Advances in Computer, Signals and Systems (2020) 4: 7-12
Clausius Scientific Press, Canada
DOI: 10.23977/acss.2020.040102
ISSN 2371-8838

Electric power transaction of electric vehicle based on smart contract and double auction

Baoyi Wang[a,*], Xiaoyuan Liu[b] and Shaomin Zhang[c]

School of Control and Computer Engineering, North China Electric Power University, China
a. wangbaoyiqj@126.com, b. liuxiaoyuan9@126.com, c. zhangshaomin@126.com

Keywords: electric vehicles, smart contract, double auction

Abstract: The increase of the number of electric vehicles leads to serious peak valley imbalance in the power grid. In order to achieve "peak cutting and valley filling", according to the energy storage characteristics of electric vehicles, this paper proposes an electric vehicle group (EVG) energy trading method based on smart contract and double auction matching mechanism, and constructs the electric energy transaction process of the electric vehicle and electric vehicle in the electric vehicle group under the unbalanced load of the power grid. Through deploying the double auction matching algorithm to the smart contract, the automatic execution of matching transaction and automatic clearing of transaction cost are realized, which saves the economic cost of manual matching mode. In addition, the multi-stage quotation method proposed greatly improves the number of transactions. The simulation experiment based on Monte Carlo simulation shows that the power transaction method can not only effectively alleviate the peak valley problem of power grid load, achieve the effect of "reducing peak and raising Valley", but also can improve the transaction efficiency.

1. Introduction

Electric vehicle (EV), as a kind of low-carbon, environment-friendly and energy-saving transportation, is becoming more and more popular. According to the statistics of literature [1], by 2020, the number of electric vehicles in China will be close to five million. At that time, the large-scale EV will charge intensively, which is bound to cause the demand growth of EV charging. However, the energy storage characteristics of the electric vehicle itself provide the possibility to relieve the peak and valley load pressure of the power grid. For example, reference [2] propose to use V2G (vehicle to grid) technology to realize the bidirectional flow of energy between the electric vehicle and the power grid, so that the electric vehicle can supply power to the grid as a distributed energy. Literature [3] Based on the scale effect of electric vehicles, encourage electric vehicle users to participate in peak load regulation, propose V2G peak load regulation system architecture, and dispatch electric vehicles to participate in peak load reduction and valley filling through the prediction of power load curve by dispatching center. In reference [4], a variable threshold optimization algorithm and a charge discharge rate adjustable optimization algorithm are proposed to improve the imbalance of power supply and demand in microgrid. The demand response mechanism is used to manage the power distribution of pure electric vehicles from vehicles to the grid in reference [5].The charging strategy of hybrid electric vehicles is proposed in reference [6]. However, the enthusiasm of electric vehicle users to participate in peak reduction and valley improvement is different. Many users of electric vehicles lack the initiative because of considering the cost of battery loss and other issues. In recent years, with the development of block chain technology, its application scope is more and more extensive, and gradually develops from the financial industry to the energy field. For example, the block chain technology is applied to this distributed power market in reference [7]. Literature [8] combined with the current situation of block chain development, analyzed the applicability of block chain application in the multi-energy system, and proposed the method of building heterogeneous block chain multi-energy system. In addition, competitive auction as an important way of resource allocation, has a certain impact on the fairness and efficiency of transactions. Literature [9] compares Sequential Auction and combinatorial auction based on Petri net, which is a bold attempt to apply Petri net to auction. Through the comprehensive analysis of the characteristics of block chain technology, it is found that the block chain is transparent and tamper proof, which makes the transaction more transparent and secure, and the smart contract automates matching transactions.

In summary, this article is based on smart contract and double auction matching mechanism (DAMM) can solves the problems of high manual cost in the traditional auction matching mode and serious imbalance between peak and valley, and can ensure that in the case of imbalance between peak and valley in the grid, the electric vehicle users in EVG can sell the electric energy to the charged electric vehicle, so as to realize "peak reduction and valley lifting" and benefit the users.

The rest of the paper is as follows. The second part constructs a transaction model based on smart contract. The third part introduces the matching mechanism of double auction, and the fourth part introduces the power transaction process based on block chain and double auction matching mechanism. The fifth part is simulation experiment. The sixth part is the summary of this paper.

2. The model of electric energy trade based on smart contract

Block chain technology is the product of the development of information technology in the Internet era. It is a distributed network storage structure integrating multiple advantages. It ensures the safe operation and maintenance of the whole network through the decentralization and distrusted method, and has the advantages of tamper proof, non-repudiation, and non-forgery. Smart contract as one of the main features of block chain, it is not only a piece of program code that can be automatically executed, but also a participant in the network. It can accept the response information and automatically respond. Finally, through consensus, the transaction is recorded in the distributed bill of block chain. Through the deployment of smart contracts, the decentralized EV transaction will be effectively realized, and the Settlement will be automatically carried out after the transaction is completed. Two smart contracts will be deployed in this paper, and we will deploy a continuous double auction algorithm on the first smart contract to automatically complete the matching transaction. The second contract is used to measure the trading power by the smart meter install on the electric vehicle, and broadcast the power purchase information of the power grid at peak time, and broadcast the power sale information in valley to remind the electric vehicle users of the current power transaction information. Its basic structure is shown in Figure 1.

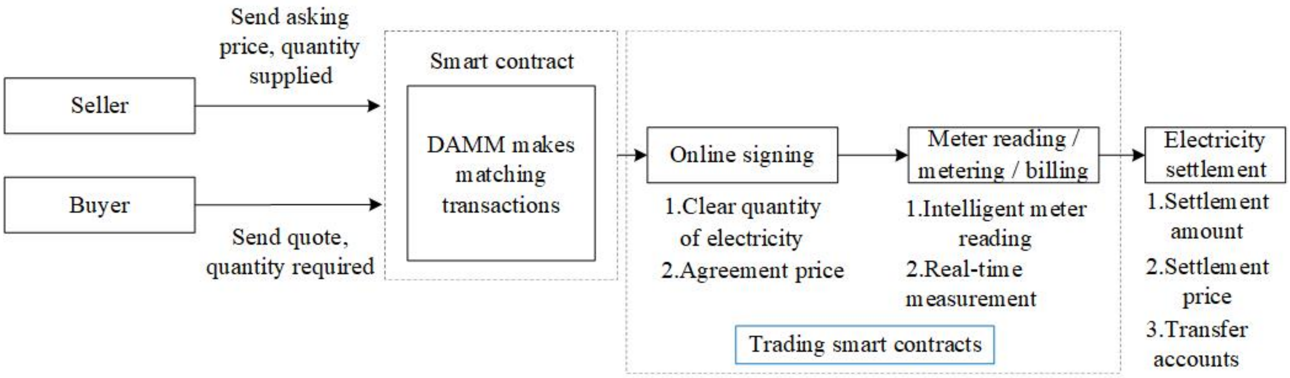

Figure 1: Transaction model based on smart contract.

3. Double auction matching mechanism

3.1. Pricing strategy of electric energy transaction

During peak hours, the grid load is large and the price of electricity is relatively high. At this time, the electric vehicle user needs to respond to the power supply request in time. In the process of DAMM, transaction price and quantity are important indicators of transaction service satisfaction. This paper set $C_i(CP_i,CQ_i)$ is the purchase request of electricity purchaser i, where CP_i is the bid of electricity purchaser to purchase unit electric energy, and CQ_i is the amount of electricity purchase required. Let $S_i(SP_j,SQ_j)$ be the supply request of electric vehicle user j, where SP_j is the price required for electric vehicle to provide unit electric energy, and SQ_j is the amount of electric energy to be provided. In order to ensure the satisfaction of both parties to the transaction results, the peak time pricing strategy in this paper is as follows.

The profit pc_i of the purchaser i is equal to the conventional electricity price CV_i from the grid purchase unit power minus the bid CP_i of the unit electric energy purchased from the electric power supply vehicle, and then multiplied by the amount of electric energy successfully traded. The profit expression is as follows.

$$pc_i = (CV_i - CP_i)CQ_i \tag{1}$$

The income ps_j of power supply electric vehicle user j is equal to the price SP_j required to provide unit electric energy minus the cost SC_j sell unit electric energy, and then multiplied by the quantity of Electric energy trading. The profit expression is as follows.

$$ps_j = (SP_j - SC_j)SQ_j \tag{2}$$

The cost consists of the cost of charging at valley time and the battery loss, the expression is as follows.

$$SC_i = ps_{cj} \times SQ_j + B_j \tag{3}$$

$$B_i = b_i \times Q_{i,j} \tag{4}$$

Where ps_{cj} is the charging price of the power supply vehicle in valley, B_i is the loss cost of the battery, b_i is the depreciation factor of the battery of EV. The average cost of the power battery is \$227/KWH, about RMB 1500/KWH. Taking BYD E6 as an example, the residual value of the battery is only 36.7%, and the charging and discharging life of the battery is 10000 times. Therefore, the depreciation cost per charged battery is: b_i= (1500-1500×36.7%) /10000≈0.1 RMB/KWH.

3.2. Matching strategy

With the improvement of the concept of energy conservation and emission reduction, the number of electric vehicles in China will increase exponentially in the next few years, and the number of electric vehicles participating in peak valley regulation of power grid will also increase relatively. In order to increase the trading volume, this paper will discuss the rules of DAMM power auction under different supply and demand conditions.

3.2.1. Supply exceeds demand

The oversupply of this paper refers to the electric energy that the electric vehicle can supply more than the electric energy required by the purchaser. In the case of oversupply, the seller and the purchaser will be arranged in descending order according to the reported price, and the arrangement curve is shown in Figure 2.

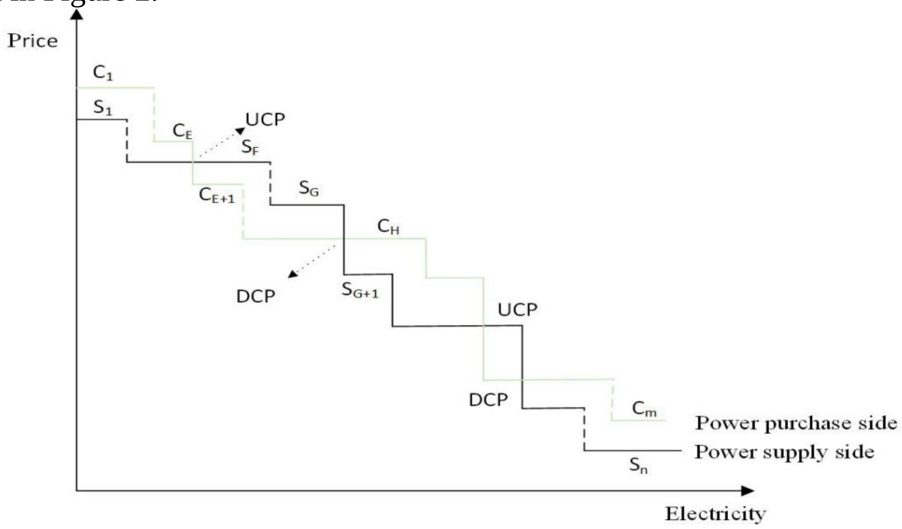

Figure 2: Arrangement curve of UCP and DCP existing at the same time.

In this paper, the multi segment quotation rule is proposed. Figure 2 is a quotation graph of a multi-segment quotation that has deleted an electric car user who is unlikely to successfully trade (Electric vehicle users whose selling price is higher than all bidding users). Multi segment quotation refers to that the electric vehicle users can divide the electric energy that they are prepared to provide into several parts (no more than 3 segments), each of which provides a different price, while the power purchasers are similar. Through multi-stage quotation, the price range is increased and the transaction rate is increased. In Figure 2, there are intersections between seller's and buyer's curves, which can be divided into up crossing point (UCP) and down crossing point (DCP). As shown in the figure 2, the UCP meets the following requirements:

$$CP_E < SP_F < CP_{E+1} \tag{5}$$

$$\sum_{i=1}^{E} CQ_i < \sum_{j=1}^{F} SQ_j \tag{6}$$

UCP states that the price charged by the power supplier is higher than the price offered by the power purchaser after this point. DCP states that the price of the power buyer will be higher than the price of the power supplier after this point. DCP at the descent intersection meets the following requirements:

$$SP_G < CP_H < SP_{G+1} \tag{7}$$

3.2.2. Supply less than demand

The supply less than demand means that the electric energy provided by the electric vehicle participating in the sale of electricity cannot meet the electric energy demanded by the electric vehicle for purchase, and in this case, the priority of the successful transaction of the low-priced electric vehicle is higher. Therefore, the purchaser and the power supplier are arranged in ascending order according to their quotation. There are still some intersections in the matching process, and the meaning is similar to the situation of oversupply. The DAMM auction rules are similar, and will not be described in detail here. The only difference is that the electricity purchaser between the intersections and the part of the electricity purchasers that are not successfully traded will not be sacrificed, but will purchase electricity directly from the grid, because the grid itself is for the users, the electric vehicle The sum of the electricity sold and the electricity available to the grid must be greater than the electricity demanded by the electric vehicle users. Therefore, there is generally no situation where supply is less than demand. The only difference is the price at which the user purchases the electricity price.

4. Power transaction process

1) Power grid broadcast energy load demand.

2) The electric vehicles are encouraged to charge directly from the grid in the valley. In case of peak, electric vehicles are encouraged to discharge. Users of discharged electric vehicles submit the maximum saleable energy and electricity price (the electricity price cannot be higher than the peak electricity price of the grid) through special software. At this time, electric vehicles with power purchase demand can submit the purchase price and electricity price.

3) After receiving the reported information, the smart contract uses DAMM to match the electric vehicle transaction.

4) If the match is successful in the transaction cycle, both parties of the transaction sign an online contract, consult the price of electricity, and measure it in real time.

5) Settle electricity bills after the transaction is completed.

5. Simulation experiment

In this paper, Monte Carlo simulation method is used to simulate the daily charge and discharge load of electric vehicles. It is set that the number of electric vehicle sales group is 600, the model is BYD E6, and the rated battery capacity is 57kwh. According to the peak and valley time of TOU price, EV is set to sell electricity in the peak time of 8:00-12:00 and 17:00-21:00, and purchase electricity from the grid in the valley time of 0:00-8:00. The charging mode is all medium charging, the charging power is 13kw, and the charging is once a day, and the ratio coefficient k of discharge and charging is 60%. The comparison between the daily load of the original grid and the grid under DAMM mechanism is shown in Figure 3.

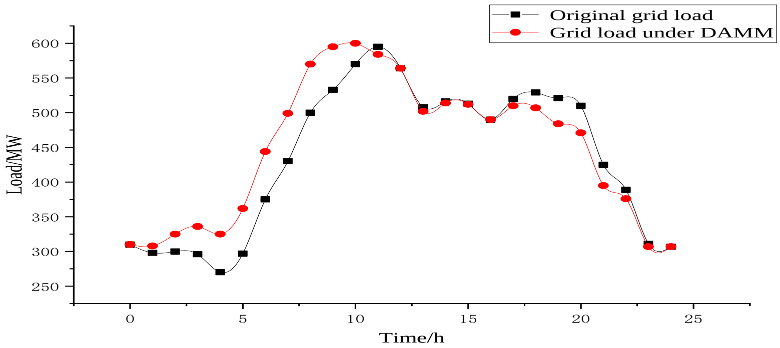

Figure 3: Daily load comparison chart of the original power grid and DAMM Trading.

6. Conclusion

In this paper, the smart contract and double auction matching algorithm are used to establish the electric vehicle power transaction model, realize the automatic transaction matching, and solve the problem of traditional manual matching transaction cost. At the same time, the "peak load cutting and valley filling" of power grid load is realized by using the energy storage characteristics of electric vehicles. However, although electric vehicle users can obtain benefits, their willingness to participate in the transaction is not great, therefore, it needs to be further improved in the future.

References

[1] State Council. Energy saving and new energy vehicle industry development plan (2012-2020) [EB / OL] (2012-07-09). Http://www.miit.gov.cn/n1146295/n1146557/n 1146619/c3072778/content.html.

[2] Li Jiazhuang, Ai Xin, Hu Junjie. Modeling and control strategy of electric vehicle participating in grid secondary frequency modulation [J]. Grid technology, Volume: 43, NO. 2, Pages: 495-503, 2019.

[3] Ding Ding, Luo Siwei, AI Lihua. Adaptive cloud computing resource allocation mechanism based on two-way auction [J]. Journal of communications, Volume: 33, Pages: 132-140, SEP 2012.

[4] Zhou Tianpei, Sun Wei. Interaction technology between electric vehicle and power grid based on Microgrid [J]. Power system automation, VOL: 42, NO. 3, Pages: 98-104, 2019.

[5] Geng B，Mills J K，Sun D．Two-stage charging strategy for plug-in electric vehicles at the residential transformer level[J]. IEEE Transactions on Smart Grid,VOL. 4, NO. 3, Pages: 1442-1452, 2013.

[6] Rassaei, F., W. Soh and K. Chua, Distributed Scalable Autonomous Market-Based Demand Response via Residential Plug-In Electric Vehicles in Smart Grids. IEEE Transactions on Smart Grid,VOL. 9, NO. 4, Pages: 3281-3290, 2018.

[7] S cheng,Bzeng,Y z huang. Research on application model of blockchain technology in distributed electricity market [J]. IOP Conference Series: Earth and Environmental Science, VOL: 93, NO. 1, Pages: 1-11, 2017.

[8] Li Bin, Cao Wangzhang, Zhang Jie, et al. Multi energy system trading system and key technologies based on heterogeneous blockchain [J]. Power system automation, VOL. 42, NO. 4, Pages: 183-193, 2018.

[9] Zhang, X., et al., Comparative Analysis of Sequential and Combinatorial Auctions Based on Petri Nets. IEEE Access, VOL. 6, Pages: 38071-38085, 2018.