

Towards the Application of Blockchain technology for Smart Grids in Kazakhstan

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Abstract— The concept of smart grid infrastructure is already being implemented and progressing rapidly. The number of countries are transforming the traditional power grid so that it will be able to maintain the smart grid requirements. Smart grid is known as an evolutionary power grid which is proposed to make intelligent decisions on its own based on a current state of electrical power system. Microgrid (MG) is a "building block" of smart grid which supposed to provide wider control capability into the system, thus allowing to operate without connection to the grid. However, the remote and autonomous control of the smart grid may result in problems related to security. The main purpose of this paper is to consider various application scenarios of the Blockchain technology in smart grid. The utmost example is smart contract feature. It allows to reduce cost and increase security of trading operations without including third parties. In other words, direct communication between seller and consumer is implemented. Particularly, paper explain how the security and resilience of the system can be improved by the application of Blockchain technology. Furthermore, decentralized machine-to-machine interaction scheme is proposed. First of all, auction based electricity trading platform is established in Jade platform, and further on electricity trading history is stored in blockchain. The proposed case study shows implementation possibility of smart contracts in smart grid environment.

Keywords — Blockchain technology, Smart grid, Electric vehicle, Distributed energy, Internet of Things.

I. INTRODUCTION

The conventional power grid is used to deliver required amount of power to the consumers from generation points by means of Transmission and Distribution systems. First one delivers power to the designed distribution substations, while second system distributes power to final consumers. Traditionally, analog technology is used to conduct the process described before [1]. On the other hand, the expression Smart Grid seems to be a nebulous and unfinished term which integrates different functionalities in order to modernize the working procedure of usual power grid.

Digital communication and various control systems to regulate power flow in the grid aimed to increase the cost and system efficiency, the degree of resilience of the power grid are the fundamental approaches implemented in Smart Grid technology. In other words, the smart grid can be explained as an advanced electrical power system which is able to make intelligent decisions taking into account the current state of

electrical power system, provided by various sensors and actuators, in order to maintain the system stability [2].

As the rapid progress of smart grid technology is observed at present time, a number of countries are making investments to transform to smart grid. They are rearranging the whole organization of traditional power grid, so that it will be fully suited and able to maintain the vision of new technology. The developing smart grid will result in the increase of power management complexity. Therefore, several software models, such as Smart Grid Interoperability Maturity Model (SGIMM), Smart Grid Investment Model (SGIM), Smart Grid Maturity Model (SGMM) and Smart Grid Conceptual Model (SGCM), which are able to handle the complexity level of smart grid, are already available nowadays [3]. These models are used to analyze the current operation of smart grid in order to raise its progress to the next level and get maximum benefit from its utilization.

The smart grid technology lean on remote access and automation principles. These principles are able to increase the security concerns bound up with hacking and stealing personal information or any other confidential data. The Blockchain technology may be an appropriate solution to improve the integrity and reliability of the complex energy transactions and data interchange [4].

The term Blockchain is defined as a database which is used to record each and every transaction made via the help of cryptographic signature which has intrinsic resistance to the modification of data. The author of the book known as "Blockchain Revolution" – Don Tapscott claims that: "The Blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value" [5]. Therefore, the application of smart contracts based on Blockchain technology makes it possible to increase the speed, scope and the level of security during the process of energy transaction is conducted [6].

This paper presents and evaluates the various applications of the Blockchain technology in a smart grid system. The paper is structured as follows. Brief introduction and motivation are presented in Section I. The Section II contains information about the state of the art. In the Section III the working principles and possible benefits of the Blockchain technology are explained in details. Section IV shortly considers the most prevalent applications of blockchain at all, whereas section V

directly discusses the applications of Blockchain technology in smart grid. Section VI dives in the explanation of smart contract implementation in smart grids. Section VII consider a case study of blockchain in smart grid. The conclusion sums up everything in section VIII.

II. STATE OF THE ART

Increasing number of Distributed Energy Resources(DER) injected to the grid, as well as emerging number of microgrids in the network lead to an issue of optimum transactive energy management system. Blockchain technology application rises an opportunity to modernize the grid, resulting in higher operation speed, security and data integrity of the modern grid. Through this technology decentralized real-time transactive energy management may be obtained, providing a path for the Energy Internet of Things. Microgrids operating as an independent energy supplier require high level of data security, and its integrity. Despite mentioned requirements, energy deliver systems need real-time energy transactions with relevant control.

Smart contracts developed in blockchain environment can meet all the requirements, creating optimum, autonomous and robust trading platform by providing a distributed ledger of energy transactions, that are verified by other network users. Mention ledger can contain essential data such as, time, user, energy transaction data.

III. BLOCKCHAIN TECHNOLOGY

A. Principles

Emerging blockchain technology is based on distributed electronic database, and operate with predefined set of rules used to update this database. All transactions are broadcast to the network, and the validity of message are checked by network users. Records of transactions are saved in so called blocks, which are linked to each other with a string values, that are called hashes. Each block contains its hash code in the front of the block. Hash code is received from the hash function (i.e for Bitcoin it is SHA-256). Validity of the transactions is recorded by miners, who verify the records and collects them as a sealed block. Further on, relying on hashing each block is linked to another [7]. Proof of work mechanism is relied on hashing, which basically connects computing power with consensus. Proof of work is basis for so called "miners", who are responsible for all data transactions to be verified, validated and linked properly. Interest of "miners" relies on getting award as cryptocurrency, for each sealed block [8].

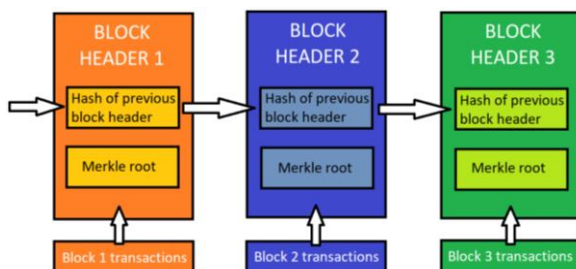


Figure 1. Simplified view of the Blockchain technology

B. Possible Benefits

As the current situation in power grid management is facing lack of security and resilience from cyber-attacks on DERs, implementation of blockchain technology may be the solution for this issue. Despite this, blockchain technology is able to detect if any data abnormality happened and response to possible system hacking intended to change configurations or extract critically significant information. Furthermore, introducing smart-contract systems may have other beneficiaries, but not limited to: .

- 1) Trustworthy consensus among the energy traders;
- 2) Distributed ledger, that support multifactor verification;
- 3) Data security;
- 4) Elimination of third parties in energy transactions, so overall energy cost will decrease;
- 5) Real-time transactive environment, so improved demand management;
- 6) Introduces environment for microgrids to participate in energy trading. Rising an opportunity to microgrids to trade their excessive energy, and thus lowering the stress on the main grid;
- 7) Obtained data analysis, which may be leveraged to charge the consumers [6];
- 8) Improved EV charging and discharging scheduling [9];
- 9) Shift of high load household devices to off peak hours, resulting in reduced electricity cost [10];

IV. BLOCKCHAIN APPLICATIONS

Blockchain is not a BitCoin as most of the people may thought about it. As it was explained earlier blockchain is a one type of database which is used to be saved in decentralized system and is not able to be changed or manipulated [11]. Therefore, the area of its application is very wide. Here are some major examples of its application which are not going to be discussed in details in this paper:

A. Financial Applications

• BitCoin

It is known as a crypto-currency that was first implemented and published as a whitepaper by an anonymous hacker or a group of hackers under the name of Satoshi Nakamoto. The idea was to conduct peer-to-peer and decentralized financial operations [12]. It was launched after the crisis in 2007-2008. Bitcoin allows to transfer large currency in large amounts internationally without any transaction fees or with insignificantly low fees.

• Ripple

Another popular financial system in base of which the trust between peers lies is known as

ripple. Its unique feature is that it can be used as a bridge in transition from traditional banking to electronic banking system [13].

B. Non-Financial Applications

- **Ethereum**

One type of smart contract system which is software based and publicly available for everyone. The main goal of ethereum is to develop the programming code for each and any decentralized system [14].

- **Hyperledger**

Hyperledger is a project which is focused in blockchain application in business. It was invented by Linux foundation.

V. APPLICATIONS IN SMART GRID

Xigao Wu et al. [15] suggest that the most auspicious application of blockchain technology in power industry is record storage and contract execution. They present a method that may be used to manage demand and transactions of the grid via blockchain technology. Smart meter devices will be acting as a measuring tool, which will be able to ensure the power quality in the grid. For the payment procedure electricity trade and encrypted money are regulated via smart contracts and operated with the help of blockchain. Proposed case study, showed the relevance of blockchain technology application in demand side management in terms of machine-to-machine interaction. Integrating smart contract systems into the power industry may result in offset of energy bills. Despite this, it raises an opportunity to enhance the speed, scale and security of the modern grid, which is facing injection of DER, and thus increasing speed and real time energy transactions are the main milestones of grid modernization.

C.Liu et al. [9] proposed decentralized Adaptive Blockchain-based Electric Vehicle Participation (AdBEV) scheme, that is used to minimize the power fluctuation level of smart grid. The scheme is based on Iceberg algorithm, that operates well to face charging and discharging demand of EVs. Received result revealed that EV charging and discharging processes may be scheduled dynamically via AdBEV.

VI. SMART CONTRACT APPLICATION IN SMART GRID

As it was mentioned before, the application of smart contract in smart grid technology is the most favorable one. The main idea is to eliminate third parties in order to reduce cost. Also, via this application the opportunities of individuals to produce and sell energy to each other can be significantly increased. The smart contract technology allows the peer-to-peer energy exchange directly between each other without including the transmission and distribution systems that are transacting on different scales. For instance, in April 2016, in New York city one of the first time uses was implemented between neighbours. They sold the generated energy between each other via blockchain technology and without the help of

any third-party intermediary, thus decreasing the costs and time spent for conducting the whole procedure.

In addition to this, blockchain technology offers more secure transaction of data implementing the multifactor verification and other possible techniques designed to improve the security such as decentralized storage of transactions [16].

The overall procedure starts from the generation of energy which is then bought by consumers. Then, unique block, used for verification process, is created by special meters which are based on blockchain in order to update the whole blockchain. The working principle described before introduces reduced data requirements and faster speed of transaction clearance.

Advanced metering techniques (AMI) which are permitted by blockchain facilitates execution of smart contracts and recording of transactions. This allows to exchange an excess amounts of generated energy, thus supplying substations with extra storage and preventing from the consequences of bulk effect. Hence, it is possible to reduce or even remove the meter operator in a peer-to-peer system because the smart contract data is secured via the use of decentralized storage.

However, as it usually happens, new opportunities are followed by new challenges. Firstly, the need in submitting timetable plans and prognosis to transmission system operator still exists because they can help to define the important roles for energy companies. Also, it still seems to be a complicated procedure to integrate individual blockchain consumers into a balanced party and feel certain that they will obey market requirements and provide precise forecasts to network operator [17].

VII. CASE STUDY

This paper proposes energy trading platform that may be established in Kazakhstan. Developing smart grid environment in the country would attract people to use DERs. For instance, potential of Kazakhstan to generate solar power is estimated to be 3,760,000 MW per year, but the actual installed capacity was found to be less than 1MW per year. It utilizes the solar panels to supply the mosque with electricity, and also able to sold it.

For Astana city typical average daily solar radiation during July is estimated to be around 500W per meter square. In order to meet the typical demand 5 solar collector with the area of 2 m² is used. So, on average each solar collector generate 1.0 kW per day in July in Astana.

During case study simplified Simulink model of the microgrid is taken, which is designed by Hiroumi Mita. Power generation from solar collectors is 0 during night times, namely from 20pm to 4 am. Its peak value of 5 kW correspond to the time period between 2pm to 3pm. Load conditions at typical household users reach peak energy consumptions at 9am(6.5 kW), 7 pm and 10 pm(7.5 kW). The load used in the simulation is a combined electricity consumption of two houses. The overall energy surplus of the system is found to be 9.045kWh between 12 pm and 3 pm. So, obtained surplus energy may be sold back to the main grid via blockchain.

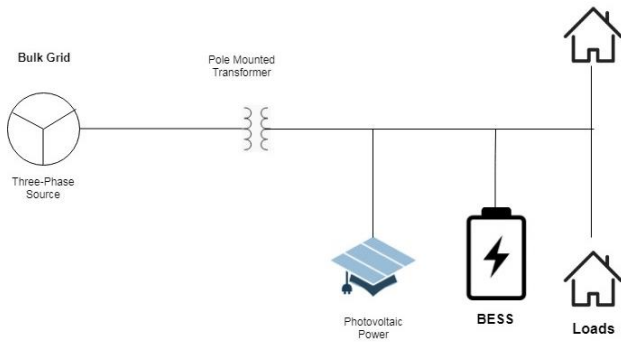


Figure 2. Simulink model of microgrid

In this section the implementation of blockchain technology in energy trading between peers is discussed. For couple of last years the agent technology is known as one of the most innovative approaches to develop the software model of the distribution system [18]. Therefore, for simulation purpose multi-agent Jade platform was used in order to initiate trading between the agendas. Actually, the Jade platform is separate library package for Java programming language that allows P2P trading between the agendas.

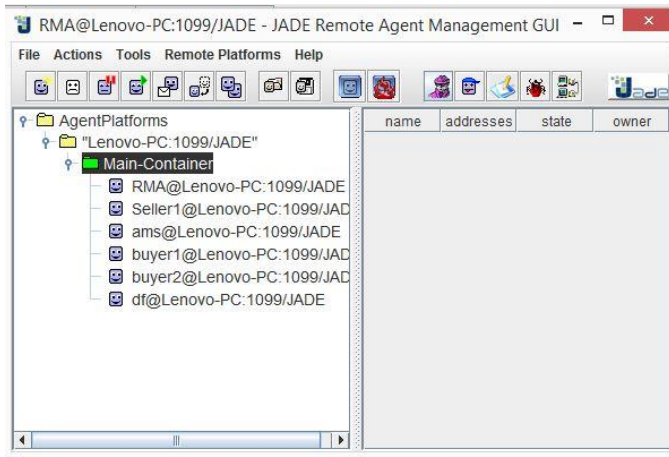


Figure 2. JADE agent management GUI

In order to implement any simulation several assumptions should be made to simplify the task. Assumption that each agenda, which operate at each node, have relevant smart terminals and corresponding infrastructure was made. Thus, actual hardware infrastructure of the smart nodes is out of the scope of this study.

Overall, it is assumed that each-node is a microgrid or households that can generate its own power and have Battery Storage System(BSS), which make it possible to participate in trading. Furthermore, each agenda may participate as a seller of excess energy or as a consumer. The trading is performed as an auction in specified time interval. Seller agendas set the amount of electrical energy, that they need to sell, and also they establish first bidding. The trading process follows conventional auction mechanism at which the highest bid wins the auction. Digital signature of each block is designed to be

dependent on transaction data, namely on the amount of kWh energy and price, hash of the previous block and the timeStamp, as a number of milliseconds since 1/1/1970. Cryptographic algorithm used is SHA256, which digest the input String into hash. The following figure illustrates auction results at which 3 agendas participated in trading. The first block of the chain is initiated without any relevant data. The following blocks has actual transaction history and corresponding timestamps. Surplus energy obtained from microgrid simulation is sold partially for each virtual buyers.

hash	0b23d71421459697c95efe333812f57....
previousHash	0
data	First Block
timeStamp	1541609544124

hash	91a2011631f3170924707fb7aa8c7c9....
previousHash	0b23d71421459697c95efe333812f57....
data	Power sold 3.350kWh
timeStamp	1541609552745

hash	ef6b2cde3021ae7d4676712d29b4a38....
previousHash	91a2011631f3170924707fb7aa8c7c9....
data	Power sold 2.200kWh
timeStamp	1541609588874

hash	42e8b2dd9378f6c222a2891c3d77868....
previousHash	ef6b2cde3021ae7d4676712d29b4a38....
data	Power sold 3.495kWh
timeStamp	1541609609871

Table 1. Obtained Blockchain from smart grid

Having a price of 39.61tg per kWh energy, simulated microgrid may have gain a profit of 358tg per day. So, in one summer month simulated microgrid with 5 photovoltaic solar cells may obtain a profit of 11106tg. As it is shown above corresponding transactions history may be saved in distributed ledger implemented by blockchain.

Depending on the agenda the electricity purchase history on each smart node. The case study clearly illustrates the implementation possibility of the M2M interaction in the blockchain environment. Conducted case study may be further improved by introducing the GUI based blockchain wallet system, which will enable to use the full capabilities of blockchain technology.

VIII. CONCLUSION

As the application of distributed energy resources for domestic or industrial uses are increasing every day, a secure and effective peer-to-peer energy transaction between supplier and consumer is required. The method presented in this paper offers possible demand and transaction control procedure based on blockchain technology. Particularly, this paper is considering the application of smart contract technique which allows to conduct energy trading without involving third party companies, thus reducing the cost and time spent for the whole process. The simulation of energy transaction was performed by multi-agent JADE platform which is in fact one of the libraries for Java programming that allow the implementation of peer-to-peer trading. The case study made in this paper assumes that trading occurs as in a conventional auction and final results of trading are shown in figure 3. The blockchain technology has a tremendous potential to fulfill an industrial revolution by facilitating its exploitation. Also, there are still many undeveloped areas of research and appliance to conduct further innovations.

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X. BIOGRAPHY



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