How Smart Grid System using Renewable Energy Based on Internet of Things is affected by Industry 4.0

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Abstract: *This study depicts the integration of the internet of things and blockchain into the smart grid renewable energy system. The smart grid evokes the application of digital technology and information management practices and is a core ingredient in the ongoing modernization of the electricity delivery infrastructure. Due to recent advancements in technology and industry 4.0 all the factors in the increased need for smart, efficient, and reliable energy systems.*

Keywords: **Internet of Things, Smart Grids, Industry 4.0, Cloud, Cyber-physical systems, Big Data**

1. INTRODUCTION

The discovery of electricity marked the beginning of industry 2.0. The industry has been growing rapidly, there are limited sources to generate electricity mostly from fossil fuel. The equipment to generate electricity was very expensive and it was not economical for small scale or personal use. Customers bought electricity from power plants have their electricity delivered by the power grid and pay for what they consume.
To understand what the smart grid is we need to know what exactly a grid is, A grid also referred to as the “electric grid” is a network of complex systems that provide electricity to a user or a consumer, the complex network is a group of power plants in the case of India majorly power plants such as thermal plants, transformers, substations, and transmission lines.

The conventional electrical grid uses a limited one-way interaction. That is power flows from the power plant to the consumer. On the other hand, the Smart Grid uses a two-way interchange where both electricity and information can be exchanged in both directions which are from consumers to power plants. Now since the network is bidirectional it requires to be controlled in a much better and more efficient manner, here comes the automation and cloud factor which helps to make things easier.

A smart grid system is improved because of its flexibility and Reliable to use (both economic and energy-efficient) of the electric system from large generation through the

delivery systems to Customers/ Consumers and a growing number of distributed generate, and Storage resources.

Networks that are transforming our economy in other Platforms are also being applied to applications for dynamic optimization of electric system operations, maintenance, and planning. Resources and services that were separately managed are now being integrated and rebounded as we address traditional problems in new ways and adapt the system to tackle new challenges and discover new benefits that have transformational potential.

2. Literature Review

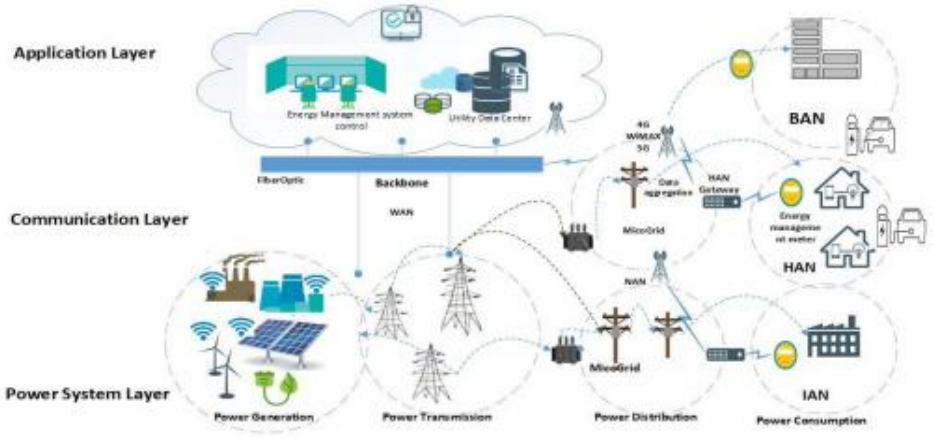
The Internet of Things (IoT) describes the network of physical objects that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet. (Saswat Mohanty, Bikash Narayan Panda, 2014)

The web browser works as an interface for monitoring the grid system and offers us real-time information which is measured through energy meters that are connected to an embedded system such as a microprocessor. The Melike Erol-Kantarci (Member, IEEE) and Hussein T. Mouftah define the smart grid as “Smart grid have restructured the way electricity is generated, transported, distributed, and consumed by integrating smart sensing, communicate ones, and control in the day-to-day operation of the grid. Electricity is a fundamental utility for the functioning of society and the services provided by information and communication technologies.

3. Basic Smart Grid Architecture

The basic architecture of the smart grid is divided into mainly 3 layers, they are:

1. Power Systems Layer: This layer is mainly responsible for all the transmission of the power to and from producers and consumers.
2. Communication Layer: This layer is responsible for interconnection between all the systems components by collecting data from the sensors at the producer and consumer and transmit to servers.
3. Application Layer: This layer is mainly responsible for the processing of all the data that was collected by the servers and is used for monitoring and sending notifications to consumers and producers when the power demand is high and low to maximize the profit and efficiency of the whole system.



4. Components of Smart Grid

Some industry 4.0 components make the smart grid system a possibility, The main components that differentiate the conventional power grid from the smart grid are:

4.1. Internet of Things

A network that connects any object to the internet via an exchange protocol to communicate monitoring, management, tracking, and identification information between different smart devices is known as the Internet of things IoT). It has become the focus of research in various applications over the last couple of years and has allowed for connecting a multitude of network-embedded devices used in daily life to the internet. IoT is also considered revolutionary in that it adds functionality to existing network systems and allows them to provide solutions to time-critical applications in many fields such as healthcare, manufacturing, logistics, military retail, etc.

4.2. Cyber-Physical Systems

A Cyber-Physical System (CPS) is a system that integrates cyber and physical elements effectively. An ideal CPS consists of a computing system, networking tools, and physical components such as sensors. The physical aspects of a smart grid are monitored by controllers by connecting the sensors via a communications network, it is possible to keep track of the overall status of the smart grid and its working conditions, the sensors send all relevant data to the controllers to take an action.

4.3. Cloud Computing

Cloud computing provides applications and services with data storage and processing capability over the internet, Cloud computing pools resources to eliminate the need for dedicated physical systems and can allow for higher levels of automation.

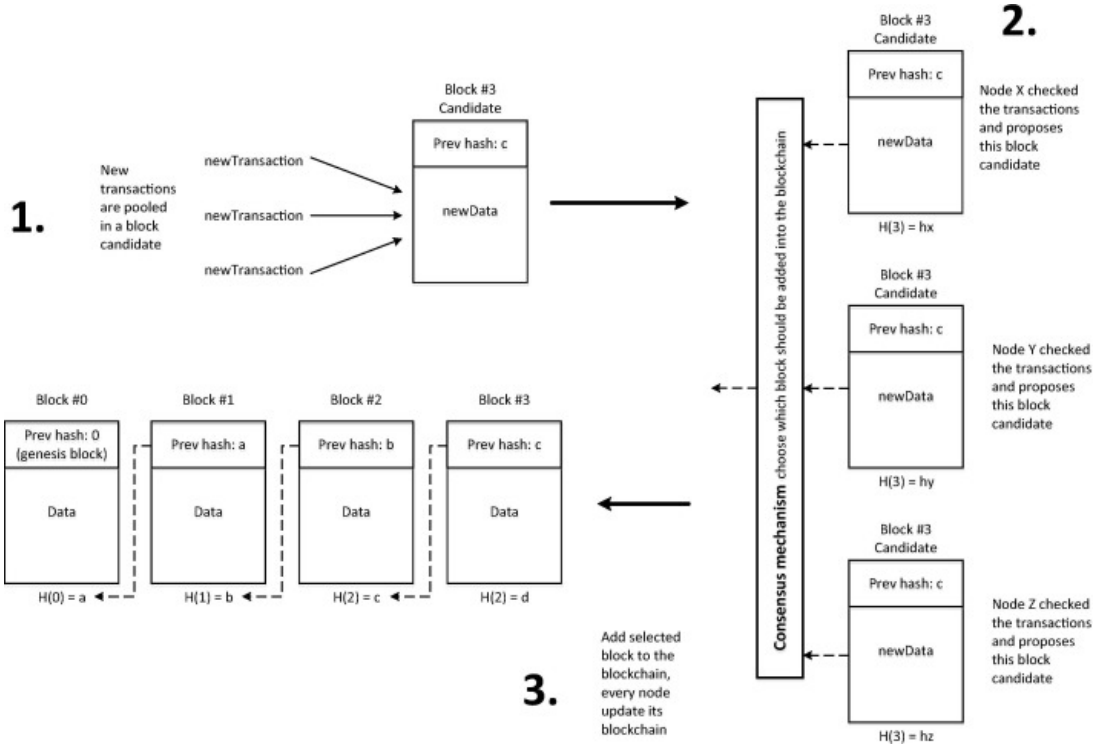
5. Challenges associated with smart grid system

Smart grid systems are cyber-physical, so they are vulnerable to cyber-attacks that can affect physical systems. There are many economic and political reasons that motivate targeting smart grid in order to compromise the vital energy market.

Cloud computing offers an efficient solution for processing data in the smart grid. There are security concerns due to lack of consistent policies regarding data location can compromise privacy and lack of disaster recovery plans can possibly lose all the data.

6. What is Block chain

Blockchain is an industry 4.0 technology that will help provide security for the cyber-physical system and to avoid manipulation of the data and protect user's privacy. The concept of blockchain came into the picture when Satoshi Nakamoto implemented the bitcoin blockchain technology in the year 2008 for the transaction of money without the need for any third-party services or intermediary.



6.1. History and evolution of Blockchain Concept

The concept of Blockchain came into the picture to avoid the problem of double-spending. In a conventional transaction, when a buyer purchases something, he gives the amount of money physically to the payee. In the digital world, money exists as data, which can be copied precisely with minimal effort. A payer can easily copy the money, spend the original, and spend the other copy, this is known as the double-spending problem.

To overcome the problem some intermediary is needed to verify the transaction and to manage all the disputes that may arise due to failure or any other issue. This method will give more power to the intermediary who can exploit the payer and the payee by

collecting their data. Blockchain eliminates the intermediary and the transaction written in the blockchain is immutable.

The idea and the concept of blockchain can be implemented anywhere since the idea is just making the data immutable so the blockchain can be implemented in a smart grid system to avoid manipulation of data and improve the security of the system.

6.2. Structure of Blockchain

A blockchain consists of blocks that are linked using a hash function. A hash function is a complex mathematical expression for the encryption of data. The block is timely stamped so it cannot be backdated. It also contains a special type of number which ranges from 0 to 4 billion called nonce. A block consists of a bundle of transactions. In the case of bitcoin, a transaction is a change of ownership of money. In the case of smart grids, it is a transaction of electricity. A node is an entity that connects to a blockchain network and performs various actions such as joining and leaving the network. There are two types of nodes full nodes, which hold a complete copy of the blockchain ledger that records and verifies all transactions. Light nodes are small limited resource-based blockchains that are used for smaller amounts of data verification and do not hold a complete copy of the blockchain.

6.3. Ownership of Blockchain

The ownership determines who can participate in the blockchain network such as becoming a node or verifying or performing transactions. There are three models of blockchain ownership permissionless blockchain, which is open to all, and everyone and anyone can participate. Next comes permissioned blockchain, this type of blockchain has to be verified and validated by the main block or owner of the block. Then comes Hybrid blockchain, in this some part of the chain is private and some part is public that acts as a trusted escrow service.

6.4. Consensus Mechanism

The consensus mechanism consists of a set of rules that are used to achieve an agreement on a single data value, such as determining whether a block will be added to the blockchain. There are many concepts implemented by different blockchains such as:

1. Proof of Work: In this type of concept a creation of a block should prove its contribution to the network by solving a complex mathematical hash function.

2. Proof of Stake: In this type of concept that someone who holds an asset, the more the contribution he makes thus having priority to be chosen as a block creator.

3. Proof of Service: In this type of concept the node must lock certain assets as collateral.

4. Proof of Importance: In this type of concept, it identifies the overall contribution to the network. This includes vesting and the number of transactions over a period of time.

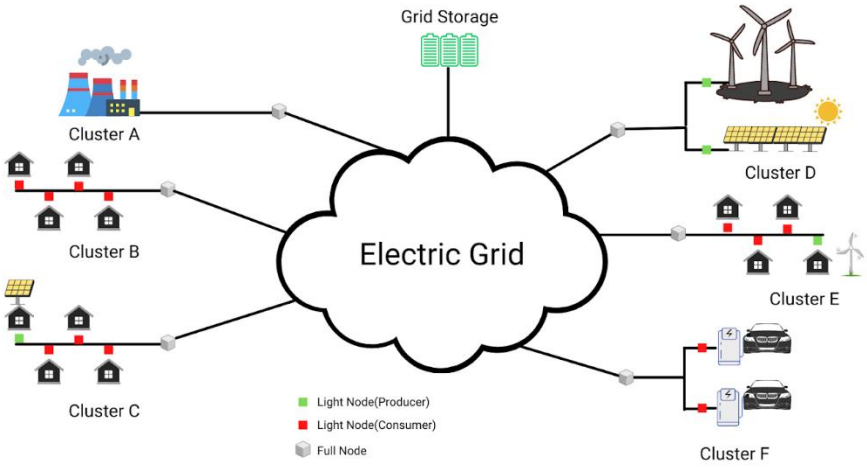
5. Proof of Reserve: In this type of concept the value of the asset is directly linked with an on-chain reserve.

7. Implementing blockchain in a smart grid

The smart grid offers more security in terms of electricity supply. However, the concept adds complexity to the existing conventional power system. On the transaction level, how to make sure generators will deliver the electricity after the consumer has paid. With multiple generators and consumers existing in the network, it also raises concerns about who will validate the transaction, and how the process is carried out. Here comes the blockchain network to manage transactions in the smart grid.

7.1. Architecture to integrate smart grid system with blockchain

Let us consider a perfectly balanced scenario of a smart grid wherein cluster A consists of the government-owned power plant, cluster B consists of residential buildings, clusters C and E consist of buildings, but they have some solar or wind turbines. Cluster D consists of privately-owned power plants, cluster F consists of EV charging stations and public energy storage stations.



At every household, there is a small computing device placed as a light node that has an address for each of the connected houses that keeps the amount of power used or generated by an individual household. There is a full node placed at substations where power is stepped down before the power is distributed to the consumers. The nodes here perform operations of storing the data recorded by IoT sensors and the transactions that have occurred in the overall grid. The full nodes are also responsible for delivering power to different consumers in an efficient manner.

7.2. Smart Grid Blockchain Model

The model we propose for implementing the smart grid technology should be pegged against a stable fiat currency INR or USD. This can be implemented by the

use of two concepts proof of reserves and proof of works concepts as a consensus method.

Every node is interconnected and has a unique address and a private key. The address is used for transactions and the private key is used for signing a smart contract to perform the transaction such as consuming and selling of energy. Depending upon how much energy the producer produces an equivalent amount of token/currency is generated and it is given. If the producer wishes to sell energy that can be done by transmitting power and receiving equivalent token/currency. If a consumer wishes to buy that energy, he can buy it using the token/currency.
A smart contract is generated between the producer and consumer which contains the details of the trade and other aspects. Now since a transaction is being taken place its data is added to the block by verifying by the miners and is linked to the blockchain and a record is generated.

8. Smart grid Application

Now to view sensor data readings, transactions and suggestions to improve the productivity of the system, a user application can be created with the help of IoT and web 4.0. This application is connected to the blockchain network and can be accessed using the unique address and the private key that was generated by the node.

9. Conclusion

The integration of blockchain into smart grid systems solves the issue related to cybersecurity of the systems, it is a more reliable method of transaction and eliminates the use of third-party services that may exploit you. The blockchain is immutable so it solves the issue of double-spending. If the adoption of the smart grid system takes place it could increase the GDP by almost 15% in India due to the rapid growth of expansion in the adoption of using cryptocurrency. India's cryptocurrency market in April 2020 was $923 million and in May 20221 it reached $6.6 billion. This can lead to high expansion and sales in domains such as solar, power systems, mobile phone industry, IoT, Electric vehicle industry, and a step in strengthening the value of the Indian rupee.

The data collected by the cyber-physical systems and is stored and analyzed using machine learning technology. Increasing the automation and decentralization of the grid will be key in the development of a smart grid system. IoT technology can create smaller sections, or microgrids, that allow smart meters and substations to make changes in configuration based on user consumption levels, weather patterns, and other predictive elements without the need for human interference or centralized decision making.

The designed system is easy to implement and very customizable according to the needs of the Customers/ Consumers. It provides very efficient methods of monitoring and controlling our renewable energy resources which would otherwise have been underutilized. It ultimately saves money and helps to minimize pollution because the use

of non-renewable energy will reduce a carbon emission footprint. Finally, it gives a very effective solution for implementing green energy techniques on a larger scale.

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