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Presenting an economic interaction bi-level model between electricity retailer and customer in bilateral electricity market contract

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Abstract. Players, especially electricity retailers have an important role in achieving optimal economic models in the electricity market. They act as intermediaries between customers and energy suppliers. In this regard, this study proposed an interactive bi-level model in bilateral electricity contracts from the retailer's viewpoint. At the first level of this interaction, the retailer maximizes its profit by selecting some customers and determining the length of the bilateral contract with each customer. At the second level, customer cost is minimized based on new interactive parameters that are introduced for maximum interaction. In this regard, the optimal amount of energy sales to each customer is also determined based on the proposed bi-level model. Finally, after linearization and determination of the single-level equivalent of the proposed model, the mixed-integer linear programming (MILP) model will be implemented in GAMS software and solved via the CPLEX solver. The results indicate the effect of the proposed interactive model on maximizing retailer profit and minimizing customer costs in bilateral electricity contracts.

Keywords. Bilateral contract; Electricity market; Economic modeling; Power retailer; Optimal decision making.

1. Introduction

Electricity markets have globally turned out to be reformed in recent years and electrical energy is now exchanged based on competitive laws. Electricity pools were frequently began with deregulation, where all producers, traders, and large customers can now buy and sell energy in the specific market [1–4]. There has been a shift from competing at the generation level to competing at the retail level in many previous research. Retail companies act as an intermediary between consumers and suppliers, so implementing a suitable supply and demand policy is crucial and can help to increase profit whereas reducing losses. Therefore, the optimum policy for power retailers in bilateral contracts should be based on determining their relationship with wholesalers and customers. Retailers in a restructured power system would endeavor to maximize profits. In this restructured environment, after having been purchased energy by retailers at variable prices from wholesalers, energy is sold to consumers at fixed prices [5, 6]. [7] Proposed a new structure for restructured power system, especially the retail market in China. In this structure, there are multiple buyers and sellers of various resources. Finally, the objective function of this problem is optimum allocation of considered resources. In this research, risk assessment is also considered. The scenario method was used for simulating random risk variables (i.e., real-time price and user demand) in this study. Moreover, time-of-use (TOU) and real-time pricing were employed as the measure of energy purchases to maximize retailer profits. In another study, [8] introduced new mixed-integer linear programming for determining the optimal strategy of bidding for shiftable loads in the electricity market. The considered loads can be shifted based on the settings related to the constraints of consumption levels. In this research, customers shift their demand from undesirable peak hours to favorable off-peak hours, participate in demand side management programs and have different demand elasticities. In another study by [9], the problem of minimizing operating costs while improving environmental indicators was evaluated as a multi-objective problem based on the epsilon constraint and a fuzzy approach. In this study, demand response programs were also used to flatten the load curve. Various studies have discussed the presence of retailers in the electricity market, especially [10] focused on the purchase of energy and the participation of retailers in this market. This study mainly aimed to achieve a model to increase the impact of retailers

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and customers in the electricity market. Power system security studies are also included in this paper. Likewise, A model of price and load uncertainty based on the normal distribution was presented in [11], which addressed the problem of profit maximization in the short term while balancing risk faced by retailers. In the study by [12], an energy management model was presented to minimize retailer costs and retailer risk improvements in energy procurement based on the demand response program, electric vehicle, and energy storage system. Energy purchase sources in this study include bilateral contracts, pool market, wind turbine, and photovoltaic system. Further, a forward contract model is presented in [13]. The wholesale power market uses this type of contract to exchange electricity, similar to a bilateral contract. In the power market, electricity retailers serve as an intermediary between wholesalers and customers to purchase a large amount of energy in a forward contract. In addition, [14] provided a framework for retailers to take decisions regarding risk management, including setting an energy price based on TOU pricing and participating in various electricity market contracts. Moreover, [15] suggested an optimal bidding strategy for retailers to purchase energy in the day-ahead electricity market for a short-term period. The proposed model was optimized via the genetic algorithm and ultimately minimized retailer costs in energy procurement. Also, [16] presented a bi-level model for retailers' optimal decision-making that has distributed generation and supplies the energy of price-sensitive customers. The proposed model is optimized based on the robust optimization technique. In this study, the information gap decision theory approach was applied for risk measurement. Fang *et al* [17] introduced an optimal bi-level model to manage energy storage systems by increasing the penetration of wind energy generation. The goal of the upper level was to maximize the profit of energy suppliers while that of the lower level was to minimize the energy generation cost based on the economic dispatch approach. [18] Proposed a model for optimal retailer decision-making by considering demand response programs including real-time pricing and TOU. In this model, the retailer makes optimal decisions after participating in bilateral contracts and the pool market in the presence of wind and solar resources. In addition, the fuzzy approach and interval optimization were used to determine the optimal Pareto points in this model. In a similar study, [19] provided a model for determining the energy price by the retailer for the end-users based on real-time, TOU, and fixed pricing. Accordingly, a robust optimization approach was applied to determine an optimal bid and offer of the retailer in the day-ahead market. In [20], the selling price of energy for the customer was set based on demand response programs by the retailer according to the robust optimization approach. This study sought to determine retailer risk and retailer-expected profits in the presence of market price and weather (solar and wind) uncertainty. To model whether customers and electric retailers depend on each other, [21] proposed a model using the Stackelberg game. In this model, retailers and customers play the role of leaders and followers, respectively, and both groups attempt to economically optimize their goals. In the bi-level model, which eventually becomes the equivalent single-level model, the retailer and the customer seek to maximize profits and to optimize the load pattern which leads to cost minimization, respectively. In their study, [22] provided the two-step linear structure for the electricity retailer to obtain the bidding curve. In this study, the retailer is the price-taker and tends to maximize its daily profit after participating in the wholesale market. Another goal of the retailer is to reduce the profit deviation caused by price uncertainty in the power market. In addition, A bi-level modeling approach is proposed for energy pricing and dispatch by [23]. In this study, based on the game theory approach, demand response is performed by the customers, and then optimal energy is dispatched relying on robust optimization. The equivalent single-level model according to the Karush-Kuhn-Tucker condition ultimately leads to optimal retailer bidding and increases its profit. Moreover, [24] presented a combined algorithm for scheduling an optimal energy purchase for an electricity retailer, by mixing a binary-style imperialist and competitive algorithm, and particle swarm optimization. Similarly, [25] controlled the peak load of the grid using a demand side management program. The presented model in this study minimizes the energy purchase cost of retailers during peak hours and hours with market price uncertainty. Lastly, [26] utilized economic risk analysis for modeling the uncertainty of the electricity price in pools by using the downside of risk management.

According to recent studies, less research has been done to determine the optimal model of retailer-customer interaction in bilateral electricity market contracts. Thus, this paper presents a bi-level model from the retailer perspective. At the first level of this model, the formulation of retailer revenues and expenses during the bilateral contract is provided in the presence of the introduced interactive parameters. The formulation of customer cost minimization based on the introduced interactive parameters is proposed at the second level of this model. The mathematical formulation of the proposed model is such that the customer goal at the second level is considered as a constraint of the retailer goal at the first level. This model will be solved and optimized by McCormick linearization and determination of the equivalent single-level model. Discounts desired by the customer for extending the length of the bilateral contract are included in this interactive model as well. The other features of the interactive model are the selection of some customers from the customer group by the retailer and the optimal duration of the contract with each customer. Thus, the contributions of this paper can be considered as follows:

1. Bi-level economic modeling based on interaction from a retailer point of view:
    - Maximizing the retailer's profit in bilateral electricity market contracts.

- Minimizing the costs of the customer having a contract with the retailer by replacing the customer's aim as the constraint of the retailer's profit maximization equations.

2. Economic modeling in bilateral electricity contract in order to determine the optimal length of each bilateral contract in addition to the selection of some customers based on introducing new interactional parameters (e.g., δ_{cp} and β_{cp}).
3. Determining the optimal amount of energy sales to customers in each hour.

Section 2 presents the formulation related to retailer profit and customer cost during the bilateral contract, followed by developing the process of solving the proposed model in section 3. Section 4 focuses on defining the input parameters of the interactive model. The result and discussion are provided in section 5. Finally, the conclusions are provided in section 6.

2. Problem modeling

2.1 *Formulation of retailer revenues and costs during the bilateral electricity market contract*

Equation (1) shows the objective function of the proposed problem. The first part indicates the revenue from the sale of energy to the customer by considering the desired discount by the customer. In addition, the second and third parts denote the cost of purchasing energy from wholesalers and cost for increasing the contract length with customer, respectively. Eventually, the fourth part depicts the income for increasing the contract length.

$$\max \mathrm{Obj}_1 = \left[\sum_{c\in C}\sum_{t\in T}(1-\alpha_{ct})\varphi_t s_{ct}\right] - \left[\sum_{w\in W}\sum_{t\in T}\rho_{wt}x_{wt}\right] - \left[\sum_{p\in P} p\left(\sum_{c\in C} y_{cp}\delta_{cp}D_c\right)\right] + \left[\sum_{p\in P}\sum_{t\in T}\beta_{cp}y_{cp}\right] \tag{1}$$

2.2 *Constraints*

Constraint (2) depicts that energy is sold to the customer in the presence of a bilateral contract. M represents a large number. constraint (3) proves that only one contract with each customer is concluded, and constraint (4) depicts the presence of a bilateral contract with a particular subgroup of customers for make the problem more real. Additionally, constraint (5) certifies that the whole energy obtained from wholesalers in each hour equals the quantity of the sold energy to the customers. It means that, that the retailer does not have the permission to store energy. Constraints (6)-(8) show that the energy delivery to customer in per time period is the same as the customer's demand for that time period ($r_{ct}D$). Further, constraint (9) indicates that retailer must supply all customers' demands and finally constraints (10)–(11) demonstrate the relationship between the full capacity of energy wholesalers and the quantity of the supplied energy for the customer in each hour.

$$s_{ct} \le M \sum_{p\in P:p\ge 1} y_{cp} \;\forall\, c\in C,\; t\in T \tag{2}$$

$$\sum_{p\in P} y_{cp} = 1 \;\forall c\in C \tag{3}$$

$$\sum_{p\in P:p\ge 1} y_{cp} = 1 \;\forall c\in C' \tag{4}$$

$$\sum_{w\in W} x_{wt} = \sum_{c\in C} s_{ct};\; \forall\, t\in T \tag{5}$$

$$s_{ct} \le r_{ct}D_c + \kappa_{ct}\alpha_{ct}; \forall c\in C,\; t\in T \tag{6}$$

$$s_{ct} + I_{ct-1} = I_{ct} + r_{ct}D_c;\; \forall\, c\in C,\; t\in T \tag{7}$$

$$0 \le I_{ct} \le V_c \quad \forall\, c\in C,\; t\in T \tag{8}$$

$$\sum_{t\in T} s_{ct} = D_c \sum_{p\in P:p\ge 1} y_{cp};\quad \forall\, c\in C \tag{9}$$

$$x_{wt} \le \mathrm{cap}_{wt};\; \forall\, w\in W,\; t\in T \tag{10}$$

$$\sum_{w\in W} x_{wt} \le \sum_{w\in W} \mathrm{cap}_{wt};\; \forall t\in T \tag{11}$$

2.3 *Customer costs formulation during the bilateral electricity market contract in the proposed model*

Equation (12) shows the optimization of model in internal level for the presented bi-level programming (BLP) model so that the customer goal is cost minimization and this optimization is used as a constraint for retailer profit maximization. The problem of internal optimization related to the minimization of the cost of each customer is expressed the same as Eq. (13) as follows:

$$\begin{cases} \min \sum_{t\in T}(1-\alpha_{ct}a_{ct})\varphi_t s_{ct} + \sum_{t\in T} h_c I_{ct} \quad \forall\, c\in C \\ s_{ct} + I_{ct-1} = I_{ct} + r_{ct}D_c \quad \forall c\in C,\; t\in T \\ 0 \le I_{ct} \le V_c \quad \forall c\in C,\; t\in T \end{cases} \tag{12}$$

$$\begin{cases} \min \sum\limits_{t\in T}(1-\alpha_{ct}a_{ct})\varphi_t(I_{ct}-I_{ct-1}+r_{ct}D_c)+\sum\limits_{t\in T}h_cI_{ct} \\ I_{ct}-I_{ct-1}=\begin{cases}\Phi(\alpha_{ct}), a_{ct}=1\\ \le 0, a_{ct}=0\end{cases} \\ I_{ct}\le V_c\ \forall c\in C,\ t\in T \\ I_{ct}\ge 0\ \forall c\in C,\ t\in T \end{cases} . \tag{13}$$

2.4 *Bi-level economic modeling of the problem from a retailer point of view*

Discount suggestions by the power retailer will make the customers to obtain more electricity based on the proposed model for the energy contract in electricity market. Supposing $(\Phi(\alpha_{ct}) = \kappa_{ct}\alpha_{ct})$, thus κ_{ct} depicts specific discount to increase electricity delivery for customer c in time period t. Factor of the non-linearization for the presented model is $\alpha_{ct} \times s_{ct}$ (multiplication factor) in equation (12). By controlling optimization in internal level and eliminating the model from the BLP, the presented model is a mixed quadratic programming model (MIQP). The solution of MIQP model typically yields more time compared to the linear models and the final optimal solution is not certainly warranted [27], therefore, an approximation in linear form according to the McCormick technique can be used in this regard [28, 29]. Finally, based on the above explanation and the right approximation, the programming model becomes a MILP model that can be solved by CPLEX. Accordingly, the model is re-written from the BLP mode to the MILP model in Eqs. (14)-(15).

$$\max\left(Obj=\left[\sum_{c\in C}\sum_{t\in T}(\varphi_t s_{ct}-\varphi_t q_{ct})\right]-\left[\sum_{w\in W}\sum_{t\in T}\rho_{wt}x_{wt}\right]\right.$$
$$\left.-\left[\sum_{p\in P}p\left(\sum_{c\in C}y_{cp}\delta_{cp}D_c\right)\right]+\left[\sum_{p\in P}\sum_{t\in T}\beta_{cp}y_{cp}\right]\right) \tag{14}$$

$$\begin{cases} q_{ct}\approx\alpha_{ct}\times s_{ct}:\alpha_{ct}\in[Lo_{ct},Up_{ct}], s_{ct}\in[0,V_c+r_{ct}D_c] \\ q_{ct}\ge\alpha_{ct}(V_c+r_{ct}D_c)+Lo_{ct}s_{ct}-Up_{ct}(V_c+r_{ct}D_c) \\ q_{ct}\ge\alpha_{ct}(0)+Lo_{ct}s_{ct}-Lo_{ct}(0)=Lo_{ct}s_{ct} \\ q_{ct}\le\alpha_{ct}(V_c+r_{ct}D_c)+Lo_{ct}s_{ct}-Lo_{ct}(V_c+r_{ct}D_c) \\ u\le\alpha_{ct}(0)+Up_{ct}s_{ct}-Up_{ct}(0)=Up_{ct}s_{ct} \end{cases} \tag{15}$$

3. The process of solving the proposed model

Figures 1 and 2 show a schematic of the problem and the flowchart of the presented interactive model, respectively. Based on this interactive economic modeling, retailers in the electricity market seek to maximize profits in the bilateral contract. On the other hand, the retailer will also consider the customer's goal of minimizing cost. Therefore, the proposed bi-level economic model is from the retailer's perspective while taking into account customer goals in bilateral electricity market contracts.

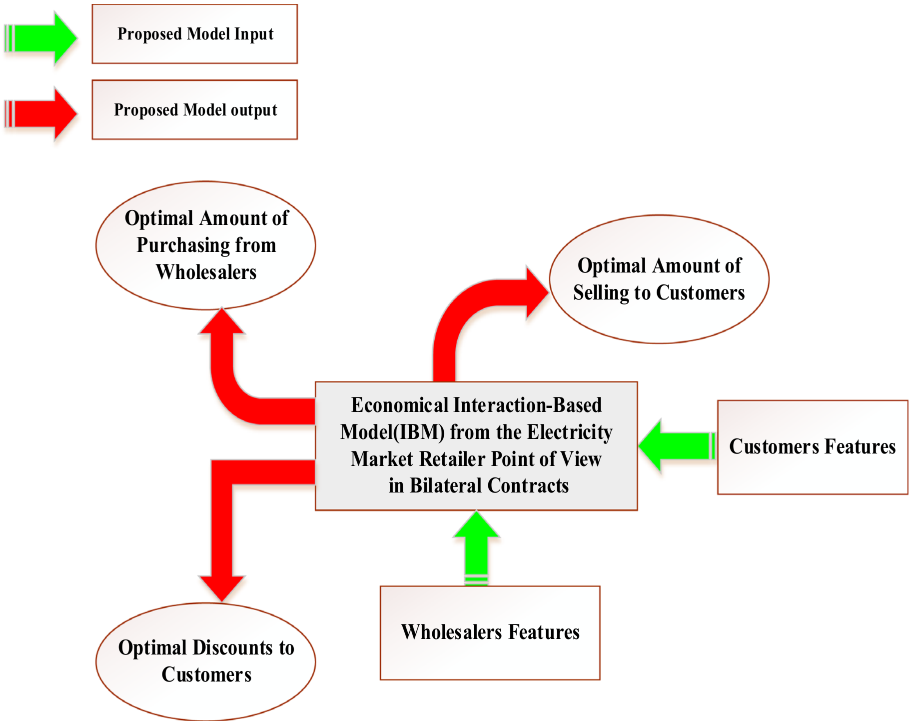

Figure 1. The proposed model for the problem of retailer-customer interaction in the electricity market.

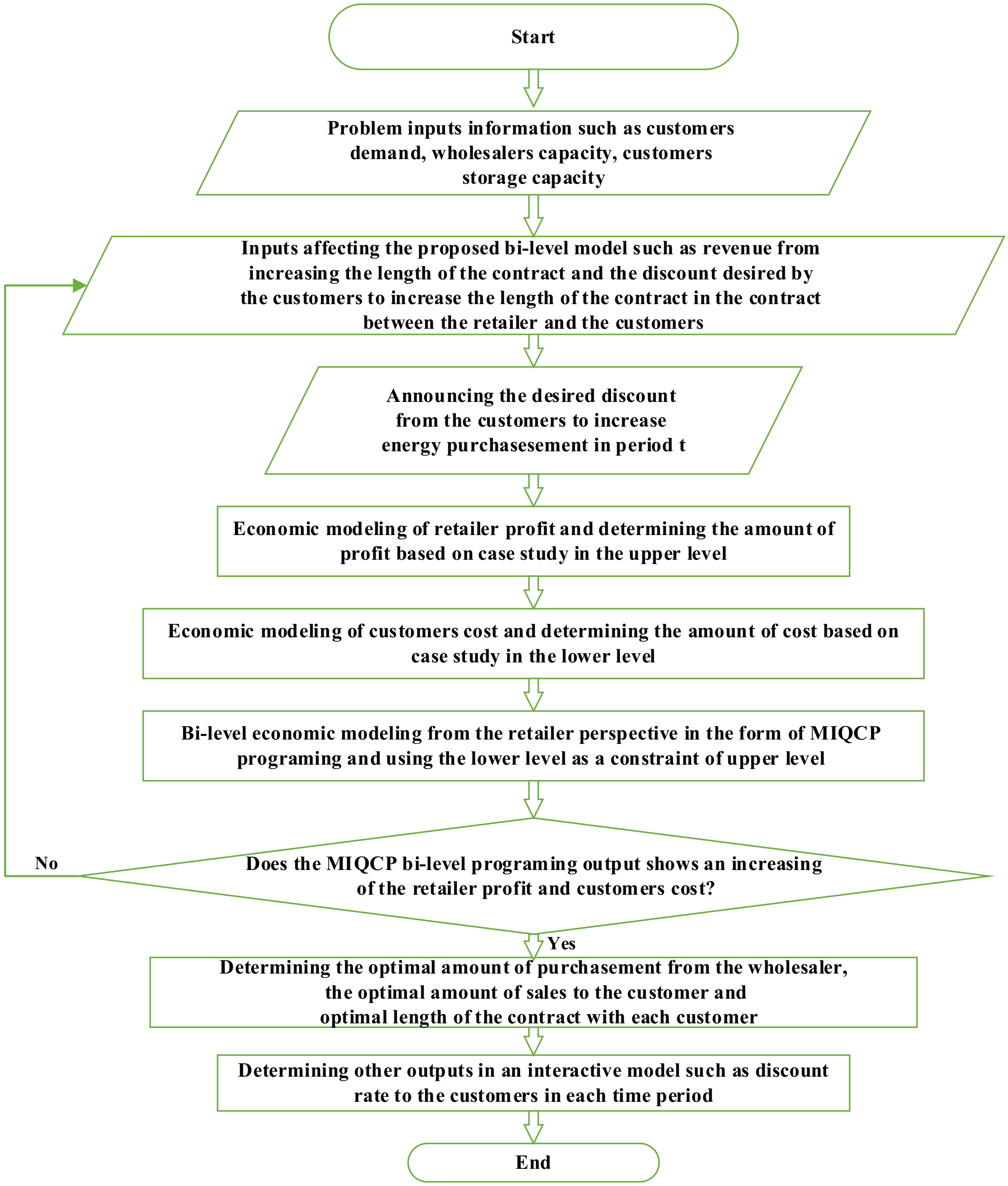

Figure 2. Flowchart of the presented model.

4. Input parameters

4.1 *Demand*

Figure 3 shows the electricity demand for customers. As shown, customers 7 and 2 have the maximum and minimum demand, respectively.

4.2 *Storage capacity of customers*

The storage capacity of customers is illustrated in figure 4. The power retailer will be aware about the capacity of customers' storage for making the ideal decisions. Customers 7 and 1 have the maximum and minimum storage capacity, respectively.

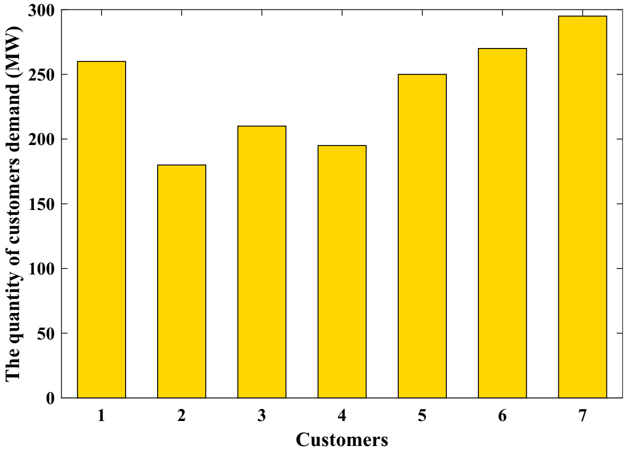

Figure 3. customers demand.

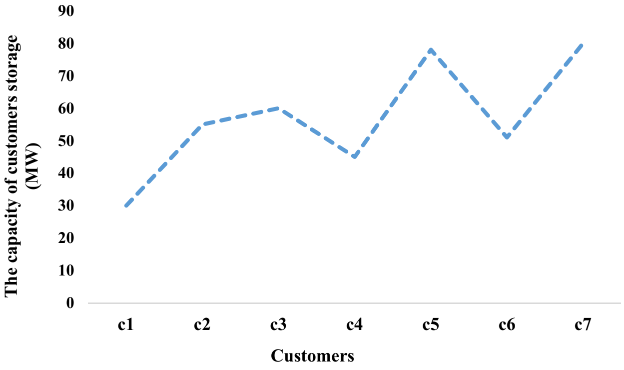

Figure 4. Customer storage capacity.

4.3 *Energy prices*

Figure 5 displays the price of energy for 24 hours of a day. Naturally, the market prices for electricity bilateral contract are medium, low, and peak types, as given in figure 5.

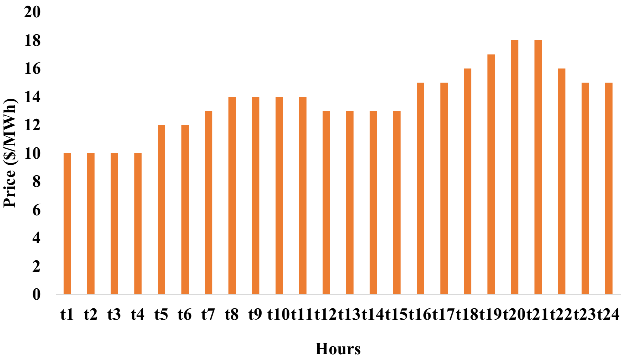

Figure 5. Energy prices in a day.

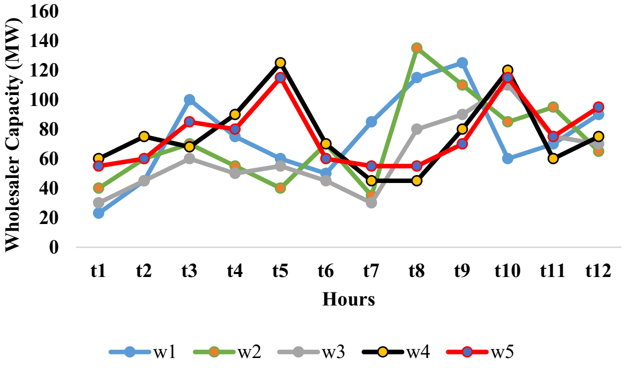

Figure 6. Wholesale capacity in the first 12 hours.

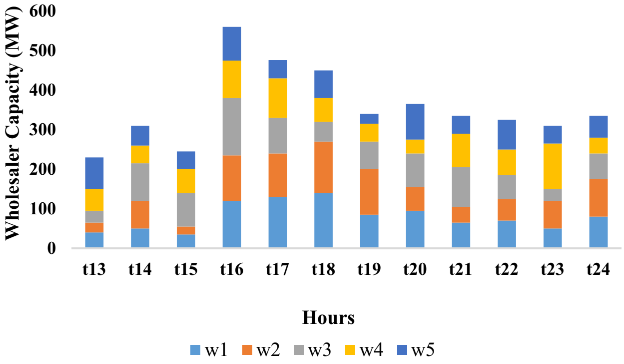

Figure 7. Wholesale capacity in the last 12 hours.

4.4 *Energy generation capacity of wholesalers*

Figures 6 and 7 illustrate the energy generation capacity of wholesalers. Customer demand is supplied based on the retailer's information about the wholesalers' capacity. Figure 6 shows the capacity in the first 12 hours and figure 7 depicts the capacity in the last 12 hours for the five considered wholesalers. The energy capacity of wholesalers is quantified from a real case study that has participated in bilateral electricity market contracts.

The proposed bi-level model is solved using the CPLEX solver within GAMS software in Windows operating system for 300 seconds during different iterations [30].

5. Result and discussion

5.1 *Determination of the optimal length of bilateral contracts with customers based on the proposed interaction model*

The optimal length of the retailer's bilateral contract with each customer is determined based on Eq. (1) in the presented model. In this regard, a bilateral contract for more than a month with some customers is executed by the retailer aiming

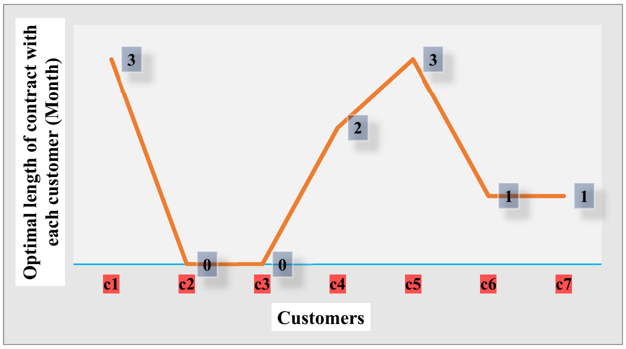

Figure 8. Optimal length of the contract with customers based on the proposed interaction model.

at retailer profit maximization and considering the customer discount for buying more energy and extending the contract with the aim of cost minimization. As shown in figure 8, a long-term contract has been concluded with some customers, including the first and fifth ones.

5.2 *Optimal amount of selling energy to customers during the bilateral contract based on the proposed interactive model*

The amount of the sold energy by the retailer to the customer is displayed in figures 9 and 10. In the presented interactional model that is for the electricity bilateral contract among players in the electricity market, all customers announce their demands in times of a day and offer their favorite discounts for receiving additional energy in different times of a day. Selling energy to customer in different times of a day by retailer is carried out based on the favorite amounts and acquaintance about the capacity of customer's storage. Figures 9 and 10 depict the energy sale to the customer from first to twelfth hour and from thirteenth to twenty-fourth hour, respectively. These values of energy sales to customers are optimal. Therefore, determining the energy exchange between the retailer and customers at different hours of the day is another feature of the formulation for the proposed bi-level model. The maximum storage capacity of each customer is naturally taken into account when determining this optimal value.

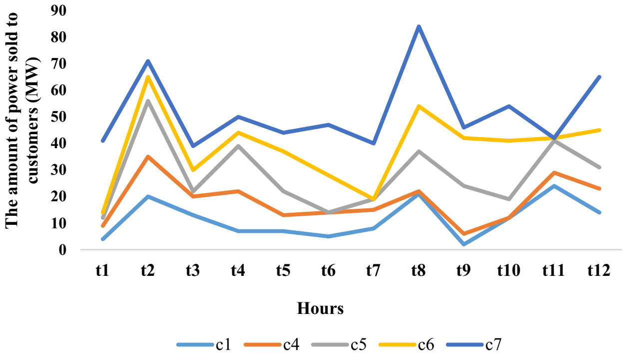

Figure 9. The optimal amount of energy sold to customers in the first to twelfth hours.

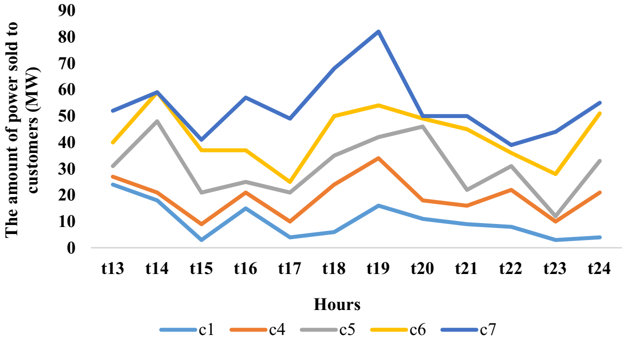

Figure 10. The optimal amount of energy sold to customers in the thirteenth to twenty-fourth hours.

5.3 *The amount of the desired discount by customers for increasing the length of the contract*

To increase the length of the contract to two or three months, the customer announces the optimal amounts for the discount $\left(\delta_{cp}(\%)\right)$ to receive more energy per unit from the retailer. The desired discount by customers for increasing the length of contract for two or three month contract are shown in figure 11. In fact, by the introduced interactive parameter, customers and retailers simultaneously achieve their goals in the bilateral contract, namely, having the minimum cost while receiving maximum profit. For example, to increase the length of the contract to three months, customer 6 requests a 9% discount per unit of additional energy.

5.4 *Retailer's profit maximization analysis in the proposed model*

Figure 12 illustrates the effect of the interactive model formulation on the retailer's profit by comparing interaction and non-interaction state based on considering or not

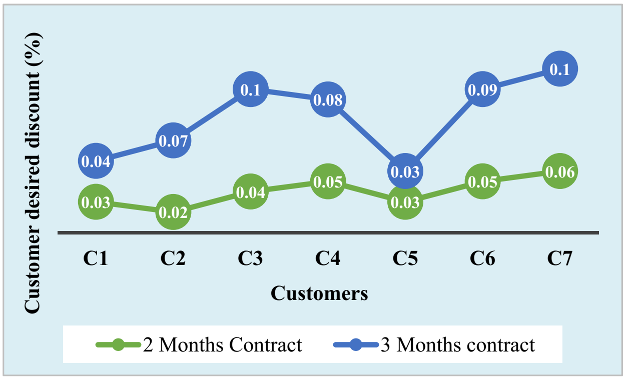

Figure 11. Discounts desired by customers in percentage for a two- and three-month contract.

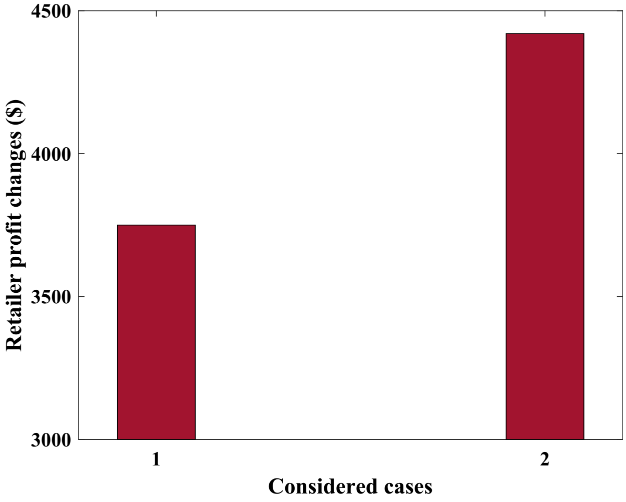

Figure 12. Comparison of retailer's profit with and without interaction between retailer and customer.

considering interactive parameter (α). Cases (1) and (2) display the retailer's profit in the state of interaction and non-interaction between customers and the retailer, respectively. The 13.5% increase in retailer profit in 24 hours shows the best operation of the model and influence of the presented model for retailer profit maximization.

5.5 *Customer's cost analysis in the proposed interactive model*

Another feature of the proposed model is customer cost minimization. Based on the suggested interaction model, the retailer will have a contract with customers 1, 4, 5, 6 and 7 and without considering the interaction, the retailer has a contract with customers 1, 2, 3, 4 and 6. As mentioned in equation (4), it is assumed that some customers will have a contract with the retailer in any condition. Therefore, according to figure 13, there is no change in the cost of customer 1 compared to the case where the proposed model is not considered while the customer's cost for customers 4 and 6 decreases 1.9% and 1.7% in comparison to the case that suggested interaction model is not considered, respectively.

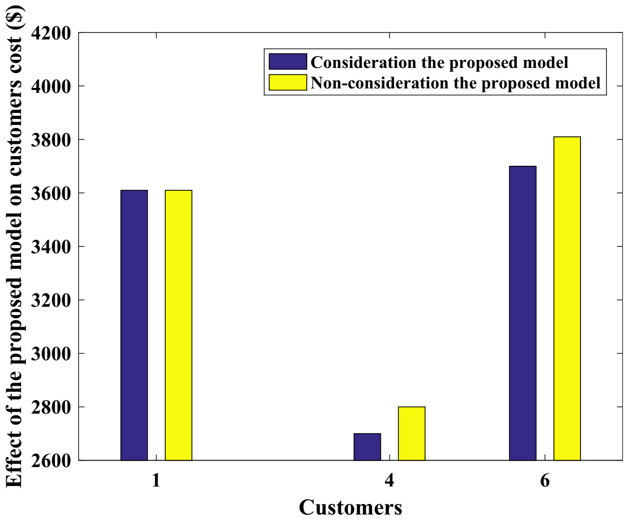

Figure 13. Comparison of customer's cost with and without considering suggested interaction model.

5.6 *Sensitivity analysis for the validation of the proposed model*

The possibility of more interaction between the retailer and customers is provided by increasing the generation capacity of energy from wholesalers. Accordingly, the retailer will attempt to buy more energy from the wholesalers. An increase in the retailer's purchases will create maximum interaction with the customers to increase the length of the bilateral contract. Figure 14 illustrates variations in the retailer profit in the range of variations between −5% and +5% of the capacity of wholesaler generation in the presented model.

Figure 15 illustrates the sensitivity analysis for the power retailer profit according to variations in power retailer incomes in contracts for two or three months. The results represent the power retailer profit on variations between −5% and +5% income through different length of the contracts. For the increasing of contract length, 2.92% increase in power retailer profit in 24 hours is seen which is satisfactory. Figure 16 shows the retailer's profit in the following three cases:

1. Considering all presented parameters in the proposed model.
2. Not considering the parameter for discount rate (α_{ct}).
3. Not considering the parameter for discount rate besides the specific parameter for contracts extension in two or three months (y_{cp}).

According to the suggested model, figure 16 depicts the effect of the interactive parameters of the bi-level model on the retailer's profit maximization. As shown, the retailer's profit in (1), where all the effective parameters on the suggested model are counted, compared to (2) and (3), where

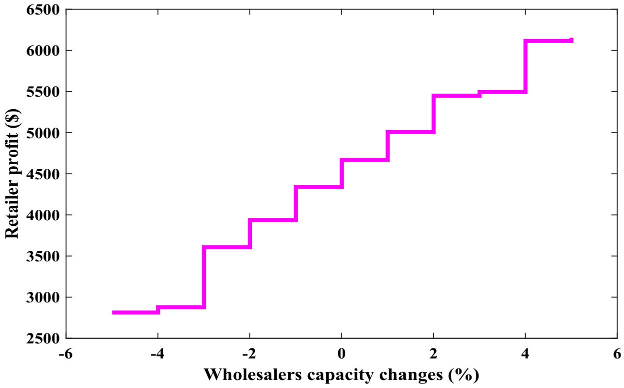

Figure 14. Sensitivity analysis of retailer's profit due to changes of wholesaler generation capacity.

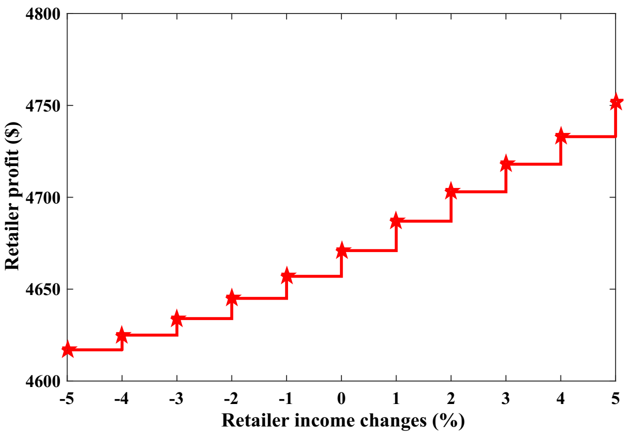

Figure 15. Retailer's profit for retailer's revenue deviation.

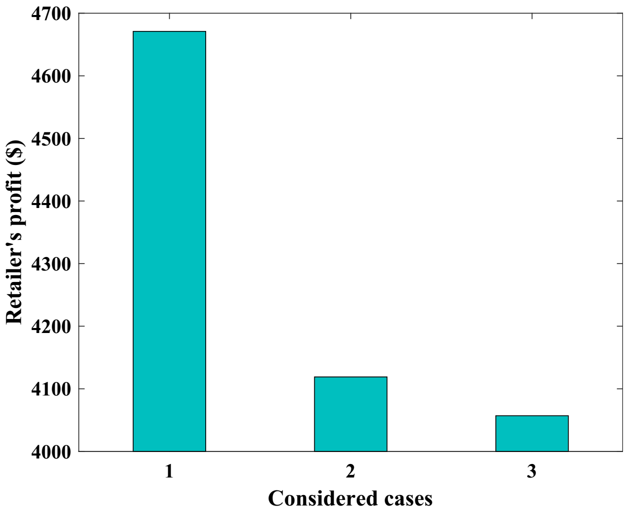

Figure 16. Retailer's profit in different cases of the proposed interaction model.

introduced effective parameters of the suggested model is not counted, increases 13.42% and 15.1%, respectively.

6. Conclusion

In this paper, a bi-level economic model was presented aiming at retailer's profit maximization and customer cost minimization in interaction with each other by introducing interactive parameters in a bilateral contract. It is noteworthy that determining the optimal length of contract with each customer and the amount of energy sales to customers was a feature of the proposed model, finally leading to the appropriate decision-making of the retailer in bilateral contracts. For future research, the proposed model can be applied to other common contracts in the electricity market. Eventually, the analysis of the proposed model based on the congestion management of the transmission line in the power network can be examined as well.

List of symbols

Sets

$W = \{1, 2, \ldots, w\}$	Sets related to wholesalers
$C = \{1, 2, \ldots, c\}$	Sets related to customers
$T = \{1, 2, \ldots, 24\}$	Sets related to hours time periods of a day
$P = \{0, 1 \ldots, p\}$	Sets related to duration of bilateral contract between retailer and customers
$C' \subseteq C$	A customer subset with whom the retailer has a contract in any situation and supplies their energy needs

Problem inputs

$D_c(MW)$	Amount of demand for customer C in a day
$r_{ct}(\%)$	The rate of consumption for customer C during time period t
$V_c(MW)$	The capacity of storage for customer C
$\delta_{cp}(\%)$	Discount desired by customer C (per unit of energy) in contract with length P (per contract length)
$\beta_{cp}(\$)$	The revenue from extending the contract with customer C with length P
$h_c\left(\frac{\$}{MWh}\right)$	Storage cost for a customer C
$\varphi_t\left(\frac{\$}{MWh}\right)$	Energy prices during time period t
$\rho_{wt}\left(\frac{\$}{MWh}\right)$	Cost of energy supplied by wholesaler W during time period t
$cap_{wt}(MW)$	Capacity for wholesaler W during period t

Problem outputs

$x_{wt}(MW)$	Quantity of supplied energy via wholesaler W during time period t
$s_{ct}(MW)$	Sales of energy to customer C during time period t
$\alpha_{ct}(\%)$	Rate of discount offered to customer C during time period t
y_{cp}	This variable is binary and equals to 1, if retailer has a bilateral contract with customer C for length P, otherwise this variable is 0
$I_{ct}(MW)$	Customer's energy storage during time period t
a_{ct}	This variable is binary and equal to 1, if customer C agrees to obtain additional energy during time period t via discount offered by retailer/otherwise this variable is 0

References

[1] Pilipovic D 2007 Energy risk: Valuing and managing energy derivatives, Chapter 1. 2nd edn. Irwin Professional Publishing, McGraw Hill, Maidenhead

[2] Kaminski V 2004 Managing energy price risk: The new challenges and solutions, Chapter 2. 3rd edn. Risk Books, London

[3] Weron R 2017 Modeling and forecasting electricity loads and prices: A statistical approach, Chapter 3. Wiley, Nashville

[4] Benth J S, Koekebakker S and Benth F E 2008 Stochastic modeling of electricity and related markets. World Scientific Publishing, Singapore, pp 1–35

[5] Shahidehpour M Yamin H and Li Z 2008 Market operations in electric power systems: Forecasting, scheduling, and risk management. New York, NY: Wiley-IEEE Press, pp. 1–30

[6] Deng S and Oren S 2006 Electricity derivatives and risk management. *Energy (Oxf.)* 31(6): 940–953

[7] Sun B, Wang F, Xie J and Sun X 2021 Electricity retailer trading portfolio optimization considering risk assessment in Chinese electricity market. *Electric Power Syst. Res.* 190: 106833

[8] Kohansal M and Mohsenian-Rad H 2016 Price-maker economic bidding in two-settlement pool-based markets: The case of time-shiftable loads. *IEEE Trans. Power Syst.* 31(1): 695–705

[9] Nojavan S, Majidi M and Zare K 2018 Optimal scheduling of heating and power hubs under economic and environment issues in the presence of peak load management. *Energy Convers. Manag.* 156: 34–44

[10] Kirschen D S 2003 Demand-side view of electricity markets. *IEEE Trans. Power Syst.* 18(2): 520–527

[11] Gabriel S A, Conejo A J, Plazas M A and Balakrishnan S 2006 Optimal price and quantity determination for retail electric power contracts. *IEEE Trans. Power Syst.* 21(1): 180–187

[12] Wu T, Li G and Bie Z 2019 Power procurement strategies of retailer considering demand response program. *8th Renewable Power Generation Conference (RPG)*

[13] Carrion M, Arroyo J M and Conejo A J 2009 A bilevel stochastic programming approach for retailer futures market trading. *IEEE Trans. Power Syst.* 24(3): 1446–1456

[14] Hatami A, Seifi H and Sheikh-El-Eslami M K 2011 A stochastic-based decision-making framework for an electricity retailer: Time-of-use pricing and electricity portfolio optimization. *IEEE Trans. Power Syst.* 26(4): 1808–1816

[15] Herranz R, San Roque A M, Villar J and Campos F A 2012 Optimal demand-side bidding strategies in electricity spot markets. *IEEE Trans. Power Syst.* 27(3): 1204–1213

[16] Khojasteh M and Jadid S 2015 Decision-making framework for supplying electricity from distributed generation-owning retailers to price-sensitive customers. *Util. Policy* 37: 1–12

[17] Fang X, Li F, Wei Y and Cui H 2016 Strategic scheduling of energy storage for load serving entities in locational marginal pricing market. *IET Gener. Transm. Distrib.* 10(5): 1258–1267

[18] Nojavan S and Zare K 2018 Optimal energy pricing for consumers by electricity retailer. *Int. J. Electr. Power Energy Syst.* 102: 401–412

[19] Nojavan S, Zare K and Mohammadi-Ivatloo B 2017 Robust bidding and offering strategies of electricity retailer under multi-tariff pricing. *Energy Econ.* 68: 359–372

[20] Nojavan S, Zare K and Mohammadi-Ivatloo B 2017 Risk-based framework for supplying electricity from renewable generation-owning retailers to price-sensitive customers using information gap decision theory. *Int. J. Electr. Power Energy Syst.* 93: 156–170

[21] Zugno M, Morales J M, Pinson P and Madsen H 2013 A bilevel model for electricity retailers' participation in a demand response market environment. *Energy Econ.* 36: 182–197

[22] Wei W, Liu F and Mei S 2015 Offering non-dominated strategies under uncertain market prices. *IEEE Trans. Power Syst.* 30(5): 2820–2821

[23] Wei W, Liu F and Mei S 2015 Energy pricing and dispatch for smart grid retailers under demand response and market price uncertainty. *IEEE Trans. Smart Grid* 6(3): 1364–1374

[24] Nojavan S, Mehdinejad M, Zare K and Mohammadi-Ivatloo B 2015 Energy procurement management for electricity retailer using new hybrid approach based on combined BICA–BPSO. *Int. J. Electr. Power Energy Syst.* 73: 411–419

[25] Feuerriegel S and Neumann D 2014 Measuring the financial impact of demand response for electricity retailers. *Energy Policy* 65: 359–3680

[26] Ahmadi A, Charwand M and Aghaei J 2013 Risk-constrained optimal strategy for retailer forward contract portfolio. *Int. J. Electr. Power Energy Syst.* 53: 704–713

[27] Boyd S and Vandenberghe L 2004 Convex optimization, Chapter 3 & 4. Cambridge University Press, Cambridge

[28] Boland N, Dey S S, Kalinowski T, Molinaro M and Rigterink F 2017 Bounding the gap between the McCormick relaxation and the convex hull for bilinear functions. *Math. Program* 162(1–2): 523–535

[29] Castro P M 2015 Tightening piecewise McCormick relaxations for bilinear problems. *Comput. Chem. Eng.* 72: 300–311

[30] "CPLEX 12", *Gams.com.* [Online]. Available: https://www.gams.com/33/docs/S_CPLEX.html