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Predicting daily energy production in a blockchain-based P2P energy trading system

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Abstract: Many governments are reducing conventional energy production using natural gas or coal as they spread much CO2 to into the atmosphere, leading to global warming. Moreso, with a sharp increase in electricity demand, renewable energy sources are gaining more popularity around the world. A renewable energy source such as solar energy offers one of the easiest ways of generating renewable energy as it can be done by anyone/household through the installation of solar panels in an open place such as house roofs. Therefore, deleting the centralized exchange of the generated energy by the household will provide huge economic benefits as well as optimize the flow of renewable energy. However, the current conventional centralized energy trading makes it impossible for individuals (prosumers) to participate because of the need for third parties to enable transactions which in turn adds extra financial burden and discomfort. To eradicate the need for a third party through decentralization while ensuring non-comparability, transparency, security, and integrity of transactions, previous works have proposed the integration of blockchain systems into the trading system. However, to ensure the sustainability of blockchain technology for trading, there is a need to consider energy consumption and prediction in the system to enable planning about the energy demand.

Keywords:

Introduction

Purpose of the work

There is a big role of energy in the development of each industry sector in every country. Since electricity was invented, it has affected to human lifestyle a lot. There are basic ways of sources to generate electricity and are divided into two categories: renewable and nonrenewable sources [1].

Renewable energy sources such as solar, wind, land, and wave power play an important role in each community intending to reduce the impact on nature from energy production. Utilizing renewable energy sources may significantly reduce environmental damage and decrease energy prices tremendously. However, renewable energy has also drawbacks such as geographical dispersion, discontinuous production, randomness, and uncontrollability [2]. That is why traditional centralized energy providing is difficult to adapt to the large-scale utilization of renewable energy power plants. Because of the drawbacks of renewable energy, it is more likely to store the batteries and sell when it is needed. Therefore, we can utilize a decentralized system such as blockchain. As technology progresses, blockchain has become a dynamic and rapidly growing area of research, since, in blockchain, information is stored and shared among all participants of the network. Besides, there is no need for trusted third parties to process electronic payments in internet commerce since two parties can transact directly using blockchain [3]. The blockchain uses cryptographic methods to generate data blocks that ensure the security and integrity of the transaction data [3].

Problem statement

Trading over the untrusted Internet is not recommended, since the Internet is not safe from attackers and non-reliable sellers. Buyers may easily be lied to or steal their money from their cards during unsafe transactions. Therefore, trusted third parties operate to provide secure transactions between sides. However, it costs extra money and time to commit to a successful transfer. To tackle these problems blockchain technology was developed which we discussed in the previous section. The drawback of the first blockchain-based applications was publicity, which means any user can participate in the network and commit transactions.

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This kind of blockchain cannot be utilized in business uses, because the network is fully decentralized and cannot be controlled or ruled by the network admin. Therefore, permissioned blockchain frameworks were implemented to solve these problems. In our proposed energy trading network, we used open permissionless blockchain technology which is Hyperledger Fabric provided by IBM and Linux Foundation.

Related Works

Decentralized energy trading

Nurzhan and Davor from [4] implemented a decentralized energy trading system using blockchain technology. They performed security analysis for various cases and performance evaluation of the system in their proposed work. However, their proposed work is a token-based key exchange method, which is believed to be not efficient in large systems. Xin et al. [5] introduced SDN based decentralized energy trading network providing systematic security and applicability analysis. But, overheating for decentralization in huge data is a major drawback. Lee et al. [6] designed a power trading system under blockchain that provides sustainable energy transactions between prosumers and consumers. They provided a cost analysis of the establishment of the whole system and the time to take money back from transactions. However, they did not provide system performance analysis. Rajat et al. [7] proposed a blockchain-based secure energy-trading network for EVs ensuring resilience against the single point of failure. Moreover, they utilized SDN technology to provide low latency and real-time services for transferring data of the EV to the global controllers. But using PoW computational difficulty for energy trading network is not suggested since this operation requires considerable computer performance. Zhitao et al. [8] proposed a secure and efficient blockchain-based energy-trading scheme. In their system, a credibility-based equity proof mechanism was used to increase network availability in relatively weak computing power. Shen et al. [9] designed an optimization model and blockchain-based architecture to accomplish peer-to-peer energy trading on crowdsourced energy systems. They explored day-ahead, hour-ahead scheduling of generation, and real-time operation algorithms for their system. But, they did not provide an analysis of network performance. Ashish et al. [10] discussed various operating algorithms, principles, characteristics, and features of the P2P energy trading system. They proposed an energy-trading model on micro/mini-grids in Nepal. Shivam et el. from [11] proposed a blockchain-based energy trading platform for residential communities. There were double auction mechanism and permissioned blockchain infrastructure with smart contracts used in their system. However, a double auction mechanism may affect the computation throughput. Shuai et al. [12] explored blockchain technology in energy trading in China's energy sector by surveying the advantages and disadvantages of the technology. Table 1 presents the summary results of characteristics and approaches to P2P energy trading.

Table 1. Characteristics of different approaches to P2P energy trading.

Author	Year	Objective	1	2	3	4	Pros	Cons
Nurzhan and Davor from [11]	2016	To develop ETS using blockchain and check security and privacy	√	✗	√	✗	Checked their proposed network for lots of cyber attacks	Token-based not efficient in large systems
Xin et al. [12]	2017	To develop SDN based ETS using blockchain with security analysis	√	✗	✗	✗	They proposed an SDN technology with blockchain	Slowing down when data is huge. Lack of hardware security
Lee et al. [13]	2018	To design and cost analysis of	√	✗	✗	✗	Cost analysis for returning money investment for	No performance analysis of

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		decentralized ETS system					the establishment ETS	the proposed system
Rajat et al. [5]	2019	To propose energy trading between EV owners with low latency	√	✗	√	✗	They explained about miner nodes which increase system security	They used the PoW mechanism which slows down computer performance
Zhitao et al. [14]	2019	To propose blockchain-based ETS using the proof mechanism	✗	✗	√	✗	Proof of Stake mechanism which is lighter than the PoW	Performance and scalability
Shen et al. [15]	2019	To develop an optimization model on decentralized ETS and future prediction	√	√	√	√	Permissioned network and future price analysis	No regression algorithms and hyperledger caliper not used
Ashish et al. [16]	2019	To propose P2P ETS in micro/mini-grids in Nepal	✗	✗	✗	✗	A good analysis of energy used and generated in Nepal	Algorithms were not explained, no explanation about used blockchain
Shivam et al. [17]	2019	To propose blockchain-based ETS with an auction mechanism	✗	√	✗	✗	Permissioned blockchain network and bidding system for ETS	No system performance and algorithms provided
Shuai et al. [18]	2020	To survey blockchain-based energy trading in China's energy market	✗	✗	✗	✗	Analysis of various business spheres used blockchain in China	No results provided
Proposed approach	2020	To design and propose blockchain-based ETS system with power generation prediction	√	√	√	√	P2P trading on permissioned network with smart contract. Performance analysis with Hyperledger Caliper. Power	-

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							generation prediction with regression algorithms	
1: Algorithms 2: Framework 3: Performance evaluation 4: Power generation prediction								

Day-ahead power prediction

Today, many researchers are using deep neural network models for future predictions in various fields. Mingming et al. [13] compared various prediction algorithms such as Back Propagation (BP), Wavelet Neural Network (WNN), Least Square Support Vector Machine (LSSVM), and Long-Short Term Memory (LSTM) for day-ahead power output forecasting under ideal and non-ideal weather conditions. The RMSE value from LSTM was by far the smallest between all other three algorithms. From the results of [14], the power generation forecasted quite much in summer than in other seasons. Benali L from [15] predicted hourly sunshine intensity using air temperature mean value, radiation mean value, and date as the input values. The result from the proposed network was well enough with the correlation coefficient between 97-99%. Moreover, researchers from [16] and [17] utilized back-propagation artificial neural network (ANN) and support vector machine (SVM) forecasting methods to make a model. By using these two algorithms, the error was approximately 15% in ideal weather conditions. However, SVM was also used to predict PV's power generation in [18]–[20] but the results were not efficient in non-ideal weather conditions. From [21], [22] it is clear that most of the techniques used to predict power demand have included Recurrent Neural Network (RNN)-based LSTMs that utilize time series data. Fei et al. [23] analyzed a day-ahead power prediction using different Machine Learning algorithms, namely LSTM, Back Propagation Neural Network (BPNN) model, Support Vector Machine (SVM), and Persistent model. They explored Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) was quite less in LSTM than others were. The recurrent neural network (RNN) and its next improved architecture LSTM was developed to get a notable increase in future prediction mechanisms. Therefore, we employ the LSTM algorithm to obtain the day-ahead power generation prediction of a single node.

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