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CYSENI 2017, May 25-26, Kaunas, Lithuania
ISSN 1822-7554, www.cyseni.com

INTEGRATION OF THE BLOCKCHAIN IN A SMART GRID MODEL

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ABSTRACT

Nowadays, one of the principal concerns of the scientific community is the energy transition and energy efficiency. Indeed, the expansion of objects consuming and IoT leds to a significant increase in energy demand. To find a solution to this phenomenon is essential. Currently, one of the solutions that can be applied is the Smart Grid. It would optimize the energy consumption by setting consumption patterns, adapted to a specific situation, taking into account different parameters like the pricer, the user preferences, or the parameters of the appliances of the house. Promoting renewable energies such as solar or wind power, are also part of the issues of the Smart Grid. The goal is to promote local energy production, and then avoid the energy transport loses over long distances. However, the produced energy by renewable energies is erratic, thus a numerical management is needed. A blockchain is a distributed, decentralized transaction ledger, which is owned, maintained and updated by each user. It carries peer-to-peer energy exchanges among citizens of a same microgrid, without a central control body, based on smart contracts. The smart contracts will have the role to automatically satisfy some conditions or rules of consumption, among citizens. These contracts might contain the user preferences or the consumption patterns of appliances. A city contains several microgrids, each with their own blockchain, the inhabitants would have solar panels or other energy sources, and then would feed those which claim energies by making a transaction following the smart contracts. This paper focuses on these peer-to-peer transactions in a microgrid validated by a blockchain.

Keywords: Peer to Peer, Blockchain, Smart Contract, Game Theory

1. INTRODUCTION

In its balance sheet for the year 2015, RTE (Réseau de Transport d'Electricité /Electricity transmission network) reports an electricity consumption of 475.4 TWh in France[1]. This growth in consumption concerns not only France but the whole world. The world's electricity consumption in 2013 is 21 538 TWh[2]. This phenomenon tends to increase, due to many electrical appliances and the IoT. Today, connected objects are integral parts of our everyday life, from the simple watch to the whole house.

Worldwide, 48% of the electrical energy comes from fossil energy, which leads to a major problem due to the scarcity of these energies (e.g. oil, coal, natural gas)[3]. In addition to the scarcity, this kind of energy pollutes considerably the environment, both atmosphere and waters, due to greenhouse gas emissions. It is in the interest of all to come up with solutions. The energy consumption increases from year to year. Getting to better management of our energy consumption seems paramount. A possible solution could be the exploitation of renewable energies as primary energy. This would amount to integrate a numerical regulation of the energy production. The solution of renewable energies is a good initiative, but it does not remain without flaws. The disadvantages of renewable energies are their intermittent production, it depends on the weather (sun, wind, tide).

A numerical aspect able to manage these disadvantages could optimize the integration of clean energies within the current production system. It is in this perspective that the Smart Grid was born [1], by setting up a network connected to homes, consumer's appliances and renewable energy

[1] http://rte-france.com
[2] https://www.edf.fr
[3] https://worldenergy.org

power plant, in order to smooth consumption curve. Another digital aspect could achieve an optimization of the consumption, it is the Blockchain technology.

To arrive at a conclusion on the feasibility of integrating Blockchain into a Smart Grid model, it is necessary to know the issues and parameters to be considered. For this purpose, an in-depth study of this technology is expected, to have an overview of what is happening in terms of Blockchain, the different types existing, or the technological advances of the field through the scientific community.

The Blockchain is a kind of transaction history, like a huge ledger that appeared with the Bitcoin [2]. This technology allows for peer-to-peer monetary transactions without a central control body. The Blockchain is based on the decentralization of the data in order to remove the central part representing the confidence part of the current system. The Bitcoin has given birth to other types of Blockchain, like the Ethereum [3]. It has a peculiarity that is the implementation of smart contracts, contracts allowing to establish various rules, between the protagonists. More recently, an Energy Blockchain was created[4] to promote local energy production. Peer-to-peer energy transactions could reduce the high electrical demand for the existing grid, and Blockchain could secure and memorize transactions.

2. THE BLOCKCHAIN TECHNOLOGY

2.1. Environmental situation

The current state of the environment requires the implementation of local energy production, based on renewable energy, in order to manage the rise in electricity consumption leading to an increase in energy production (Fig. 1), it induced to CO2 emissions which is proportional to the population growth. It has a direct impact on the power lines because, due to the excessive demand, the lines no longer support the excessive electrical flow, i.e a peak consumption at full hours, and a drop in off-peak times. In order to lighten the lines, it is necessary to smooth consumption curve, and for this it would be interesting to use its own electrical production.

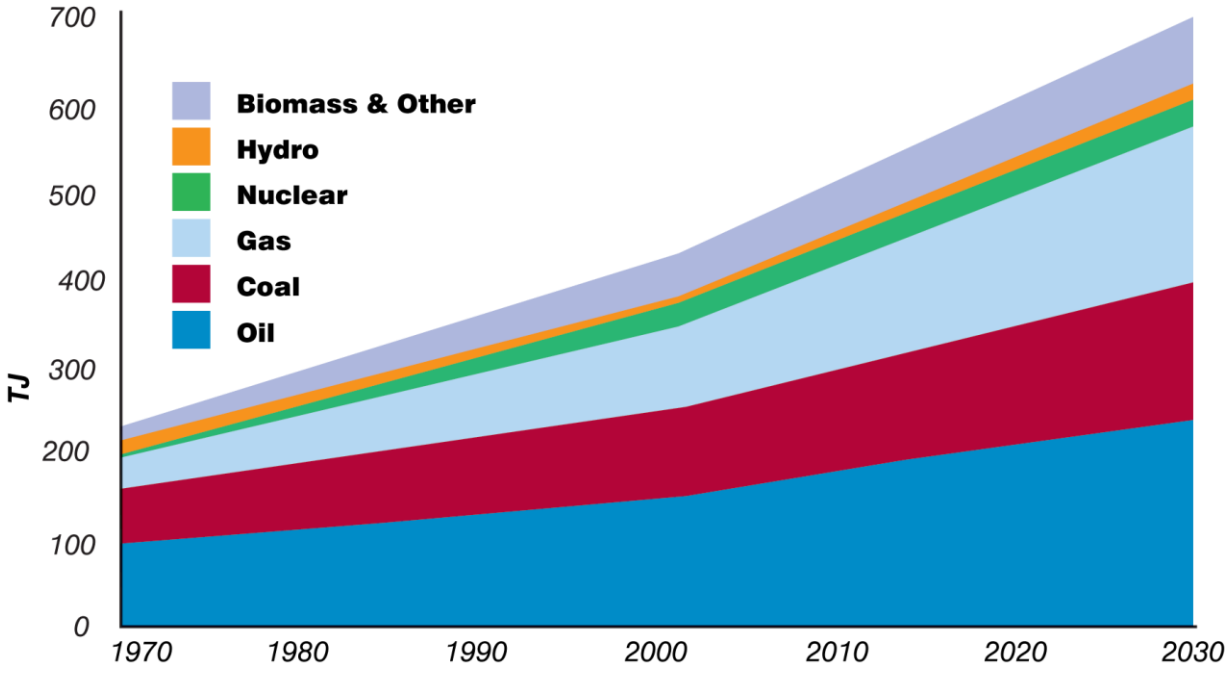

Fig. 1. Primary energy consumption, past and future
(*Source:* OECD/IEA *World Energy Outlook* 2004)

[4] https://solarcoin.org/fr/

Promoting local energy production means the integration of renewable energies within the existing network. However, this integration requires good management because these energies, such as wind or solar, generate electricity intermittently, which is why digital management seems essential in order to achieve a stable electrical system.

This digital management could be the Smart Grid but not only. A peer-to-peer energy transaction between neighborhood would be a good solution. That's why we thought to integrate a Blockchain in the large scale Smart Grid project [1].

2.2. Definition and examples

2.2.1. Bitcoin

This famous technlogy was born with the Bitcoin [2], we count several types of Blockchain with each a specific application. Globaly, a Blockchain allows to decentralize data and to perform peer-to-peer transactions [4], [5]. For the Bitcoin the transactions are only monetary. The Fig. 2 illustrates a bitcoin transaction between two people.

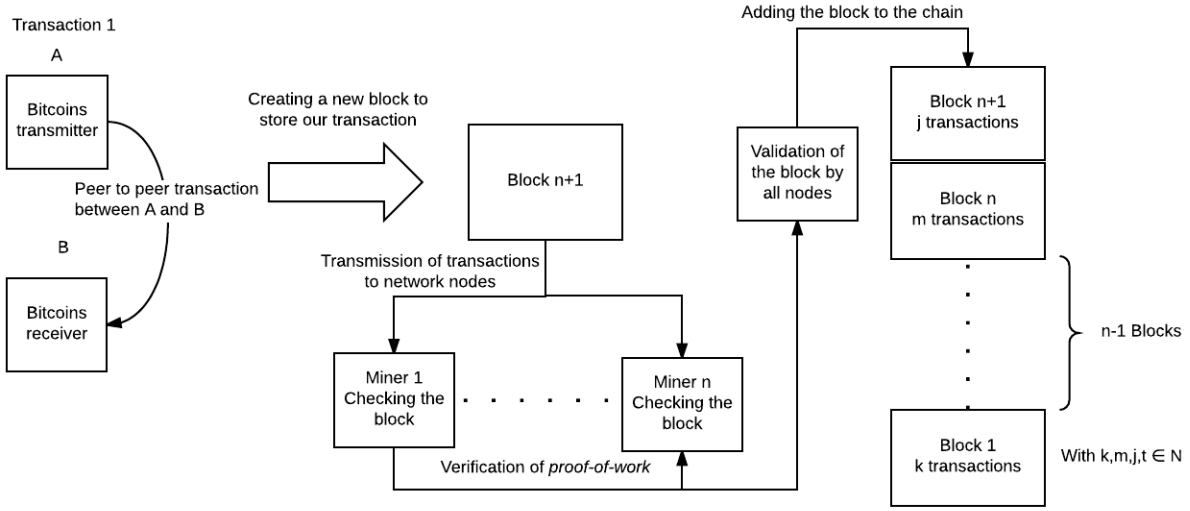

Fig. 2. A bitcoin transaction

The transaction can be divided into three parts:

1. The willingness to make a transaction (specifying the amount and the receiver), this creates a new block.
2. All miners of the network check the blocks, based on the *proof-of-work* protocol (PoW) (calculation algorithm for checking whether a work has been performed) [2], [5], [6].
3. The validation of the block, and the addition of the latter to the oldest chain.

2.2.2. Ethereum

The Ethereum Blockchain was created by Vitalik Buterin [3]. He judged that the Bitcoin is not performing enough and possessing too many flaws. He devised a Blockchain capable of overcoming these failures.

The principle remains the same as for the Bitcoin, it is a matter of a transaction in peer-to-peer, this time based on smart contracts. The transaction exchanges ethers [7].

The difference with the bitcoin, in addition to smart contracts, is that the validation is based on a *proof-of-stake* (PoS) [3], [8], [9]. It is no longer a proof of work but a proof of possession, it consumes less energy than the bitcoin.

A smart contracts is nothing more than a code [10], stored in the blockchain, it could be not modify, so if you want to change some parameters of the contract, you should remove it and create another one.

2.2.3. SolarCoin[5]

This new application of Blockchain seems promising because it allows to achieve an optimization of the electrical consumption. Nowadays, there is not much information about the solarcoin, nevertheless in Brooklyn in the USA an energy exchange system was established based on the Blockchain Ethereum[6]. This system is limited to a microgrid, it allows to exchange energy produced from solar panels of the inhabitants of this same microgrid. Each MWh produced makes the producer benefit from a SolarCoin.

2.3. Pros and Cons of blockchain's technology

Not all blockchains have the same specificities and areas of application. Despite its growing popularity, it is nevertheless a subject of controversy and debate. Any new technology has its advantages and disadvantages, we could maybe minimize the disadvantages and bring out the good aspects. The three Blockchains that interested us for our research are: Bitcoin, Ethereum, and SolarCoin. So we weighed the pros and cons of these different blockchain, to highlighted the points to improve or avoid (Table 1).

Table 1. Pros and cons of different Blockchain

Blockchain technology	Pros	Cons
Bitcoin	Decentralized data	PoW
	Peer-to-peer transaction	Only monetary transactions
		Public blockchain
Ethereum	Smart contracts	Smart contracts
	PoS	Lack of security
Solarcoin	Energy transaction	Same as Ethereum

In regards to Bitcoin, the heaviest disadvantage remains the consensus protocol (PoW). Its mode of operation remains rather long and very greedy in energy [3].

PoS is often referred to as a PoW solution, because of its green consumption electricty. But it should not believed that the PoS is the miracle solution. One of its cons is its lake of security [9], because by comparing with the PoW, PoS does not ask for work in return for its validations.

Ethereum is characterized by its Smart Contracts, and it seems very useful. But if contracts are badly programed, the system could be ill-suited.

Finally, concerning SolarCoin it is difficult to decide on its advantages and disadvantages because it is not very widespread, there is not enough information about this technology. However, it is based on the Ethereum platform therefore the disadvantages of Ethereum apply to Solarcoin. The innovative aspect remains its energy transaction.

3. THE BLOCKCHAIN APPLIED TO THE SMART GRID

After knowing the various variants of the Blockchain and retaining the interesting points concerning them, we tried to develop a Blockchain adapted to a smart grid model. This first blockchain approach is a combination of several blockchains, which gives us the ElectricChain[7], in reference to the electrical aspect of the chain. The aim is to set up a microgrid electric network, as

[5] https://solarcoin.org/fr
[6] http://brooklynmicrogrid.com/
[7] http://www.electricchain.org/

in the case of the Brooklyn district[8], to allow the inhabitants of the same microgrid to exchange their energy production, not only solar energy, but all other energy produced (wind, solar, battery, other), and so benefit Energycoin for every kWh of energy produced. And thus promote the production of local energy and alleviate the high energy production, in order to achieve an erasure of the curve of energy consumption. The decentralization aspect provides peer-to-peer exchange flexibility.

By merging the initial Smart grid model and the ElectricChain, Fig. 3 summarizes the process which relates the progress of a transaction between two inhabitants of the same microgrid.

Background:

- "A" produced 8 kWh, he consumes 5 kWh, he still has 3 kWh.
- "B" needs 4 kWh.
- A smart contract is established between those two persons (transaction rules).

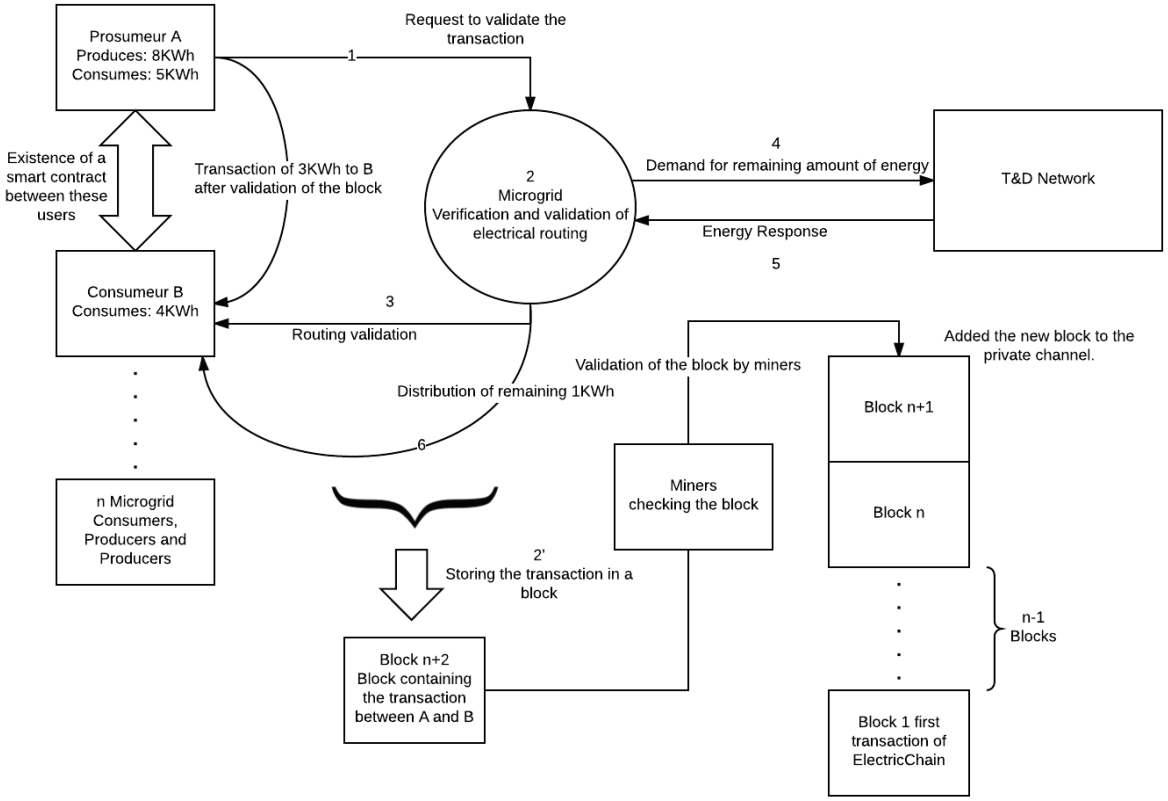

Fig. 3. Process of an energy transaction

Microgrid level:

1. A Transaction wanted to be carried out between two persons of the same microgrid according to the rules of the smart contract (A and B), "A" wants to send 3 kWh to "B".
2. The microgrid checks whether it is possible to perform a transaction, based on the electrical routing and the power line support.
3. Once the routing is validated, the microgrid allows to "A" to transmit the amount of energy to "B", concerning the capacity of the lines to support the transaction.
4. The microgrid demand the 1 kWh left for "B" to the T&D network for meeting conditions of the transaction.
5. The network provides the remaining 1 kWh to the microgrid.
6. Finally, the microgrid sends to "B" the 1 kWh.

[8] http://brooklynmicrogrid.com/

Miners level :

1. A transaction wanted to be carried out between two persons of the same microgrid according to the rules of the smart contract (A and B), “A” wants to send 3 kWh to “B”.
2. The transaction between “A” and “B” is stored in a block with other transactions, and ready to be verified by miners. If the PoS is verified, the block is validated and then stacked on the oldest chain.

In this new model, the smart contracts possess the strategies and consumption patterns [1] of the Blockchain participants. So, as smart contracts are stored in the chain, to add or remove consumption strategies, it will be necessary to remove the smart contract to replace it with the smart contract updated, because let’s remember, the blocks can not be altered.

4. ITEMS STILL TO BE DEALT WITH

This first approach of Blockchain applied to the Smart Grid is not without flaws. Several points still need to be improved and deepened. We have compiled these points in Table 2.

Table 2. Areas for improvement

	Questions to ask
1	Is it possible for a user to leave a blockchain when he has knowledge of certain private data?
2	If it is possible to join or leave a blockchain network, what will be the procedure to follow?
3	Is it possible for a neighbor to switch from one ElectricChain to another?
4	Should we include a monetization aspect?
5	If one wishes to exchange this currency with another currency of another Blockchain, is it possible to have an equivalence?
6	Could a non-energy consumer buy Energycoins in any way?
7	Could the Energycoin only be resold against the energy of a neighbor, or the conventional network?
8	Is it better to return this energy to consumers and thus benefit from a profitability in its production?
9	In the full period, is it better to feed on the classical network or the blockchain network?
10	What pattern should be applied for known situations?
11	How to remove the third part in the system, which is the microgrid?

The choice in the consumption pattern shown in Fig. 4, illustrates the different possibilities of algorithm consumption. It is difficult to know which path will be the best, because several parameters are involved (peak of consumption, price of the energy, energy produced by the prosumers, … etc).

It is also important to note that, from Fig. 3, it can be seen that the transaction can not be done without a third organ. Indeed, concerning the routing of the energy, the presence of EDF (Électricité de France/ French Electricity), or other organization as such seems to be indispensable to allow the validation of a transaction from an energy routing point of view.

This shocks the very concept of Blockchain, which is to establish a peer-to-peer transaction system without a central body. Today, it is impossible to remove the electrical routing part of the network. As we can see in the Fig. 4.

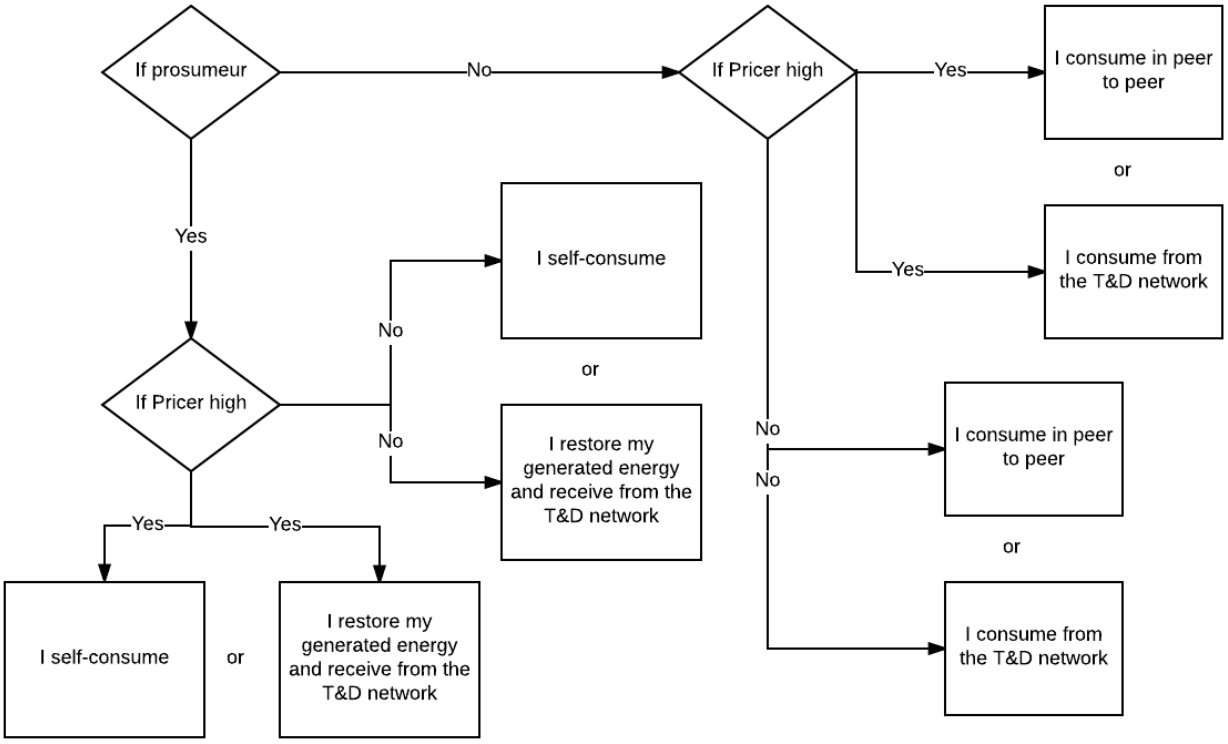

Fig. 4. Problems about the consumption algorithm

5. CONCLUSION

The importance of the Blockchain in a Smart Grid does not seem obvious but it is the case. This means of exchanging energy could promote the production of renewable energy locally, thus avoiding energy losses in the lines. On that day, we do not have concrete answers on questions in Table 3, but we have plans to resolve the problems encountered.

Our model is based on the installation of several ElectricChains in the same city, in order to distribute and homogenize the demands in electricity and thus avoid too much disruption of the network. Dividing a city's network into a microgrid [11] would allow for better management of energy flows and peer-to-peer transactions.

The aspect that we did not want to integrate into the model is a monetary aspect because it would imply a tendency to haggle the energy produced and possibly get to an energy traffic. If this is the case, it is necessary to establish tariff standards.

To be rewarded with an amount of energy produced, the producer will benefit a certain amount of energycoin.

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