A PROBABILISTIC FRAMEWORK OF COOPERATIVE DISPERSE GENERATION RESOURCES SCHEME FOR PRODUCING REQUIRED REACTIVE POWER THROUGH SIMULTANEOUS ACTIVE AND REACTIVE POWER MARKET

Morteza Shamani	Hamed Ahmadi	Mohammadreza Ramezani
Tehran Province DISCO – Iran	Tehran Province DISCO – Iran	Tehran Province DISCO – Iran
mortezashamani@yahoo.com	h.ahmadi44@gmail.com	g.mr.ramezani@gmail.com

ABSTRACT

One of the challenges faced by electricity industry is to provide reliable, high quality and low cost ancillary services. This is particularly important in reactive power market and in order to maintain voltage profile of the network. Since the value of reactive power is more important especially in emergency situations and during the incidents such as some producing units going offline; pricing reactive power should be such that any unit receives payments of its effectiveness on maintaining the voltage profile in contingencies. Furthermore, due to the dependence of reactive power market on the energy market, any decision about reactive power market needs to go through energy market considerations and the effects of energy market on reactive power market has to be taken into account. Hence in this article, a structure is presented to implement the active and reactive power markets simultaneously. Moreover, reactive power production cost become fair by imposing a contingency situation impact on the price of reactive power. To evaluate the performance of the proposed structure, active and reactive power markets has been implemented over a 24 node IEEE network in order to investigate the performance of hereby proposed structure while considering probabilities of units getting offline. Results are discussed accordingly.

INTRODUCTION

Transmission of active power in high voltage systems would be impossible without reactive power support; and a generator would be able to bid for its generated active power only when sufficient reactive power exists in the system to maintain voltage levels within an acceptable interval [1]. Insufficient reactive power in the system can possibly lead to undesired voltage loss in some system buses; and in case the system is not able to overcome those losses, it might result in instability of voltage throughout the network [2]. Existence of reactive power would be of more importance especially in contingencies and cases of other incidents such as some units going offline [3-4]. Inadequate infrastructures in critical situations and times would likely impose significant costs for reactive power generation and voltage profile stabilization at any contingency case. Identification of influential nodes and units which would more strongly affect the network in contingencies can be of significant importance for discretionary action plans. Although the effect of offline units on nodal pricing has been considered by reference [3], the payment received by each generator unit is not calculated based on the relative capacity provided by that unit in contingencies. Hence, all units within a bus will receive equal amounts of payment regardless of the capacity which they provide. Therefore, the present study suggests that contingency cases and down turning units have to be considered when pricing the reactive power; and proposes a pricing scheme in which every unit receives payments according to its available capacity of reactive power generation and its level of efficiency maintaining voltage profile at contingencies. So, a fair price is determined for reactive power generation and protects the system operator against substantial increases of costs for reactive power generation in contingency situations.

On the other hand, active and reactive forms of electrical power are technically related to each other through various ways including load flow equations, network lines capacity limits and capability curves of synchronous generators [5]. As a result, holding those markets separately cannot lead to an optimal solution. Therefore, the present study proposes a Simultaneous Active and Reactive Power Market (SARPM). As references [5-6] suggest; holding the Reactive Power Market (RPM) simultaneously with the Active Power Market (APM) when the interactions between those two markets are considered, would lead to lower power generation costs and improvements in performance for both markets. Those studies, however, did not consider the effect of contingencies on how the prices are actually determined.

All that said, a model is proposed throughout the present paper which facilitates reactive and active markets to be held simultaneously while considering the effect of contingencies on prices of reactive power, so that the network performance is improved at all times for system operator. Furthermore, dispersed producing units will participate in active and reactive power markets along with other generating units and compete for power generation; and the present study considers this situation in order to analyze the performance of those units regarding improvements of the markets and reducing costs.

In the following sections, the proposed active and reactive power markets are presented and the procedure of holding those markets simultaneously is stated along with the objective function. The proposed model is then applied to a 24 bus IEEE network [7] in order to investigate the performance of that structure considering probabilities of some units to go offline. Obtained results are analyzed afterwards.

ACTIVE POWER MARKET (APM)

Within the APM, all electricity producing units provide the Independent System Operator (ISO) with their proposed prices for certain amount of electrical energy. ISO determines the amount of needed output from producing units through solving the problem of Optimal Power Flow (OPF) considering the objective function of total proposed costs which should be minimized [8]. In this study, the procedure of price proposition by units has been improved, so that units propose their prices as a stepwise function instead of a fixed value (Figure 1). This leads to more real and fair curves of costs [9]. So the units will propose their prices as the form of equation (1) in order to participate in energy market.

$$\mathrm{Cost_{APM}} = \sum_{i=1}^{NB}\sum_{u=1}^{NU_i}\sum_{bl=1}^{N_{bl}}\left(W_{P_{bl}}^{i,u}.\rho_{bl}^{i,u}.P_{G_{bl}}^{i,u}\right) \quad (1)$$

NU_i and NB in equation (1) represent the number of generating units connected to bus *i* and the total number of buses in the network. N_{bl} is the number of blocks proposed by units for producing active power. $W_{P_{bl}}^{i,u}$ is a binary variable which indicates the selected block of generator for producing active power while $\rho_{bl}^{i,u}$ is the price associated with block proposed by the unit. And $P_{G_{bl}}^{i,u}$ represents the amount of active power generated at the block.

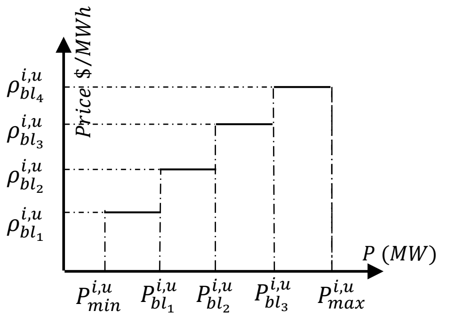

Figure 1. Stepwise prices proposed by units to participate in active power market

Additional constraints for APM are stated as the following:

$$P_G^{i,u} = \sum_{bl=1}^{N_{bl}}\left(W_{P_{bl}}^{i,u} \times P_{G_{bl}}^{i,u}\right) \quad (2)$$

$$W_{P_{bl}}^{i,u} \in \{0,1\} \quad (3)$$

$$\sum_{bl=1}^{N_{bl}}\left(W_{P_{bl}}^{i,u}\right) \leq 1 \quad (4)$$

$$W_{P_{bl}}^{i,u} \times P_{bl}^{i,u} \leq P_{G_{bl}}^{i,u} \leq W_{P_{bl}}^{i,u} \times P_{bl+1}^{i,u} \quad (5)$$

Variable $P_G^{i,u}$ in equation (2) indicates the amount of active power produced by the unit number *u* which is connected to Bus number *i*. This would be equal to total production of power generation blocks for that unit. Equations (3) and (4) suggest that $W_{P_{bl}}^{i,u}$ are binary variables related to different blocks of generated power and only one of them can have a value of 1 at any given time. Equation (5) is derived from Figure (1) and suggest that active power which is produced on each block needs to be within the proposed limits for that block.

REACTIVE POWER MARKET (RPM)

Considering the capability curve of the synchronous reactive power generator as indicated by reference [10], total cost imposed by a generator which provides reactive power is consisted of availability costs, operation costs and Lost Opportunity Cost (LOC). In the present study, "availability cost" for each unit is multiplied to its available capacity, so each unit will receive payments only based on amount of its available capacity [6]. Therefore, reactive power cost function would be stated as the objective function of the optimal load flow problem in order to determine clearing prices in RPM as the following:

$$\mathrm{Cost_{RPM}} = \sum_{i=1}^{NB}\sum_{u=1}^{NU_i}\begin{pmatrix} a_i.W_0^{i,u}.\left(Q_{max}^{i,u} - Q_{min}^{i,u}\right) \\ -m_1^{i,u}.W_1^{i,u}.Q_{1G}^{i,u} \\ +m_2^{i,u}.W_2^{i,u}.\left(Q_{2G}^{i,u} - Q_{base}^{i,u}\right) \\ +m_2^{i,u}.W_3^{i,u}.\left(Q_{3G}^{i,u} - Q_{base}^{i,u}\right) \\ +\frac{1}{2}m_3^{i,u}.W_3^{i,u}.\left(\left(Q_{3G}^{i,u}\right)^2 - \left(Q_A^{i,u}\right)^2\right) \end{pmatrix} \quad (6)$$

Reactive power from each generator unit is divided into three phases of Q_1, Q_2 and Q_3 which represent the amount of reactive power provided at zones (Q_{min}, 0), (Q_{base}, Q_A) and (Q_A, Q_B) respectively. Binary variables $W_1^{i,u}$, $W_2^{i,u}$ and $W_3^{i,u}$ in this scheme are the components which indicate generator *u* connected to node *i* is operating within which operational zone. Also a_i in these equations indicates the proposed cost of availability while $m_1^{i,u}$ and $m_2^{i,u}$ are the prices proposed by the generating unit for losses related to absorption and generation of reactive power, respectively. Variable $m_3^{i,u}$ indicates the LOC for generators.

The variable of availability cost (a_i) is calculated while taking contingencies into account in order to include critical situations and units going offline through contingencies. For this task, equation (6) needs to be revised under the contingency conditions. Then, the optimal load flow problem should be solved; the nodal price and amount of reactive power required to be produced by each unit under contingencies should be calculated. An important point to note here is that when OPF is being calculated considering the contingencies, availability cost [first term in equation (6)] would not be taken into account here. Since we aim to investigate the levels of sensitivity of production on each bus and to calculate nodal price, assuming zero availability cost for all units would not cause any problem [7]. So the equation (6) would be written as the following when contingency cases are included:

$$\mathrm{Cost_{RPM}^{j}} = \sum_{i=1}^{NB_j}\sum_{u=1}^{NU_{ij}}\begin{pmatrix} -m_1^{i,u}.W_{1,j}^{i,u}.Q_{1G,j}^{i,u} \\ +m_2^{i,u}.W_{2,j}^{i,u}.\left(Q_{2G,j}^{i,u} - Q_{base}^{i,u}\right) \\ +m_2^{i,u}.W_{3,j}^{i,u}.\left(Q_{3G,j}^{i,u} - Q_{base}^{i,u}\right) \\ +\frac{1}{2}m_3^{i,u}.W_{3,j}^{i,u}.\left(\left(Q_{3G,j}^{i,u}\right)^2 - \left(Q_A^{i,u}\right)^2\right) \end{pmatrix} \quad (7)$$

The index *j* in above relations indicates the contingency and its value shows the contingency number. So that *j=0* indicates the normal condition.

After calculations of optimal load flow for each contingency, we can obtain the availability cost (a_i) for each unit as the following [3]:

$$a_i = \sum_{j=1}^{m} \left[pr^j \times \Delta\rho_{Qi}^j\right]/m \quad (8)$$

$$\Delta\rho_{Qi}^j = \begin{cases} \rho_{Qi}^j - \rho_{Qi}^0, & \rho_{Qi}^j > \rho_{Qi}^0 \\ 0, & \rho_{Qi}^j \le \rho_{Qi}^0 \end{cases} \quad (9)$$

The index j in above relations indicates the contingency number while m is the total number of contingencies. pr^j and ρ_{Qi}^j show the possibility of contingency j to occur and the nodal price i in that contingency, respectively. As proposed by the present paper, the availability cost a_i is multiplied by the available capacity at contingency situations of the same unit [first term of equation (6)] instead of being multiplied by a fixed value; therefore, each unit will receive payments based on the value of its position within the network and amount of available capacity which it provides at contingency situations.

In order to consider the contingency situations, this study only takes the possibility of power generating units to go offline into consideration. The likelihood of a contingency j as stated by [3] is given as:

$$pr^j = \prod_{c=1}^{b} U_c \times \prod_{c=b+1}^{N} A_c \quad (10)$$

A_c and U_c in this relation are associated with states of a network component being available and not available.

The nodal price is calculated using the Lagrange function (L^j) which is built by objective function of relation (7) and RPM execution constraints which are explained in the following section. So the nodal price of the reactive power at contingency j is given as the following [3].

$$\rho_{Qi}^j = \partial L^j / \partial Q_{ig}^j \quad (\$/\mathrm{MVar}) \quad (11)$$

When the availability cost a_i is calculated in consideration of contingencies, the obtained value is substituted into equation (6), optimal load flow problem is solved, and nodal clearing prices as well as reactive power generation costs are calculated as in the normal conditions.

PROPOSED MODEL FOR SARPM:

In this case, the LOC is calculated for the generators based on the difference of active power amounts generated in simultaneous and separate markets, and also the difference of clearing prices in those markets [5]. Hence, LOC payment scheme in the present paper considering the stepwise active power price proposition is stated as the following:

$$LO_{i,u} = \begin{pmatrix} \left(\rho_{p,i}^{sep} - W_{P_{bl}}^{i,u} . \rho_{bl}^{i,u}\right) P_{G,sep}^{i,u} \\ -\left(\rho_{p,i}^{sim} - W_{P_{bl}}^{i,u} . \rho_{bl}^{i,u}\right) P_{G,sim}^{i,u} \end{pmatrix} \quad (12)$$

$$LOC_{i,u} = \begin{cases} LO_{i,u} & \text{if } LO_{i,u} > 0 \\ 0 & \text{if } LO_{i,u} \le 0 \end{cases} \quad (13)$$

In which $\rho_{bl}^{i,u}$ is the stepwise costs proposed by generators for generating active power, $\rho_{p,i}^{sep}$ represents the nodal clearing price for active power in separate markets; and $\rho_{p,i}^{sim}$ is the nodal clearing price in simultaneous market. Also $P_{G,sep}^{i,u}$ and $P_{G,sim}^{i,u}$ are the amounts of energy produced by unit u connected to bus i in separate and simultaneous markets, respectively.

Moreover, the present study also considers the contribution of dispersed generating resources along with other generators. Those units participate in active and reactive power markets like the other types of units. Therefore, the objective function in simultaneous market when including dispersed generating resources is presented as:

$$Cost_{SARPM} = \begin{pmatrix} \sum_{i=1}^{NB} \sum_{(u,k)=1}^{N(u,k)_i} \sum_{bl=1}^{N_{bl}} \left(W_{P_{bl}}^{i,(u,k)} . \rho_{bl}^{i,(u,k)} . P_{G_{bl}}^{i,(u,k)}\right) \\ + \sum_{i=1}^{NB} \sum_{(u,k)=1}^{N(u,k)_i} \begin{pmatrix} a_i . W_0^{i,(u,k)} . \left(Q_{max}^{i,(u,k)} - Q_{min}^{i,(u,k)}\right) \\ -m_1^{i,(u,k)} . W_1^{i,(u,k)} . Q_{1G}^{i,(u,k)} \\ +m_2^{i,(u,k)} . W_2^{i,(u,k)} . \left(Q_{2G}^{i,(u,k)} - Q_{base}^{i,(u,k)}\right) \end{pmatrix} \\ + \sum_{i=1}^{NB} \sum_{(u,k)=1}^{N(U,K)_i} LOC^{i,(u,k)} \end{pmatrix} \quad (14)$$

In which k indicates dispersed power generating units. However, components associated with dispersed power generating units and producing units are integrated together in this express notation. For example, $W_0^{i,(u,k)}$ is in fact consisted of two components $W_0^{i,u}$ and $W_0^{i,k}$ which indicate availability of generator unit number u and dispersed generating unit number k as binary variables, respectively.

Since LOC is calculated separately in this scheme, prices of reactive power proposed by the generators are divided into two zones of production and absorption of reactive power.

The objective function [equation (14)] for the SARPM would be under the following constraints:

Load Flow constraints

$$\sum_{(u,k)=1}^{N(u,k)_i} P_G^{i,(u,k)} - P_{D,i} = \sum_{j=1}^{NB} |V_i||V_j||Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij}) \quad (15)$$

$$\sum_{(u,k)=1}^{N(u,k)_i} Q_G^{i,(u,k)} - Q_{D,i} = \sum_{j=1}^{NB} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij}) \quad (16)$$

in which, $P_G^{i,(u,k)}$ and $Q_G^{i,(u,k)}$ are equal to amounts of active and reactive power produced by generators and dispersed power generating resources which are connected to *i-th* bus, respectively. Also, $P_{D,i}$ and $Q_{D,i}$ are equal to active and reactive power demand on *i-th* bus.

Constraints related to bus voltage limits and current passing from the buses

$$S_{i,j} \le S_{i,j}^{max} \quad (17)$$

$$V_j^{min} \le V_j \le V_j^{max} \quad \forall j \in \text{ Loaded buses} \quad (18)$$

in which $S_{i,j}$ is the current flowing between line i and j while V is the lines' voltage.

Constraints related to active and reactive power generation in units

Constraints related to active power generation are the same as relations (2) to (5).

In the simultaneous market, reactive power produced by each provider is divided into two components of Q_1 for absorption of reactive power and Q_2 for generating it. The following constraints govern the performance of the unit in those zones and limitations over reactive power generation:

$$W_0^{i,(u,k)}, W_1^{i,(u,k)}, W_2^{i,(u,k)} \in \{0,1\} \quad (19)$$

$$Q_G^{i,(u,k)} = Q_{1G}^{i,(u,k)} + Q_{2G}^{i,(u,k)} \quad (20)$$

$$W_1^{i,(u,k)} Q_{min}^{i,(u,k)} \leq Q_{1G}^{i,(u,k)} \leq 0 \quad (21)$$

$$W_2^{i,(u,k)} Q_{base}^{i,(u,k)} \leq Q_{2G}^{i,(u,k)} \leq W_2^{i,(u,k)} Q_{max}^{i,(u,k)} \quad (22)$$

$$W_1^{i,(u,k)} + W_2^{i,(u,k)} \leq 1 \quad (23)$$

$$W_0^{i,(u,k)} = W_1^{i,(u,k)} + W_2^{i,(u,k)} \quad (24)$$

$$Q_G^{i,(u,k)} \leq \sqrt{\left(V_t^{i,(u,k)}.I_a^{i,(u,k)}\right)^2 - \left(P_G^{i,(u,k)}\right)^2} \quad (25)$$

$$Q_G^{i,(u,k)} \leq \sqrt{\left(\frac{V_t^{i,(u,k)}.E_{af}^{i,(u,k)}}{x_s^{i,(u,k)}}\right)^2 - \left(P_G^{i,(u,k)}\right)^2} - \frac{\left(V_t^{i,(u,k)}\right)^2}{x_s^{i,(u,k)}} \quad (26)$$

Constraints (20) to (22) above indicate the limits of reactive power generation in each zone. Constraints (25) and (26) are related to armature current and field for power producing units.

Following the optimal load flow calculations, the nodal clearing prices for active and reactive power are calculated and payable amount to each generating unit is calculated as below:

$$\text{Payment}_{SARPM}^{i,(u,k)} = \left(\rho_{pi} \times P_G^{i,(u,k)}\right) + \left(\rho_{Qi} \times Q_G^{i,(u,k)}\right) \quad (27)$$

In which ρ_{pi} and ρ_{Qi} are nodal clearing prices for active and reactive power respectively. Those prices are obtained as:

$$\rho_{Pi} = \partial L / \partial P_{ig} \quad (\$/MW.h) \quad (28)$$

$$\rho_{Qi} = \partial L / \partial Q_{ig} \quad (\$/MVar.h) \quad (29)$$

The function L in those relations would be the Lagrangian consisting of relations (14) to (26).

SIMULATION AND NUMERICAL ANALYSIS

The proposed model is applied to a 24 bus standard IEEE RTS network. This network is consisted of 24 buses and 32 generating units. More data regarding the network under examination and its generating units are presented in references [6-7].

Total demands of active and reactive load in load peak are 2850 MW and 580 MVar respectively within this network. In this study, as references [6-7], each unit offers suggested components to ISO to participate in SARPM. It should be noted that the proposed model uses a stepwise combination with 4 equidistant steps (Figure 1) instead of a fixed value for active power price proposition. This leads to better modeling of active power production costs curve.

The simulation was carried out using GAMS optimization software which benefits from mixed integer programming techniques.

First, the simulation was carried out on simultaneous market without consideration of a_i cost effect. No availability cost is paid to producing units in this case. The results are shown in Table (1) below.

Table 1. Results of SARPM simulation without effect of availability cost (a_i)

Node No.	P_i *MW*	Q_i *MVar*	ρ_{Pi} $\$/MW$	ρ_{Qi} $\$/MVar$	*payment ($)*
1	140	8	21.91	0.72	3070.39
2	152	48.65	21.92	0.68	3364.97
7	210	69.25	22.18	0.65	4706.42
13	306	167.1	21.07	0.5	6532.58
14	-	66.10	-	0.81	53.54
15	175.57	73.33	20	0.75	3566.71
16	155	53.33	20.09	0.75	3154
18	400	20	19.40	0.57	7773.27
21	400	20	19.31	0.54	7736.60
22	300	9.6	18.71	0	5614.07
23	660	36.46	19.98	0.8	13219.26
Total	**2898.57**	**571.83**	**-**	**-**	**58791.81**

Amounts of generated active and reactive power are shown in second and third columns respectively. Fourth and fifth columns show nodal clearing prices for active and reactive power production respectively. Finally, the last column shows payable amounts to each unit.

As the last row of the Table (1) shows, total produced amounts of active and reactive types of power by the units are 2898.57 MW and 571.83 MVar respectively. Total payable amount is 58791.81 Dollars.

This analysis considers the contingency of only one generating unit going offline when calculating the availability cost. Table (2) shows calculated values of a_i in various buses in consideration of contingency situations.

Table 2. The a_i values calculated for buses considering contingencies

Node No.	$a_i(\$/MVarh)$
1	0.00284
2	0.0025
7	0
13	0
14	0.004
15	0.016
16	0.00716
18	0.0125
21	0.0106
22	0
23	0

Table (2) suggests that calculated availability cost for some buses are higher than for others due to network topology and likelihood of deficiency. This is generally due to higher importance of some nodes in contingencies.

Table (3) shows the calculated results for SARPM using the method proposed in the present paper. As it is evident from those results, inclusion of availability cost causes a slight increment in clearing prices and eventually in power generation costs. Inclusion of availability costs affects both clearing prices of active and reactive power markets, since APM and RPM are simultaneously held in the present study. In this scheme, each unit receives payments based on its available power generation capacity and the likelihood of it going offline in contingencies. In fact, we

Table 3. Simulation results for SARPM in consideration of a_i and the proposed payment scheme

Node No.	P_i MW	Q_i MVar	ρ_{Pi} \$/MW	ρ_{Qi} \$/MVar	payment (\$)
1	155	8	21.95	0.72	3407.53
2	136	52.58	21.97	0.68	3024.19
7	180	72.16	22.80	0.65	4151.28
13	338	169.12	21.04	0.5	7196.58
14	-	71.79	-	0.81	58.15
15	176.12	73.33	20	0.75	3575.48
16	155	53.33	20.09	0.74	3153.66
18	400	20	19.40	0.56	7773.2
21	400	20	19.31	0.52	7736.65
22	300	9.6	18.72	0	5614.82
23	660	38.72	19.98	0.8	13220.14
Total	**2900.12**	**588.63**	**-**	**-**	**58911.68**

were able to encourage units to participate in a more fair competition and make their capacity available for critical situations and contingencies with only a slight increase (approximately 120 Dollars) in costs.

Two Dispersed Generating units (DG) with active and reactive power generation capacities of respectively *5 MW* and 1 MVar are assumed here in order to investigate the effects of dispersed power generating units on SARPM. Those units are connected to nodes 6 and 8 in the network under study here. Those nodes are selected due to their higher clearing price (22.78 and 23.23 \$/MWh respectively). Also calculated a_i values are higher in those nodes in comparison to others (0.0207 and 0.120 \$/MVarh respectively). So that DG units are added to those nodes which impose stronger effects on both active and reactive power markets. Table (4) shows the results for the case of market simulation.

As the results in Table (4) suggest, adequate selection of the position of dispersed power generating units within the network would contribute to reduction of nodal clearing prices and eventually can lead to lower power generation costs. Addition of those units in those suitable positions has resulted in a reduction (around *\$300*) of total cost.

Table 4. Simulation results for SARPM in presence of dispersed power generation units

Node No.	P_i MW	Q_i MVar	ρ_{Pi} \$/MW	ρ_{Qi} \$/MVar	payment (\$)
1	152	8	21.70	0.71	3304.4
2	152	44.01	21.71	0.68	3330.64
6	2	0.67	22.52	0.92	45.65
7	263.73	57.93	21	0.65	5575.93
8	2	0.67	22.03	0.94	44.69
13	306	163.27	20.99	0.50	6504.73
14	-	33.18	-	0.81	26.88
15	175	69.93	20.11	0.73	3570.08
16	155	53.33	20.17	0.73	3164.97
18	400	20	19.56	0.57	7835.56
21	325	20	19.49	0.53	6345.44
22	300	-9.6	18.87	-0.23	5663.58
23	660	31	19.97	0.77	13205.81
Total	**2892.73**	**511.59**	**-**	**-**	**58618.36**

CONCLUSION

A pricing method is proposed in the present study which allows for interaction between active and reactive power markets while considering the effect of some units going offline. Simulation results show that an adequate pricing scheme can potentially encourage power producing units to keep their available capacity high in case of a contingency. This contributes to the fair competition in APM and RPM markets while causing lower electricity production costs. Higher available capacity from generating units would lead to a better performance for the system operator at contingencies and increases the opportunities to maintain system voltage profile in such situations. Moreover, simulation results suggest that adequate selection of disperse power generating resources can potentially improve the performance in active and reactive power markets which eventually lead to reductions in total production cost.

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