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Blockchain-based Energy Trading for Decentralized Energy Generation

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Abstract: **Fundamental to Saudi Vision 2030 is to maximize the potential of renewable energy. This can be achieved by enhancing the regulatory framework that allows the private sector to buy and invest in the renewable energy industry. The presence of many energy providers into a grid could present a loophole for cyberattacks and reduce the power system's reliability. A very efficient scheme for proper energy transactions is the adoption of blockchain for decentralizing power generation. The blockchain transactions eliminate the need for a third party and provide a secure and cost-effective meter to cash processes. This article will present successful case studies for implementing the blockchain power exchange, provide a feasibility study, and suggest a framework for the implementation of such a technology in Saudi Arabia.**

Keywords: **Blockchain, Cryptocurrency, Cybersecurity, Energy Transactions, Microgrid, Smart Grid, Smart Contracts, Tariff, distributed ledgers, Ethereum.**

I. INTRODUCTION

Saudi Vision 2030 aims to maximize the potential of using renewable energy. Although renewable energy is not a new concept, many have questioned the impact of renewables integration to the grid. As the world energy demand has increased tremendously, the idea of utilizing different methods to produce energy has become a necessity to study and implement. Research has shown the many benefits of integrating PV systems into national grids, such as minimizing distribution line losses, increasing grid resilience, and lowering generation costs. However, while research has also shown solar-grid integration can cause disturbance in the grid, there are technologies that can minimize these impacts [1]. This has led the Saudi Electricity and Cogeneration Regulatory Authority (ECRA) to introduce regulations to promote their uses. These regulations could be improved to accommodate expected improvements to renewables and electrical storage technologies. The cost of photovoltaic panel generation is expected to drop significantly as a result of mass scale production of such panels in China [2]. In addition, many electrical storage technologies are being developed, such as magnesium batteries, which can drop the cost of electrical storage [3]. Enhancement of the regulatory framework for the cogeneration, along with the formerly mentioned factors, can stimulate the growth of distributed energy resources in the grid. A very efficient scheme for enhancing the framework is the adoption of blockchain technology. Such a technology has been widely used in the financial sector due to its effectiveness in addressing trust issues. Blockchain is a public, distributed ledger of cryptographically linked blocks that enables transactions between two parties without the need for an intermediary. Instead, transactions are verified through parties' common consensus. This would significantly reduce verification cost and eliminate single point of failures. The Bitcoin and Ethereum platforms are successful implementations of the blockchain technology. While bitcoin is well known, Ethereum is another cryptocurrency platform that comes with the smart contract feature, which allows cryptocurrency transfer between peers only when a certain outcome occurs.

An emerging application for the blockchain and smart contact technology is the coordinating of Distributed Energy Resources (DER) through a very effective meter to cash processes, which would encourage investment in the DERs.

The rest of the paper will further explain blockchain technology and how it can be used for energy transactions, provide successful implementation cases, and suggest a framework for the implementation of the technology in Saudi Arabia.

The paper proceeds as follows: We first define Blockchain in Section II. In Section III, we review the literature for the use of blockchain in coordinating cash-to-meter processes. Section IV provides a framework for the implementation of blockchain in Saudi Arabia.

II. BLOCKCHAIN

Blockchain is a distributed ledger of cryptographically linked blocks that can enable transactions between two parties without the need for an intermediary. The ledger contains a sequence of blocks that, once formed, become immutable. Each block contains data (transaction details), a hash of the previous block, and a hash of the current block that is calculated using the data in the block (see Figure 1). Therefore, changing the hash of any block would make the complete ledger invalid. Blockchain participants communicate directly in a peer-to-peer architecture and transactions are verified by participants in the network and stored as blockchain with all participants (see Figure 2). The immutable blocks, distributed ledger, and the common consensus verification makes the blockchain architecture very secure. A competitive security advantage for the blockchain over the traditional centralized entity verification is the absence of a single point of failure or attack in the blockchain architecture.

Practical implementation of the Blockchain technology, especially in the financial sector, has proved that such a technology is secure and effective. The market value of the blockchain-based cryptocurrencies has reached more than $263 billion [4]. Bitcoin and Ethereum are the blockchain-based platforms with the highest market value [4]. While bitcoin is a purely financial platform that uses blockchain for financial transactions, Ethereum uses blockchain to verify and enforce contacts. The Ethereum enforces contacts that are written using codes. The code execution is verified using blockchain. The Ethereum is well secured against Denial of Service attacks (from codes) though using the EVM gas fuel concept, which is a tariff paid by the contact initiator per CPU power utilized.

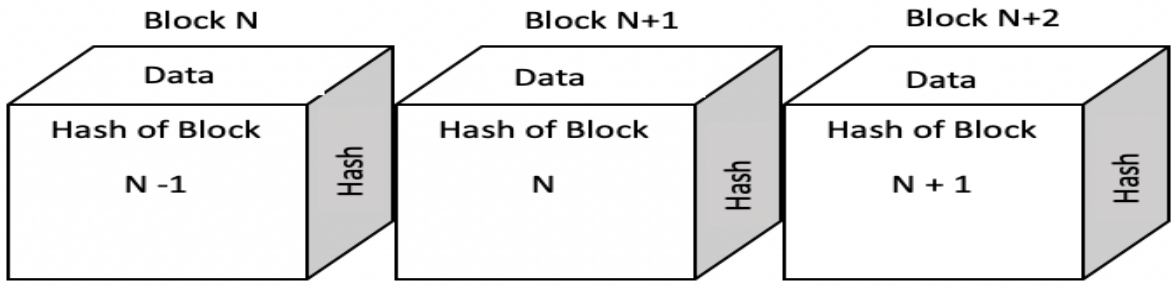

Figure 1: A Blockchain ledger. Each block contains the transaction details, the previous block hash, and a hash of the current block, which is calculated using the data in the block (transaction details). Changing the data in any block would make the subsequent blocks and the ledger invalid.

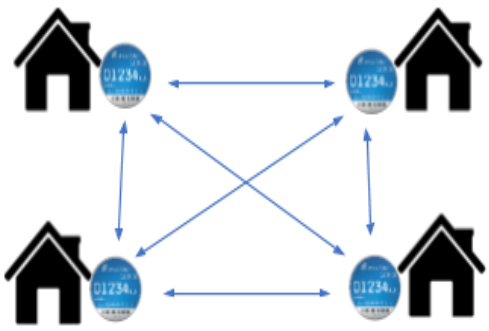

Figure 2: Blockchain participants communicate directly in a peer-to-peer architecture and transactions are verified by participants in the network and stored as blockchain with all participants.

III. BLOCKCHAIN FOR DISTRIBUTED ENERGY RESOURCES

The world is evolving very quickly, especially in energy technologies where we find many promising startups and companies that are going to change and transform the future of energy transactions by capitalizing on blockchain. In the United States, many startups are utilizing the blockchain and they are trying to be the pioneers in this sector such as LO3. LO3 is trying to disrupt the energy industry and attempting to localize the energy industry by combining blockchain and microgrid technology. Brooklyn Microgrid is one of their projects, which is a small-scale energy system that connects

Brooklyn residents and business owners who support local solar energy and who want to be pioneers in changing how we purchase and sell energy.

The Brooklyn Microgrid network connects people in Brooklyn who own solar arrays ("prosumers") with people who want to purchase local solar ("consumers"), where prosumers can trade their excess renewable energy capacity with their neighbors using a secure blockchain platform [5]. Brooklyn Microgrid is trying to introduce a new business model that will disrupt the energy industry. The business model of Brooklyn Microgrid is mainly capitalizing on peer-to-peer transactions, where neighbors can sell their excess solar energy to each other effortlessly through a blockchain-verified system.

The Brooklyn Microgrid Company uses Ethereum cryptocurrency, which is the same technology that shares the same fundamentals as other currencies such as bitcoin. This technology uses an electronic ledger that records and cryptographically verifies all in and out transactions. Brooklyn Microgrid is using Ethereum because it creates accurate smart contracts that can't be changed with a secure manner. All transactions between parties are done in a peer-to-peer network. According to LO3, the owner of Brooklyn Microgrid, they are working on developing and deploying their own blockchain-based transactive energy platform across multiple markets. In April 2016, Brooklyn Microgrid has successfully tested its system, while the first transactions occurred among neighbors who didn't have their own solar systems and those who produced excess solar electricity. According to LO3 [6], they are developing their own system, which will be capable of embracing:

Smart meters: measuring a building's energy production and communicates with the network to manage energy.

Blockchain: used to decentralize a digital ledger where private computers verify transactions automatically; as each new transaction is verified, it adds to the ledger.

APIs: The LO3 Application Program Interface enables collaboration by creating an open path that encourages participation (and innovation) from members across the network.

Grid: The technology complements the energy grid(s) already in place while making it easy to establish a community of buildings that can generate, store, and trade energy locally.

The concept of Brooklyn Microgrid could be adapted in Saudi Arabia, since all the resources exist. Adopting such a technological concept and new trends can produce a much more flexible, reliable, secure, and efficient energy.

IV. SAUDI ARABIA FRAME FOR BLOCKCHAIN

The Grid Code rules and regulation are written and continuously updated by National Grid SA, a wholly owned subsidiary of the Saudi Electricity Company. However, the final approver and authority for these rules and regulations is the Saudi Electricity and Cogeneration Regulatory Authority (ECRA). Regulations must be complied with by all the different types of grid users, such as power generators, distribution entities, and directly connected customers. The code defines user's responsibilities, technical requirements, and transparency to ensure the grid provides safe, reliable, and efficient operation to the end users.

The ECRA has issued the regulations for the connection of small-scale Solar PV Systems to the distribution system within the Kingdom. The regulations target all solar PV systems that are greater than 1 KW and less than 2 MW and aim to achieve the following [7]:

a) Specify the terms, conditions, regulatory requirements, processes, and charges pertaining to promoting Distribution System connected small-scale Solar PV systems in the Kingdom of Saudi Arabia (KSA);

b) Establish a framework for net metering arrangements of surplus energy exported to the Distribution System.

c) Ensure the efficient and safe construction, installation, maintenance, and operation of small-scale Solar PV systems in all premises in KSA.

V. CONCLUSION

The Saudi Arabian Energy and Cogeneration Regulatory Authority has undertaken a tremendous effort to help consumers in the process of construction of small-scale solar PV system and integration with the National Grid, but limits the amount of capacity that can be injected into the grid. Therefore, blockchain technology offers a second way of compensation for PV system owners. Excess renewable power can be sold to those connected with the same blockchain platform.

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