ASSESSMENT OF RELATIVE EFFICIENCY OF DIFFERING ENERGY MARKETS FOR COMMUNITY ENERGY

Lanqing SHAN, University of Bath – UK, L.Shan@bath.ac.uk
Heng SHI, University of Bath – UK, H.Shi@bath.ac.uk
Liz SIDEBOTHAM, Northern Powergrid – UK, Liz.Sidebotham@northernpowergrid.com
Furong LI, University of Bath – UK, F.Li@bath.ac.uk

ABSTRACT

With the integration of distributed energy resources there is an increasing demand for small-scale trading platforms to utilise this distributed community energy effectively. The characteristics of a variety of trading methods need to be explored in order to establish a suitable trading market for community trading. However, there is minimal literature considering the distributed energy market and its trading arrangements. This paper presents a comprehensive assessment on the perspectives of theory and empirical cases of different market platforms. It: i) classifies trading methods from an economic point of view and explores their principles ii) sets up market assessment criteria from the economy and society perspectives iii) evaluates electricity markets using listed criteria and reveals the characteristics of diverse trading arrangements according to the assessment results.

1 INTRODUCTION

The last century has witnessed a continuous increase in energy consumption which is predicted to continue. According to the International Energy Agency (IEA), global energy consumption will have a two-thirds rise in the coming 25 years, and the demand for electricity in the UK will double by 2050 [1]. In the meantime, the way of meeting demand are changing rapidly: Half of the new generation investment will be occupied by renewable energy sources, and distributed energy generation capacity will be doubled in the next ten years [2]. The development of energy supply makes it necessary to change the distribution system so that local generation and demand-side management meet the end-users' requirements and expectation.

Although the new distribution system is introduced because of its advantages of low cost, high efficiency, supply security and limited emissions, a suitable market has not been established. Therefore, there is an increasing demand for small-scale energy trading platforms to serve distributed community energy. To fulfill the requirements, it is necessary to explore the characteristics of a variety of trading arrangements through analyzing existing electricity markets worldwide.

Existing research of electricity trading arrangements mainly focused on two aspects [3]~[6]: 1) setting up and improving one trading model and 2) simulating current a trading model to suit the technique development (such as renewable energy involvement). This research has the following gaps: 1) Research on trading methods are likely to focus on one, specific arrangement, but fail to consider alternatives as a whole in the energy market. 2) Trading methods are not explored from the theoretical perspective, leading to ignorance of their economic principle.

To fill the research gap and deliver efficiency comparisons among existing trading methods in relation to community energy trading, this paper presents a comprehensive assessment. i) It analyzes trading methods from not only the system efficiency but also the economic efficiency perspectives. The economic principles of diverse trading arrangements are investigated, based on auction and contract theory. ii) Sets up evaluation criteria ranging from the layers of economy and society. iii) Typical electricity markets using different trading methods are estimated using the assessment criteria above. The trading method characteristics and their influences on the market are analyzed, making it possible to explore their applicability in the distribution energy system.

This paper is organized as follows: section 2 introduces different trading methods and the typical electricity markets waiting to be evaluated; section 3 presents the detailed market assessment criteria and indicators; section 4 demonstrates the performance of typical electricity markets, analysing trading methods from the perspectives of both theory and market operation results; whilst section 5 draws conclusions and gives the next steps for future work.

2 TRADING METHOD CLASSIFICATION

There are different methods of outlining the trading method classification and this paper accepts the definition put forward in ***Fundamentals of Power System Economics*** [7]. Two trading methods, namely Bilateral Trading (including long-term contract, trading over the counter and electronic trading) and the Pool Model, are proposed and considered from the point of not only theory but also implication.

Comprehensive market assessment criteria and their indicators from perspectives of both quantity and quality are illustrated, under which the operation of two typical wholesale electricity markets (the UK's Bilateral Trading market and the Australian Pool Model market) are estimated.

3 ASSESSMENT CRITERIA

To estimate the application of different trading methods, assessment criteria from the perspective of economic efficiency and the society are established. Since this paper aims to evaluate trading methods from the view of market operation in theory, some technical conditions of real grids, such as network congestion, are ignored.

The indicators combine the quantity and quality analysis with the required calculation parameters and their equations are demonstrated in Table I.

Table I Numerical Calculation Parameters

Criteria/Indicator	Calculation Parameter	Formula	Description
Liquidity	Herfindahl-Hirschman Index (HHI)	$H = \sum_{i=1}^{N} s_i^2$	s_i: Market share of firm i N: Firm number
	Bid-offer spread	SP=B-O	B: Bidding price O: Offer price
Stability	Price standard deviation	$s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}}$	x_i: Sample item observed number $\bar{x}$: Observation mean value N: Observation number
Manipulation	HHI	IB	IB

The assessment criteria details and the indicators of each criterion are listed in Table II.

Table II Electricity Market Assessment Criteria

Benchmark Category	Criteria	Indicator
Economic Efficiency	Cost reflectivity	Liquidity (HHI & Bid-offer spread)
		Market signal
		Risk
	Stability	Price standard deviation
	Market manipulation	HHI
Society	Transparency	Price publicity level
		Counterparty publicity level
	Simplicity	Ancillary mechanism number
	Feasibility	Technology friendly level
		Customer negotiation position

4 CASE STUDY AND RESULTS

4.1 Cost reflectivity

4.1.1 Liquidity

Theoretically, a market with a better competitiveness degree also has the advantage in liquidity, since active market participants provide more trading opportunities and a stronger transaction willingness. The liquidity of the market can be reflected by the Herfindahl-Hirschman Index (HHI), a higher value meaning a greater competitiveness. The HHI in the UK wholesale energy market is 1600, calculated from the market shares of companies who supply electricity in 2017 [8], which is below the 2250 of the Australian National Electricity Market (NEM) [9].

The liquidity of the bilateral market can also be assessed by bid-offer spreads, which are shown in Fig. 1 for the UK wholesale market at different time periods [8].

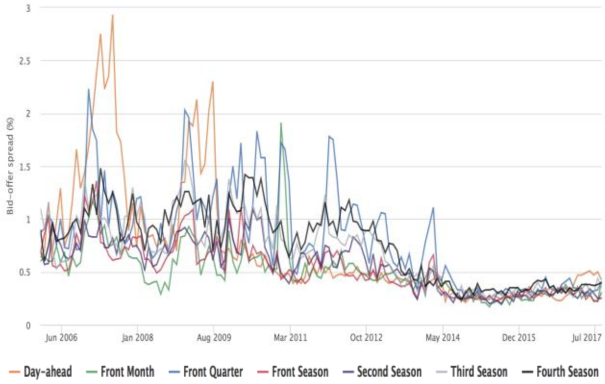

Fig. 1 Bid-offer spreads of UK wholesale market

Fig. 1 indicates a downward trend of bid-offer spreads in the UK since 2010, stabilizing at a low level in 2014. The results provide evidence of good-performance liquidity in Bilateral Transaction operation, while the Pool Model has a relatively poor performance in this criteria assessment.

4.1.2 Market signal

The definition of an efficient price signal is that a settled price could provide adequate information about market conditions (such as the relationship between supply and demand, changes in cost, etc.). Empirically speaking, the market using Bilateral Trading has a better price signal than that using the Pool Model. The price of bilateral contracts reflects more about the willingness of contracted parties, while the clearing price of marginal cost in the Pool Model can only represent the marginal information.

4.1.3 Risk

Four species of risk, caused by diverse trading method choices, are extracted.

Premium risk: risk of paying spread between contracted prices and spot prices

Balancing risk: risk of taking part in the balancing market and accepting the unforeseen balancing market price

Counter-party credit risk: risk that counterparts may fail to perform

Capital risk: risk of affording cash deposit against counter-party credit risk and lack of cash flow

The information of risks and their relationship between trading methods are shown in Table III:

Table III Risk Comparison Result

	Bilateral Trading	Pool Model
Premium risk	✓	
Balancing risk	✓	
Counter-party credit risk	✓	✓
Capital risk	✓	

As displayed in Table III, fewer risks are faced by the Pool Model, indicating an advantage in risk control and limitation.

4.2 Stability

The essence of market stability is the constancy of the price. Small fluctuations in price increase the confidence of market participants, which is beneficial for the market forecast and management.

The variability of market prices under diverse trading methods is assessed through practical market operation results. The electricity contract price of day-ahead base load in the UK wholesale market [8] and the volume weighted average spot price in the Australia NEM [9] are considered, with the cumulative curves of the different fluctuation degrees in the two markets are depicted in Fig. 2.

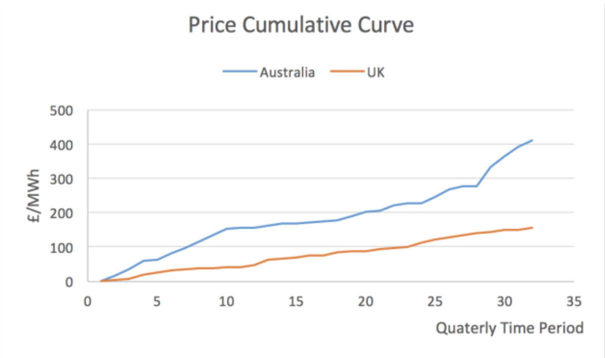

Fig. 2 Price Cumulative Curves

The price standard deviation in Australia (using the Pool Model) is 17.8 £/MWh, which is larger than the 6.34 £/MWh in the UK (using bilateral contracts), reflecting a more variable market. The low cumulative curve also reflects Bilateral Trading has a better price stability. This phenomenon can be explained as participants in bilateral contracts set prices through negotiation, which provides space for both sides to control the price scale, while prices in the Pool Model are only determined by the clearing result, dependent on marginal generation units.

4.3 Manipulation

Theoretically, more market manipulation exists in the Pool Model, where collusion is easy to achieve.

The electricity price shown in the current Australia market illustrates the possible existence of manipulation. The history of the average annual capacity used by the largest generator in each region in NEM provides evidence of price control [9].

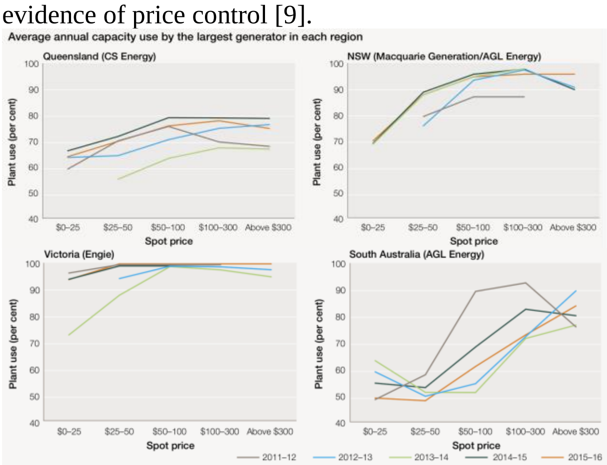

Fig. 3 Average Annual Capacity Use in NEM, Australia

In a competitive market with rational generators, more power is likely to be produced when the price rising. However, the price charts above show that generators chose to reduce their output with increasing electricity price in some years. This phenomenon reflects a possibility of deliberately withholding capacity to reduce supply and influence the price.

Market manipulation can be measured by HHI, sufficient competition (low HHI) reduces manipulation as no participant has enough power to control the market result. As mentioned previously, the UK has a smaller HHI (1600) compared with Australia NEM (2250) which showed a higher market concentration.

4.4 Transparency

The transparency of Bilateral Transactions is better than the Pool Model according to the operation process of the two trading models. Three typical Bilateral Trading modes are the customized long-term contract, over the counter (OTC) and exchange trading. Closed information is used in the customized long-term contract and OTC, as only contracted parties know settled prices. The situations of the exchange transactions within the Pool Model are different, which make the clearing price of each trade public although participants are anonymous.

Both exchange trading and the Pool Model have transparent clearing prices but the transparency initiative of the two models are different. For market participants, the Pool Model is automatically transparent in price, as there is only one clearing price for the Pool Model. The price of exchange trading, on the other hand, can be seen as a mandatory disclosure--market participants can't acquire price information of other transactions through their own trading. The transparency situation of Bilateral Trading is better than that of the Pool Model for market participants but for the society the transparency of Bilateral Trading (whose price is not published) is worse than that of the Pool Model.

The opinion of the market transparency degree should be treated dialectically. On one hand, market manipulation is directly linked with poor market transparency, providing opportunities and convenience. On the other hand, the low transparency electricity market trading method is accompanied with high competitiveness, which helps to reduce the market power. The conflicted relationship between market transparency and market manipulation should be judged upon not only theory, but also experienced market operation results.

4.5 Simplicity

It is inaccurate to justify whether a trading method is simple and effective, since the trading operation under the specific arrangement is fixed. Rather than to describe a simple trading method, the level of a market's simplicity using that method is considered.

There is an appeal to value market simplicity, especially from industry, nowadays which has already been achieved in management science. Market simplicity itself

gives efficiency and economy, as the simplification of process and mechanism saves both operation and human costs. A market which could remain simple while reaching construction goal must maximize utilization of resource and operation process.
Many existing mechanisms to counteract the negative effects of one trading method will change the market simplicity degree. The additional mechanisms under different trading methods reducing market simplicity are summarized in Table IV.

Table IV Mechanisms Reducing Market Simplicity

	Extra mechanism	Against
Bilateral Trading	Contract for differences	Premium risk
	Balancing market	Balancing risk
	Individual data publishing	Low-transparency
Pool	Regulation and investigation	Market manipulation

The table illustrates that Bilateral Trading needs more matching steps to cope with potential problems, thus the Pool Model has strength in the simplicity criteria from this point of view.

4.6 Feasibility

The distribution energy community has particular characteristics, and a feasible trading method must satisfy those points.

From the perspective of technique, typical participants in distribution energy systems, such as storage, renewable energy and demand-side response, are small-scale and decentralize-controlled. Thus, the expecting trading method should suit the small trading volume and diversification quotation, clearing close-zero bidding normally. From the community feature point of view, the contribution of distribution energy community is to provide an efficient trading platform, mainly for incentivizing end-users. To encourage their involvement, both the economic benefits and the transaction position need to be guaranteed.

A comprehensive estimation needs to be made between two trading methods in exploring and comparing their feasibilities, thus the result of comparing feasibility will be drawn in the conclusion part.

5 CONCLUSION

According to the theoretical analysis and wholesale electricity market operation comparison in the UK and Australia, the result of horizontal research among different trading methods is illustrated.

- Bilateral Transaction has advantages in liquidity. market signal providing and market manipulation control.
- The Pool Model has a better performance in risk limitation, transparency, and market simplicity degree.

The number of benefits appears equal, but the final conclusion of deciding which is the better trading method involves more issues. Importance proportion and criteria preferences are practical judgments to ensure suitable characteristics for the distributed energy community. Generally speaking, Bilateral Transaction may be more applicable in dealing with close-zero bidding and ensuring all market participants' right. Nevertheless, its potential high risk, low transparency and complexity also bring problems, especially to the new and immature trading platform.

In summary, the advantages and disadvantages of different trading methods are obvious, but it is too early to jump to a final conclusion in constructing the distributed energy community. More work about the relationship between trading methods and their technical environments should be carried out in the future, and the situation of the trading method combination should also be considered as an important development direction.

REFERENCES

[1] International Energy Agency. "Key World Energy Statistics," https://www.iea.org/publications/freepublications/publication/KeyWorld2017.pdf

[2] A. a. Siemens. "Distributed Energy Systems," https://www.siemens.com/content/dam/internet/siemens-com/fairs-events/fairs/2016/intersolar-2016/DES_Summary%20for%20decision%20makers.pdf.

[3] T. Dai, and W. Qiao, "Finding Equilibria in the Pool-Based Electricity Market With Strategic Wind Power Producers and Network Constraints," *IEEE Transactions on Power Systems*, vol. 32, no. 1, pp. 389-399, 2017.

[4] F. Lopes, H. Algarvio, J. A. M. Sousa, H. Coelho, T. Pinto, G. Santos, Z. Vale, and I. Praça, "Multi-agent Simulation of Bilateral Contracting in Competitive Electricity Markets," in 2014 25th International Workshop on Database and Expert Systems Applications, 2014, pp. 131-135.

[5] J. M. Morales, A. J. Conejo, K. Liu, and J. Zhong, "Pricing Electricity in Pools With Wind Producers," *IEEE Transactions on Power Systems*, vol. 27, no. 3, pp. 1366-1376, 2012.

[6] Z. Zhou, F. Liu, and Z. Li, "Bilateral Electricity Trade Between Smart Grids and Green Datacenters: Pricing Models and Performance Evaluation," *IEEE Journal on Selected Areas in Communications*, vol. 34, no. 12, pp. 3993-4007, 2016.

[7] Daniel Kirschen and Goran Strbac, 2004, "*Fundamentals of Power System Economics*", John Wiley & Sons Ltd, Chichester, UK, pp. 52-58

[8] Ofgem. "Wholesale market indicators," https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators.

[9] A. E. Regulator. "State of the Energy Market "; https://www.aer.gov.au/system/files/AER%20State%20of%20the%20energy%20market%202017%20-%20A4.pdf.