Implementation of Blockchain in Net Metering Scheme of Bangladesh

A Thesis Submitted to the Academic Faculty in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

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We hereby declare that this thesis has been prepared in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering at Islamic University of Technology (IUT), Boardbazar, Gazipur-1704 and has not been submitted anywhere else for any other degree.

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List of Acronyms

TI	Transparency International
PV	Photovoltaic
IEA	International Energy Agency
PoW	Proof-of-Work
PoS	Proof of stake
EVM	Ethereum Virtual Machine
P2P	Peer-to-peer
SLR	SolarCoin
AC	Alternating Current
RE	Renewable Energy
NEM	Net energy metering

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Abstract

The thesis work is carried out to implement blockchain technology in the net metering scheme of Bangladesh. The government is promoting the generation and distribution of energy from renewable sources and this is expected to be effectively promoted by the net metering process. The security and integrity of the whole process is pivotal to running the entire system efficiently. Hence comes the proposal of blockchain technology and its application, the smart contracts, to make the process more secure and accurate and much easier. This thesis outlines how to secure and automate the net metering system with the implementation of smart contracts using blockchain technology.

Chapter 1

Introduction

1.1 Overview

Electricity is an essential element of any country striving for its socio-economic growth and enhancement of life standard. According to the Vision 2021, the Government of Bangladesh has pledged to bring all the citizens of the country within the reach of electricity access [1]. In order to ensure electricity access for all and energy security, the Power Division has taken fuel diversification to be one of its major strategies [2]. Measures have been taken to generate electricity from environment-friendly renewable sources in conjunction to conventional fossil fuels. Not only can this help increasing the total power output for our country, but it can also contribute to reducing pollution and depletion of natural resources. Increasing the utilization of renewable energy to a considerable extent is one of the targets of the Sustainable Development Goals (SDG-7) declared by the United Nations [3].

According to the Renewable Energy Policy of Bangladesh, a target has been set to generate 10% of the total electricity, i.e. 2000 MWh from renewable sources by the year 2020 [2,4]. Due to its geographical location, the source with most potential in Bangladesh is the solar energy. A total of 270 MW of electricity has been produced so far by utilizing solar energy [2], but since more than 3 acres of land is required to produce 1 MW of electricity from solar energy, it has been difficult to arrange vast stretches of land to build large scale solar power plants. Therefore, the possibility of producing electricity by installing solar systems on the available rooftops of various grid-connected buildings such as residents, industries etc. is considered with due importance. This will increase the share of renewable energy in the production of electricity. This is where the net metering system arrives.

The government has introduced the net metering system as a way of distributing the additional energy generated from the solar panel system installed in the premises of a consumer. The electricity bill of the consumer will be adjusted with his/her bill the following month for the export of the excess electricity. This can cut down the consumer's electricity bill. Since electricity bill will be reduced, consumer can be motivated to produce electricity from renewable systems and use the net metering system. There is a Net Metering Guideline developed in 2018 [2] so that consumers can avail the system by installing renewable generation systems on their premises.

Over 50 countries including our neighboring countries like India and Sri Lanka have adopted the net metering scheme [2]. But this project aims to combine blockchain technology in parallel with net metering with the application of smart contracts.

1.2 Motivation

Our country, Bangladesh, is undeniably a highly corrupted state. According to the Corruption Perceptions Index (CPI) released by Transparency International (TI) for 2018, Bangladesh has scored 26 out of 100 and secured a ranking of 149 out of 180 countries [5]. The score indicates the perceived level of public sector corruption on a scale of 0 (highly corrupt) to 100 (very clean), and the lower the ranking the more corrupt the country.

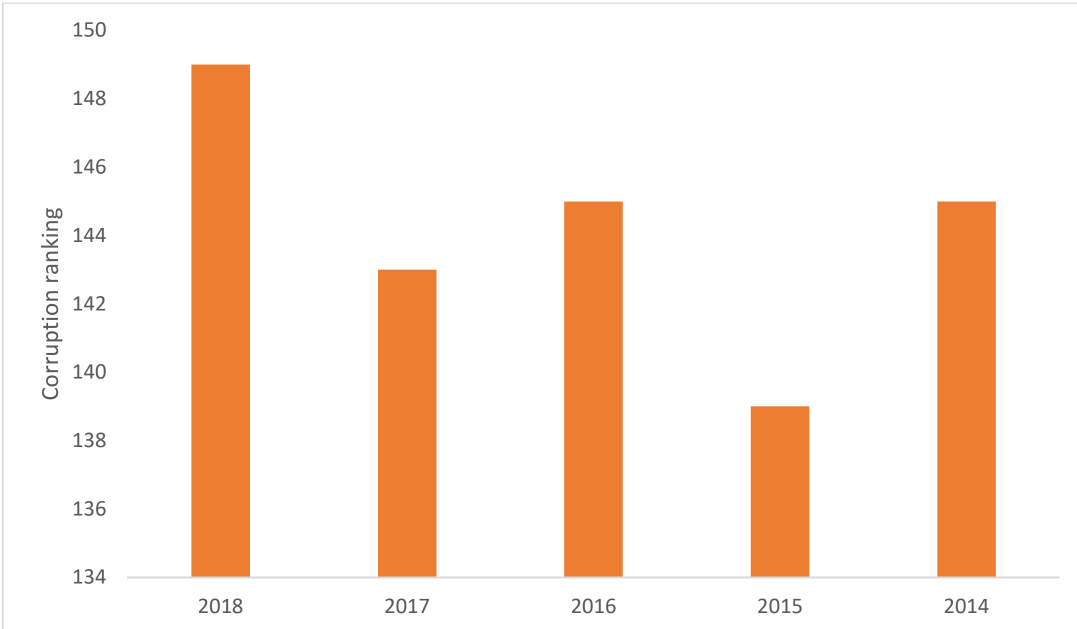

Fig 1.1 TI Corruption Ranking of Bangladesh over the last 5 years

According to Fig 1.1 [6], we can see that the corruption ranking of Bangladesh has always been very low. Part of this corruption statistics comes from the energy sector. Corruption in the electricity supply industry here takes many forms, ranging from 'higher-level' corruption – the inappropriate use of high-ranking government offices by insiders for private gain – to 'low level corruption' – bribery or other illegitimate transactions made to provide illegal services or manipulate or break laws [7]. TIB (2007), World Bank (2003) & Smith (2004) think that Bangladesh electricity supply industry suffers from all sorts of malpractices and inefficiencies, specifically 'corruption' [8, 9, and 10].

Specific corrupt practices may include tampering the electricity meter in both ways – increasing the reading or decreasing it, and supplying illegal electric lines with no official meter and declaring this unlawfully supplied power as system loss. In the new net metering scheme, these problems can prevail. If the net metering system cannot be utilized effectively because of these issues, the basic goal of increasing the share of renewable energy in the production of electricity gets hampered.

1.3 Objectives

Our objective is to design the net metering system of Bangladesh in such a way so that the problems that may arise in it may be eradicated effectively. We plan to devise a system that is autonomous, decentralized, immutable, secure and transparent. Our proposed system is about running the net metering system corruption-free. If the system can operate being clean from fraudulent activities, plus if its accuracy can be enhanced due to autonomy, it is believable that it can operate much more effectively, making it easier to reach the goal of producing 10 % of the total electricity from renewable means. Though our method involves digitizing the data of energy transactions, it is free from the risks of cyber-attacks and loss of data. We aim to achieve our objectives by the use of blockchain technology in the net metering scheme of Bangladesh.

1.4 Thesis Outline

Our thesis work is basically implementing the proposed net metering system of Bangladesh in blockchain using smart contracts.

Our idea is generating smart contracts which will define the net metering policies and run them. These smart contracts will be embedded in the blockchain which will also contain all the data related to the installation and operation of the system. The smart contracts will be made through programming in the Ethereum platform, using Solidity Programming Language. We have written two codes and run them:

- A code simply calculating the net energy flow using the total import and export for a period of time
- A code representing one of the many policies of the proposed net metering system of Bangladesh.

Chapter 2

Literature Review

2.1 Net-metering

Net energy metering is a mechanism which allows prosumers to connect their renewable energy systems to the distribution grid. Prosumer is a person who consumes and produces a product. We will discuss about the net metering scheme approved by the Government of Bangladesh here, since our work is on the net metering system of our country.

Any excess amount of electricity after self-consumption which is generated from renewable sources is supplied to the distribution grid. For the amount of energy supplied to the grid, the prosumer can either import equal amount of energy from the grid or receive price of net amount of energy that he/she has supplied to the grid at the end of settlement period. [2]

In a net metering system, electricity can flow in both directions via a bi-directional meter. The consumer has the ability to adjust the amount of electricity consumed from the grid and the amount of extra electricity produced by the renewable energy source, for example, a rooftop solar system, after self-consumption. The measured data can be stored inside the meter or transferred to a centralized aggregator service. The bill is calculated according to the net energy recorded by the meter, i.e. the total energy consumed from the network minus the total energy delivered to the network over the specified billing period. If the energy drawn from the grid is greater than the energy supplied to the grid from the solar PV system, the prosumer will have to pay for the net energy consumed. However, if the energy exported to the grid is greater than the energy imported from it, then the system allows all the credit (in terms of kWh) of the prosumer to roll over to the next billing period. For example, if a prosumer consumes 500 kWh of energy from the grid while he supplies 300 kWh of energy to the grid after self-consumption in one month, he has to pay the bill for:

$$500 \text{ kWh} - 300 \text{ kWh} = 200 \text{ kWh of energy}$$

On the other hand, if a prosumer imports 200 kWh of energy from the grid while he exports 300 kWh of energy to the grid in a month, his credit will be:

$$300 \text{ kWh} - 200 \text{ kWh} = 100 \text{ kWh of energy}$$

This means he will get 100 kWh of energy free of cost from the grid in the following month.

At the end of the settlement period, which is the end of June, if a prosumer has any kWh credits left, he will be compensated for it by getting paid for the credits by the concerned distribution Utility at bulk purchase rate (tariff) for the Utility set by the Bangladesh Energy Regulatory Commission (BERC).

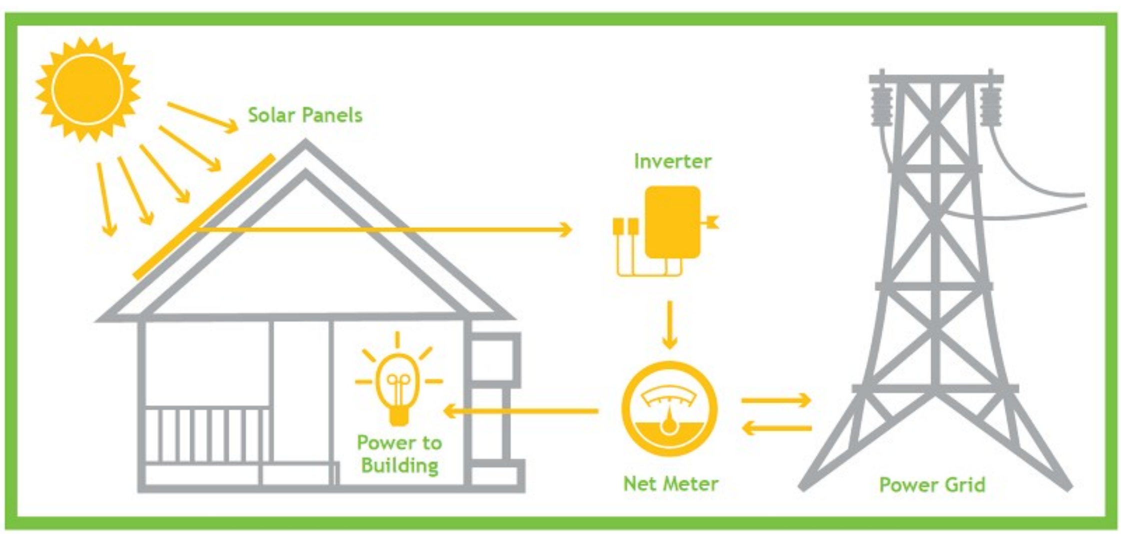

Fig. 2.1 Visual representation of the net metering system [11]

The rate at which the customer is billed is determined by various factors like consumer tariff class, type of renewable energy technology, installed capacity and export limitations.

Global electricity capacity from renewable sources is set to grow by 50 % over the next 5 years, an increase equivalent to adding the current total power capacity of the United States, according to a very recent IEA market report and forecast [12]. This indicates how important net metering system policies are supposed to be in the near future internationally.

The safety and integrity of the entire net distributed energy system is vital to the success of net metering systems. In our country, meters can be tampered with and data manipulated. To eradicate this, we seek help of blockchain technology and its benefits.

2.2 Blockchain

Blockchain is a chain of digital blocks that contain transaction records like conventional ledgers. Blocks are sequentially chained to each other via hashes of the header of their respective parent blocks. Each block is composed of a block header and a block body. The block body contains the specific transactions. Typical block metadata consists of the following [13]:

- Block version: version number that defines the set of validation rules to follow
- Parent block header hash: a hash value that links to the previous block
- Merkle tree root hash: a hash of all the transactions in the block
- Timestamp: current time as seconds since January 1, 1970 in universal time
- nBits: the threshold which a block's header hash must not exceed for the block to be valid
- Nonce: a random number that can only be used once as additional input to a hashing function; used to show Proof-of-Work (PoW) (explained later)

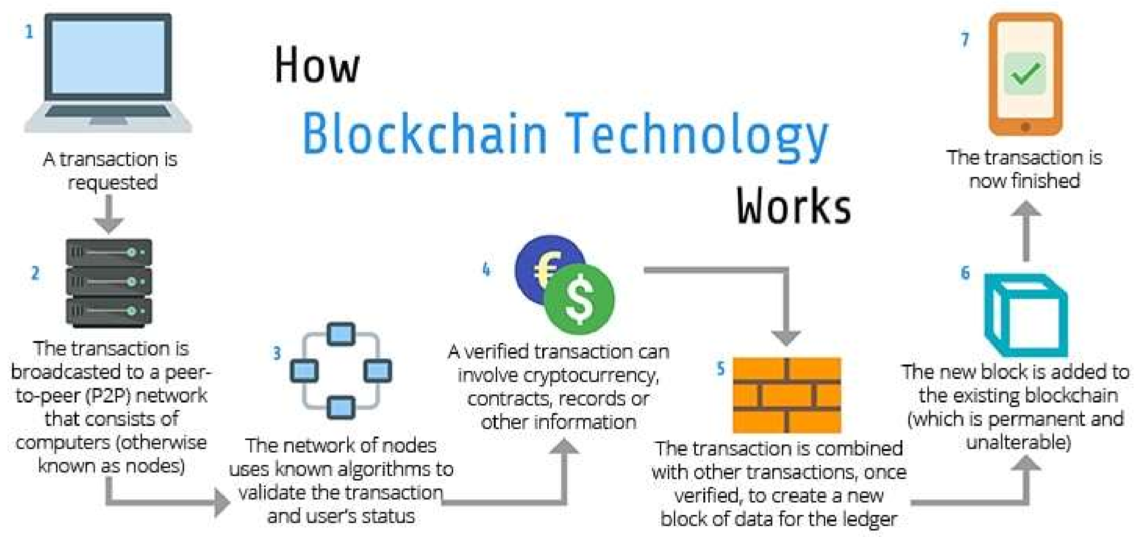

Fig 2.2 Operation of Blockchain Technology [14]

When a transaction is initiated on a blockchain, public key cryptography and digital signatures are used to identify and authorize accounts. A transaction is a data package such as a monetary value. The transaction is signed by its initiator via a private key and sent to a node that belongs to the blockchain network. The node then validates the data package with the user's public key and propagates it to other nodes, which additionally validates the package and propagates it to their peers until all nodes are reached. Meanwhile the valid transactions are added into blocks. Through consensus mechanisms discussed below, the network reaches an agreement for the latest block to be chained to the blockchain.

2.2.1 Classification of Blockchains

There are mainly three types of blockchains: public blockchain, private blockchain and consortium blockchain.

Public blockchain can allow participant nodes to enter the network without any limitations. On this network, all transactions are verified and shared by all nodes.

However, in private blockchains, the participant nodes are designated in advance. In addition, specific nodes can be added or removed as needed. Hence it is not possible for malicious nodes to enter the network.

Consortium blockchains are a hybrid of public and private blockchains. Constructed by several organizations, the network allows pre-selected nodes to join the consensus process. Read access may be public or restricted as determined by the original founding organizations. Due to limited number of nodes, records are not completely immutable. Propagation time is low and transaction throughput is high in this partially centralized network.

The comparison is shown below:

Table 1: Comparison among different types of blockchains [13]

Property	Public blockchain	Consortium blockchain	Private blockchain
Consensus determination	All miners	Selected set of nodes	One organization
Read permission	Public	Could be public or restricted	Could be public or restricted
Immutability	Nearly impossible to tamper	Could be tampered	Could be tampered
Efficiency	Low	High	High
Centralized	No	Partial	Yes
Consensus process	Permissionless	Permissioned	Permissioned

2.2.2 Consensus mechanisms

Proof-of-Work (PoW)

In proof-of –work, mining occurs where nodes compute the cryptographic hash of the block's header by spending computational power. The resulting hash is required by consensus to be under a certain threshold, which is set by nBits in the block metadata. If the resulting hash is too large, the Nonce value can be changed and the hash recomputed. This threshold changes dynamically every 2,016 blocks to adjust the difficulty of mining and ensure successful creation of one block every 10 minutes [15, 16]. Once a match is found, the miner is rewarded and the block cannot be changed without redoing the computational work. This is because any changes to the nonce or contents of the block also change the hash value. As blocks are chained one after another, any changes to a single block requires the re-computation of the hashes for that specific block as well as all the other blocks after it. If a dishonest mining pool is able to control majority of the network's mining power, only then validation of new blocks can be suspended and transactions can be reversed or modified. In other words, the data that will be saved permanently in any block is that specific data for which the highest number of network participants have mined.

Proof-of-Stake (PoS)

The proof of stake model was devised as an energy-saving alternative to PoW. Rather than the expenditure of computational power to find a nonce, PoS requires validators to use their cryptocurrency as stake to purchase the ability to create blocks. Here, a validator is randomly selected to create a block based on how much cryptocurrency each node holds. If the block is successfully added to the chain, the validator receives a reward. If the validator acts in a malicious manner, they get punished. They may no longer participate in the consensus process.

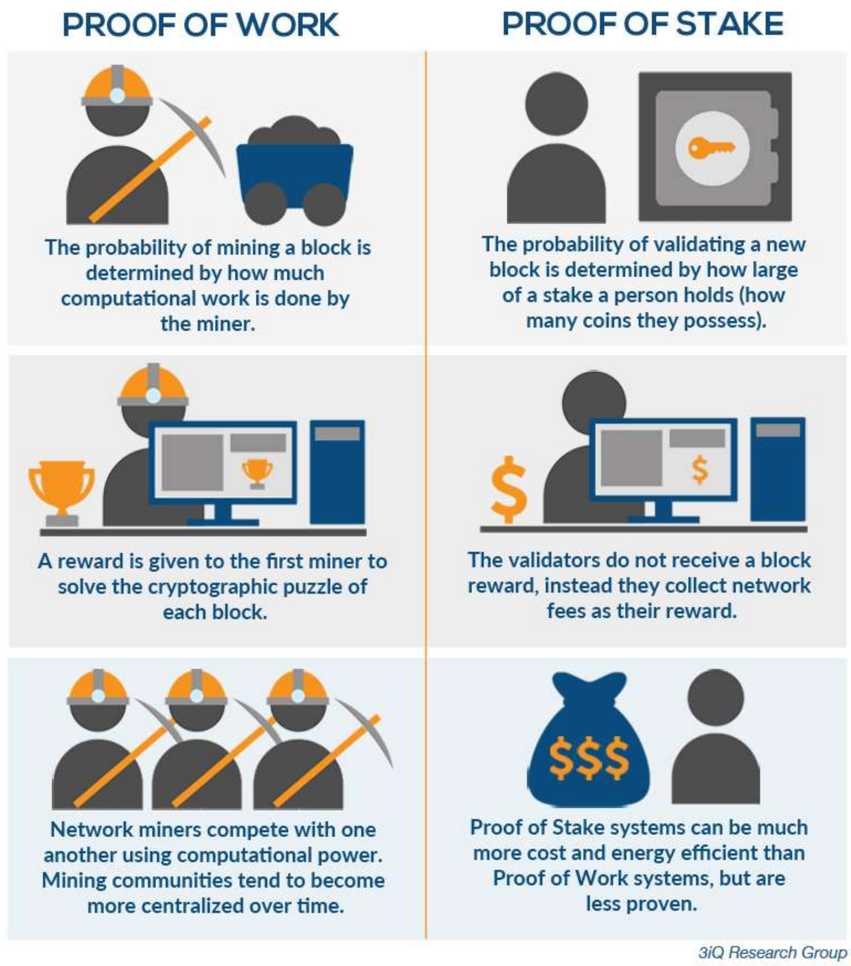

Fig 2.3 Proof-of-Work Vs Proof-of-Stake [17]

2.3 Smart Contracts

Smart contracts can be defined as a computerized transaction protocol that executes the terms of a contract. It runs on blockchain technology and includes rules that the involved parties have agreed upon in order to interact with each other. In the case that these rules are satisfied, the smart contract agreement is automatically activated. In this way, smart contract code verifies and executes the terms of the smart contract, providing a simple form of decentralized automation. In short, smart contracts have the ability to turn legal obligations into automated processes, guarantee a greater degree of security, reduce reliance on intermediaries and lower transaction costs.

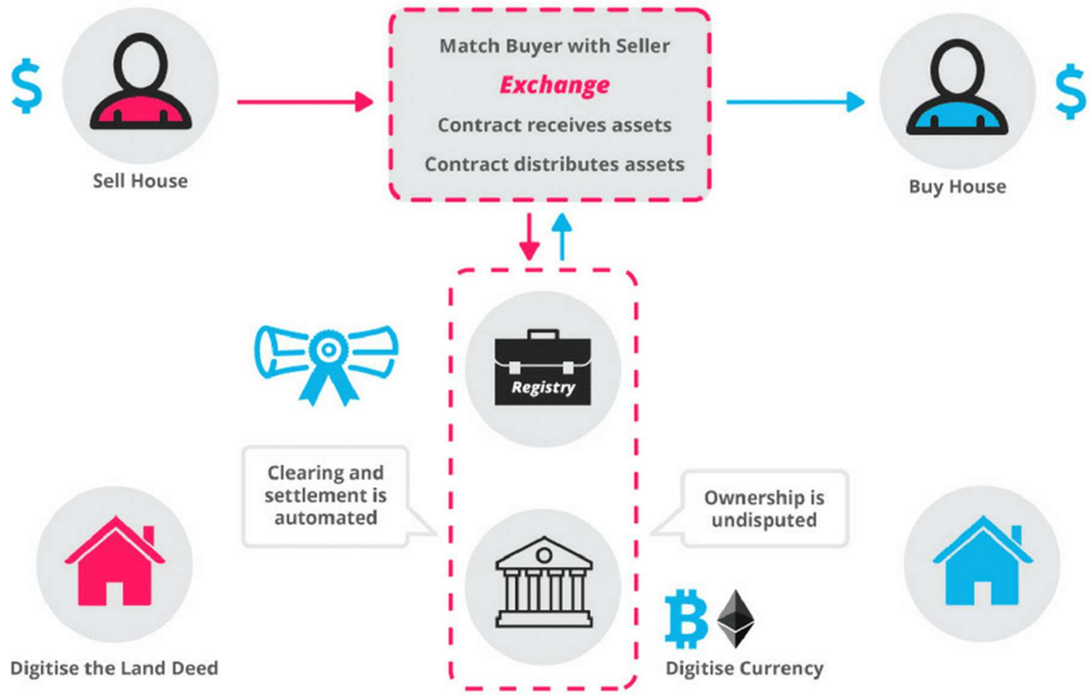

Fig 2.4 Simple example of the operation of a smart contract [18]

2.4 Ethereum

Ethereum is an open source, blockchain-based decentralized computing platform. Solidity is the most popular programming language for coding on this platform [19]. Using Solidity, the code is written and compiled. Once compiled, it can run on the Ethereum Virtual Machine (EVM). Compiled code gets translated to assembly code and then to binary code, which will be executed on the EVM environment. Ethereum combines the computing system with blockchain technology. It gives the opportunity for developers to write codes that can effectively run on the blockchain. It is quite difficult to manipulate or tamper the code due to the layers of immutability present in Blockchain technology, such as the implementation of Proof-of-Work consensus mechanism.

With the help of the Ethereum platform, smart contracts can be designed and deployed to help with the transactions and usage of net metering.

2.5 Overview of current P2P Energy Trading Platform

A number of P2P energy trading projects exist in the world. The Brooklyn Microgrid project in the United States is about a microgird where residential neighbors can trade locally produced solar energy with the help of blockchain technology [20]. There are projects of Power Ledger, an Australian blockchain-based energy trading platform, such as the solar power trading for Gen Y Demonstration Housing Project in White Gum Valley, Australia and the peer-to-peer solar power trading in Bangkok, Thailand [21]. In the community development of White Gum Valley, residents can share electricity harnessed from solar panels via P2P energy trading. At the T77 urban precinct in Bangkok, Power Ledger in collaboration with Thai renewable energy business BCPG, had conducted a world-first peer-to-peer renewable energy trading trial [22]. LO3 Energy is developing blockchain based innovations to revolutionize how energy can be generated, stored, bought, sold and used, all at the local level [23].

2.6 SolarCoin

The SolarCoin foundation is a US-based organization which is operating in 73 countries. The mechanism of their operation is that they give solar energy producers blockchain based digital tokens at the rate of one SolarCoin (SLR) per Megawatt-Hour (MWh) of solar energy produced. [24]

Solar energy producers have to find a SolarCoin affiliate and get their production verified. Then the producer will be given an SLR wallet and can earn SLR at the mentioned rate.

SolarCoin is a cryptocurrency which is sent to addresses (accounts) in digital wallets. It can be stored long-term in offline (paper) wallets or directly used as a currency by trading it for government currencies on cryptocurrency exchanges or spending it at businesses that accept it.

Chapter 3

Methodology

3.1 Setting up the system

Our core concept is that the whole net metering system will be introduced in a blockchain and the policies included in it will be embedded in smart contracts. The calculative policies include [2]:

1. The output AC capacity of the renewable energy converter can be a maximum of 70% with respect to the consumer's sanctioned load.

2. The maximum output AC capacity of the installed RE system for NEM cannot be more than 3 MW.

3. In case of a medium-voltage (MV) consumer, the installed capacity of the renewable energy system cannot be more than 70% of the rated capacity of the distribution transformer or, cumulative capacity of the distribution transformers.

The net metering system looks like this:

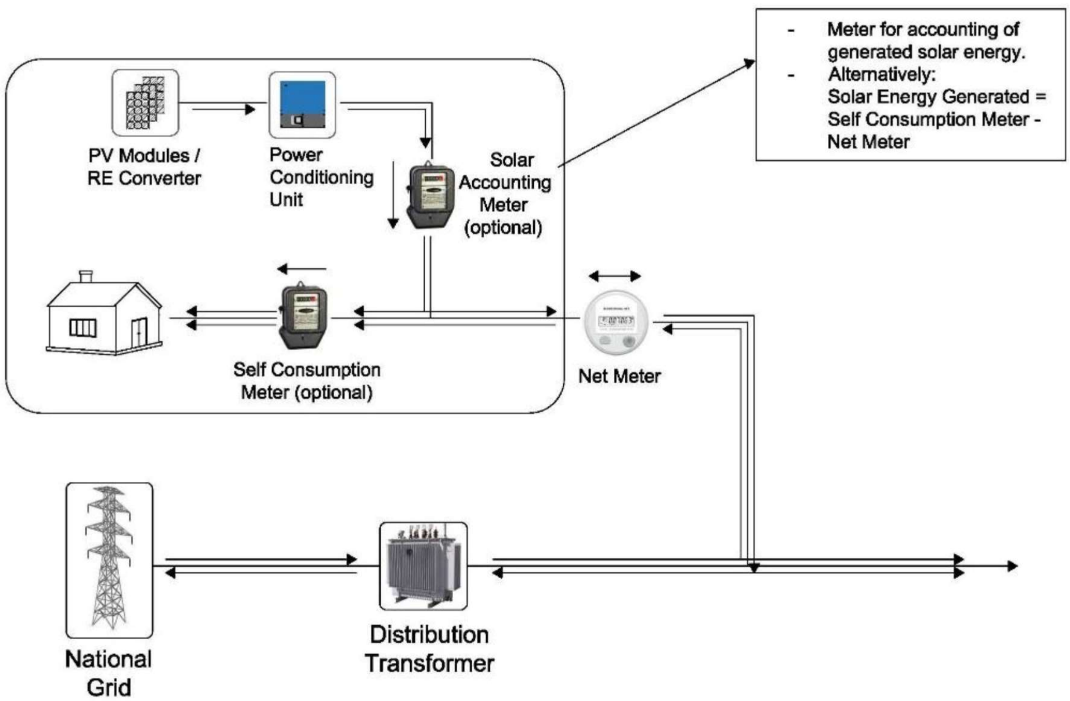

Fig 3.1 Typical net metering architecture [2]

For our task, we have to have digital devices embedded in the distribution transformer, net meter and the power conditioning unit as seen in this architecture and enable digital communication among them. We have to run the blockchain in these devices. The smart contracts in the blockchain will define the net metering policies and the system will run according to the policies autonomously. Due to the implementation of blockchain and smart contracts, the system will gain properties such as immutability and autonomy, which may be able to cut down corrupted activities, like, meter tampering and adoption of illegal power lines, and may also lower costs. The possible outcomes are explained in detail in Section 3.4.

3.2 Details of an energy transaction in blockchain

All data input to the blockchain, including the smart contracts and all the energy transactions and billing information, will be immutable. The following diagram summarizes how an energy transaction will be input to a block in the blockchain:

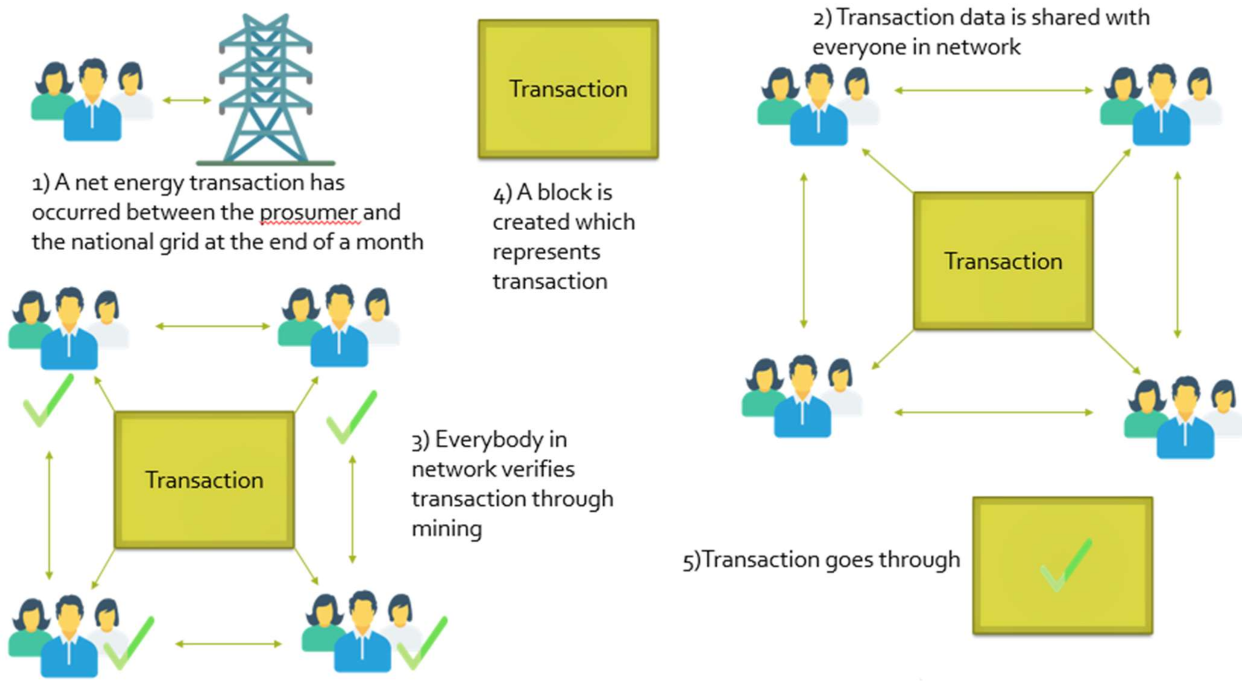

Fig 3.2 How an energy transaction is input to a block in the blockchain

Suppose the net meter of a prosumer reads 300 kWh of net import of energy at the end of a month. This transaction data is shared among all the users in the blockchain network, meaning the network is basically an open distributed ledger. The users verify this data through mining. Mining is done by the users in the system through their computers. We intend to use Proof-of-Work as the consensus mechanism here. When verified, a block is created containing the transaction data. Now if any user or probably the prosumer himself wanted to alter this data, that wouldn't be possible due to the Proof-of-Work mechanism. After this transaction goes through, the block will take in the next data, and so on.

3.3 Smart Contract Coding

The smart contracts will be implemented in the blockchain through coding in the Ethereum platform. There is a number of programming languages to run in the Ethereum platform. Solidity Programming Language is the most popular of them all. We have used this contract-oriented language to code for:

- The introduction of a contract which simply calculates the net amount of energy imported or exported after net metering:

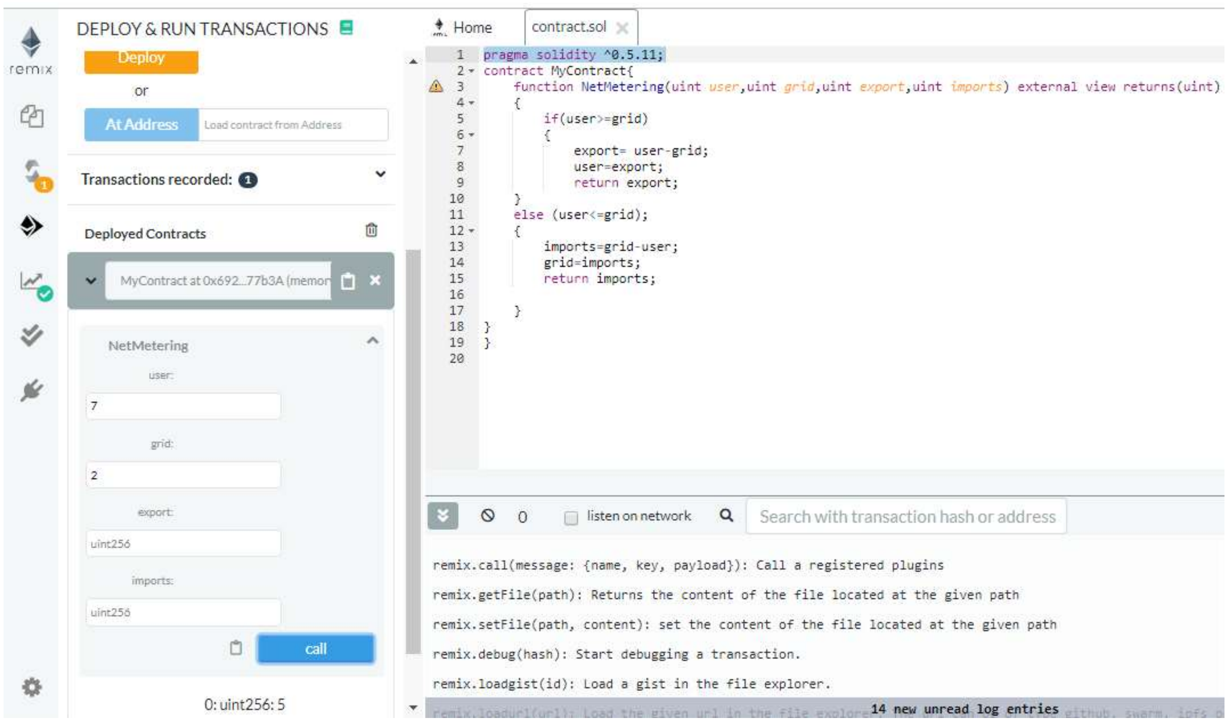

Fig 3.3 Solidity code in Ethereum platform – 1

Here, *user* indicates the amount of energy supplied by the user (prosumer) to the grid, *grid* represents the amount of energy supplied by the grid to the user, *export* indicates the net amount of energy exported by the user and *imports* indicates the net amount of energy imported by the user. In this case, the user supplies 7 arbitrary units of energy to the grid while the grid supplies

2 units to the user. The program calculates the net export which is shown to be 5 units at the bottom left corner of the screen.

- The 2nd policy as mentioned in Section 3.1:

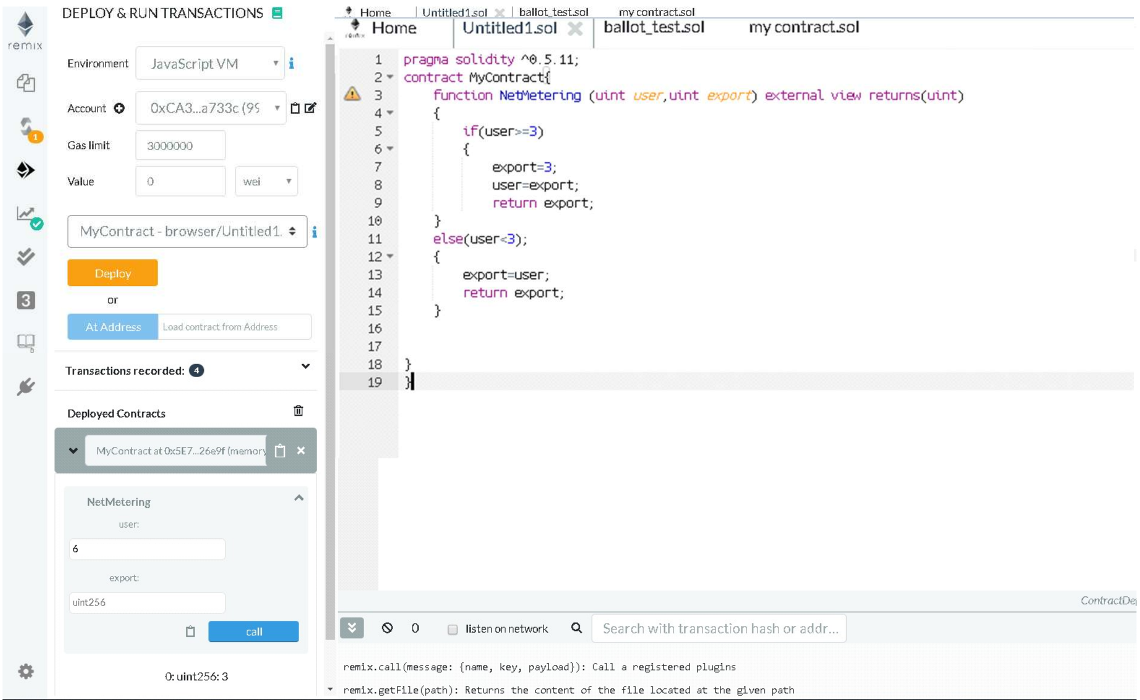

Fig 3.4 Solidity code in Ethereum platform – 2

The 2nd policy states that the maximum output AC capacity of the installed RE system for NEM cannot be more than 3 MW. Here, *user* represents the actual amount of power generated by the user (prosumer) from renewable means and *export* indicates the expected amount of power generated by the user. The unit of power in this program is assumed to be MW. If any value less than or equal to 3 is input to *user,* the same value appears in *export.* This indicates that the amount of power generated by the user is lawful. For all values greater than 3 input to *user,* the program shows the same value, 3, in *export.* This indicates that the amount of power generated by the user is unlawful. The code can be extended to build a program which will send a notification to the concerned authority whenever the values of *user* and *export* don't match. In this case, 6 was input to *user* and the program shows 3 in *export.*

We haven't written codes for the other two policies mentioned in Section 3.1. If those codes can be prepared, then all three codes for the three policies have to be combined by another code to find the minimum '*export*' value among the three. That minimum value have to be ultimately considered as the limit for the value of *user.*

Now we have to represent the other factors of the program such as hash. Below is a kind of figure that is generated when a smart contract like the ones above is deployed and the necessary data input. We can see that a transaction made e.g. the calculation of *export/import* in the first program, generates a hash. This hash is unique. We can also see other information for a transaction such as 'from', 'to', transaction cost etc.

[vm] **from:**0xca3...a733c **to:**MyContract.(constructor) **value:**0 wei **data:**0x608...c0032 **logs:**0 **hash:**0x1e0...9e945

status	0x1 Transaction mined and execution succeed
transaction hash	0x1e010016a9cf8623519f416dec20e487cd205161ba25abac26da78ae34a9e945
contract address	0x692a70d2e424a56d2c6c27aa97d1a86395877b3a
from	0xca35b7d915458ef540ade6068dfe2f44e8fa733c
to	MyContract.(constructor)
gas	3000000 gas
transaction cost	108301 gas
execution cost	40293 gas
hash	0x1e010016a9cf8623519f416dec20e487cd205161ba25abac26da78ae34a9e945
input	0x608...c0032
decoded input	{}
decoded output	-
logs	[]
value	0 wei

Fig 3.5 Information panel for a transaction governed by a specific smart contract

3.4 Possible Outcomes

If we can design the whole net metering system in blockchain using smart contracts, our country can enjoy the benefits of blockchain and smart contracts in this system:

- Immutability: The smart contracts, once installed, cannot be manipulated by anybody unless the government decides to change them officially, for which a new blockchain has to be introduced since the old one cannot be altered. Plus, every energy transaction, billing etc will also be unchangeable once their data has been input.
- Decentralization: The system will be decentralized, eliminating the need for a continuous central management, thus reducing costs. This also means all data is distributed among all users instead of being in a central server, which would be prone to cyber-attacks. Furthermore, since the data stored in the blocks are contained in numerous computers participating in the chain, there is no possibility that the data, if lost by the government/electricity-supplier, cannot be recovered.
- Autonomy: Since the system will become autonomous, it will become faster and more accurate and there will be less need of management, lowering costs.
- Security: Blockchain uses protected cryptography to secure the data ledgers, resulting in a secure net metering system.
- Transparency: The transactions that will take place will be transparent. The individuals who will be provided authority can view the actual transactions.

Chapter 4

Conclusion

This thesis work has been carried out to eliminate the problems lingering with the current net metering scheme of Bangladesh. The net metering scheme is a very crucial thing for our country, and for it to operate effectively avoiding the current level of corruption in our country, we think our thesis work would be very helpful.

For our future work, we aim to implement all declared policies in the net metering guidelines of Bangladesh through smart contracts, generated by coding in the Ethereum platform. When the smart contracts are ready to operate through the proper hardwares and softwares, we plan to test run a prototype system involving two or three houses. Our final goal is to develop the system to a level where it would be suitable to actually run it on a large scale in our country. If that is possible, we would love to propose the entire system to the government.

Blockchain is an emerging technology globally, and it is believable that Bangladesh could make good use of it in the energy sector.

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