BLOCKCHAIN INTEGRATION IN POWER SYSTEMS

INTEGRAREA BLOCKCHAIN ÎN SISTEMELE ELECTROENERGETICE

Gabriel TUDOR[1], Cornel-Cristian ANDREI[2], Madalina ARHIP-CĂLIN[3]

Abstract: *The power system is currently undergoing a process of transformation from conventional electrical power system to smart system. This transition is enabled by the need to ensure high reliability and continuity in the daily power grid operation. Also, an important role in electrical power system transformation is played by the evolution of the information technology layer, in fields like internet of things, blockchain, cloud/cloud computing and big data, that overlaps across the technological layer present in the electrical power grid.*

Keywords: Blockchain, Smart-Grid, Electric Vehicles, Energy Market.

Rezumat: *Sistemul energetic convenţional a suferit o serie de transformări ce a determinat o penetrare crescută a tehnologiilor de tip smart grid, menite să crească robusteţea sistemului în ceea ce priveşte procesul de producţie, transport şi alimentare cu energie electrică a consumatorilor. Inovaţiile aduse în domeniul tehnologiei informaţei în cadrul Internet of Things (IoT), Blockchain precum şi Cloud (Cloud Computing, Big Data) s-au dovedit importante pentru evoluţia sistemului energetic.*

Cuvinte cheie: Blockchain, Smart Grid, Vehicule Electrice, Piata de Energie.

1. Introduction

[1] Eng., Dept.of Power Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: gabi.tudor912@gmail.com
[2] Eng., Dept.of Power Engineering, University POLITEHNICA of Bucharest Romania, e-mail: cristian.cornel91@yahoo.com
[3] Eng., Dept.of Power Engineering, University POLITEHNICA of Bucharest Romania, e-mail: madalina.arhip@upb.ro

Blockchain technology is a peer-to-peer system of transaction with the purpose of eliminating third parties. Originally the concept of Blockchain appeared in a scientific paper called "How to Time-Stamp a Digital Document" by Stuart Haber and W. Scott Stornetta in 1991, which described the mechanism of blocks chained together and secured with encryption.

The actual implementation of Blockchain technology began in 2009 with the introduction of a digital currency called Bitcoin. This is the first iteration of Blockchain, also known as public version 1.0 started by one person or group of people under the name of Satoshi Nakamoto.

Public version 2.0 is commonly referred as the Ethereum Blockchain, and introduces the concept of "Smart Contracts" used to automate the execution of an agreement. When the predetermined conditions are met, the programs that run on top of Blockchain or Smart Contracts will execute the task automatically eliminating the need of an intermediary.

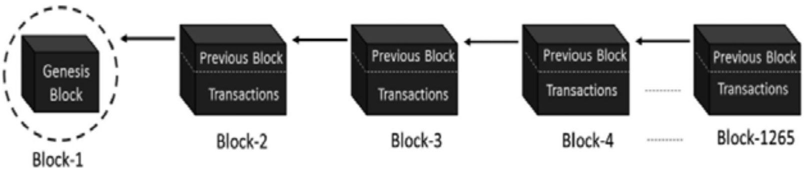


Figure 1 – Blockchain data structure [1].

In Figure 1, each block inside the Blockchain contains multiple transactions representing a record of an event. Senders and recipients use addresses in order to perform transactions. Addresses are unique identifiers and are usually public keys.

The header section of the block contains:

- A reference to a previous block (hash pointer) unless it is a genesis block. Every time the data inside the block is changed a new hash is generated and depending on the type of blockchain the data transmitted may also vary.
- A timestamp marks the creation time of each block.
- Nonce, which represents a number generated and used only once, mostly for cryptographic operations and to provide authentication, encryption and protection.

- A hash of all nodes of a Merkle tree is represented by a Merkle root. Merkle trees are used to validate transactions securely and efficiently.

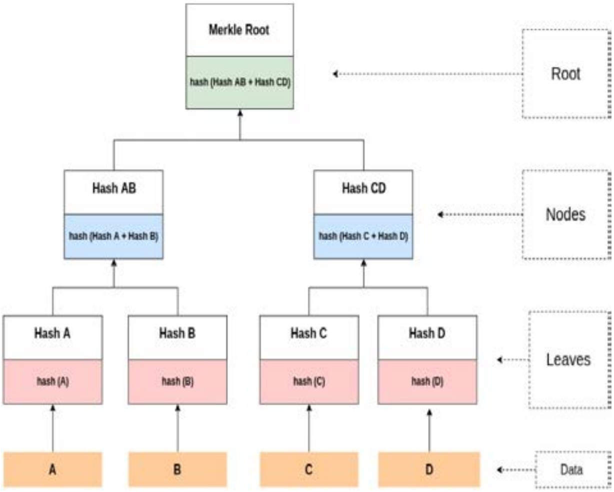


Figure 2 – Merkle tree structure [11]

In a peer-to-peer network all the participants (nodes) talk to each other directly and there is no central controller in the network. Each node is an individual player having processing power and memory and together with other nodes is working to achieve a common goal, thus forming a distributed system.

The advantages of distributed systems are:

- Higher computing power.
- Cost reduction.
- Higher availability.
- Ability to grow naturally.

2. Energy Trading using Blockchain

Energy trading is usually composed from a number of participants with different market roles. The electricity passed on to power grid from the producer is managed by the Transport System Operator (TSO) or Distribution System Operator (DSO) by case, who are responsible for the infrastructure and the transmission and distribution routes.

The supplier procures the necessary quantities of electricity contracted by the consumer via organized trading centers such as OPCOM in Romania. Among other things, the electricity supplier ensures smooth process operation and billing.

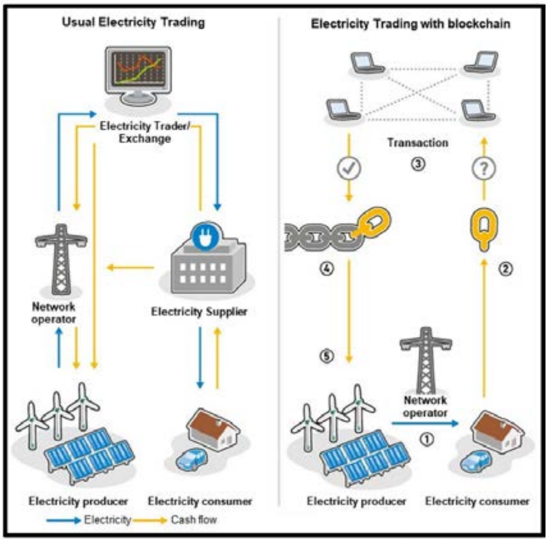


Figure 3 – Electricity trade, with and without blockchain comparison [2]

In Figure 2 the role of the electricity trader or supplier are eliminated by enabling direct interaction between peers using blockchain, resulting in a decentralized transaction and energy delivery system as follows [9][10]:

1. The electricity producer supplies power to the consumer in its vicinity.
2. Each transaction is combined with other transactions to form a data block.
3. The transaction is checked and confirmed in the network on decentralized computers.
4. The block is appended to the existing data chain (blockchain).
5. The electricity producer receives the payment.

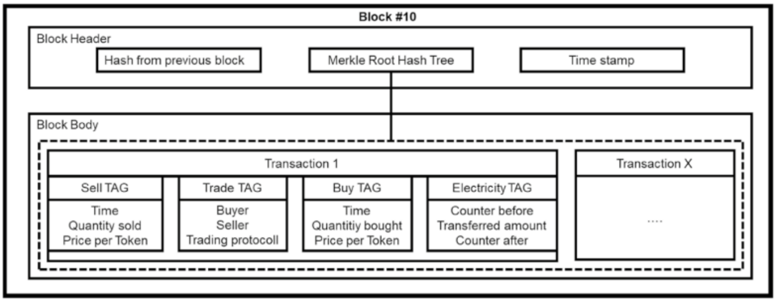


Figure 4 – Block contents [2]

3. Electrical Vehicle Management using Blockchain

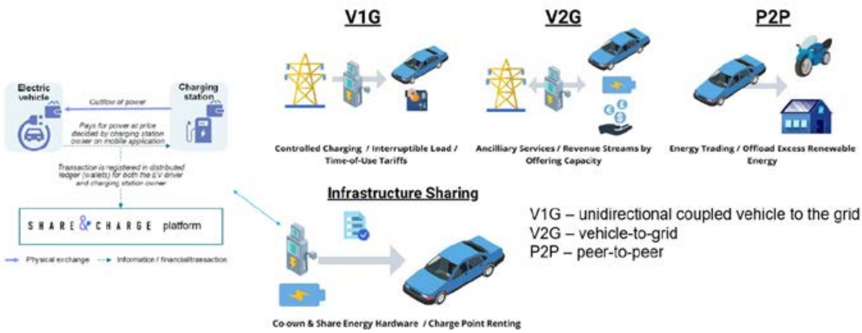


Figure 5 – Use cases for electrical vehicle management [3]

Due to the increase in numbers, electric vehicles (EVs), have the potential to create disruption in power supply because they introduce an increase in energy demand in localized areas of the grid. Although electric vehicle charging follows a relatively predictable time frame, the sudden spike in demand may cause the transformers to overload and fail.

With the implementation of a two-way charging control mechanism, energy resource aggregators are able to sell pool capacity to grid operators.

A standard for secure Vehicle to Grid (V2G) charging is currently under development (ISO 15118-20), thus enabling the creation of several business cases using Digital Ledger Technologies (DLT) in order to provide trust, security and privacy in the process of analysis and decision making between different entities.

Different data sets are used by TSOs, DSOs, and energy aggregators to determine which type of service EVs can provide. The goal the V2G standard is to make visible on the network the capabilities EVs have to offer, together with the various charging points through the use of DLT, to create an immutable secure record of the data required.

4. Sharing Energy Storage using Blockchain

The main characteristics of blockchain, such as being distributed and decentralized, are consistent with the distributed nature of Shared Energy Storage (SES) networks. In a blockchain the participants of SES act as nodes that maintain the distributed database together with other nodes, creating a database backup for each participant locally.

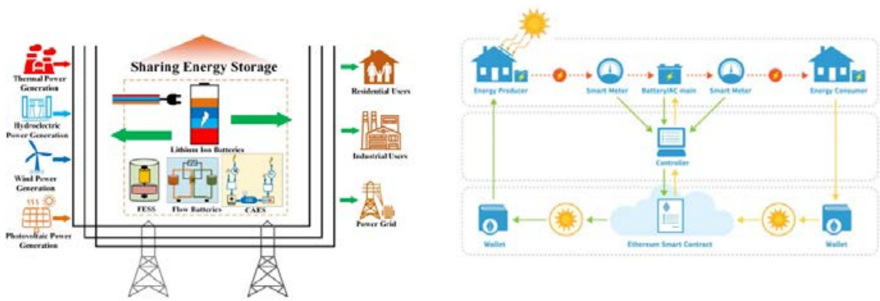


Figure 6 – Sharing Energy Storage [4][5]

In Figure 5 one or more energy storage facilities store the electricity from distributed or centralized generation sources when the solar and wind curtailment happens or power is generated in excess. SES can also purchase energy when the price drops. In the energy discharge mode, the stored energy is released to different users such as residential users, industrial users, and power plants.

In a traditional sense, the energy trade is possible using an off-line platform, making the signing auditing and executing of new contracts as being a time-consuming manual process and introduces many human factors affecting fairness. With the help of smart contracts which offers automation of such actions, transaction efficiency is improved and labor costs are reduced.

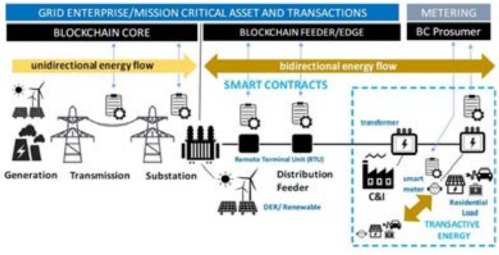
5. Grid Management using Blockchain

In a typical grid we have distinct processes to consider, types of assets and functional requirements, for example mission critical assets need to be isolated from the grid-edge and enterprise processes.

The core segment of the grid consists in the transmission and distribution, substation and grid edge (feeder side). These assets are being run with the help of synchrophasor networks which are a component of the SCADA system, using DNP3 protocol and IEC 61850 object-oriented protocol.

The last segment of the power grid is at the edge and involves the prosumer customer-facing side, which includes electric vehicle charging stations, residential and commercial with increased renewable energy penetration. In this scenario blockchain energy grid solutions can be classified as blockchain core, blockchain edge/feeder and prosumer.

By creating these blockchain segments grid security is improved, scalability and performance, addressed by the 2P2S (performance, privacy, security, scalability) design principles, enabling each element of the grid to be a source that generates its own smart contract. Enterprise and mission-critical permissioned blockchain platforms can connect to existing grid enterprise/SCADA management system, such as energy management systems (EMS), distributed energy resources management systems (DERMS) and advanced metering infrastructure (AMI) solutions.



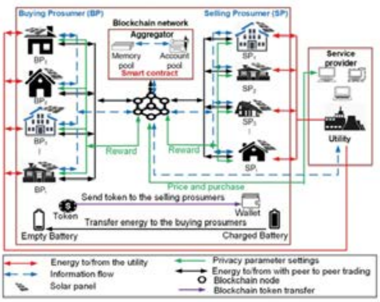


Figure 7 – Proposed system model [7]

6. Conclusions

Blockchain technology promotes decentralization and eliminates the need for a trusted third party, as blockchains are shared and everybody can see what is on the blockchain, transparency and trust emerges as a result.

Data inside the blockchain is immutable, once the data has been written to the blockchain it is extremely difficult to change it. Information inside the blockchain is replicated on each node making the system highly available, offering a traceability of assets and provides the possibility to distinguish where energy is coming from, which enables end users to contract energy based on how it is generated from fossil fuel or from renewable sources.

Ultimately blockchain enables users to establish peer-to-peer energy trading platforms without third-party intermediaries, enabling prosumers to produce, consume and trade energy across existing grid infrastructure without any barrier, and brings a more flexible and adaptable system.

R E F E R E N C E S

[1] *Bikramaditya Singhal, Gautam Dhameja, Priyansu Sekhar Panda,* Beginning Blockchain: A Beginner's Guide to Building Blockchain Solutions, Apress, July 2018.

[2] *Bartek Mika, Alexander Goudz,* Blockchain-technology in the energy industry: blockchain as a driver of the energy revolution? With focus on the situation in Germany,Received: 17 October 2019 / Accepted: 7 May 2020 Springer-Verlag GmbH Germany, part of Springer Nature 2020, https://doi.org/10.1007/s12667-020-00391-y.

[3] Blockchains for Electric Vehicles & Grid Integration Review, EVGI Working Group August 2020.

[4] *Yiting Wang, Weiqiang Qiu, Ling Dong, Wei Zhou, You Pei, Li Yang, Heng Nian and Zhenzhi Lin,* Proxy Signature-Based Management Model of Sharing Energy Storage in Blockchain Environment,Published: 26 October 2020, doi:10.3390/app10217502.

[5] *Toshiyuki Sawa*, Blockchain technology outline and its application to field of power and energy system, Wiley, DOI: 10.1002/eej.23167.

[6] *Imran Bashir*, Mastering Blockchain - Third Edition, Packt Publishing, August 2020.

[7*] Daniel Drescher*, Blockchain Basics: A Non-Technical Introduction in 25 Steps, Apress 2017.

[8] *Omaji Samuel Nadeem Javaid*, A secure blockchain-based demurrage mechanism for energy trading in smart communities, Wiley, DOI: 10.1002/er.5424.

[9] *Green Energy Advances, R. Porumb and G. Serițan*, Integration of Advanced Technologies for Efficient Operation of Smart Grids, Published: January 28th 2019, DOI: 10.5772/intechopen.83570, ISBN: 978-1-78984-200-5, Print ISBN: 978-1-78984-199-2

[10] *R. Porumb, D. Apetrei, E. Macsim*, Knowledge-based decisions in smart grids, 2016 International Conference and Exposition on Electrical and Power Engineering (EPE), pp.733-737, 20-22 Octomber 2016, Iasi, Romania, ISBN:978-1-5090-6128-0, INSPEC: 16525930, DOI: 10.1109/ICEPE.2016.7781436

[11] *Alessandro Parisi*, Securing Blockchain Networks like Ethereum and Hyperledger Fabric, Packt Publishing, April 2020.