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Published in: The 38th European Photovoltaic Solar Energy Conference and Exhibition

Publication date: September 2021

Document Version

Peer Reviewed

THE APPLICATION OF BLOCKCHAIN IN COMMUNITY ENERGY TRADING: A STUDY ON SOLAR ENERGY EXCHANGES IN MALTA

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ABSTRACT: The power grid is changing rapidly with the advancement of technology and recent grid innovations. Blockchain offers the possibility of contributing and advancing these emerging technologies. Integrating various distributed generation in energy infrastructure has brought many opportunities. Self-consumption and localised energy communities therefore have an important role in the development of this transition and to contribute to the advancement of renewable energies. This paper discusses a blockchain-based system which is designed to serve the demands of communities which share solar energy. This system includes smart-meters and analytical techniques to monitor the characteristics, uses and trends of consumption in a community and the potential of blockchain technology that facilitates energy exchanges.

Keywords: solar energy, photovoltaics, self-consumption, electric vehicles, energy storage, Blockchain, energy trading, peer-to-peer energy management, smart contracts, transactive energy, community energy consumption.

1 INTRODUCTION

The costs of renewable energy technologies has been on the decline over the past few years and has made it much easier for residential PVs to be installed in a domestic setting. Self-consumption is being encouraged through various schemes offered by the local government [1]. The Green New Deal, as laid out by the European Union, aims to address climate change and economic inequality [2]. The EU aims to be the first climate-neutral continent and places a lot on emphasis on the use of renewable energy. Despite the challenges which come with the deal itself, it poses many opportunities for businesses and households to progress ahead in the field of photovoltaics [3].

Centralised systems, whereby power is generated, transmitted and distributed from production plants to the consumers is moving towards become decentralised, by integrating distributed power generation and flexible loads in order to enable end users to re-inject their own surplus power to maintain a balance between their own generated power and the loads. [4]Therefore, this shift is giving more importance to citizens and localised businesses to act on their environmental responsibility.

One of the technologies which has been being explored over recent years is the use of blockchain as a platform for trading energy. Blockchain is a decentralised database which stores data and allows various transaction to take place. As this system is meant to be decentralised, It makes for a suitable platform to exchange energy in almost real-time. This paradigm shift, gives rise to the need of further advancement in such technologies. The introduction of smart-meters has been responsible for advances as real-time data has been made available; and these continue to be the primary enablers in the development of new technologies as it helps to monitor production and consumption and therefore helps policy makers better manage the system to be more efficient and integrated, with potentially less loses and making better use of our natural resources [5].

Blockchain technology is no longer solely used for cryptocurrency trading. Blockchain allows for peer-to-peer trading, which is were a lot of potential lies. Numerous pilot studies have been carried out in various fields [5], and the energy sector is no exception. An ever-developing technology may also materialise further on Smart Grids.

PROSUMERS AND DISTRIBUTED SELF-CONSUMPTION

The main areas being explored in this paper are the consumption and production trends of energy within a community which is sharing locally-produced renewable energy. The sharing and distribution of energy within the community helps to cope with the energy demands within the community.

This does not come without its challenges and obstacles. Firstly, energy consumption of households is not uniform on a daily basis and neither is it exactly the same as another household; though trends can be extrapolated. Secondly, there may be times of complete absence therefore providing a gap in consumption patterns and/or inconsistent production of electricity due to for example, adverse weather conditions. Buildings may have different profiles; like for example, multi-dwelling buildings (apartments) and different insulation systems; and finally, installation of such panels may come with technical difficulties, such as inadequate sun exposure and urbanism regulations or the sole impossibility of installing panels on the roofs of multi-dwelling buildings [5].

On the other hand, community sharing of electricity also provides benefits such as reducing 'wasted energy' and limits over production in cases where all the energy being produced is not being used; creating a PV pool or farm which works according to the necessities of the community.

This system gives rise to various technical and economic opportunities; mainly in relation to maximum use of resources and meeting energy demands in a sustainable manner. In this study, two different scenarios are being explored. In the first scenario serves a community of six industrial PV prosumers and the second scenario which asses the same six prosumers utilising a collective installation.

Energy consumption and production come from real measured data (to be updated) and the data is assessed based on self-consumption and self-sufficiency rates. The self-consumption rate is the part of energy produced and consumed locally while the self-sufficiency rate is the ratio of the electrical needs which are covered by the production of energy form the PVs.

The six individual consumptions are provided for seven days in September 2020 (to be updated), as well as the production of a 6kWc PV plant in Malta, Figure 1.

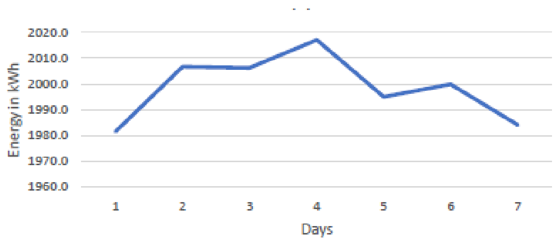

Figure 1 - Graph showing the average consumption trends over a 7-day period

The benefits of distributing within the community has significant benefits; mainly where energy produced is not being used by one household, this is being used by another and not being wasted. Individual self-consumption does give the individual unit its' anonymity however, from an environmental perspective, the aim is to reduce losses and enable a community to benefit from their production. These results give policy makers to implement incentives to develop models to further such technologies within a community.

From a technical perspective, solar power generated from the power plant or individual cells is fed into the main electrical grid, where it is distributed according to the consumption of each household. Energy consumption and production are measured by using smart meters. The virtual network tracks the household trends at various time periods; in the case of this study, every 15 minutes. The energy which is generated by the buildings is aggregated and then distributed according to the riles laid down in the smart contract. These rules take into account the individual consumption needs of the buildings and will obtain extra energy from the main grid if necessary, however that is calculated separately.

The above graph shows the consumption rates, based solely on the grid supplement of the same buildings over another 7-day period. The energy which was required is significantly lower however this may be due to several factors such as absence from the premises, or the lack of necessity to use certain appliances; or the participants were much more conscious of their consumption. In this scenario, the buildings did not produce their own energy and relied solely on the grid; however, the grid was being supplemented with energy produced from the solar farm.

BLOCKCHAIN MECHANISM FOR ENERGY TRADING

A. Peer-to-Peer Model Outline

As mentioned, this system is based on six buildings in two scenarios; one where each building produces and uses its' own energy and where the demand is higher than the production, it is topped up with electricity from the grid and the second scenario where the buildings are supplied by electricity from a PV plant directly to the buildings, depending on their consumption trends. Smart meters play an important role as they indicate trends in production and consumption. This mechanism has been carried out using the normal channels, however, there is a possibility of using a more modern system which is based on blockchain technology. In this proposed mechanism, buildings participating in this system would have a common platform to trade energy without passing it through the distributed system operators (DSO) and would enable the participants to engage in energy trading [6] Blockchain is a database which can store data records called blocks. These blocks are linked to one another, through hashes, to form the blockchain. A new block is formed when new data is entered or mined by people carrying out transactions using the platform and each new block would contain data from the previous block to ensure reliability and transparency. As blockchains are a decentralised system, it does not require a regulator. A prominent aspect in the use of blockchain are smart contracts, as mentioned earlier, which contain all the rules which are to be followed by those using the particular blockchain. Smart contracts are the protocols which facilitates, verifies and implements the agreement which is agreed upon by users. Ethereum, a type of blockchain which is written in Solidity programming language, is the ideal platform as it allows the running of these smart contracts.

B. Consensus Mechanisms

As mentioned earlier, there is no regulator on the blockchain – no third parties to verify transactions. Therefore, blockchain is a distributed system whereby anybody can verify the written information, as everyone will have a copy of the blockchain. Each person would have the right to verify and the first one to solve the hash, will contribute to the block. The blocks are then updated on each persons ledger. To verify these transactions, a consensus mechanism is in place, which can be either proof-of-work or proof-of-stake.

i. Proof-of-work (PoW)

In the proof-of-work consensus mechanism, miners are competing to solve the hash or computational puzzle which makes up the block. Mining serves two important purposes: to create new coins, as a currency needs to be used in trading, to reward the miners; and secondly, to verify the legitimacy of the transactions being carried out. One of the major disadvantages of this is that it requires a large amount of energy to run the miners.

ii. Proof-of-stake (PoS)

In the proof-of-stake consensus mechanism, the miners are not in competition with one another but instead, they validate the consensus algorithm. Two types of systems exist: chain-based PoS and Byzantine-fault-tolerant PoS. In both cases, much less energy is required to run the proof-of-stake and there's increased protection against cyber-attacks [7].

C. Blockchain types

Effectively, there are various types of blockchains and the one used depends on the purpose of the mechanism itself.

i. Public blockchain

This is a type of ledge which is open and completely decentralised; meaning that anyone is able to read the blockchain including all the transactions, and participate in the consensus mechanisms. Since more entities have the possibility of accessing a public blockchain, it is considered to be safer due to the fact that consensus and trust is much higher.

ii. Private blockchain

Private blockchains are those owned by private entities or persons who has the write permissions and verifies the transactions; meaning that, it is not publicly accessible by anyone unless the owners decide to make it public. There are various advantages to this, mainly the blockchain is alterable (transactions can be amended); the validators are known and not chosen at random; transactions turn out to be cheaper and there's no known risk of a 51% attack. A 51% attack is an attack on a blockchain by a group of miners which manage to control over 50% of the network's mining hash rate or computational power [1]. On a private blockchain, consensus algorithms run faster, there's a higher level of privacy and read permissions are restricted according to the exigencies of the blockchain owners.

iii. Consortium blockchain

A consortium blockchain is one which is controlled by a specific group of people, which have a specific set of nodes to participate in the consensus process. These kinds of blockchains are partly decentralised and right permissions may be restricted or public. The advantage of these types of blockchains are that they provide privacy and are faster than private and public blockchains. This kind of blockchain is often used in the financial sector and can also be used for the purpose of this project.

D. Blockchain based mechanism

As stated above, Peer-to-Peer trading is being proposed on Ethereum, facilitated with a smart contract amongst participants. Each prosumer participating in the project would have an account of the Ethereum Blockchain and each will have a specific address. Just as an App, production and consumption will be fed into the system in real-time, therefore allowing each user to log in and observe and analyse their own production and consumption trends. At any point that the users would like to sell their extra energy, they would be able to put it on the market and visible through the app so that other users can purchase that energy. Likewise, the participants who require extra energy over and above their own production, can log into the app and buy energy from their peers. This would help the prosumers make use of their energy efficiently and make a profit on their production. Pricing of energy would need to be capped to avoid abuses, however, a maximum and minimum price bracket would be given to allow for bidding for energy in an auction. The users are given the opportunity to adjust their own demand in line with their production to level out the market and support it without much human interaction.

The five essential components or functions for a smart contract are:

1. Dictating and announcing the start of each iteration of the auction,
2. Obtaining resource information from the seller and announcing it to the potential buyers,
3. Waiting for a time period to lapse or until bidders have cast their bids,
4. Comparing the entered bids and finding the 'winner',
5. Transferring the funds to complete the transaction.

These tasks are all programmed into the smart contract and therefore it acts autonomously without needing someone to oversee the data transacting. The algorithm of the smart contract is exhibited below [5].

All the data received through the smart contract is cryptographically signed and secured, and stored on the cloud with a very high level of trust and security. The programme is easily auditable and the solution needs to comply with the following requirements:

1. Auditability – every transaction needs to be recorded and easily accessed by blockchain users, according to the smart contract. Every participant is able to verify and confirm that the energy allocations according to the demand are done in the appropriate manner.

2. Reliability – according to the nature of a blockchain, it is a default fact that individual participants do not trust each other and therefore need a system to make sure that the transactions are reliable. This is where the PoW and PoS are used. The integrity of the data provided is just as important as everything else.

3. Scalability – the architecture needs to be flexible to cater for diverse sizes of energy communities and would also need to process several types and amount of data in efficient time through meters and will have to perform well with multiple participants.

4. Security – data processed on the system needs to be tamper-proof. It's important to note that given the

circumstances of blockchain operation and even though identity reveal can be worked around, the GDPR act will need to be by-passed.

5. Resilience – the system needs to be robust and reliable to ensure good quality of service.

6. Energy efficiency and sobriety – the system needs to be able to handle transactions related to renewable energy and needs to be as energy-efficient as possible [5] [8] [9]

BLOCKCHAIN TECHNICALITIES

The blockchains mentioned above are all options for the proposed platform, however a consortium blockchain based on Ethereum would be the ideal due to the level of accessibility required and the governance which is being sought.

A specific smart contract would need to be programmed to meet the project demands and enable the self-consumption experiment. Allocation of energy to the participating buildings is carried out through the Smart Contract and all processes will be followed by the energy community.

Most of the time, the type of consensus mechanism chosen is the main source of energy consumption as is seen when using the Proof of Work consensus. PoW is extremely energy intensive and needs quite a supply to power the mining transactions which are taking place every minute over possibly a great number of computer systems. Ideally, a token-less system is adopted to avoid such mining and therefore, no cryptocurrency would be needed. However, the latter would need to be explored further. With this method, the blockchain would need almost negligible power to operate and would contribute to making the project sustainable and not run at a loss.

Under the current local legislation, energy would need to go to the grid before distribution and the DSO is centralised; therefore, further studies would be needed into the political and legal aspects of such a project. Following this, a specific client would need to be developed and implemented into an IoT device and the data collected will be cryptographically signed and secured with an embedded code to keep the cryptographic keys under complete protection. The integration of IoT is a challenge as memory and CPU usage need to be limited to the smallest amounts possible.

The parameters chosen above would lead to the architecture of the smart contact and needs to be able to meet the requirements of the project. The main purpose is to provide a secure but open platform to enable trading as efficiently and safely as possible. Traceability is guaranteed and therefore, amongst other things, this can be used for green certification [5] [6]

CONCLUSION

The research on the possibility of using blockchain as a trading platform opens many doors to further research. There are several similar ongoing projects around the world, as well as prototypes and various IoT infrastructures. Countries within the EU have are also constantly creating incentives for people and businesses to continue to invest in solar power energy; and further the countries' contribution towards a zero carbon community and lower levels of CO_2 as laid out in the Paris Agreement and the New Green Deal, amongst others.

ACKNOWLEDGEMENT

The work is supported in part by the European Commission H2020 TWINNING JUMP2Excel (Joint Universal activities for Mediterranean PV integration Excellence) project under grant 810809 and H2020 TWINNING NEEMO (Networking for Excellence in Electric Mobility Operations) project under grant 857484.

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POSTER ID 7DV.1.12 PRESENTED AT THE EU PVSEC 2021
European PV Solar Energy Conference and Exhibition, SEPTEMBER 2021

MCAST

The Application of Blockchain in Community Energy Consumption and Trading

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INTRODUCTION The Maltese Islands enjoy a Mediterranean climate and therefore benefit from many hours of sunshine throughout the year. The harvesting of renewable energy from grid-connected photovoltaic systems (PVs) is estimated to be 217.3 GWh in 2019, which showed an increase of 14.6% from the previous year [1]. The country has one of the best solar potentials within the twenty seven EU member states, enjoying an incoming radiation energy value close to 1800 kWh/m^2.

The costs of PVs has been on the decline over the past few years and close to grid parity which made it much easier for residential PVs to be installed in a domestic setting [2].

Consequently, the blockchain industry is making radical advancements. This research aims to combine these two sectors: the energy market and blockchain technology, by exploring the potentials of decentralising the energy market and using blockchain technology as a platform to trade energy produced from sources such energy generated from PVs through peer-to-peer smart contract [3].

Within the theme of energy transition, transport electrification and PVs, the study is aligned with the JUMP2Excel and NEEMO projects research themes and thereby its main aim is to investigate the potential of using blockchain to trade energy in a community using peer-to-peer smart contracts, considering real-case scenarios and data from real-time sources.

SMART CONTRACTS AND PEER-TO-PEER TRADING

The five essential components or functions for a smart contract are highlighted in Figure 1 as:

i. Dictating and announcing the start of each iteration of the auction,
ii. Obtaining resource information from the seller and announcing it to the potential buyers,
iii. Waiting for a time period to lapse or until bidders have cast their bids,
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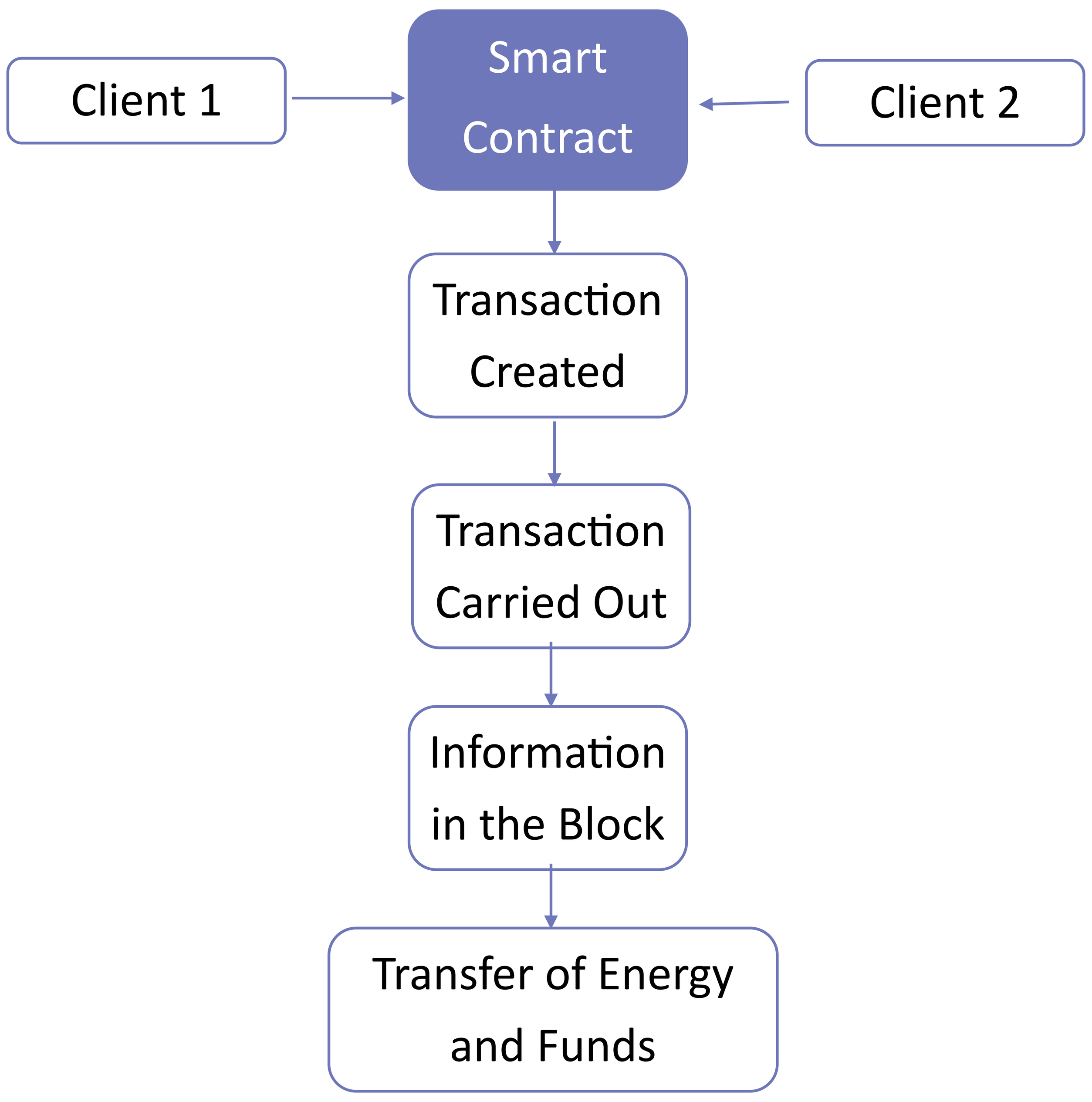

Figure 1 — Blockchain and smart contract flow diagram

i. Proof-of-work (PoW) - miners are competing to solve the hash or computational puzzle which makes up the block. Mining serves two important purposes: to create new coins, as a currency needs to be used in trading, to reward the miners; and secondly, to verify the legitimacy of the transactions being carried out. One of the major disadvantages of this is that it requires a large amount of energy to run the miners.

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