ELECTRICITY MARKET STRUCTURE IN THE DISTRIBUTION SECTOR

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ABSTRACT

This paper proposes an electricity market structure in the distribution sector which connects all market components. Whilst existing research on the market is mostly focused on transaction arrangements and market adaptability under differing situations. The market structure of distribution systems proposed in this paper offers a systematic view of all markets in the entire supply chain, illustrating their roles and relationships. Meanwhile, a future electricity market structure of distribution systems is also discussed. This paper contributes in three areas: i) The proposed electricity market structure provides a method to study market structure from the whole picture, offering a benchmark of the current electricity market structure. ii) The functions and potential changes of market participants are explored and discussed, complying with the transition from DNO to DSO. iii) The demonstration of future market structure provides a glance of future market options, paving the way for future energy development and their commerce.

1 INTRODUCTION

The decarbonisation agenda has increased the penetration of low carbon technologies and distributed energy resources (DERs) at the end of the supply system. A large volume of distributed generation will be installed in the next ten years in the UK. The installation of distributed generation has already taken over 12% of the new capacity in the USA [1, 2]. In the meantime, the current distribution network operators (DNOs) are concerned about their roles under this energy revolution. Existing projects in the UK, such as Open Network and From Distributed Network Operator (DNO) to Distributed System Operator (DSO), reflect the enthusiasm of studying DSO business, indicating the potential value of DSO transition[3-7].

Through substantially enhanced operational efficiency at the distribution domain, a smart and flexible energy system can convert these DERs into highly valuable assets to improving the utilisation of distribution networks and critically the utilisation of distributed energy. A key step towards a smart and flexible energy system is the creation of vibrate markets at the distribution level, through which, buyers and sellers of DERs can meet at the distribution level, enabling the existing system to absorb growing DERs whilst delivering major value for DERs. It is therefore critically important to create efficient energy markets that reflect the characteristics of DERs and the needs of customers and deliver customised energy products and services to address local energy needs.

A structure of the electricity market is expected to illustrate the market from a macroscopic perspective, but unfortunately there is no mature version. The current research of electricity market structure is divided into two categories [8-13]: i) The structure only emphasizes the energy market. The components of the energy market are proposed alongside time sequence in those research, involving day-ahead market, adjustment period, real-time market and ancillary services. ii) Although being called a electricity market structure, some research put forward structure components according to the market liberalization degree, which is actually the power industry structure. (i.e. vertical unbundling without horizontal unbundling, partial vertical unbundling, full vertical and horizontal unbundling in generation, vertical unbundling in lesser forms than ownership unbundling, and unbundling of generation services in wholesale power markets). Very few research explores the market from the entire supply chain perspective, thus difficult to tackle the huge changes brought by the introducing of distributed energy resources and markets in the distribution sector.

To address the existing issues and promote energy transition, three pieces of work have been done in this paper: i) Proposing an electricity market structure in the distribution system and visualising the situation of each market, offering an intuitional understanding of the entire electricity market. ii) Putting forward the future electricity market structure in the distribution system, providing a fundamental understanding of the future energy transaction platform. iii) Exploring the roles of DSO in the future electricity market and comprehending their responsibilities in the future business.

This paper is organized as follows: Section 2 introduces the multi-layer electricity market structure in the distribution system and provides a detailed discussion on market components at each layer; Section 3 proposes the future electricity market structure in the distribution system; Section 4 draws conclusions for this work.

2 CURRENT ELECTRICITY MARKET STRUCTURE IN THE DISTRIBUTION SECTOR

2.1 Reference Architecture

As discussed above, neither the accurate scope of the electricity market nor a clear market structure has been put forward. However, a reference architecture is valuable to electricity market construction. The Smart Grid Architecture Model (SGAM) developed by Smart Grid Coordination Group/ Reference Architecture Working Group provides reference architecture. By using different perspectives and methodologies considering the development and conceptualization of the
Smart Grid [14], the SGAM architecture proposes an overall Smart Grid-domain construction from a holistic perspective. The Smart Grid Architecture Model is illustrated in figure 1:

Three sections (organizational, informational, and technical) are expressed in the architecture, with corresponding five layers, directly seen in the model. One single layer of the SGAM includes two dimensions, which describe not only the electrical energy conversion domains but also the electrical process management.

Taking the SGAM architecture as a reference, a similar multi-layer concept is adopted by the electricity market structure in the distribution sector proposed in this paper, which also contains necessary descriptions of a single market in each layer.

2.2 Current Market Structure

The electricity market structure in the distribution sector proposed in this paper presents a multi-layer architecture. The structure integrates commercial elements of the electricity system in the distribution sector with different layers and corresponding markets. The specific markets in each market layer are introduced and the function and participants are explained, providing the convenience for further exploration of each market layer. Figure 2 shows the proposed electricity market structure in the distribution sector under the UK electricity market background.

2.3 Introduction of Market Dimension

Three layers are contained in the electricity market structure, corresponding to three markets from the market dimension. The energy layer only contains the energy market, responding for energy transaction. The second layer, network layer, contains two markets: i) Ancillary service market, ensuring system security and power quality ii) Connection and use of system market, recovering the cost of the transmission system. Two perspectives of the network are illustrated in this layer, which fulfils network function (dealing with technical issues that may happen in the network delivery process) and satisfies the financial requirement.

The entire supply chain of the electricity market is expressed in the structure, whose operation and management processes are demonstrated through energy market and ancillary service market, and the financial issues are addressed through the connection and use of system market.

2.4 Introduction to different Layers

Apart from different layers and corresponding markets from a macroscopic view, the major elements of markets - function and participators, are also indicated in the proposed whole-system market structure. A detailed introduction to each market layer towards those angles will be illustrated in the following parts.

2.5 Market Components

2.5.1 Energy Market

The energy market is the energy transaction platform. The only component of the energy market layer in the current distribution sector is the Cornwall Local Energy Market (in the UK). Operated by Centrica’s Distributed Energy and Power Business, this trial in Cornwall is expected to set up a local transaction platform providing flexible demand, generation and storage, in order to fulfil the optimization of local grid capacity. The initial stage of establishing this regional local retail market is to solve the heavy grid constraints in Cornwall, which happens due to the large penetration of renewable generation with the
limited network capacity. Compared to the traditional network reinforcement, the cost of the building local energy market is less and could save several years’ time.

Although being constructed under specific demand, the participants of this regional retail market are similar to all other energy markets, which are generator, retailer and customer.

2.5.2 Ancillary Service Market

Also known as balancing services in some countries, the ancillary service market is responsible for balancing the demand and supply physically and ensuring electricity security and quality. The market, operated by Transmission System Operators (TSO), happens between TSO and corresponding service providers. The tradeable services are integrated and settled as components in the ancillary service market layer, including frequency response market, reactive power market, reserve market and security service market. The only component included in the current distributed sector is the trial of reactive power service, illustrating the penetration and participation of distributed energy resources. The reactive power service market fulfills voltage management, whose existence ensures system voltage level within an acceptable range. All the reactive power services, no matter those obligatory or enhanced, could participate in the reactive power market.

2.5.3 Connection and Use of System Market

The connection and use of the system market is the platform where network owners charge system users. Taking the function of cost recovery, the existence of connection and use of the system market ensures the long-term operation of networks and economic benefits.

There is a distribution use of system tariff market in the distribution sector, covering the cost of operating and maintaining electricity infrastructure (overhead lines, underground cables, substations and transformers) between the transmission system and end users. Accounting for around 15% of the overall electricity bill, the distribution use of system tariff has already been included in the electricity expense and does not need to be charged specifically [15]. However, the distribution use of system tariff market is still settled to guarantee the systematization and symmetry of connection and use of the system market layer.

Because the components of connection and use of system market appear between the network owner and system users, the Distribution Network Operator (DNO, the distribution network owner currently in the UK), is taking the responsibility of charging distribution use of system tariffs from distribution system users.

3 FUTURE ELECTRICITY MARKET STRUCTURE IN THE DISTRIBUTION SECTOR

3.1 Future Market Structure

The number of market components in the future distribution sector for both the energy market and the ancillary service market. It is mainly due to the incremental independence degree of the distribution sector, as more markets for distribution level are needed when services of original markets are not covered. A future market structure in the distribution sector is provided in figure 3 to illustrate a clearer overview of the components.

3.2 Future Market Components

3.2.1 Future Energy Market

There are local energy markets, local balancing markets and local retail markets in the future distribution energy market layer. Taking similar responsibilities of the national markets, the ‘local’ indicates the market transition from nation to distribution systems. The match of electricity supply and demand happens in the wholesale market, where generators trade with retailers or sometimes directly with customers [16]. Wholesale markets around the world adapt different trading methods. For example, transactions in the UK wholesale market take place bilaterally or on the exchange. And the National Electricity Market (NEM) in Australia is under the pool model that trades and dispatches electricity centrally. The balancing market, i.e. the balancing mechanism in some countries, exists to ensure the real-time balance of supply and demand. Although this second-to-second balancing process in some countries may completely be synchronous with the wholesale transaction (NEM in Australia, for example), the component of balancing market is still put forward in the structure for the market symmetry. Given the opportunities to select retailers, customers in the retail market shop around their electricity suppliers to choose the one they are most satisfactory with. The retail market could be considered as a link between customers and energy, as retailers purchase electricity from the wholesale market and settle the delivery towards end consumers.

The penetration of DERs makes it a trend to construct a market specifically for the distribution sector, as the characteristics of DERs could be optimized under special market operation such as p2p trading. The current trial of the local energy market in Cornwall that introduced before also indicates the same direction. The different trading
arrangement compared to national markets leads an independent transaction system to be a better option, which means constructing the whole set of the energy market in the distribution level.

3.2.2 Future Ancillary Service Market
Other than the only reactive power market in the distribution sector of the current ancillary service market, the local reactive power market and the local security service market are settled in the future distribution ancillary service market.

The Open Network Project has put forward future DSO services, namely future ancillary services [17]. The real power service for constraint management, the reactive power service for voltage control, the whole-system approach to black start and restoration support are mentioned in the report. The voltage control corresponds to the local reactive power market, while the constraint management, black start and restoration support could integrate to the local security service market.

3.2.3 Future Connection and Use of System Market
To recover the network cost, the future connection and use of system markets in the distribution sector remain unchanged compared to the existing markets. Relating to the electricity infrastructure between the transmission system and end users, the distribution use of system tariffs exist in the connection and use of the system market layer.

For distribution use of system tariffs, there are common distribution charging and EHV distribution charging for low voltage (LV), high voltage (HV) and extreme high voltage (EHV) respectively.

3.3 Future Market Participators
Apart from the market components, the participators of markets in the distribution sector are also different between the current and future situations. In summary, the changes can be integrated as the transition from the DNO to DSO. The DNOs in the current electricity market structure are transferred to DSOs. To adapt the penetration of DERs, the DNO is developing from the current one-way delivery to future multiple points of variable supply and consumption of DSO. The existence of DSO in the ancillary service market layer are responsible for providing both operation and balancing services. The service providers trade with DSO, and many DSO services could also be expected according to the study of Open Network Project[17]. By charging from distribution system users, the DSO in the connection and use of system market share the same roles of DNO.

4 CONCLUSION
A multi-layer electricity market structure in the distribution sector is constructed in this paper, expressing entire commercial elements in the electricity system. The proposed electricity market structure covers operation and management, completing to describe the process from energy transaction, network delivery and participators’ cost recovery. Three products are offered in this paper:

- A structure to describe the current electricity market in the distribution sector is constructed, providing a macroscopic perspective of market research.
- The future market structure in the distribution sector is established, offering market situation under developing energy scenarios.
- The comparison of participators is made between current and future market structures, proposing deep understanding from perspectives of not only the structure itself but also market active parties. This paper contributes in three areas: i) The proposed electricity market structure in the distribution sector offers a mentality to research market structure from entirety point of view, laying a foundation in understanding, constructing and operating distributed energy business. ii) The functions and possible changes in market participators are explored and discussed, complying with the transition trend from DNO to DSO. iii) The demonstration of future market structure in the distribution sector provides a glimpse of future market options, paving the way for future energy development and their commerce.

REFERENCES


