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A Conceptual Model for Peer to Peer Energy Trading using Blockchain

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***Abstract*—Power grids are undergoing significant changes due to rapid growth in renewable energy resources. While these changes enhance sustainability and efficiency, they also create significant management challenges as the complexity of power systems increases. To tackle these challenges, decentralized solutions are emerging, in which local communities are arranged in microgrids. Within the microgrid a prosumer (i.e., consumers with energy generation and consumption capabilities) and the consumer can trade energy with each other without involving any arbitrator, thereby smoothing the load on the main grid. It is very important to design a reliable transaction platform for the energy trading. This paper describes the efficient and reliable model for peer to peer energy trading based on Blockchain. Peer to peer transaction platform build on smart contracts, coupled with blockchain removes the reliance on the central system between transaction parties.**

***Keywords*—Blockchain; Distributed Energy Resources(DER); Proof of stake; Smart contracts; Smart grid; Smart meter**

I. Introduction

Major economy of any country are inextricably linked to energy availability. Traditional, nonrenewable sources of electricity like coal, natural gas, and oil, cater to the vast majority of the world's electricity demand. However, these sources are censured for exaggerated greenhouse gas emissions, availability concerns, economic expediency uncertainties, and association with dependence on foreign energy supply. Renewable sources, like solar photovoltaic (PV), wind, hydroelectric, geothermal and biomass, are becoming attractive options because of their low carbon impact, price stability in the energy market and economic benefits.

Solar energy is an important source of renewable energy. This energy can be used enormously when harnessed sustainably. Proper utilization of the upcoming technologies may assist countries towards a more sustainable resource base.

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In the recent Paris agreement, all the countries united to legally ratify action against pollution [1]. India is among the countries that are on track to achieve the targets set to address climatic change under the Paris Agreement. It aims to produce 40% of its installed electricity capacity from renewable sources by 2030 [2]. For this India will have to significantly shift its power generation to renewable energy sources. India currently targets to install capacity of 100 GW solar energy by 2022. In India, the utility-scale solar power plants require about 1 km2 of land for every 40–60 MW generated [3]. But land is scarce in India.

The major part of India is covered by rural area. According to the 2011 census definition, 68.84% of the population lives in the rural region [4], and energy consumption in this region is low. The amount of total area available for implementation of distributed solar energy resource such as rooftop solar panels is large. Thus, tapping into distributed solar energy resource system holds a huge potential in India to meet its massive energy needs.

During peak time, the excess energy produced will be traded between prosumer and consumer within a microgrid. To trade this distributed generated solar energy, there is a need for a transparent decentralized peer to peer network.

This paper provides a conceptual model for the development of Smart Grid System integrated with the decentralized platform using blockchain for the trading of electricity. A different approach for the future of micro-power grid systems is emerging; the local communities are arranged in microgrids in a decentralized distributed system. In this approach, energy generation, transmission, distribution, and even storage can be strategically used to balance load and demand spikes [5]. Blockchain technology will eliminate the need of any arbitrator to carry out energy transaction while ensuring all data is secure and transparent. In a peer to peer (P2P) energy trading platform, all participants of the network could directly enter into energy exchanges with any other participants without restrictions from a centralized authority. P2P model allows greater tractability and could be a powerful enabler for customer-centric transactive energy. Furthering the concept of smart microgrids with peer to peer network model has been proposed to support the trading of distributed solar energy resource system evolution.

II. Defination

A. *Blockchain*

Blockchain is a shared ledger technology that allows any participant to securely store data and execute smart contracts in a peer to peer network to view a particular system of record or ledger [6]. This is potentially disruptive, as trusted intermediaries could become antiquated. Cryptocurrencies such as Bitcoin underlying of Blockchain, but Blockchain applications can be also nonmonetary, for example, smart contracts that are automatically executed once specific conditions are fulfilled.

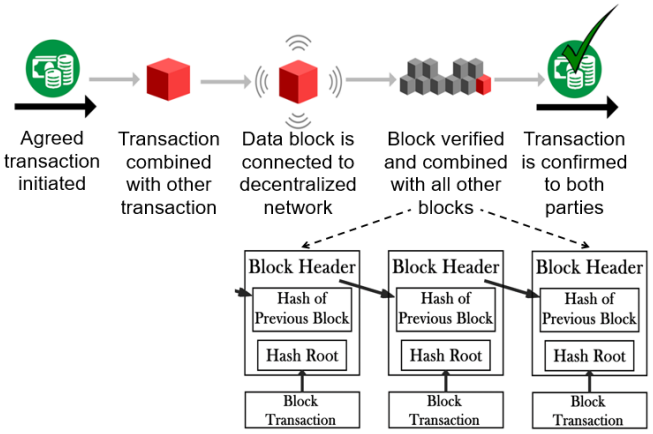

Figure 1. Structure and verification in Blockchain

Blockchain is essentially a distributed ledger that records transaction between two parties in a verified and immutable way with a timestamp. Blockchain operates as a distributed information that contains an unceasingly growing list of information records, called as the blocks. These blocks are timestamped, shared, irreversible, and connected to leading blocks. They contain information and programs, batches of individual transactions, and executables. Transactions are verified by the network's users, the nodes. In the structure of blockchain, blocks hold batches of valid transactions that are hashed and encoded into a hash tree. Each block includes the cryptographic hash of the paired block in the blockchain linking the two. The linked blocks form a chain. Structure of Blockchain is shown in Figure 1. Each block consists of a header and transaction data. The header contains a hash of the previous block. Hence, all block contains a hash of the previous block and this leads to form a blockchain. A typical transaction on Blockchain consists of following steps.

- A message is transmitted to the network that contains data on the assessment of the transaction and a digital signature that confirms the legitimacy of the sender, transaction, and receiver's address.
- The nodes of the network receive the message and they verify the validity of the message by decrypting the digital signature. The attested transaction is placed in an exceeding pool of pending unsettled transactions.
- One of the nodes within the network aggregates unsettled transactions in a block that contains accordant, replicated, shared, and synchronic digital knowledge. At a particular interval, the node broadcasts the block to the network for validation.
- The validator nodes of the network receive the pending block and validate it through a repetitive process, which requires consensus from a superiority of the network. If all transactions are validated, the new block is integrated into the present Blockchain, and also the new current state of the ledger is communicated to the network.

Blockchain based exchange of value can thus be computed more quickly, more safely and more cheaply than with traditional systems.

B. Proof of Work

The proof-of-work idea is the consensus mechanism most often utilized in conjunction with blockchain technology, and depends on "miners". Every block is verified through mining before its data is stored. The data present in each block is validated using algorithms which attach a unique hash to each block based on the information stored in it [7].

C. Proof of Stake

The proof-of-stake approach simplifies the mining method wherever a large variety of tokens ought to be verified. Whereas in the proof-of-work principle, a large group of distributed users are continuously validating the hashes of transactions through the mining process in order to update the current status of the blockchain assets, the proof-ofstake concept requires users to repeatedly prove ownership of their own share in the underlying currency. Wherever the proof-of-stake methodology is employed, the work needed to hold out the verification method is allotted among individual members who are supported by their stake in percentages. For instance, if a user owns a tenth share of the full outstanding blockchain assets, the user may be compelled to perform 100% of the desired mining activity. This approach reduces the complexness of the decentralized verification method and may, therefore, deliver massive savings on energy and operational costs.

D. Smart Contracts

The smart contract is a piece of software in which the rules for negotiating the terms of the contract are stored. It automatically executes the agreed terms after verifying the contract. The blockchain is coupled with the smart contract technologies which remove the reliance on the central system between transaction parties [8]. Smart contracts are completely distributed and immutable. The output of the contract is validated by everyone on the network. All transactions are recorded in chronological order on the blockchain for future access along with the complete audit trial of events. Smart contracts enable parties to transact directly with each other.

E. Peer to peer energy trading using tokenization

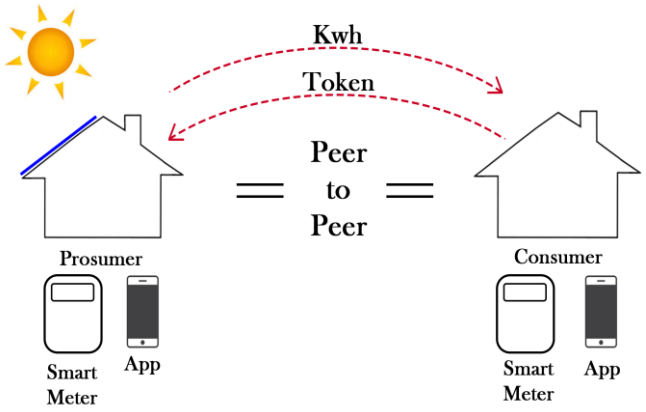

Figure 2. Peer to Peer trading of Energy

Traditionally, excess electricity produced by the solar panels is fed back into the national electricity grid. In Peer to peer trading, the excess electricity produced is exchanged among the producers and consumers in the microgrid.

This energy is made tradable by tokenizing and putting it onto blockchain. Tokens are the digital assets that can be exchanged in peer to peer network without the need of an arbitrator. In P2P energy trading, tokens are issued to the prosumer for supplying energy. The energy is accessible and tradable to anyone within the microgrid due to its tokenization.

F. *Smart meter*

A smart meter is an electricity meter that automatically records consumption of electricity and sends that information back to the utility for monitoring and billing [9]. Smart meter enables communication between the meter and the utility grid. It also gathers data for remote reporting. This data can be processed. The technological development in the Internet of Things and high-speed telecommunication networks is leading to the acceleration of smart meter platforms.

III. Proposed Model

The proposed conceptual model highlights implementation of the smart grid coupled with the smart contracts in the rural regions of the country. The rural region is arranged in a blockchain based microgrid. This smart microgrid comprises of prosumer and consumer. The Prosumer is the group of local communities that produce as well as consumes energy; such as owners of houses with solar panels. These prosumers are the source for the distributed solar energy resources. The consumer will demand energy from these prosumers according to the need.

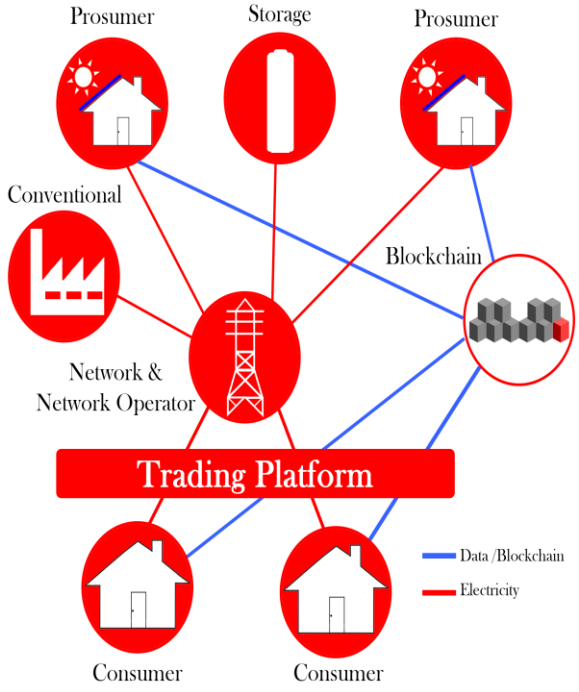

Figure 3. Blockchain based Microgrid

During peak time of the solar energy generation, if the prosumers have excess energy, they can inject excess energy into a local microgrid. The generation or the consumption of this energy is recorded by the blockchain based smart meter. Similarly, when a consumer demands for energy, the injected energy by the prosumer in the local smart microgrid is supplied to the consumer. The energy is traded between a prosumer and a consumer without involving any arbitrator.

Initially, the smart microgrid checks the possibilities of trading based on electrical routing and the power line support. Once it is validated, a smart contract is established between a prosumer and a consumer which comprises of rules of transaction. The microgrid will then allow transmission of energy between prosumer and consumer according to the need. The smart contract automatically verifies the contract and then executes the transaction. The transactions between prosumer and consumer are recorded in a distributed ledger along with other transactions. This ledger, known as the block is then stacked on to the oldest chain after validation [10]. The distributed ledger is designed based on the blockchain with proof of stack consensus. All the transactions made between individual parties are directly executed through a peer to peer network. The supply and demand of the energy are balanced by smart contracts.

The settlement is concluded with the exchange of tokens. The consumer should buy tokens from the token exchange. These tokens are transferred to the prosumer after receiving energy. The transaction between the network is validated and executed by the smart contracts. The exchange of tokens between parties takes place automatically. During non-peak hours of energy generation, the prosumer will exchange tokens with the central grid or the other prosumer according to his energy need.

To monitor the transaction record between prosumer and consumer a mobile application is introduced. The mobile application is used by both the parties for the trading of energy. It will let users join his local microgrid community. The amount of energy traded between prosumer and consumer is notified to them through a mobile application.

If in certain cases when demand is high than the production of energy, then the microgrid receives electricity from the central electricity grid to be distributed among consumers and prosumers.

IV. Conclusion

The proposed model explores the capability of distributed energy resources to maximize benefits to the local communities while modernizing the grid. The decentralized microgrid platform will help in smoothing the load on the main grid. As per the proposal, for successful implementation of this model, there needs to be a very strong regulatory framework that promotes the use of blockchain based microgrids. For higher returns from DER implementation, all the members should participate including consumers, prosumer, conventional electricity providers on a single platform. Such microgrids offer much better solutions in disaster situations such as extreme weather or storms when the conventional grid fails.

The concepts represented in this paper are meant to frame the potential application of an energy services token

system to enable a more participative energy paradigm. It is focused on how technology can empower humans and improve their lives. This platform will enable anyone to be part of clean and cheaper energy resources.

Blockchains, the technology underpinning the cryptocurrency and smart contracts, will revolutionize the global economy. It is on the verge of revolutionizing the way information is stored, accessed and shared.

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