Blockchain applications in smart grid

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Abstract
The rising demand for electrical energy, the vast expansion in sources of renewable energy, and the emergence of cyber-physical security threats are some of the issues and risks that modern power systems face. These difficulties highlight how crucial it is to create a method for the power system to run securely and consistently. With the introduction of blockchain, innovative concepts for smart grid solutions have been invented and implemented. As one of the most secure technologies of recent years, blockchain can be adapted in different applications such as smart grid. Blockchain technology has numerous potential applications and solutions for the issues that smart grids are currently experiencing and will face in the future. Some of these issues stem from the lack of security and privacy of data collected by smart meters. This article will present some of the advantages and drawbacks of the blockchain-controlled smart grid as well as energy trading.

Keywords: Renewable Energy, Internet of things, Cryptocurrency, Distributed Ledger.

1. Introduction
The Internet of Things (IoT) is regarded as the most uncontrollable innovation in today's world; it improves our everyday lives by transforming the physical items that surround us into a data ecosystem. Security, transportation, industrial, retail, healthcare, home automation, military, agriculture, surveillance, and good infrastructure are just a few of the many applications of IoT and big data in everyday life. Indeed, IoT and big data have heavily influenced current smart grid developments, and smart meters are evolving to include more vital sensing capabilities and higher connectivity. In the smart grid, ICT devices such as Wide Area Management System and Control (WAMS), Intelligent Electronic Devices (IEDs), and Remote Terminal Units (RTUs) for service systems, as well as Advanced Metering Infrastructure (AMIs) for smart building/home management, control and explicitly maintain the smart electricity generation, transmission, and distribution system, as well as SG. By combining blockchain control and field quantification with smart communication to these ICT devices in Home, Neighbourhood, Wide Area Networks (HAN/SN, NAN, WAN), IoT-enabled wide - area monitoring data

can be safely and automatically collected . Furthermore, blockchain-enabled AMIs can use Decentralized Applications (DAPPS) services in a cyber-secured environment to perform decentralized capacity of the system, local power management, and trading.

Science is becoming more powerful over time. In addition to the problems that the modern world presents, scientists and engineers face challenges in meeting market demand at various levels for a variety of reasons. Due to a lack of raw material supply, raw electricity generation, corruption on both the transmitting and receiving ends, transmission line and distribution system losses, the total electricity generation, transmission, and distribution system is not generating profits. Therefore, the SG technology was created to meet consumer demand, improve the efficiency of the electricity generation and distribution systems, protect customers, and monitor and regulate the entire system via communication (generating and receiving end). As a result, the paper's primary focus is to provide an overall view of blockchain (BC) in smart grid and energy trading.

The remainder of this paper is outlined as follows. Section 2 gives an overview of blockchain technology background. Section 3 presents Secure Energy Trading Framework for Smart Grid. Section 4 summarize Distributed Generations. Section 5 discusses the Related Work. Finally, section 6 concludes the paper. The acknowledgments are highlighted in section 7 and the references in section 8.

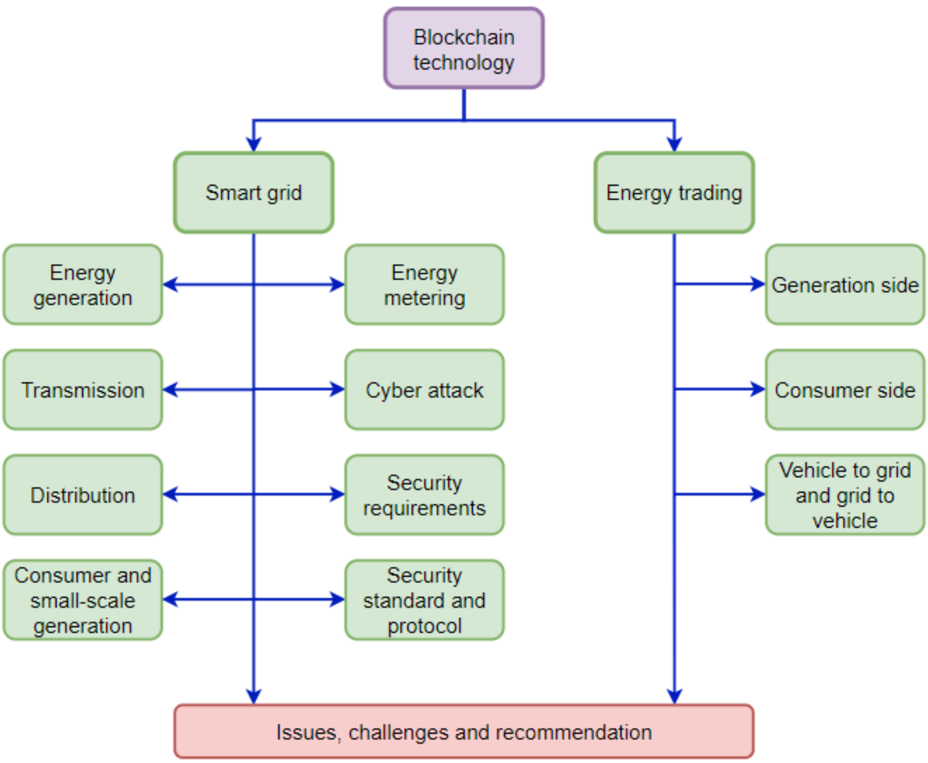

Fig. 1. Blockchain Technology

2. Blockchain

In simple terms, blockchain is a distributed database that contains an ordered list of various records that are linked together via links known as chains. These blocks store information about individual transactions, and only authorized users have access to them. User authorization is maintained by a complex set of self-managed encryption keys: each authorized user receives a time-sensitive unique key that autoblocks it if the time for decryption runs out. Blockchain technologies enable a distributed computing environment in which no central authority is required. Blockchain is used for more than just cryptocurrency. It has a wide range of applications in businesses, including information storage and exchange in a variety of organizational settings [8]. Also, Blockchain technology has a wide range of applications in the field of Smart Grid, particularly in the distribution and transmission of power. This is due to the involvement of an interconnected power network, advanced communication control technologies, and advanced metering infrastructure, all of which are commonly used to improve the use of green energy resources and to mitigate energy scarcity [9].

3. Secure energy trading framework for smart grid

A private blockchain is a peer-to-peer (P2P) connected and distributed ledger in which each node communicates with one another and shares information without the involvement of a trusted third party (TTP). It is made up of several blocks that are linked together, and each block contains a number of Energy Trading (ET) transactions. The primary function of blockchain technology is to secure energy data, record each trading event, manage transactions, and prevent faults. SMs can participate in ET by using blockchain-based ET to buy or sell energy from other SMs or utility providers (UPs). These ET transactions must be secured in order to balance energy demand and supply at the UP. As a result, before communicating with one another, these ET transactions in the form of cryptocurrency (i.e., ETCoin in Indian Rupee (INR)) are stored in the distributed ledger. There are numerous trustworthy platforms where ET participants can purchase cryptocurrency for ET purposes. Platforms such as ZebPay, Unocoin, Coinsecure, and others allow anyone to purchase cryptocurrency.

The traditional ET scheme (TETS) workflow, in which energy is generated from various sources such as solar photovoltaics (PV), wind, coal, and other non-RES/RES. The energy is then transmitted and distributed to consumers via power stations and UPs. TETS has a number of problems, including imbalanced energy flow (high demand and low supply, high supply and low demand), technical loss, non-technical losses (energy theft), privacy and security concerns. TTP plays a critical role in addressing the TETS system's issues, but data privacy and security are not fully guaranteed. As a result, incorporating blockchain into the existing SG system provides high security and resolves other TETS issues. Nodes in the proposed Smart Energy Trading Scheme (SETS) framework are in charge of maintaining the ETCoin and the flow of ET transactions.

The energy generation process at the power/grid station is the same in SETS as it is in TETS. This is the supply side DRM system, in which energy is transmitted and distributed to meet consumers' energy needs. The ideology of the SETS framework is to manage the demands locally at the demand side DRM system without requesting the required amount of energy from the grid.

Table 1. TETS and SETS comparison

Issues and challenges	TETS	SETS
Demand response management	Centralized (using trusted third party)	Self Governing (using smart contracts)
Customer data security and privacy	No	YES
Load profile aggregation	Centralized system	Distributed Ledger between all peer nodes
Load Aggregation verification	Centralized System	Consensus between all peer nodes
Single point of failure	Yes	No
Energy load secrecy	No	Yes
Payment settlement	Within 60 days (depending on settlement policy)	Real time settlemenet

Source: Author own work

In TETS, an electricity producer will attempt to meet local demand by generating electricity, with the risk of causing overvoltage during peak consumption hours (around 5-8 pm, when people come home from work). As these hours are not in sync with the peak electricity production hours, a method for storing and releasing the excess energy into the power grid is required. Currently, there are a lot of methods for power storage, each of them with its own ideal use case, benefits and disadvantages [10], [11], which will be explored in the following paragraphs:

- Pumped Hydroelectric Facilities account for more than 90% of energy storage in the electrical grid, because of their efficiency (70 – 85%) and reliable long-term storage capacity, despite their small power density (0.2 – 2 Watt-hour / liter).
- Lithium Ion batteries [12] have been developed in 1991 and have been the subject of the latest trends in energy storage for portable electronics and electric vehicles, electrification in rural areas as well as a method to restore energy to areas affected by natural disasters. This is because of their high power density (200 Watt-hour / liter), efficiency (85-95%) and their fast discharge and recharge time, which makes them a portable source of energy. Their main disadvantage is their short lifespan (only 1 000- 10 000 life cycles) and power degradation.
- Other methods include compressed air facilities, molten salt (thermal), hydrogen, flywheels (which are used mostly for energy regulation), lead-acid and solid-state batteries. These alternative battery storage methods are now under research, as the Lithium Ion battery technology is approaching its Physicochemical limits in terms of efficiency and degradation.

Because a malicious user can infiltrate unsecured local ET transactions and use energy without paying, a secure method of registering electricity consumption is needed. Smart grids and respectively, blockchain are a viable solution for these problems. Each consumer becomes a prosumer and can generate their own energy using renewable energy sources such as PV solar panels. If a prosumer has excess energy that they want to sell to other consumers, they can participate in ET by using SETS. The entire ET transaction can be broken down into several steps:

- ET transaction storage: Insert a new transaction into the SETS distributed ledger.
- Acceptance of the energy trading transaction: To view the stored transaction in the SETS distributed ledger.

4. Distributed generations

The smart grid technology heavily relies on distributed generation (DG). Electricity generation from various small energy sources is referred to as "distributed generation." Massive power plant generation has unavoidable consequences, including environmental effects on transmission and distribution, as well as a very stable electricity supply via the grid [7]. The current electricity networks are becoming increasingly overburdened as demand rises on a regular basis. As a result, traditional approaches add to the complexity of existing networks. A requirement for customer expectations on the distribution side comprehensive analysis of smart grid components such as distributed generation is required to meet customer expectations on the distribution side, such as lower power bills, increased comfort, reliability, and data security. In distributed generation, integrated minor nonconventional power resources can be used to generate electricity at the load end. This technology increases power quality, effectiveness, reliability, and security while reducing operational costs and impact on the environment .

5. Related work

5.1. Blockchain for Advanced Metering Infrastructure

As new regulation has made advanced metering infrastructure (AMI) mandatory in a large percentage of household applications in Europe, the traditional way of data storage and processing has remained the same, lagging behind the newly introduced technologies. Data servers (the third party managing all the stored data) have remained the traditional single points of failure in this system, while transparency and privacy risks have been introduced to the equation [13].

As presented in [14], Blockchain technology offers a solution for these challenges mainly through the use of smart contracts and the proof of work concept. The scope of the Smart contracts is to be the intermediary between the consumers and producers in the utilities sector; the smart contracts will increase the transaction rate and then the transaction information will be stored as a block on the network for future verification. Although lacking in technical detail, this work has seen implementation and testing in the upcoming years after its release.

In order to increase the functionality and energy security of smart grids [11], Blockchain ensures that the sensitive user information remains private, and decentralized data storage helps shield against malicious activities within the network and cloud. Three entities (edge devices, super nodes and smart contracts) are introduced in order to assure trustworthiness in the blockchain network.

The edge devices are similar to typical nodes in a blockchain network, while super nodes have the permission of selecting and authorizing edge devices to participate in the consensus and voting process. The study has found that by using super nodes for authorization, there is a 51% decrease in the likelihood of being compromised by an attack. However, if a malicious user manages to jeopardize the super node, the entire network can be rendered compromised.

5.2. Blockchain Mechanisms for Smart Grid

The integration of Blockchain in Smart Grid technology is becoming so sophisticated that key solutions for facilitating comprehensive security functionality SG technology are becoming available. In analyzing the key requirements, the core related interfaces, components, and applications of SG that are critically security dependent are discussed. Because of the public key algorithm, BC technology can convert the existing centralized ledger system into a distributed ledger. It also has end-to-end encryption technology and guarantees low costs due to the distribution processing structure. The concept of blockchains is currently generating a lot of research and functional attention. A BC is a cryptographic collection of node blocks that secures the headers, transaction data, and auxiliary protection metadata for each block .The BC fundamentally supports free connectivity, incorruptibility, openness, and secure data storage and transfer. Beyond the initial cryptocurrency applications, such as Bitcoins, several BC implementations have emerged in recent years.

The Bitcoin BC system is a public data database that saves the history of Bitcoin value transfers and keeps it up to date. This ledger is created using cryptographic technology to prevent forgery. The BC technology could aid in the resolution of a number of complex issues concerning the transparency and dependability of fast, distributed, and complex data exchanges and energy transactions. Smart contracts built on the BC frequently eliminate the need to negotiate with third parties, making it easier to monetize distributed and implement energy transfers and connections that include both energy flows and financial transactions.

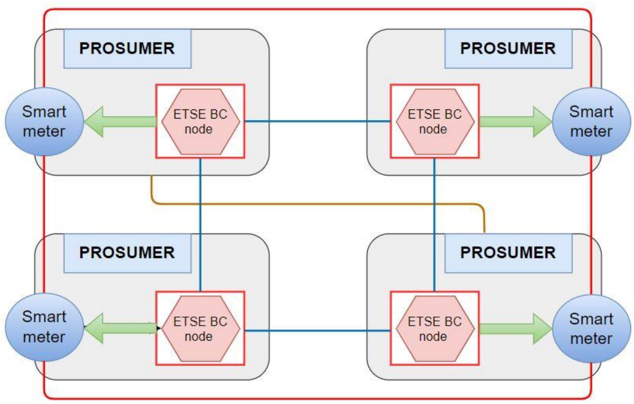

Fig. 2. Prosumers in Smart Grid

5.3. Blockchain Mechanisms for Energy Trading

Energy trading is required in BC technology for academic research and industrial application with emergency SG electricity generation and distribution. BC technology is used to reduce fraudulent activity. A certificate is issued in order to gain the trust/guarantee of the generators/consumers in this energy trading. Implementing BC technology simplifies the energy trading system and helps to reduce marketing effort and time. Conventional energy sources such as fossil fuels are rapidly depleting, and researchers and governments around the world are looking for suitable alternative energy sources, such as renewable energy. Many smaller generated companies produce energy on a smaller grid scale and must connect to the national grid in order for consumers to buy.

In addition, an individual who both consumes and generates energy (usually through solar panels) is called a prosumer. Prosumers are very useful in smart grids, as they can generate energy exactly during the peak consumption hours and ease the load off the power grid, in turn helping avoid power outages. The BC system provides an efficient peer-to-peer trading process for local consumers and prosumers while consuming very little energy and requiring a fraction of the communication infrastructure that a centralized system would need in order to be operational. The peer-to-peer topology handles this data automatically and stores it on the public ledger, where all copies are mirrored across the network. In a block node, the BC technology transmits data and communicates with the SG network. Every node is linked, and each device shares its address and information with previous devices.

5.4. Blockchain in IOT

The Internet of Things development and adoption has skyrocketed within the last decade [2] as a result, there are demands for increased scalability. These have caused bottlenecks to servers collecting data and these servers are prone to Distributed Denial of Service (DDoS) attacks.

Blockchain aims to alleviate this, by creating transparent methods through which the past transactions can be viewed by anyone on the network and by offering a robust level of encryption. Additionally, the client - server model poses a big security risk and that is why blockchain is proposed as a solution. As for the sensors, their biggest security flaw is that they can be altered by external interventions. Efforts are already undergoing for this project.

6. Conclusion

This article reviewed the most recent research progress on applying blockchain technology to smart grids. It begins by summarizing blockchain system characteristics, the smart contract paradigm, and the benefits of blockchain technology. Blockchain technology appears to have many desirable properties that can be used to build a better smart grid. Collaborations among professionals from various fields are critical in this regard. This survey will serve as a foundation for future development of blockchain-enabled smart grids. Research gaps were discovered based on the survey, which require more attention and improvement for a sustainable BC-based SG and energy trading system.

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