Smart Grid Resilience and Security Using Blockchain Technology

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***Abstract*—Due to limited nonrenewable energy sources society is moving towards renewable energy sources (RES), and the volatile production of RES is critical issue for its efficient utilisation. Smart Grids (SGs) are expected to enable distributed energy trading such that demand is maintained equal to generation without any human intervention. This should be achieved while maintaining security to avoid fraudulent transactions. SGs are facing serious challenges in maintaining security and privacy. Blockchain as a possible solution can solve these problems with its inherent trust building technology. This paper discusses an improved transaction security mechanism based on a consortium blockchain. It also helps in the trading of electricity with amount, and prices being decided using double auction mechanism.**

***Index Terms*—Renewable energy, Smart Grid, Blockchain Technology, Smart Contract.**

I. Introduction

Electricity is essential to modern society and economy. Most of the world relies on electricity systems build many years ago, which are very inefficient (more than 20 percent loss). In these system supply is constantly adjusted to match the demand, thus there have demand driven control.

Traditional grids are the one-way transfer process, i.e., generation, transmission, and distribution [1]. These grids are not secure enough towards vulnerabilities [2].However, these systems could be made more reliable and sustainable. In January 2007 Energy Independence and Security Act (EISA) in USA defined the smart grid (SG). It is an digitally controlled intelligent network of energy microgrids that can monitor, manage and heal itself in case of failures. SG gives a solution for the optimal electricity use by the customers. The key benefits of SG include improved efficiency and reliability of the electric supply, better cybersecurity of control and monitoring infrastructure, integration of distributed renewable energy sources into the existing network. It should lead to the reduction of carbon footprint by improved efficiency [3].

Next generation energy infrastructure is moving towards renewable energy which will generate energy from photovoltaic panels, rechargeable fuel cells, a large chamber of pumped hydroelectric power, wind turbines, and other sources. These network should handle bidirectional energy flows and will need smart grids for better and efficient transmission. SGs can respond to dynamic changes in energy supply which help in demand adjustments [2]. Despite having so many advantages of SGs, there are still challenges in its adaptation e.g. energy metering and control, occupancy sensing, data collection and management, energy optimisation and control, privacy and security of users and their data.

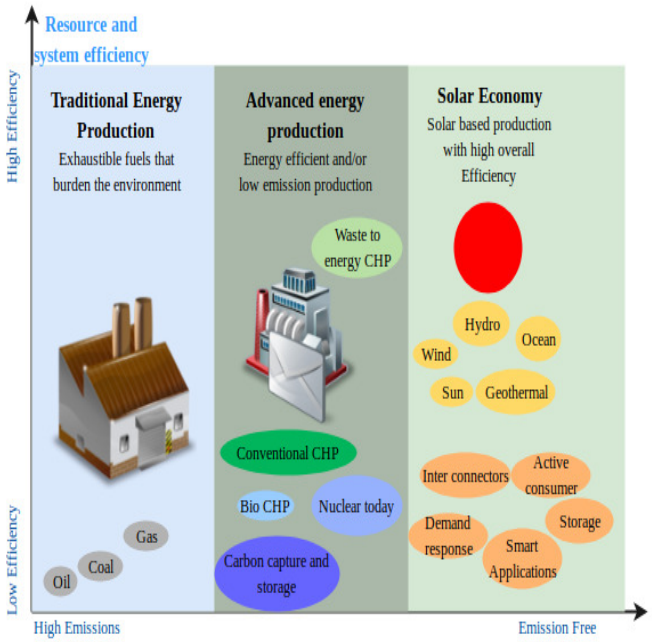

Fig. 1. Future Energy System Framework

For privacy and security, blockchain is a potential candidate technology. Blockchain can be used as a public ledger to track the transactions in the smart grid by using a virtual currency similar to Bitcoin [4]. It is a chain of blocks connected using cryptographic hashes. Each block has cryptographic hash value of the previous block, Merkle root hash (transaction data), and a time stamp. Blockchain as a technology assures the secure transaction of virtual currency. The same concept can be used in energy trading in Smart Grids. Blockchain application is not limited to secure transaction of cryptocurrency, it can also be used to keep the record of parameters related to energy flow in a distributed grid.

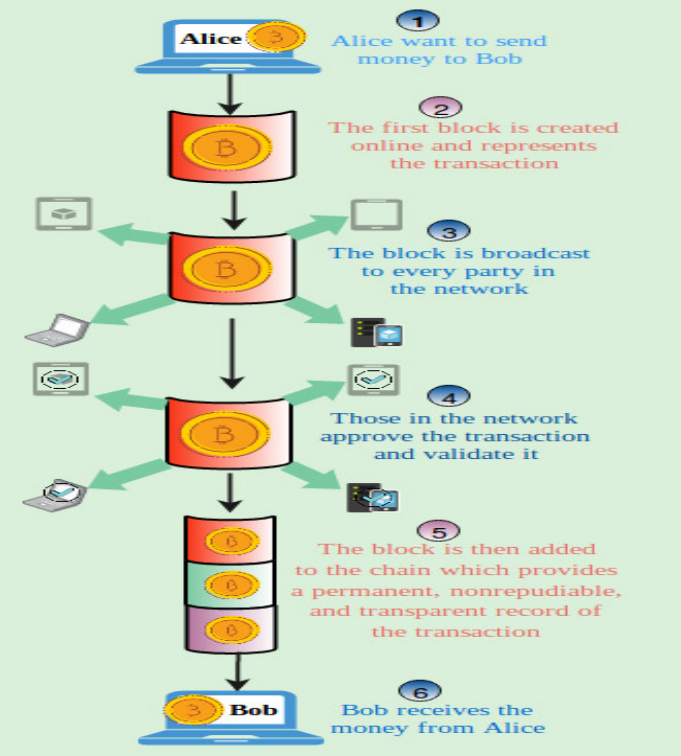

Fig. 2. How Blockchain works

The current electric system uses a grid where generation owned by companies and distributed the energy from there. But the future energy systems will be based on the duplex system. This duplex electricity system will include solar systems or local energy production system, micro-grids, energy management software, distributed computing and a lot of smart appliances shows consumer can also act as producers of electricity. These autonomous and instantaneous transaction of electricity need to be secure. Blockchain technology can provide a secure, auditable, transparent, efficient, and highly fail safe system for electricity trading.

II. What is Blockchain Technology?

In 2008, Satoshi Nakamoto, a pseudo-name, first introduced a cryptocurrency and payment system called Bitcoin. In Bitcoin network, a transaction is initiated when a node submits a request for a transfer of value.

The technology to build by which Bitcoin network is called blockchain. Bitcoin, also called blockchain 1.0 supports an optional and special feature called scripts for the conditional transfer of values. Ethereum the blockchain 2.0 extended the scripting feature into a full-blown code execution framework called smart contract [15].

A smart contract provides the capability of code execution for embedding business logic in the blockchain. Based on these capabilities three significant types of blockchains emerges from the bitcoin foundation. First one deals only with cryptocurrency, Bitcoin. The second one deals with both cryptocurrency and business logic, i.e. Ethereum. Third one deals with only business logic, Hyperledger. With addition of code execution, comes the serious consideration about the public access to the blockchain. Based on access limit, blockchains can be classified into public, private, permissionless and permissioned blockchain. Bitcoin is an example of a public blockchain. In private blockchain access to the blockchain is limited to the selected participants. The permissioned blockchain is also called consortium blockchain. It is meant for a consortium of collaborating parties to transact on a blockchain for ease of governance, provenance, and accountability.

III. Literature Survey

The recent advancement in technology has attracted researchers and industrialists towards SG. A lot of research papers have been published on the privacy and security issues in SGs. Some of the papers also discussed the solution. The trusted third party is one of the solutions to these problems, but in this paper, we have proposed a non-trusted blockchain based security solution for SG.

Mihail Mihaylov *et al.* [5] present as a novel exchange coin for buying and selling of renewable energy in SGs. The authors introduce NRG coin similar to bitcoin for payment of energy bills on an energy market exchange. They proposed a new technique in which consumers get the bill by distributed system operator which have a ledger of all the transaction and based on their actual consumption they will get some reward if they have used less than the production. The authors claim that their mechanism achieves optimal demand supply response curve by providing a reward.

Acs and Castellucia [6] proposed a minimal cost, simple, and efficient, practical smart meter which adds noise in data and gets encrypted with a dynamic stream cipher. The authors proposed a novel Distributed Laplacian Perturbation Algorithm to remove the trusted third party. The algorithm uses a cluster of hundreds of smart meters for a city and added noise for encryption such that an individual can get only their noised aggregated electricity for privacy. Differential privacy model has been used for confidentiality of individual consumption. The authors claim for a promising solution for centralized systems which is robust from smart meter failure and adversary nodes.

Karame and Dimitriou [7] discussed a way to increase privacy in SG throughput and billing address. The proposed solution preserve privacy by aggregating smart meter, anonymous tasking, and by putting energy barter between the smart meter and utility provider. The authors are using decentralized system with Bitcoin for rewards without relying on a central bank.

A. L. Kawasmi *et al.* [8] proposed a decentralized and secure system architecture for carbon emissions trading based on Bitcoin. The proposed system allows carbon credit generation, registration of participants, transaction initiation, distributed

chain of records of earned credit, and digital pseudonymous contracts. The authors claim that this decentralized system would provide security, protection for traders as well as its reduction of carbon emission.

Costas and Georgios [9] discussed a secure mechanism for smart grid by anonymizing the readings of smart meters. The proposed method uses third-party escrow mechanism for authentication of meter readings. However, this method does not provide attributable data which is used for marketing research purpose, account management, and billing. The authors use ADP setup and CDP setup separately for the security of proposed escrow service. However, the proposed method is not sufficient for privacy and security to the satisfaction of forensic analysis.

Marek *et al.* [10] proposed a consumption profile reporting protocol for smart meters which focuses on the time of use tariffs. The proposed method relies on Pedersen commitment with zero-knowledge proof by putting a communication link between a suppliers backend system and smart meter with a little bit change in software. The authors claim a full secure smart meter without changing existing hardware. However, the proposed method is not suitable for SG.
Molina Markham *et al.* [11] proposed an off-the-self statistical method for extracting complex patterns in the smart meter readings without any prior knowledge of household activities. The authors implemented their protocol into The Energy Detective (TED) energy monitor and developed embedded hardware based on ARM processor to run zero-knowledge protocol. In the proposed architecture, authors predicted future energy demand by aggregating information of smart meters.
S Cheng *et al.* [12] proposed blockchain technology to achieve peer to peer transactions in the distributed energy market. The authors claim to provide the solution for problems in traditional centralized structures. The use of blockchain technology in power transaction system architecture will provide less energy consumption loss and more secure transactions.

This paper provides plausible solution for the security of smart meter and smart grid by using blockchain technology. Rest of the paper is organized as follows. The definition of blockchain technology have been discussed in section II; Section III discussed the state of art of work; section IV discusses about plausible solution using blockchain, and section V gives the conclusion.

IV. Plausible Smart Grid Security Solution using Blockchain

Blockchain has an unique quality to distribute trust to increase security. It maintains distributed ledger with the time stamping of data blocks. It is nearly impossible to modify the data blocks which increases trust between nodes, and integrity of data both of which are significant challenges in grid infrastructure. These challenges forced the users to move towards an alternative way to purchase electricity. The blockchain-based smart contract provides an alternate method to trade electricity. By using blockchain based smart contract technology both prosumers and consumers can trade energy locally on double auction basis [14].

A. Smart meter

Most of the traditional energy grids which provide energy to us have centralized trading. Retail energy providers offer a digital meter to every customer and send bill after every billing cycle. But in this case, the customer will never know which device is using how much energy and how it can be used efficiently. Suppose you are using temperature setting of 25 degree then you will never know how much it will cost in terms of electricity bill if you will increase or decrease the temperature. In case, a owner knows the charges at every moment then according to that he can manage his comfort by increasing or decreasing cooling. As a solution, companies started using the smart meter which wirelessly sends the meter reading to the company. This reduces monthly monitoring of meters. The Smart meter allows the customer to pay by using an app which company provides to the customer e.g. Arizona's Salt River Project (SRP) provides M-Power customer app to purchase energy and pay their bill online. According to the Integrated Resource Plan Report 2017-18, this reduces electricity uses by 12 percent [16].
Smart meters allow balancing of generation and consumption and local energy trading within the community. The typical digital meter provides a monthly bill which often creates billing issues between user and company. Smart contract based smart meter can provide security and enhance the speed of payment with trust. Suppose the weather report says that next week temperature will be high or cloudy then the blockchain based smart contract will analyse the data and will purchase more electricity for that week. There will a lot of smart contracts which will be executed in smart meter and it will provide immediate feedback to the customer for their energy usage. The blockchain-based smart contract will provide greater transparency to all customers, while reducing the problems of over-billing.

B. Microgrid

Despite the peoples moving towards renewable energy sources, majority of electricity comes from natural gas and coal. Thus power is produced centrally and service provider distribute it from a centralized grid system. Centralized grid systems face many problems in case of shutdown or grid failure. Single point of control also leaves system more vulnerable. Microgrids are potential alternative for centralized grids to manage the supply locally. Rather than managing centrally, microgrid provides area wise control. It also provide prosumers (producers + consumers) to generate energy and sell it locally. This will help in better utilization of energy produced locally through solar panel or any other methods. In case of central grid failure, these microgrid will help in

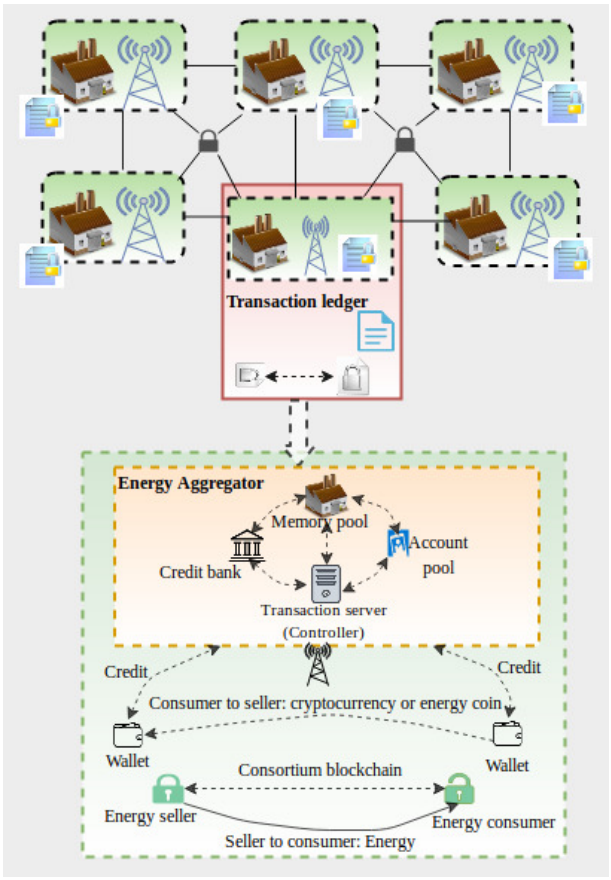

Fig. 3. Future Energy System Framework

providing electricity locally.

Park Slope Microgrid (PSM) in Brooklyn, is the first system to adopt smart contract based microgrid, which provides energy over 130 building. The idea is to provide clean renewable energy to local society and improve the efficiency and resilience of electrical grids [17]. This will also help in selling the extra energy produced at microgrid. The contract will be designed in such a way that if someone produce excess energy then it will sell automatically to others on that grid which will reduces the energy consumption from central grid. Due to strict energy industry regulation it is not easy to adapt this new technology even if it has lot of benefits.

C. Energy Trading

In the SG system, both prosumers and consumers can trade energy locally in double auction basis where electricity can be bought or sold within customers via the connected distributed grid. The blockchain will store all virtual activities like payment functions, market mechanisms etc. The consortium blockchain will provide the distributed trading of energy, anonymity of customers, and trust.

V. Conclusion

Traditional electricity distribution system lacks the privacy and security to restrain cyber attacks. It is also unable to solve security issues related to local energy trading. Smart contract based solution could provide security to smart grids, It can also help in scalability and real-time trading problems. Moreover, many customers can leverage upon the trading in energy and can verify other customers data which creates trust between peers. We discussed the SG relates security problems and a plausible solution using smart contract based consortium blockchain. Blockchain will act as a ledger for real-time data and smart contract will execute the business logic for local energy trading. Thus, with these security measures, we can improve the energy trading in the smart grid and can create a more resilient grid.

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