	0.8190	0.7070	60	20
6	6	7	0.1872	0.6188	200	100
7	7	8	1.7114	1.2351	200	100
8	8	9	1.0300	0.7400	60	20
9	9	10	1.0400	0.7400	60	20
10	10	11	0.1966	0.0650	40	30
11	11	12	0.3744	0.1238	60	35
12	12	13	1.4680	1.1550	60	35
13	13	14	0.5416	0.7129	120	80
14	14	15	0.5910	0.5260	60	10
15	15	16	0.7463	0.5450	60	20
16	16	17	1.2890	1.7210	60	20
17	17	18	0.7320	0.5740	90	40
18	2	19	0.1640	0.1565	90	40
19	19	20	1.5042	1.3554	90	40
20	20	21	0.4095	0.4784	90	40
21	21	22	0.7089	0.9373	90	40
22	3	23	0.4512	0.3083	90	40
23	23	24	0.8980	0.7091	420	200
24	24	25	0.8960	0.7011	420	200
25	6	26	0.2030	0.1034	60	25
26	26	27	0.2842	0.1447	60	25
27	27	28	1.0590	0.9337	60	20
28	28	29	0.8042	0.7006	120	70
29	29	30	0.5075	0.2585	200	600
30	30	31	0.9744	0.9630	150	70
31	31	32	0.3105	0.3619	210	100
32	32	33	0.3410	0.5302	60	40

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