Peer to Peer Business Model Approach for Renewable Energy Cooperatives

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***Abstract*— Power and energy systems are undergoing unprecedented change driven by many factors like global warming, digitalization, new sorts of renewable energy sources (RESs). Many countries incentivize the installation of RESs with subsidies and programs like a high rate of feed-in tariffs. However, these promotions are not sustainable. Some countries started to decrease the feed-in tariffs due to the cost of RESs are in decline. Since they want to reduce the volatility risk of small-scale RESs, they also don't give capacity for unlicensed plants. Renewable energy cooperatives (RECs) emerge as an alternative to encourage the installation of unlicensed RESs. They can be defined as prosumers in the system. Also, a peer to peer energy trading between cooperatives within the local community might increase the profit of cooperative in the same region. Because of this, the peer to peer business model approach is proposed in this study. The smart contract by using blockchain technology is used in this proposed approach due to making transactions faster, and to provide a dynamic market and blockchain is used to make transactions data secure.**

Keywords—Blockchain, renewable energy cooperative, peer to peer trading, smart contracts.

I. INTRODUCTION

In order to minimize the effects of global warming and slow down the climate change, carbon dioxide emission must be reduced. It is obvious that energy sector is one of the sectors that dramatically contributes to carbon emission, because of fossil fuel like coal and natural-gas based plants are mostly used to generate electricity and petroleum-based fuels are used for transportation [1]. Moreover, they are non-renewable resources which means they will run out, so more efficient, cleaner and renewable resources must be used to generate electricity. Thus, with these concerns, there is an unprecedented transformation in the power sector and as a result of this transformation power sector will be more decarbonized with renewable and clean energy resources like solar and wind energy [2,3], more digitalized with advance in technologies like sensors, electronic devices, internet of things[4,5,6], and more decentralized with new paradigms like microgrid, transactive grid and distributed energy resources (DERs) [7].

DERs includes distributed generation (DG) that consists of renewable and non-renewable generation, flexible demand and energy storage systems (ESSs). Since DERs especially DGs can help increase efficiency and build a cleaner power system with renewable resources, the integration of renewable DGs is encouraged by countries globally with subsidies and programs like a high feed-in tariff. Addition to this, some consumers have become producers at the same time in the system and they are called as prosumers. Their motivations differentiate to install DGs from financial or environmental concerns to wish of being more independent to power supplier. Therefore, too many DGs will be deployed to the power grid with their intermittent unpredictable characters.

However, these subsidies and high feed-in tariff are not sustainable. In many countries, reductions of the feed-in tariff are expected [8,9]. Addition to this, managing and maintaining the cost of electric networks is an extra burden on the back of prosumers due to these costs are reflected to prosumers when they sell the electricity they produce to the grid, so installation of the small-scale power plant will not be feasible for small investors and producers[10]. Thus, renewable energy cooperative approach is used one of the innovative solutions to increase the amount of renewable energy generation in the system [11].

Also, that much large deployment of intermittent and unpredictable resources requires new kinds of operation, management and control systems, market models, policies [12,13,14,15]. Peer to peer energy trading model has been started using in the applications dealing with the usage of DERs [16]. Especially in the microgrid system, this trading model has been considered as it can be an effective method to manage DERs and enables a more beneficial method for prosumers, due to the fact that it removes intermediaries to sell their surplus energy to their neighbors [17]. Therefore, their investment may be amortized faster, and they may make more money by using the peer to peer trading model.

A renewable energy cooperative creates a kind of natural microgrid because stakeholders of the cooperative are in the same region and usually have the same point of common coupling to the main grid. Hence, cooperatives have rules on how the market will work within the community according to their agreement. However, there is no study about the sharing of electricity between different cooperatives in the same region and distribution area.

Peer to peer energy trading model among cooperatives might be more profitable than selling the surplus energy of a community to grid in feed-in tariff. Also, it can make these cooperatives more effective, beneficial and easy to manage, if transactions are settled with smart contracts. If blockchain is used to store data of transactions, it can provide secure, trustable, robust to fraud medium. The concept of peer to peer energy trading is given in section II. After then blockchain and smart contracts briefly are explained. The

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business model for renewable energy cooperatives is introduced by using the smart contract approach in section IV.

II. PEER TO PEER ENERGY TRADING

Peer to peer (P2P) trading is new phenomena as increasing use of distributed renewable energy resources (DRER). Governments are promoting public investors to disseminate clean energy with feed-in tariff mechanisms. Basically, peer to peer trading explains electricity trading among peers, excess energy from small-scale prosumer trade locally with the consumer without the involvement of retail market. A peer can be a single person or authority such that an aggregator can act as a peer. Peer-to-peer trading would expand the popularity of small-scale DRER [18,19]. Because at saturation of renewable capacity goals, the feed-in tariff is no longer sustainable. It results in a significant fall in renewable generation promotions. In that case, P2P trading provides alternative sub-market that reduce costs for consumers and increase income for DRER prosumers [20].

In addition, net metering with the peer-to-peer trade of prosumers in a community decreases the problem of connection to transmission grid because of intermittent generation of renewable energy resources. Also decreases the loss while consuming regionally.

On the other hand, P2P trading gives local providers an option to sell their electricity fairly either within community or distribution system and change prosumers' position from electricity and price takers to electricity and price makers [20]. This makes a dynamic market structure for local communities and promotes competition and decrease prices. If prosumer's profitable sales are considered this structure incentivize both sides.

Management of DRERs is a problem in case of technical and economic perspective for the grid. P2P energy sharing is an effective way to manage distributed renewable energy resources[21]. Furthermore, new technologies such as blockchain have the enormous potential of management of the local market. It also ensures self-controlled communities which would be important because blockchain based P2P paradigm facilitates control of an increasing number of smart devices.

In peer-to-peer trading, the proposed market mechanism should well analyze for cost reduction and enhance profit. In the literature, there are mainly three types of market paradigms for a peer to peer energy trading [18]. They are:

i) Bill sharing
ii) Mid-market
iii) Auction-based

From i to iii complexity and dynamism are increasing. Also, single and double auction are existed in the auction-based model [22].

III. BLOCKCHAIN AND SMART CONTRACTS

The blockchain is recently emerging technology with its genesis description of the distributed database that maintains continuously growing ledger of data record that is immutable, transparent, tamper-proof, timestamped and secured by a combination of encryption and distributed consensus mechanism. It is called distributed ledgers shared by different participants. The reputation of blockchain started with bitcoin which is a crypto-currency. Bitcoin was created by Satoshi Nakamoto by using blockchain technology to make a peer to peer electronic cash system [23]. What Satoshi achieved has he created a trustworthy platform enabling us to make a transaction in a distributed network without any need of trust to other participants and any engagement of intermediary like a bank, and it also prevents from double-spending. The consistency of the transaction is verified by using a consensus mechanism that nodes pre-agreed upon and responsibility is shared among participants [24]. In a distributed P2P manner, everyone has copies of the ledger of records and each ledger identical, contrary to only central entity holds in centralized systems. Depending on the blockchain applications' stage of development, blockchain is separated into three phases as 1.0, 2.0 and 3.0 [25].

The blockchain is the form of continuous sequence blocks which holds a complete list of transaction records. While provider agrees on a transaction, this transaction is combined with others and it creates data block. This block is published and stored across the decentralized network in a tamper-proof manner. Then, the block is verified by other network nodes which hold all blocks from the genesis block to an older one. Thereby, the verified block is combined with all previously verified blocks so the transaction is confirmed, then it creates the continuously growing blockchain.

In the blockchain, any block consists of two key parts; block header and block body. Block body includes transaction lists and counter. However, block header mainly consists of a timestamp and the hash value of the previous block and own hash value which is unique for each block. The hash value is a fixed length series of numbers and letters created based on the information stored in the relevant data block [26]. The hash value is changed if data changes slightly. Blocks are connected each other with hash value by carrying previous block's hash value which is immutability of system. So, it guarantees tamper-proof of transactions not only the current block but also entire blocks in the network.

Another specification of blockchain is reaching consensus among untrustworthy nodes in verification which is a decentralized and automated process. There are 2 main used algorithms; Proof of Work and Proof of Stake. Proof of work (PoW) strategy is used in bitcoin systems. The system should choose participant to publish a block of the transaction. Thereby, nodes are calculating the desired hash value until one node reaches the target value. Then node broadcasts the block to other all nodes to confirm the correctness of hash value. After checking the accuracy of hash which is a one-way cryptographic function so other nodes can easily verify that required answer satisfies. After that, they add the last block to their blockchains. Proof of Stake (PoS) approach simplifies the process with giving priority to nodes that have more stake. Verification precedence that means creating a new block is proportional to node's assets "stake". This strategy reduces the

complexity and also it is efficient in case of energy usage unlike PoW. However, different consensus exists for diverse purposes [26].
In 1994, Nick Szabo outlined the concept of smart contracts. Even though information technology infrastructures were not enough for the theory level, the idea was acceptable at that time [27]. Now years later, smart contracts have gained its popularity again with the development of technology and especially with the recently emerging blockchain technology. Blockchain technology is becoming widespread, but the smart contract may unearth the true potential of it and take it one step further. Smart contracts are the phase 2.0 of blockchain and phase 3.0 will start with the deployment of blockchain in big data, machine learning and predictive task automation [28].

Without any possibility of downtime, censorship, fraud or middleman interference, smart contracts are decentralized applications that run exactly how they are programmed in a specified platform [29]. Smart contracts are mutually agreed upon terms to execute conditions which is "if this, then that" mechanism. They may be used to exchange money, property, shares, or anything of value in a transparent, conflict-free, and faster way while avoiding the service and helps of a third-party. The smart contract can be considered as cryptographic autonomous boxes that contain value and only unlock it if certain conditions and terms are met. Each counter-parties agrees on the terms of the contract as the logic of contracts and smart side comes with carriage of contracts to the digital environment in a distributed way and cryptograph assures transactions without the need of an intermediary.

IV. PRINCIPLE OF OPERATION IN THIS APPROACH

Firstly, energy cooperatives are introduced then the peer-to-peer business model approach between renewable energy cooperatives is explained below.

A. Renewable Energy Cooperatives

This is a popular concept in the USA and Europe energy system. The ambition behind those is promoting clean energy, increasing household participation for dynamic market structure and decreasing the costs [29]. They are designed for the participation of small-scale local prosumers to increase renewable energy investments. Renewable energy cooperatives have been a significant role for countries energy transition [30]. Participants net metering in the cooperative community and get paid for a generation that selling to the grid as a share of investment. It also an ideal model for energy savings in case of household because it makes a profit as how much it saves from the right of allocation in a generation. Terms and conditions of cooperatives are different each country as country's priorities and situations. Even though renewable energy cooperatives are getting widespread in regions. For example, in Germany, 46% of renewable energy capacity comes from cooperatives [31].

B. Peer to Peer Business Model Approach

As increasing number of renewable energy cooperatives, these cooperatives have excess energy for selling and requires energy for their own demand. Selling excess electricity to the grid or retail company is not as profitable as it expected. Electricity price for selling is low because getting the involvement of third parties. In addition, if generation is not enough to supply households in community grid prices are high. Those circumstances extend return of investment time. So, peer-to-peer energy trading as a business model is proposed between energy cooperatives.

Fig.1 demonstrates the peer to peer business model approach. In the figure, the relations among cooperatives and retailer show both payment transaction and energy transfer. Each cooperative act as a peer and interacts with other peers (cooperatives). When cooperative-1 has surplus energy, it broadcasts the amount and sells the electricity to other cooperatives. Price between cooperatives is specified earlier. This price should incentivize both sides means selling price should be higher than the retail price for benefit of seller and buying price should lower than the retail price. Furthermore, this approach can be described as net metering between communities. If some unbalanced situation occurs, then grid electricity is getting involved. In the proposed model, fix the price and specified rules between peers are assumed. Due to the fact that smart contracts are used to transact money and manages the system.

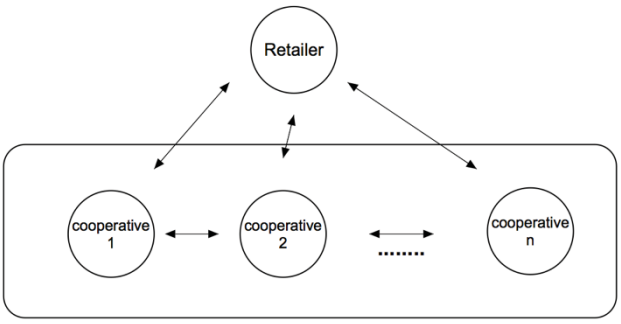

Fig.1 The P2P business model for RECs

Rules and priorities of a smart contract described as fix cost and trading nearest cooperatives between each other because of efficiency based perspective. Cost can be calculated as bill sharing method in [18] which is simplest to calculate and implement. In addition, blockchain provides a secure and reliable environment for peer-to-peer trading. Data dealing with all transactions is kept on a distributed blockchain. It means that all participants of peer to peer energy trading system store all relevant information depending on the smart contract on the computers.

In case of future applications, dynamic pricing can be used for more competitive market inside cooperatives and between cooperatives. Auction methods are suitable for dynamic sub-market structures. Also, with artificial intelligence algorithms forecast of generation and consumption data would be accurate.

V.CONCLUSION

Power and energy systems are in transition from conventional resources to renewable resources all over the world. Governments are promoting clean energy with some incentivize mechanisms in this transition stage. However, these feed-in tariff mechanisms are a lack of sustainability. So, peer-to-peer trading might be the solution to provide the sustainability of the transition. In this study, the peer-to-peer approach is proposed between renewable energy cooperatives. Smart contract by using blockchain is defined for energy trading. This approach is a useful model for the dissemination of renewable energy cooperatives and increasing the benefits of them to the power system. Especially, it is important to reach renewable goals against climate concerns. Moreover, if some other concepts consider such as demand response further benefits are expected. There needs some future study for modeling the system and proof of feasibility.

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