Chapter 5

c0025
The role of various market participants in blockchain business model

Saber Talari[a], Hosna Khajeh[b], Miadreza Shafie-khah[b], Barry Hayes[c], Hannu Laaksonen[b] and João P.S. Catalão[d]

[a]*Fraunhofer Institute for Energy Economics and Energy System Technology, Kassel, Germany,* [b]*School of Technology and Innovations, University of Vaasa, Vaasa, Finland,* [c]*School of Engineering, University College Cork, Cork, Ireland,* [d]*Faculty of Engineering of University of Porto and INESC TEC, Porto, Portugal*

s0010
1. Introduction

p0010 Decentralization of energy networks will bring generation units close to customers. This enables reduction of energy losses and emissions thanks to renewables, like photovoltaic systems (PVs) and wind turbine-based generation. Moreover, active utilization of distributed energy resources (DER) control potential can enable improvement of power system reliability and resiliency at both local (e.g., distribution network) and system-wide (e.g., transmission network) levels. Active and intelligent utilization of DER for local and system-wide needs is dependent on available enabling technologies and market and regulation schemes. For example, some countries have made some regulations to run peer-to-peer (P2P) electricity markets.

p0015 In addition to other applications, blockchain technology can be used to realize P2P markets in which transactions are done in a decentralized way without any requirements for a central entity like distribution system operator (DSO). Blockchain technology-based decentralized P2P market is able to handle hundreds or thousands of transactions almost in real time. For example, the blockchain algorithm of Bitcoin is able to handle seven transactions per second [1]. Therefore some other algorithms such as Ethereum with ability of handling tens of transactions per second or Hyperledger to deal with hundreds of energy transaction [2] can be employed, instead.

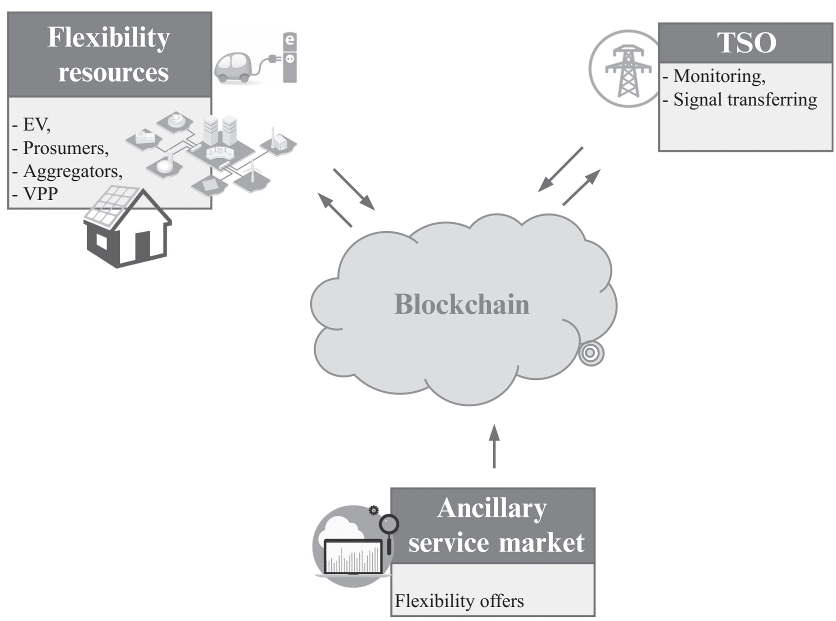
p0020 Some recent pilot projects have applied the aforementioned blockchain algorithms. For instance, a blockchain-based P2P energy trading in Brooklyn,

Blockchain-based Smart Grids. https://doi.org/10.1016/B978-0-12-817862-1.00005-1

USA, has been performed experimentally to buy and sell energy among prosumers by Ethereum platform for the smart contracts [3].

p0025 Accordingly, blockchain technology has potential to be able to integrate different market players in new and better way than today to provide, e.g., balancing services. Moreover, it can incentivized new players through special smart contracts. For example, electric vehicles (EVs) can be paid for their active role as energy supplier or demand response provider. As Fig. 5.1 shows, market participants in blockchain-based platform are communicating together in almost real time, and the platform is able to analyze big data that all leads to better trading system. Within this blockchain-based trading platform, participants can automatically settle contracts physically and financially.

p0030 For example, provision of energy balancing technical flexibility services for local (DSO) or system-wide (transmission system operators [TSO]) needs by different available flexible resources like EVs, demand response, energy storages, or distributed generation can be done either directly or through ancillary flexibility service markets as shown in Fig. 5.1. In traditional markets, ancillary service provision is done through hierarchical trading and market scheme in such a way where TSO confirms the compatibility of the service providers (i.e., flexibility sources) to participate in different ancillary service markets. Then, flexibility offers are sent to the TSO and related flexibility sources from different markets. However, in decentralized blockchain-based scheme, all



f0010 **FIG. 5.1** Blockchain-based platform for flexibility trading with market participants.

participants are connected to each other directly. Therefore a transaction can be settled automatically without need of central entity or intermediary.

p0035 The rest of this chapter contains the following section. In Section 2, different market participants are introduced, while their role in the blockchain-based market platform is discussed. In Section 3, different possible business models for blockchain platform are presented, and the position of each market participants within the models is described. Finally, some remarks and brief results regarding this study are indicated in Section 4.

s0015 2. Market participants

s0020 2.1 Prosumers

p0040 An increasing number of customers can act in the future as a prosumer, i.e., be both producer and consumer. In fact, they are able to produce their own energy while consuming. Depending on the available management systems and storage solutions, prosumers can be able to produce their own energy that they need for their consumption. On the other hand, prosumer can be also defined as a household with DERs for self-consumption and extra production (generation). Depending on the available technologies and regulation, household prosumers can participate in different type of markets with different business models like P2P, flexibility trading, over-the-counter (OTC) trading, and crowdsale trading [4, 5].

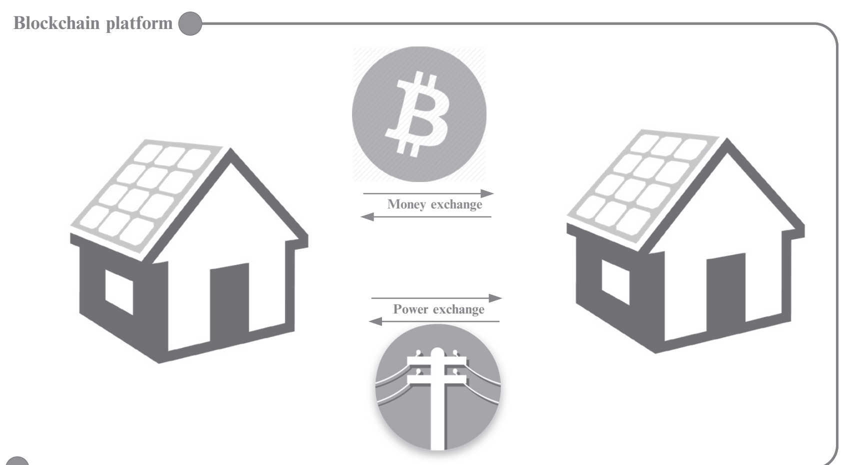
p0045 In the user-centric control and market approaches, suitable incentives to achieve maximum simultaneous collaborative benefit for all different parties should be found and aimed at. From prosumers' viewpoint, it is important to have enough possibilities to offer their flexibility services to maximize own benefits. Therefore prosumers should be able to participate in local market or make a contract with an aggregator or flexible operator. Prosumers can have several flexibilities such as renewable energy resources (RES), controllable loads, battery storage, and EVs that enable them to be active players in the market [6]. If they would like to participate in a local market, retailer price can be upper bound for them to pay, and the feed-in tariffs for distributed energy resources are the lower bounds for the price that sellers would accept. On the other hand, P2P trading with other market players is another good option.

p0050 In this sense a digital currency can be assigned for prosumers in smart grids to enable them to trade their load and generation. On the other hand, prosumers with various appliances cause huge load, generation, and flexibility forecasting uncertainties in the distribution networks, although controllable loads can use to handle this problem and minimize negative effects on power system. Moreover, with high penetration of prosumers in the low-voltage (LV) network, some barriers and limitations in terms of communication and network power flow appeared, which should be addressed by new technologies and management schemes. In addition, enabling business and market models is needed, which are compatible with new management schemes and operation principles. The target is to enable also participation of local small-size customers on providing different flexibility services. It is stated in literature that blockchain can provide innovative trading platforms where prosumers can exchange the surplus production and flexible demands [7]. These transaction can be performed in a secure way with transparent smart contracts [3, 8].

p0055 Prosumers can be considered individually in this market framework and make the transaction by their own. In this sense the P2P transaction among prosumers would be like Fig. 5.2.

p0060 Accordingly the generation and demand are measured by smart meters. The extra generation and demand are defined and transferred from one prosumer to another through some smart contract in blockchain platform. Based on smart technologies the load pattern and generation of RESs for prosumers are forecasted, and each prosumer would share the needs such as buying or selling the power within the blockchain platform in near real time, and the transaction among matched prosumers would take place. The market and transactions are performed virtually in blockchain, and the electricity would exchange through physical network as it is depicted in Fig. 5.2.

p0065 On the other hand, prosumers can be introduced and formed within different frameworks such as virtual power plants, microgrids, or aggregators that offer different values to the prosumers in the market [9]. It means that prosumers usually interact in the network as a part of a larger section of the network. Therefore the study of the prosumers has been conducted while considering one of these bigger entities. The selection of the entity is dependent on the placement of the prosumer. In the other words the prosumers who are a part of virtual power plants (VPPs) should be studied with the role of VPP. That will be the same



f0015 **FIG. 5.2** Transaction among individual prosumers through blockchain platform.

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for prosumers in microgrids or integrated by aggregators. It is noteworthy that there are also some independent prosumers that obviously can be studied in blockchain framework in a different way.

s0025 2.2 Aggregators

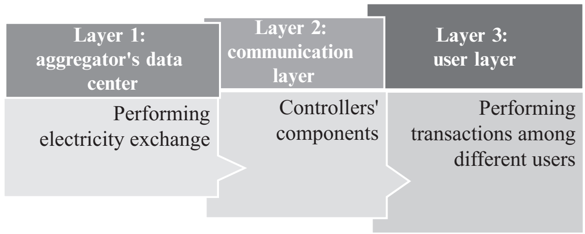
p0070 Aggregators serve as a broker for transactions between energy suppliers and several houses. These aggregators can be utility companies, commercial aggregators, commercial aggregators, or community groups who enable prosumers and customers to participate and transact in blockchain market scheme and platform [10]. Indeed, they are considered as validators for efficient use of DERs and prosumers while acting as a single entity. In blockchain scheme, it is possible that either DERs act individually or through aggregators in the market [11].

p0075 The better coordination among aggregators, TSOs, and DSOs provides a better solution for grid congestion management. Therefore blockchain developers are trying to find innovative solutions for automation and decentralized grid control. Since transaction speed for real-time grid management is also vital, suitable metering, grid infrastructure, control and communication systems in power networks, and among aggregators in this platform should be provided [7].

p0080 In a blockchain platform the transactive infrastructure has three layers as described in Fig. 5.3. The first layer is aggregators' data center where the electricity exchange is carried out. This layer is a virtualized set of servers operated by aggregators with a digital communication. The second is communication layer including all components requiring transactive controllers. The third is user layer where the transaction among different users through the IT infrastructure is performed.

p0085 The aggregators can be for VPP to deliver some services to TSO in ancillary service market. In this way, VPP aggregator is an interface among internal prosumers and external parties like TSOs, DSOs, and market operators [7]. The aggregator here refers to VPP owner or community manager.

p0090 A framework can be introduced in a way that aggregators of VPP provide generation or demand schedule for the relative prosumers while considering the network constraints. Through this schedule, aggregator can participate in ancillary service market effectively. It is supposed that the prosumers of a VPP are



f0020 **FIG. 5.3** Different layers in transactive controller of aggregator.

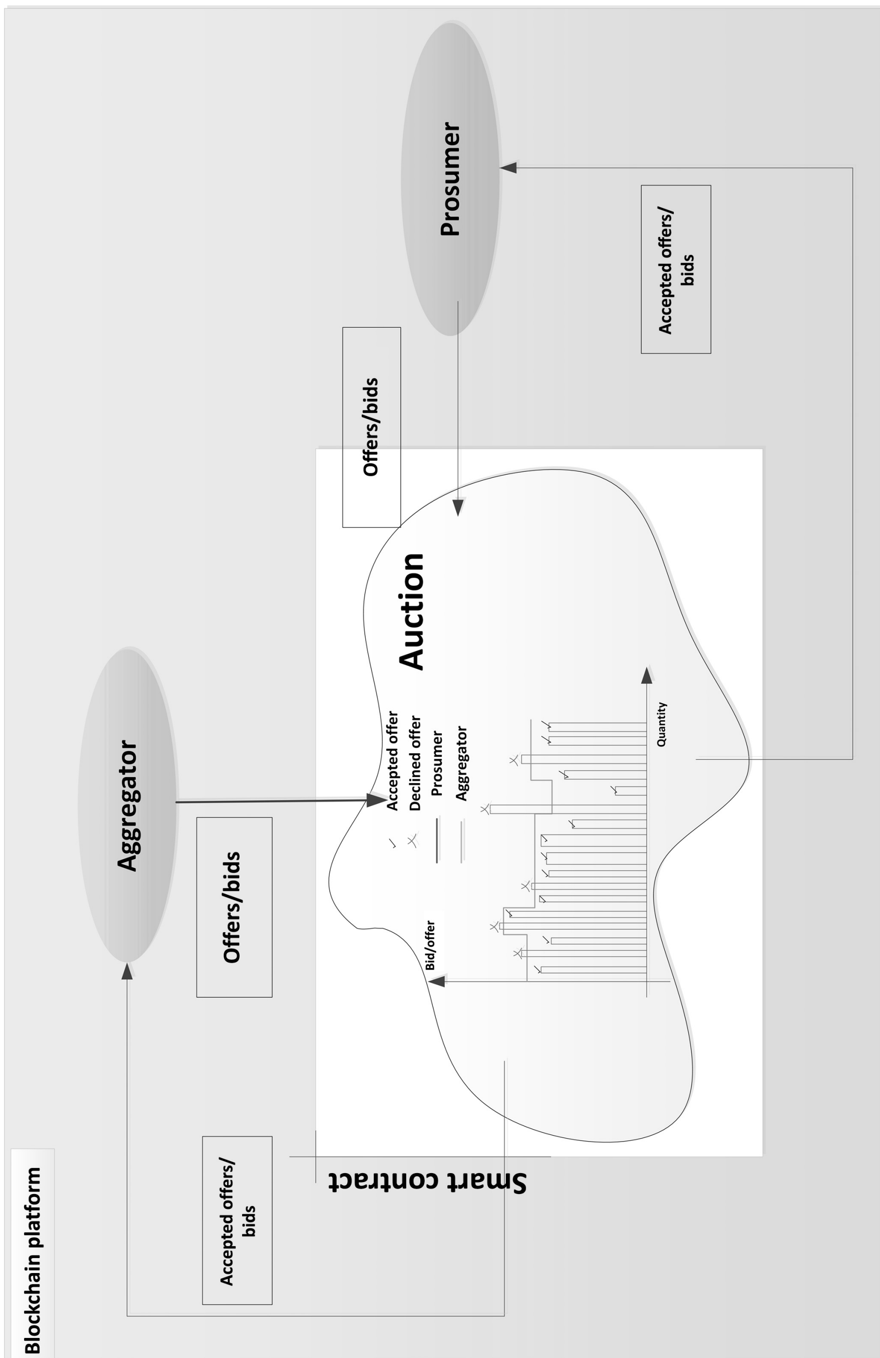
connected to the same distribution network and the aggregator schedule would occur while meeting the technical distribution constraints. In case of any deviation from the schedule, aggregators bid/offer the relative prosumers to buy/sell the required electricity in a special price via a smart contract within blockchain platform. Prosumers are able to react to the aggregator's bid in an auction by their transactive controllers. This smart contract is a set of rules encoded in blockchain to run the auction and define the accepted bids or offers for aggregators. Therefore, in the smart contract in the format of blockchain, after making bids by aggregators, prosumers with lower offers are selected until the required quantity of the bid is reached. The complete procedure is shown in Fig. 5.4.

p0095 Based on the Fig. 5.4, in a blockchain framework, the interaction of aggregators in the market can be formed in such a schematic way. Accordingly, aggregators can register their bids in the auction based on a smart contract while being lack of enough energy. At the same time, prosumers are able to register their offers. In this way, aggregators can integrate several prosumers, DERs, or other kinds of players who are able to compensate the shortage of power, although, in this example, it is supposed that prosumers are integrated by aggregators. These bids/offers are registered based on a smart contract mentioning the price and quantity of energy. Accordingly the prosumers whose offered price is lower than the aggregated bid will be selected. The blue line in the figure is all bids by aggregator, and the green bar lines are offers by different prosumers. As can be seen the offers by consumers with higher price than aggregator bid are not accepted. The selection will keep up till the all power shortage by prosumers are covered.

s0030 2.3 Virtual power plants

p0100 To coordinate a vast number of DERs with different owners, the concept of VPP can be a solution while transacting among all self-organizing prosumers. Indeed, VPP collects several numbers of coordinated DERs to have controllability, visibility, and impact at transmission grid. The concept aims to achieve upstream generation and transmission capacity reduction, network efficiency, and energy increment and pollution reduction. VPP operator is also in charge of providing upstream services to wholesale market and grid operators by aggregation of large number of prosumers and DERs [12].

p0105 The strategy to make a VPP varies based on the type of the incorporated DERs, the way of operation, and provided services. Accordingly, VPP can control the DERs directly, or this control can establish indirectly through sending incentive price signals to effect on prosumers' consumption and generation. In direct control, DERs can be dispatched according to their operating parameters and owners' preference [13]. In this case VPP has certainty over the facilities that DERs can provide like capacity and response. DERs in this control can provide fast timescale services such as frequency regulation [7]. To this end,



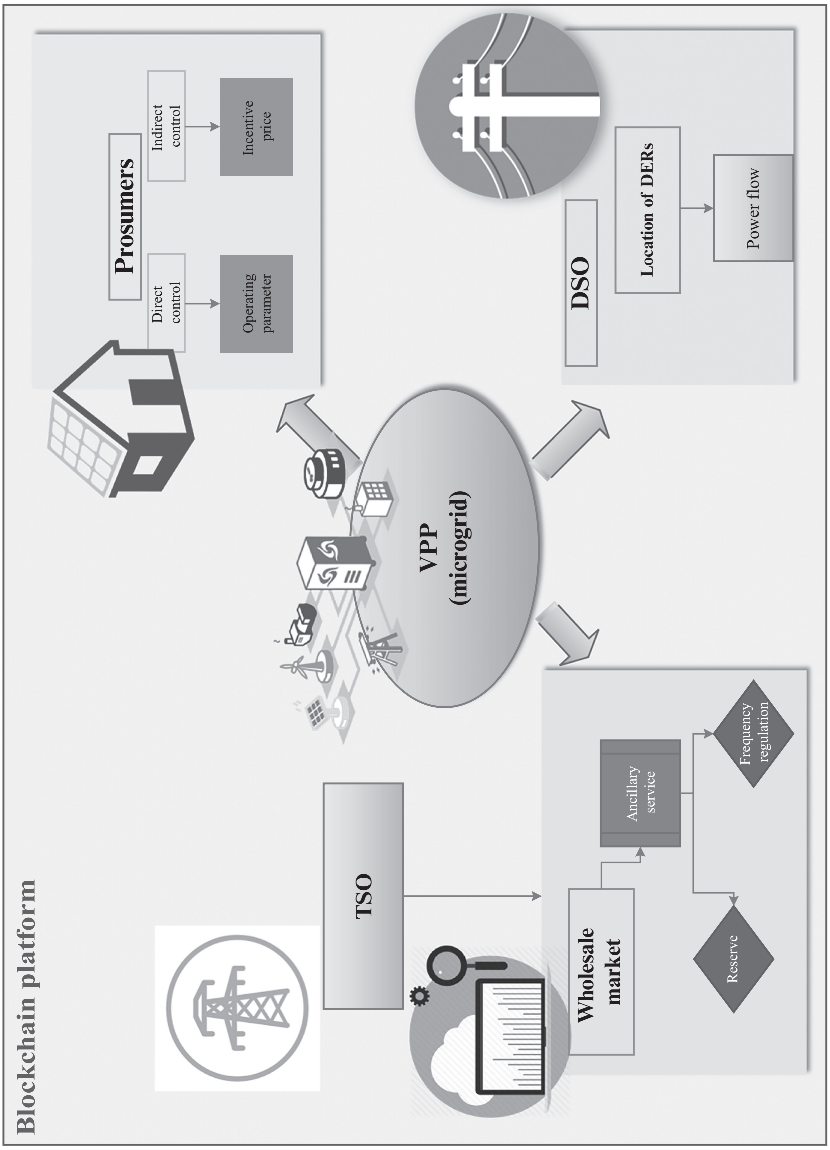
f0025 **FIG. 5.4** Smart contract in an auction among aggregator and other players within blockchain platform.

distributed optimization methods are suggested such as Lagrangian relaxation run by VPP operator. It means that the communication and processing are carried out in distributed way, yet all require design and operation by a single entity. Through indirect control, prosumers decide about the local consumption and generation based on considering the incentives and their preferences. Time-of-use (ToU) pricing is one of the incentive pricing methods that encourage prosumers to shift the loads to reduce the upstream capacity. Day-ahead hourly pricing and location-based pricing in distribution network to coordinate DERs are some other examples of incentives. The benefits of this method are independence of prosumer over the scheduling of their flexible loads and reduction of communication requirement and privacy concern due to using unidirectional signals. On the other hand the method may cause new peak hour due to risk of shifting all loads to the special off-peak time. All in all, direct control does not provide enough flexibility for prosumers, and indirect control makes difficult for operator to predict the prosumers' behavior. Therefore an intermediate solution between direct and indirect method can be a solution to overcome all obstacles for VPP.

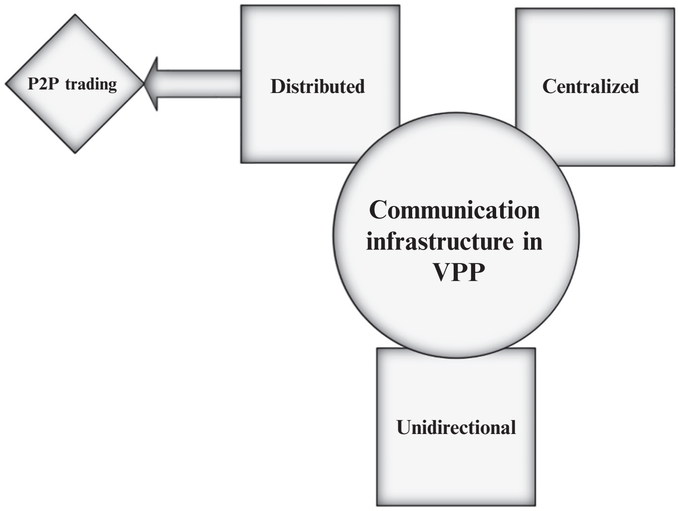
p0110 In Fig. 5.5 the possible interaction among VPP and the players in the market is depicted. As mentioned, prosumers in this structure have two ways of controlling, direct and indirect. An approach containing both of these controlling methods can be applied for a blockchain platform. Within this platform the location of DERs in distribution network is important, in the sense that the relative DSO would be able to run an accurate power flow. One of the advantages of this strategy is that VPP can participate in wholesale market and procure some ancillary services such as frequency regulation and reserve. Blockchain platform provides detailed information for VPP to be participated in the market more effectively.

p0115 VPPs with controlling large number of DERs are able to provide some grid services including ancillary services such as reserve and frequency regulation through some transactions in wholesale market organized by TSOs [14]. The interaction among DSO and VPP is also vital to reduce the loss and improve voltage regulation. Since VPPs have knowledge about the location of their DERs, they can provide some grid services for DSO for management of distribution network [15]. In this case DSOs will be able to efficiently integrate DERs by managing the power flow of the distribution network, actively.

p0120 It is noteworthy that microgrids can be also operated as VPP [16]. They include DERs and loads that can operate as a part of network or autonomously in an island mode. The communication architecture for VPP can be centralized, distributed, or unidirectional. Centralized communication is for the situation that prosumers communicate with a central VPP coordination, although distributed communication uses P2P prosumer-to-prosumer connection. In addition, in unidirectional communication, prosumers only receive information from coordinator. According to Fig. 5.6 the most suitable communication infrastructure in VPP for blockchain implementation is distributed one.



f0030 **FIG. 5.5** Possible VPP architecture in blockchain platform.



f0035 **FIG. 5.6** VPP communication infrastructure.

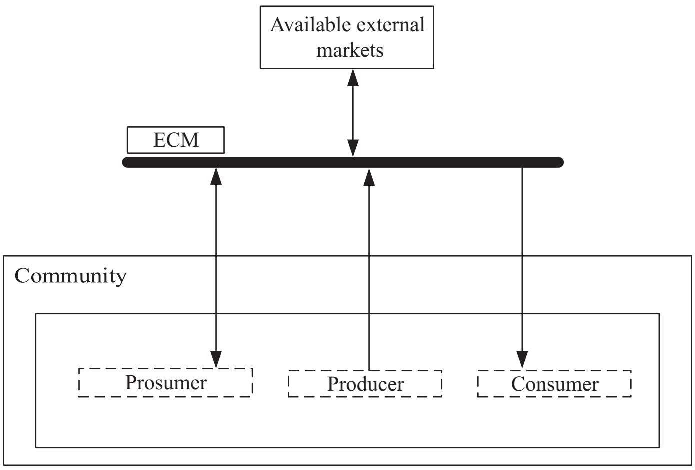
s0035 2.4 Energy community manager

p0125 An energy community manager (ECM) aims to manage business activities within a community usually known as members with common interests and aims. Hence a community can be a microgrid, or a group of neighbors such as prosumers who are geographically close to each other. In addition, ECM plays also a role as intermediator among the relative community and the other parts of the market [17].

p0130 Within each community the sum of all the trades is controlled by ECM regardless which member is trading, because all the procedure is handled centrally by ECM. Therefore one of the objectives of ECM is to minimize the costs for each community subject to meet the balance constraint within the community among members. On the other hand the energy exchange with other markets outside the blockchain platform is also controlled by ECM. To this end, import and export energy is balanced, and the expenses for the communities to trade with other markets are aimed to be minimized. This model can be almost similar to day-ahead market model. The role of ECM is depicted in Fig. 5.7.

s0040 2.5 System operators

p0135 In blockchain-enabled systems, direct energy trading among local producers and consumers takes place. Therefore this energy trading is normally carried out in small communities. Nevertheless, the main question will be how to fit the mechanism to existing system operator companies such as DSO, TSOs, and ISOs who are eventually responsible for grid infrastructure and power delivery. Operators play a key role in the stable operation of the network even



f0040 **FIG. 5.7** ECM example.

when a complete decentralized operation is carried out in the network. The blockchain market can improve the efficiency of the market though [7].

p0140 Indeed, these operators make sure that the decentralized agreed contracts can be practically settled due to physical network constraints; hence the role of operators would be essential for implementation of blockchain. The benefits of blockchain market for operators can be as follows: First, blockchain can provide more precise information for operators in using the network and relative network fees such as distribution fees. Even for P2P transaction the grid charge should be accounted. Moreover, this recorded information about P2P transaction will help operators to better manage the capacity and power flow in the relative network. However, these potential benefits would need to have new management system to record blockchain information close to real time.

p0145 System operators' actions in blockchain platform should be limited because it may lead to market distortion and social welfare reduction. DSO has a great opportunity to increase the grid efficiency. To this end, one approach is to introduce a dynamic or nodal-based grid fees that work as an incentive for participants in the market. For example, prosumers should be more market oriented to participate in the market. Moreover, DSO can purchase different flexibilities such as reserve from flexibility market within the blockchain platform [18].

p0150 Regarding the interaction among blockchain and DSO, transition from complete physical electrical system to cyber system may cause some challenges about unfamiliarity and incompetence of DSO with new technologies. Therefore, if DSOs eventually will not be able to merge the cyber electric system, the ownership of the physical network should be separated from the operation. In this case the ownership of the blockchain platform would be for other players who will control all the end users' relations and access, and DSO just owns the cables [19].

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p0155 Conventionally, network balancing was provided by TSO at high-voltage level, although nowadays, with increasing the number of RESs, the required flexibility for providing the balance can be applied within demand-side and low-voltage level. However, with large number of flexible recourses in this level, the complexity of operation would be higher for the operator. Therefore blockchain can be applied for decentralized operation of these flexible sources. This idea has been implemented by TenneT, a Dutch TSO, in cooperation with IBM as open-source blockchain provider and Vandebron as P2P trading platform in Netherlands and Germany [20]. Based on this project, EVs and customers' batteries are in charge of providing electric network balance to make the integration of RES more cost efficient. Accordingly, end users, through the electric cars and storage, provide flexibility for TSOs. There is no P2P transaction in this method, although a bidirectional communication between customers and TSO makes the transaction easier.

p0160 Blockchain is also able to remove the transmission and distribution charge for customers in which the former is about 12% and the latter is around 18% of the electricity bill [21]. In this sense, customers are able to freely transact with the generator rather than dealing with energy suppliers and grid operators. For example, large customers can purchase the electricity from PV farms or distribution network without the need of intermediary like transmission network. Therefore the transmission charge would be removed. Even in smaller scale, customers, with smart technologies in appliances, can purchase the required electricity from neighbors' PV. Therefore they can transact among themselves without need of distribution network, and its charge would be omitted.

p0165 To make all the aforementioned features practical, it is necessary to make the policies and regulations proper for DSO and TSO in all countries.

s0045 3. Blockchain business model

p0170 Blockchain technology was first employed as an effective mechanism for verifying cryptocurrencies, and later it was applied to broader economic issues such as energy transactions. Its application in energy markets was first proposed in [22] as a powerful tool for setting the value of RES based on the smart meter data.

p0175 Systems equipped with blockchain technology consist mostly of a distributed ledger, a decentralized consensus mechanism, and cryptographic security measures [23]. All users (participants or nodes in blockchain network) are allowed to directly share information and hold the copies of transaction records, called ledger. In the blockchain-based trading, the validity of a transaction is confirmed if all of the nodes achieve a common consensus [24]. Transactions should be confirmed through the use of predefined consensus in a shared execution manner, named smart contracts. Despite the unrestricted access of participants to transactions, each node can only access to transactions in which the participant was involved. Cryptographic hash functions are utilized so as to preserve privacy of inputs.

p0180 A set of rules is established in blockchain networks to approve the transactions. They are considered as consensus protocols. Today, proof of work (PoW) and proof of stake (PoS) are the most common consensus protocols [25]. All participants are required to do a complicated cryptographic puzzle so as to approve an energy transaction if the network consensus protocol is PoW [26]. Mining is the process through which the agreement is reached. This kind of protocol consumes a considerable amount of energy, time, and even money since they need to invest in the powerful hardware. In comparison, only nodes with highest stakes (stakes can be cryptocurrencies or values) can grant access to verify transactions, leading to a less energy footprint [27]. Reference [7] modifies the PoS protocol through the use of a hard-to-forge stake and a permissioned architecture. The modified protocol, named proof of energy (PoE), proved to be sufficient for energy markets as it aims at promoting self-consumption of peers in electricity markets, helping to reduce power losses.

p0185 Blockchain is categorized into private and public according to the nodes allowed to participate in the consensus process. In a public blockchain, anyone is able to join the blockchain-based network without any permission. On the other hand the accessibility options are limited for the participants of the private network. Moreover, only some designated nodes are chosen to verify transactions sharing in the private blockchain [28].

p0190 Some salient features of blockchain technology facilitate implementing a decentralized platform for energy markets. In a public blockchain-based market, there exists no central entity to manage, monitor, and approve the legibility of transactions. Accordingly, all of the users participating in the blockchain-based market have an equal right since they can submit a bid and accept an offer in a free and flexible way. Decentralization can also reduce the costs of transactions by eliminating the costs allocated for an intermediary. Besides, transactions recorded through all nodes are open and transparent, helping to solve problems related to information asymmetry [29]. As a result, it can guarantee the safety of the data information entered into the blockchain-based network. Finally the anonymity of counterparty is another key feature of utilizing blockchain so that participants can bilaterally trade with the other parties without knowing them.

p0195 Blockchain technology can be applied to wholesale, retail, and local markets. However, most of the studies analyze decentralization through blockchain in distribution networks and local markets. The most common distributed ledger technology (DLT) considered for energy markets is Ethereum, which can cope with tens of transactions per second [2]. However, Ethereum would not be suitable for a market consisting of many prosumers and consumers as it may take a considerable amount of time. Hyperledger, on the other hand, is able to support hundreds of transactions, making it a wise choice for a huge market [7].

p0200 The following sections discuss four main business models enhanced through the use of blockchain technology. Generally a business model shows the ways that the business works. To define a business model, some definitions should be introduced. Value in business models is defined as the amount of money paid to the seller [4]. A value proposition is the product offered to the customer [30]. Accordingly the value proposition defined in electricity market models can be electricity, ancillary services, and/or flexibility. The activities and resources deployed for distributing the value proposition are called the value chain [31]. In blockchain business models a value chain will be built on the platform connecting sellers and buyers of energy. The following sections introduced four blockchain-based business models including peer-to-peer (P2P), flexibility, OTC, and crowdsale trading platforms.

s0050 3.1 Peer-to-peer energy-trading platform

p0205 The recent development of information and communication technology (ICT) and new interests in managing demand and schedulable loads along with the policies on promoting distributed renewable resources have made small consumers play a proactive role of prosumers [17, 32]. These small prosumers seem to be willing to take part in electricity markets and change their roles from submissive ratepayers to the players who can schedule their resources and make profits.

p0210 However, the capacities of these small prosumers are mainly negligible, preventing them from taking part in a wholesale market and compete against conventional suppliers with huge capacities. These players are proposed to be aggregated by an aggregator. The aggregator as an intermediary would be responsible for aggregating these capacities, building offered bids on behalf of these players [33]. Although this condition can motivate prosumers to respond to the market prices and schedule their available resources more than before, they still do not have control over their offered prices and capacities. Besides, they should share the profit with the aggregator playing the role of an intermediary.

p0215 Local markets based on P2P trading give small prosumers the opportunity to make their own bids, schedule the resources, and manage their consumption. P2P trading enables the bidirectional flow of power and information in power systems while traditionally power flows in a unidirectional manner, from generators to end users. This kind of trading has a decentralized structure where all peers can participate in a pool-based local market or trade electricity or related services bilaterally.

p0220 A transition toward decentralization through local markets brings some benefits for the whole grid, local communities, and small end users. First, local markets (in a shape of virtual or physical microgrids) can keep a balance between supply and demand within their community reducing the burden on both transmission and distribution grids. Thus it would contribute to enhancing the reliability and resilience of the whole system. Power losses can also reduce owing to decentralization and self-consumption promoting through this kind of transaction.

p0225 Second, as aforesaid, regardless of the transaction costs, it reduces the costs for both suppliers and buyers participating in the local market by skipping the intermediary. Blockchain technology facilitates the aim of disintermediation by utilizing distributed ledger technology.

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p0230 Moreover, P2P trading offers customers better choices for the source of energy they will receive. Suppliers are also given a chance to manage their own flexibility resources and maximize the profits. Besides, each transaction is allowed to have different prices taking into account the peers' preferences. Decentralization, therefore, is considered to promote democracy in local energy markets.

p0235 Consumer-centric electricity markets can make a major contribution to decarbonization as they encourage small customers to invest in renewables and make profits by managing their consumptions. As a consequence, local markets may empower communities to supply their own demand, making the communities autonomous.

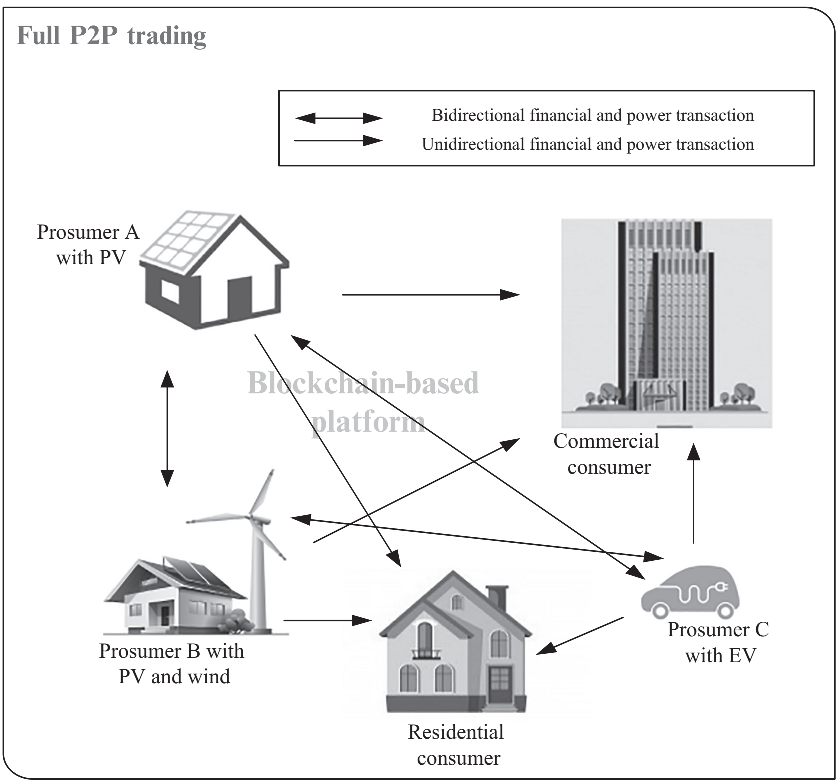
p0240 Furthermore, P2P trading would mitigate market power in electricity markets. One of the leading reasons behind market power is the low elasticity of demand in electricity markets since the demand was traditionally unable to respond to the market prices. End users were mainly submissive ratepayers who were not subjected to a variation in market prices. Consequently, suppliers could easily exercise market power using financial withholding. However, in the local markets, players can react to market prices through their flexible resources (like batteries and EVs) and manage their consumption by flexible loads. Another reason resulting in market power is a limited number of players. P2P trading leads to all end users taking part in the local markets to buy and sell electricity. Hence, it enhances the liquidity of the market, heightens the competition between peers, and avoids monopolistic behavior.

p0245 One of the determining factors that is still considered as a big challenge for P2P trading is the grid operation [17]. In fact, there exist a few studies aiming at assessing the effects of P2P trading on the distribution and transmission grids. Although it was claimed that a P2P transaction leads to less power losses and congestions in both transmission and distribution networks owing to the short distances between suppliers and demand, bidirectional flows of power can pose a threat to the operation of the grid. So the transactions are proposed to be checked by the system operator before the energy exchange time period in case of any constraint violation [16]. An inspiring work concerning the impact of business models on grid operation could be found in [34] in which peers can contribute to providing flexibility services so as to help grid operation. The cooperation between distribution system operator (DSO) and transmission system operator (TSO) is another challenging issue that can be complicated by promoting P2P transactions.

s0055 *3.1.1 Target participants*

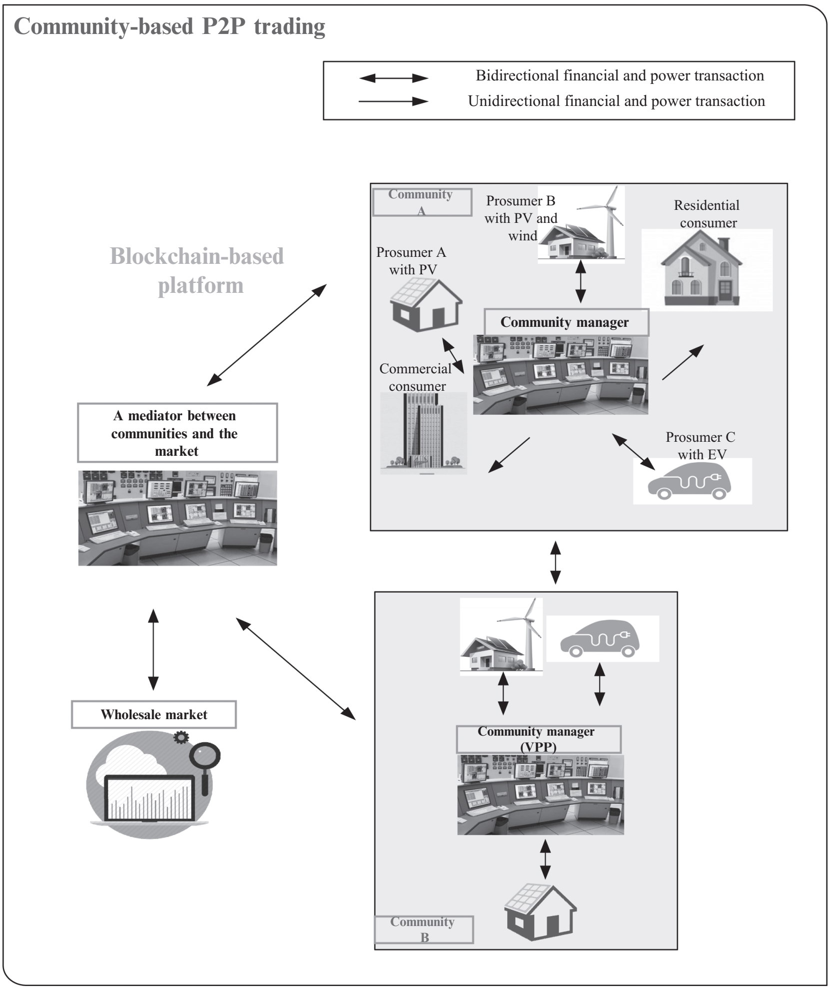
p0250 In general the main participants of local markets can be energy suppliers or sellers, energy consumers, or buyers and mediators [35]. Target participants are quite different according to the various designs for P2P markets. Small prosumers and consumers aggregated by another entity can be regarded as buyers or sellers in different market design. Considering the degree of decentralization and topology, there exist full, community-based, and hybrid P2P markets [17, 36, 37].

u0010 • In the full P2P trading, small players can individually participate in a pool-based local market or trade electricity bilaterally with another peer without any centralized supervision. Fig. 5.8 illustrates an example of a full bilateral P2P market. Possible interactions among actors are also specified in this figure. A multibilateral economic dispatch is also another form of full P2P market proposed in [38]. Participants of full P2P markets are end users playing the roles of prosumers and consumers. In this market, suppliers are small prosumers selling their extra electricity to the market. A prosumer can be any end user who owns one or several types of distributed energy resources (DER) including renewable energy resources (RES), electric vehicles (EVs), and batteries. Consumers are considered to be different kinds of end users who are not able to meet its demand by itself. However, a consumer would be able to manage its consumption according to the market prices to minimize the costs. The full P2P structure eliminates mediator, leading to the full decentralization.



f0045 **FIG. 5.8** A sample of full P2P trading.

u0015 • Community-based P2P markets consist of two types of mediator including a community manager and an intermediary connecting communities with the rest of the system. These two brokers act as the main seller and buyer. Small prosumers and consumers form a community due to geographical reasons or sharing common interests and goals [24, 25]. For instance this community can be a group of neighboring prosumers who want to trade energy with each other and some peers forming a community because they are willing to share green energy, although they are not at the same location [14]. Prosumers and consumers share their energy with a community manager. A community manager can be a kind of VPP if it integrates prosumers. Fig. 5.9 shows



f0050 **FIG. 5.9** A sample of the community-based P2P trading.

an example of a community-based P2P market with its participants and possible interactions between them.

u0020 • Hybrid P2P market: A hybrid P2P trading is a combination of both community and full P2P trading. In other words, prosumers can exchange the power individually or in the framework of the community/aggregator/VPP. The main actors of a hybrid P2P market are both energy communities and prosumers and consumers sharing energy with each other. Energy community, itself, can play the role of a mediator collecting some prosumers (forming VPP) or/and consumers to maximize the profit of these players. Reference [39] has offered small sharing zones in which they gather some prosumers so as to share energy with each other. A virtual entity called energy-sharing provider was proposed to act as a mediator who is in charge of coordinating the sharing activities within the community. Within this hybrid P2P structure, participants are prosumers, consumers, and an energy-sharing provider as a broker. The energy-sharing provider itself can act as a buyer or seller connecting a sharing zone with the other zones. A hybrid structure is an appropriate model as the preferences of all kind of end users can be considered in the model. Some small prosumers and consumers are not willing to participate solely in the markets as they do not have enough time to schedule their resources and consumption. An aggregator is assumed to take the responsibility of these peers. Fig. 5.10 shows an example of this kind of trading.

p0270 It should be noted that system operators including DSO and TSO play a vital role in all types of P2P market. Constraints associated with both distribution and transmission grids should be checked after each transaction so that they should not be violated.

p0275 Besides, prosumers mentioned in the models are not limited to the households equipped with RES. They can be an EV owner who wants to participate solely in a local P2P market, a battery storage or any player owning resources, and is able to bid to the market.

s0060 3.1.2 Roles of market participants

p0280 Roles of market participants vary according to the structure of P2P markets. The value chain of this business model unfolds on a platform through the use of private blockchain. Each participant is given a unique address in the blockchain. Participants submit their bids through their user accounts in the blockchain. The orders are settled, and the account balances connected to the users' addresses will be updated. Finally, miners verify transactions and generate new blocks [3].

p0285 While, in a full P2P market, small prosumers and consumers are allowed to submit offers through the blockchain network, only mediators are able to share energy between each other in a community-based P2P market. In fact the information related to the generation and consumption of small end users can be transmitted to the aggregators using smart meters and ICT technology. In a blockchain-based version, communities can trade energy with each other through the blockchain network without the help of any broker.

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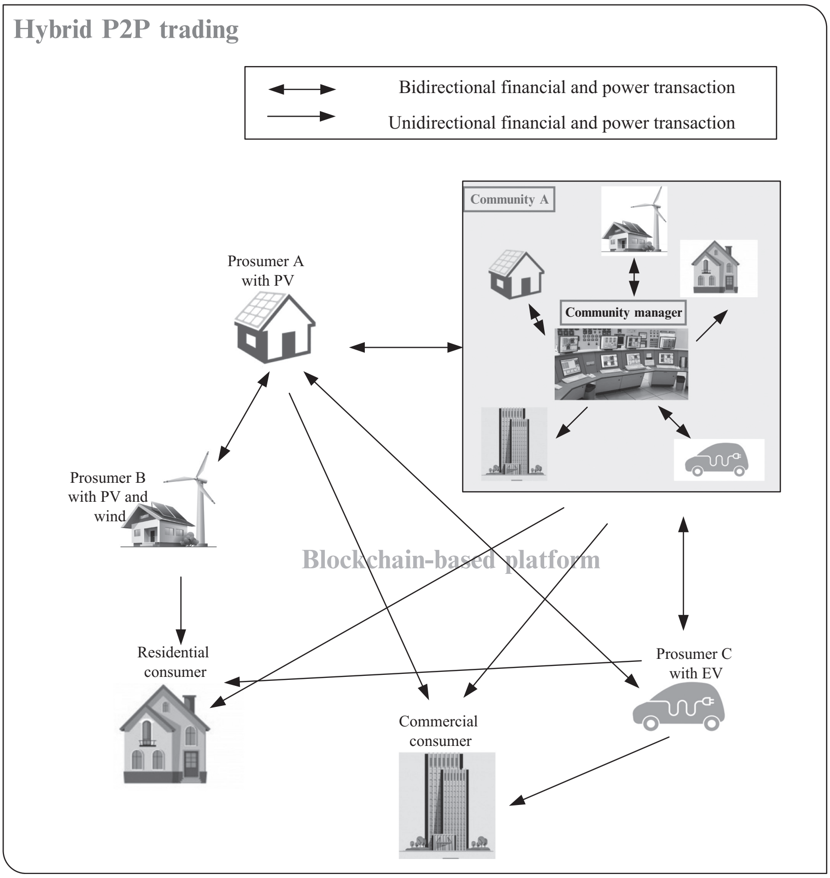

f0055 **FIG. 5.10** A sample of hybrid P2P trading.

p0290 In a hybrid technology, however, consumers and prosumers as well as aggregators can grant access to the blockchain network and submit bids so as to gain profits. As previously mentioned, end users can also decide to play a nonactive role, being aggregated by another entity.

p0295 P2P trading enables prosumers and customers to schedule the energy resources and its flexible resources aiming at maximizing the profits or minimizing the costs. Following energy-trading purposes, DGs may be scheduled through connecting or disconnecting operations. However, reference [16] proposed that it would be better if the prosumer keeps DGs connected and utilizes its maximum power owing to the low operational costs of these resources. The participant can control uncertainties stemming from renewables by providing flexibility for the P2P trading through the use of batteries, EVs, and flexible loads.

p0300 EV users are proposed to participate in the P2P vehicular trading system in [40]. In the literature a P2P trading system was employed during the business hours to reduce the effect of charging EVs at these timeslots. Drivers decide to

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sell energy to another peer providing that the battery degradation and the efficiency losses were taken into account. In other words, they should be paid above the maximum value of the off-peak tariffs. On the other hand, drivers will accept to receive energy from other vehicles if they pay less than the market price. EVs can also be utilized as flexibility sources so as to help consumers or prosumers minimize their cost.

p0305 Flexible loads are considered as other sources used by consumers and prosumers. They would be able to reduce their consumptions at peak hours through shifting and curtailing their loads. In a community-based P2P trading, an aggregator would be in charge of managing flexible loads considering a standard degree of household's comfort.

s0065 3.2 Flexibility trading platform

p0310 The prevalence of using fossil fuels in different industries gives birth to some environmental problems such as global warming. Adoption of renewables along with electrification is introduced as effective solutions. However, the huge penetration of renewables in both transmission and distribution grids results in serious challenges due to the intermittent characteristic of renewable resources such as solar and wind power. Besides, these days, electricity supersedes fossil fuels. For instance, the share of EVs is growing rapidly owing to their efficiency and environmental benefits. EVs, themselves, can cause serious problems for the electric grid since it may change net demand patterns. The charging and discharging of EVs can also be quite unpredictable as long as they are not aggregated in the power systems. In addition to uncertainties coming from the new green resources, other issues may happen for distribution and transmission grids. Since small end users are encouraged to be equipped with renewables, reverse power flows may occur, making new congestion and voltage issues.

p0315 Flexibility products are considered as one of the optimal solutions to the aforementioned problems. To date, conventional generators are in charge of providing flexibility and reserves for the grid. These flexibility products are traded in reserve and intraday markets [41]. However, new problems with the power grid cannot be resolved by conventional flexibility resources. Ramping capability of conventional generators is not mostly sufficient [42], making the operator utilizing spinning or frequency-related reserves to capture uncertainties coming from renewables. Hence, seeking additional flexibility resources is of the essence so as to maintain the security of the system in a predefined level.

p0320 Generally, flexibility can be defined as the ability or possibility of changing consumption or generation patterns to react to external signals (such as price signals) aiming to maintain the stability of the system in a cost-efficient way.

p0325 Flexibility resources provided at distribution level regarded as real-time flexibility products that can be employed in both distribution and transmission grids.

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Distribution-based flexibility products would be able to integrate renewable generations, provide real-time reserves, and mitigate market prices during peak hours. Batteries, EVs, and demand response (DR) programs are regarded as the most common flexibility sources provided at the distribution grid. Electricity can be stored at off-peak hours and injected during peak hours through the use of battery systems and EVs. As a result, these resources contribute to grid stabilization and balancing. Moreover, flexible demand can be also curtailed or shifted to other hours during peak hours that also will strengthen the power grid.

p0330 Flexibility products can be identified as the following:

o0010 1. Balancing flexibility at transmission and distribution grids [43]: This kind of product is offered to the transmission system operator (TSO), aiming at keeping the balance between generation and consumption. The current reserve and intraday markets were designed so as to provide flexibility related to balancing. However, these markets do not allow small flexibility sources to participate in them. For example, households with batteries, EVs, and responsive loads may not be able to take part and offer bids in these kinds of markets. On the other hand, balancing flexibility at the distribution grid is mainly provided by integrating small flexibility resources. To utilize flexibility products at distribution grids, the complete coordination of DSO and TSO is needed so as to check whether a flexibility product in one grid does not cause problems for the other grid.

o0015 2. Flexibility for the distribution grid [43]: The kind of flexibility is provided through integrating flexibility resources at the distribution grid to keep local balancing, manage congestion, and reduce power losses.

s0070 *3.2.1 Target participants*

p0345 Traditionally the main participants of flexibility trading at the transmission grid are conventional generators offering ramping capacities to reserve markets. However, aggregators with different sizes may also decide to contribute to transmission-level flexibility markets. Besides, distributed flexibility resources including batteries, EVs, and customers with flexible loads can play flexibility roles in local flexibility markets. Thus the target participants will be completely different according to the types of network (transmission or distribution network).

p0350 Balancing products at the transmission level were proposed to trade in wholesale markets in which both energy and services can be traded and the optimal amount of energy and flexibility products will be cooptimized in this market. In [44], flexibility products provided for the transmission grid were treated as ancillary services. In some proposed markets, suppliers submit ramp products and the corresponding costs to the operator; the operator decides to use them considering their costs if needed for the purpose of load following. A flexibility market can be proposed for providing flexibility at the transmission grid where

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huge aggregators consisting of a number of flexibility sources at the distribution grid can participate in this market. Conventional generators can also contribute to the market and submit their ramping capacities as well. TSO is considered to be another player submitting the required flexibility to the market.

p0355 Different market structures have been proposed to provide balancing flexibility for the distribution grid [45]. The studies mainly propose a separate market in which small flexibility producers would be able to offer flexibility products to the TSO. Again, TSO will have an option to choose the flexibility products needed regarding their offered prices and capacities.

p0360 Flexibility products provided for the distribution grid can be submitted in local day-ahead and intraday markets. Aggregators of flexibility sources are assumed to offer their products and the corresponding offered prices to the market. On the other hand, DSO also submits its required flexibility. Eventually the market is settled, and the optimum amounts of flexibility will be determined as well. DSO then participates in the wholesale flexibility and RT markets so as to resolve remaining security issues [2, 6]. We propose local markets constituting at the distribution grid so as to provide flexibility for the local distribution grid. Like community-based P2P trading, both flexibility aggregators and small end users with flexibility resources can submit the flexibility bids. On the other side, DSO, TSO, and also small customers may submit their required flexibility products.

s0075 *3.2.2 Roles of market participants*

p0365 The roles of the seller would be played by huge aggregators aggregating flexibility resources located at distribution grid and conventional generators, while TSO is considered as a buyer.

p0370 In local flexibility markets, small suppliers owning flexibility sources and aggregators at the distribution grid are regarded as sellers, and TSO, DSO, and small customers can purchase flexibility products. Small customers are those end users with renewables who want to compensate for the uncertainties of their resources. The implementation of the blockchain-based market would be the same, in comparison with community-based P2P markets.

p0375 In blockchain-based flexibility markets, the value chain is built on a blockchain-based platform in a way that all flexibility resources are connected through the platform. The type of blockchain would be private, so just specified players would be able to take part in the markets. With the help of blockchain technology, flexibility sources (at both transmission and distribution grids) can directly sell their flexibility products to TSO or/and DSO without any mediator. The value is better to be delivered through tokenization. Smart meters connected to the flexibility resources can share information in a real-time manner. Accordingly the flexibility provided by flexibility resources at the distribution grid is regarded to be real time.

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s0080 3.3 OTC trading platform

p0380 Over-the-counter (OTC) trading is a kind of bilateral marketplace that mainly takes place at the wholesale level. Buyers and sellers are able to trade bilaterally without the help of any intermediary. Traditionally, this kind of transaction was conducted through phone calls or websites. With the advent of blockchain technology, players can easily share their offers via the blockchain network while staying anonymous. In addition, the data shared in the network cannot be tampered easily.

p0385 OTC trading can be categorized into spot or short-term trading and future one. Blockchain technology would facilitate short-term OTC trading as it can settle transactions in real time. In future OTC trading, large-scale operators would be able to hedge against price fluctuations [46]. Therefore future OTC trading may alleviate the risk of not being supplied for huge customers and assure suppliers that their product will be sold in the market.

s0085 *3.3.1 Target participants*

p0390 As the OTC transactions are done at the wholesale level, the players should be large-scale ones. Retailers, huge customers, generating companies, and aggregators are the main participants of this market. They can share information with each other directly. As a result the transaction costs will become lower due to disintermediation.

s0090 *3.3.2 Roles of market participants*

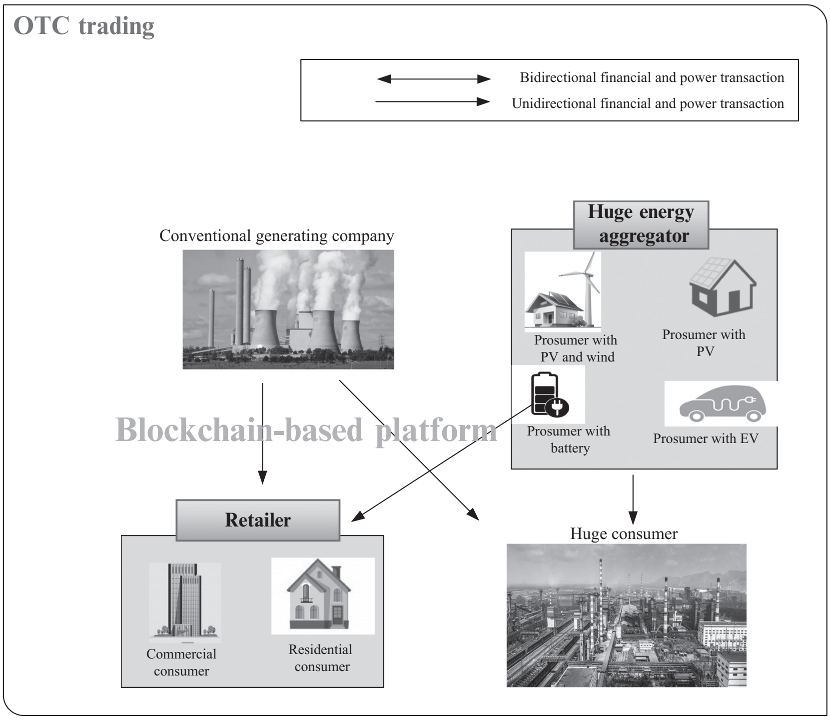
p0395 In this market the buyers can be retailers and huge customers located at the transmission grid while generating companies and huge aggregators can play the role of sellers.

p0400 Like other markets, suppliers share their offers in the blockchain network. The buyers will accept the offer according to the offered prices and their needs. The platform is set on private blockchain in which just specified parties are allowed to participate in the market. Fig. 5.11 shows a simple market for OTC trading platform.

p0405 Note that security must be checked for each individual transaction. However, in a pool-based market, it would be checked once when all transactions are initiated.

s0095 3.4 Crowdsale trading platform

p0410 Crowdsale trading or crowdfunding is a kind of trading in which a huge number of players can take part in the market, regardless of their size, capacity, and location. The trading is mostly done aiming at promoting renewable resources in the world.



f0060 **FIG. 5.11** A sample of OTC trading platform.

s0100 *3.4.1 Target participants*

p0415 Nonprofit organizations or generally private investors are players who want to invest in installing renewables (also called crowdfunder), while property owners are the main participants who are willing to install renewable sources on their private land.

s0105 *3.4.2 Roles of market participants*

p0420 There exist different business models related to crowdsale projects [47]:

p0425 In the equity-based model, the monetary profit of renewable resources would be shared between the property owners and the crowdfunders. In fact, investors offer the ratio of profit preferred to receive or the rent in exchange for investing in the green project, and the property owners accepting the offer can benefit from self-consumption and a part of profit coming from selling the surplus to the local markets. Property owners can also offer the rent paid to the investor, and the investors can decide to accept the offer.

p0430 In the reward-based business model, a property owner receives funds from an investor providing that the investor receives nonmonetary benefits such as a

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gift. The property owner will offer the benefit, and the crowdfunder can decide to accept it.

p0435 In the donation-based model, the investor donates the fund to provide the property owner with green energy. The donation is mostly received from wealthy organizations to poor developing countries.

p0440 Blockchain technology can eliminate the role of intermediary in the crowdsale trading. Accordingly, funders and property owners can easily trade with each other and share information via the blockchain network. The platform should be built on a public blockchain so that everyone can invest in renewables and every property owner is able to offer its land or a roof area for solar so as to be equipped with green sources. Note that the crowdsale market can be constituted globally. In other words an American organization may decide to invest in solar projects in Africa.

p0445 Crowdsale projects are considered as one of the best ways to promote renewables worldwide, leading to decarbonization. In addition, the global characteristic of crowdsale trading may help developing countries contribute to the reduction of greenhouse gasses. Besides the funds can be provided for very small projects that previously were neglected. Accordingly, everyone can benefit from green investment on their land.

s0110 4. Discussion

p0450 As a result, blockchain has provided a decentralized software platform enabling market participants to interact without any central entities or intermediaries. Accordingly, while running the market, blockchain platform evaluate the transaction based on predetermined policies. Therefore the roles for each market participants should be clearly and accurately defined. It should be noted that blockchain is not the only available solution for managing large numbers of (micro)transactions in P2P electricity markets, and there is strong competition from incumbent technologies that also enable very fast and secure transactions. This chapter, with classification of market participants in the blockchain framework, helps to manage and regulate the roles of market players in the future business models. Indeed, knowledge of current situation of different players in the available blockchain-based business model will help to improve the future structure.

p0455 Blockchain in electricity market is still facing many challenges in terms of implementation, fitting the available regulations and policies, and finding the best strategies and technologies to integrate all market players effectively that should be addressed by researchers. Moreover the lack of clear connection among the blockchain-based market in the lower-voltage level and upstream markets such as wholesale markets and retail markets makes the implementation of such a P2P business model more complicated. Finding a solution for this kind of interaction could move us one step forward to reach the comprehensive market scheme.

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