

Accepted Manuscript

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PII: S2314-8535(18)30320-2

DOI: <https://doi.org/10.1016/j.bjbas.2018.08.003>

Reference: BJBAS 306

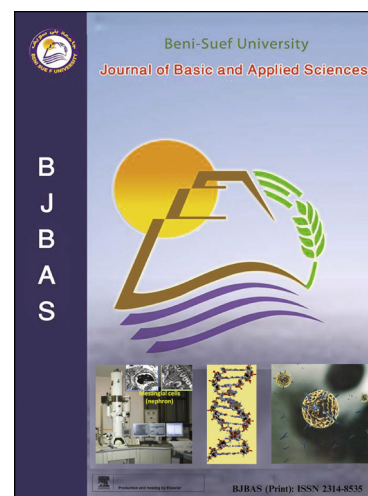
To appear in: *Beni-Suef University Journal of Basic and Applied Sciences*

Received Date: 11 July 2018

Accepted Date: 14 August 2018

Please cite this article as: N.M. Kumar, Blockchain: Enabling wide range of services in distributed energy system, *Beni-Suef University Journal of Basic and Applied Sciences* (2018), doi: <https://doi.org/10.1016/j.bjbas.2018.08.003>

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Blockchain: Enabling wide range of services in distributed energy system

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Abstract: This paper reports on how the technology behind cryptocurrency (Bitcoin) i.e. Blockchain could offer its services in distributed energy system (DES), noting on the issues related to operating conditions, energy generation monitoring, energy sharing and trading, financial flows, emission inventory, carbon emission trading and many more. Information on blockchain use cases and implications in DES is also reported.

Keywords: Blockchain, Distributed energy system (DES), blockchain technology (BCT), IoT, blockchain in energy.

1. Introduction:

Most of us who have been associated with the energy sector, have aware of the energy usage in early years before the electricity has taken birth. We will be able to visualize the days with hot, smoky, and indistinct lighting provided by the gas lamps. With the technological advancement, the concept of electric bulb has driven the electric sector to a massive utility scale leading to the development of a centralized energy network (CEN). Since its creation, the structure of CEN has not seen much difference and largely remains unchanged executing its duties in managing the energy generation, transmission, and distribution. In later stages due to various factors, the demand for electricity has increased, allowing rapid extension in the generation, transmission, and distribution aspects without much alteration in the CEN. It is an observed source from the energy industry, that there exists many prevailing issues due

to the complex structure of CEN. These issues include reliability, outdated grid infrastructure, stability, energy loss, obsolete design, environmental concerns, lower efficiency in generation, transmission and distribution.

2. Distibuted Energy System

Distibuted energy system (DES), is one of the most familiar concept for those of us working in energy fields either in academia or industry or research labs. Distributed generation is referring to the off-site power generation on decentralized levels, and it has seen wide acceptance in the recent years for its favourable features on improving the overall efficiency of the energy system interms of energy generation, economics and environment point of view. We have choosen the distributed energy generation for many valued reasons that overcome the issues related with the centralized energy network. As we know that, mostly renewable energy sources were adopted for the distributed generation due to numerous advantages. With DES, the possibility of multi player local energy system become much easier. Apart from renewable energy based DES, we have also seen many hybrid power systems either with in the renewables or the combination of renewables with non-renewables. However, with DES, we have witnessed the reduced impacts on the environments than to the usual CEN with non-renewbles. Long ago, we used to have a manual recording of the energy flow from the CEN which was very difficult to handle and maintain by the workforce. With the decentralized system, it became bit simple and easier to monitor the performance data and maintain records. DES allowed us to have multipoint control over the system with real time performance monitoring and analysis. DES has many benefits and offers a significant change in the electric utility sector giving scope for the development of renewables enabled with digital era services. The DES became more popular and easy to operate and maintain with the help of internet of things, arrtifical intelligence, meachine leanring etc.

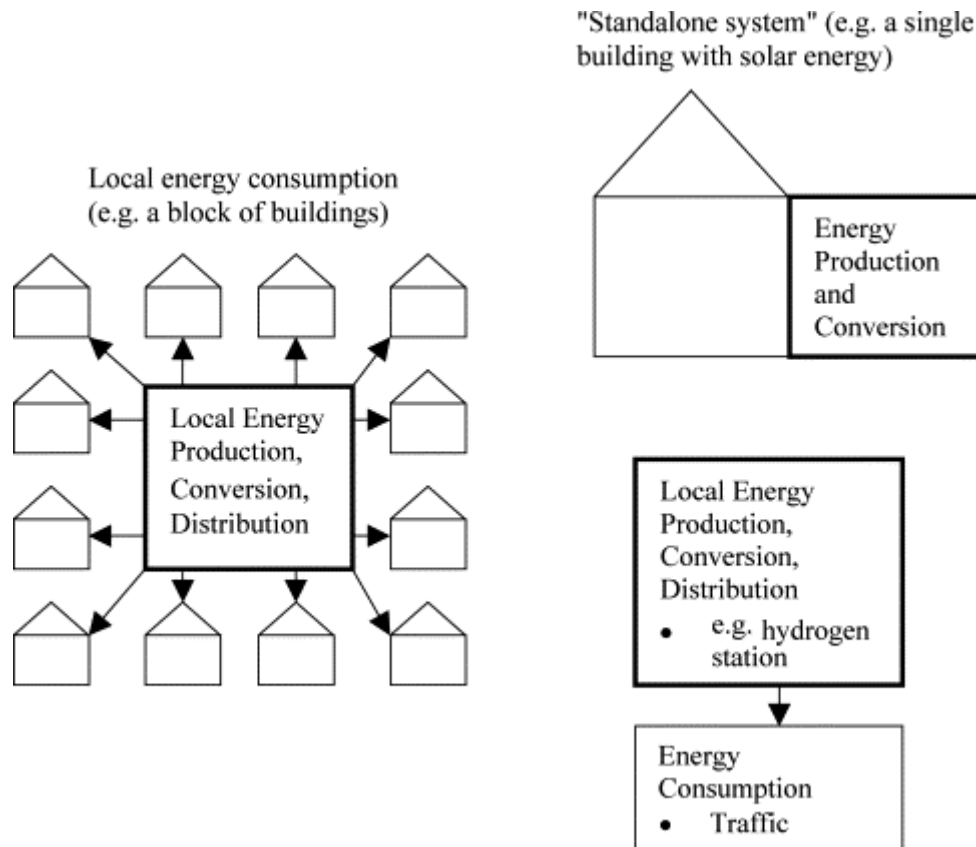


Fig.1. Distributed energy system (Source: Kari Alanne & ArtoSaari, 2006, <https://doi.org/10.1016/j.rser.2004.11.004>)

A comment published in Renewable Energy Focus by Stefan Degener, a Senior Director at First Solar Energy Services, reveals how IoT have changed our view on operating and maintaining issues with solar energy industrial parks developed on large scales. Important contributions of information and computing technologies in energy industry has given a scope for developing intelligent energy systems (IES). In the recent years, a new technology i.e. behind the cyptocurrency (Bitcoin) has proven to be a great solution provider for most of the engineering problems thinking more advanced and beyond the present IoT technology.

3. Blockchain Technology

Blockchain Technology (BCT), a distributed ledger based general purpose technology (GPT) used for doing digital trasactions. Most of us have an idea of how IoT performs information processing, but in IoT security concerns exists, hence to overcome this blockchain technology is adopted. BCT looks very complex but it operates on a simple basis having a distributed and decentralized ledger based database for the transaction information collected over the

millions of things using sensors. Blockchain is more clever than IoT ensuring a trust and value for the operation.

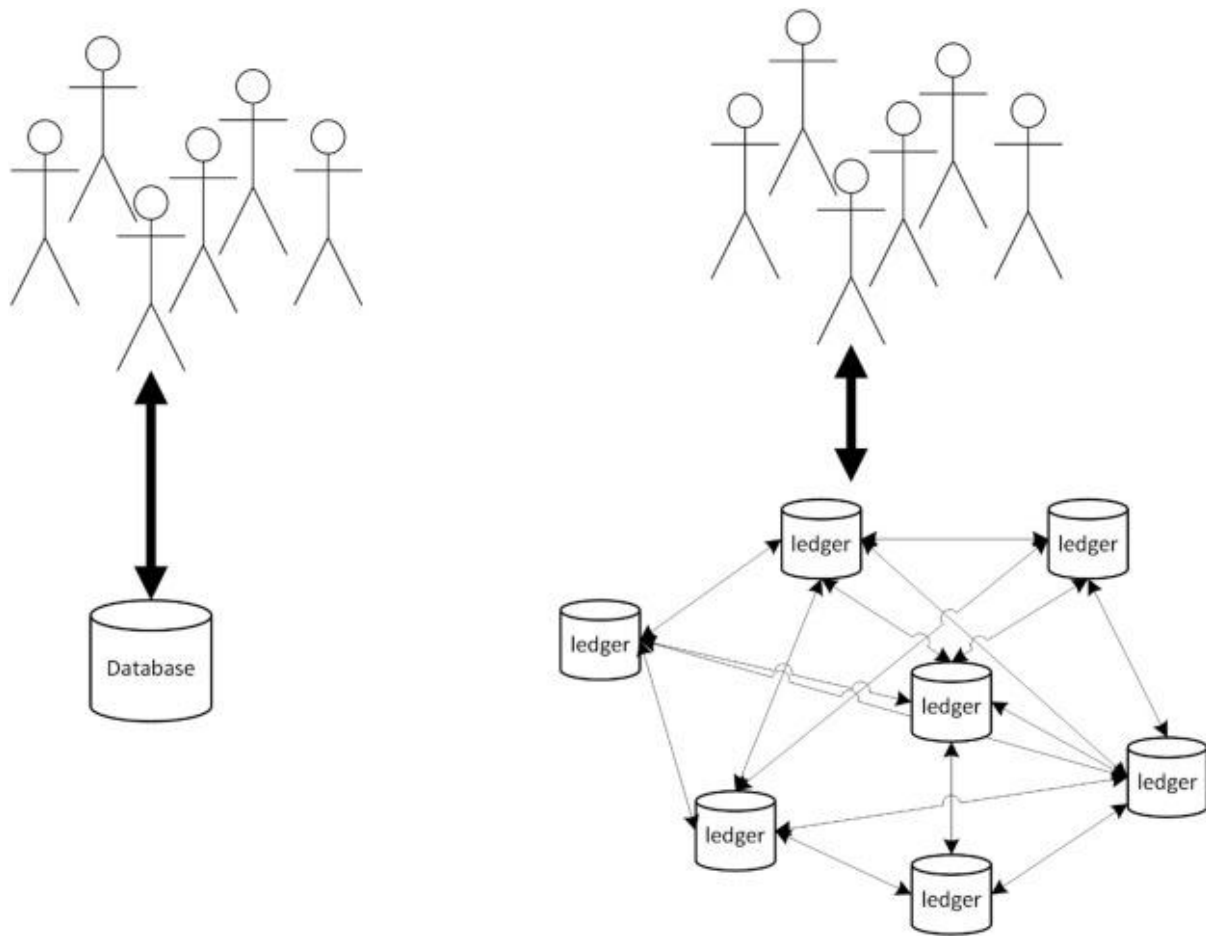


Fig.2. Shift from centralized database (IoT) to Blockchain technology (BCT) (Source: Svein Ølnes et al., 2017, <https://doi.org/10.1016/j.giq.2017.09.007>)

4. Exploring the Blockchain Implications in DES

Those of us who have been attached with electric sector have aware of problems faced with the CEN, and times we can remember the birth of DES. DES has changed over lives in reducing our efforts to build long distance transmission lines, continuous monitoring, some extent the operation and maintiance has become easier. Even with DES, we could experience some difficulties in manintaining the records of monitored real time performance, yield predictions based on weather conditions, energy demand etc, energy sharing and trading with respect to generation potentials, financial flow, emission reduction assessments and trading outcomes. At present most of the owners in small scale DES, usually sends someone around to note and maintain the data in the form of log books, also asks for maintaining the DES. But today it is not necessary for a person to go and monitor and maintain records, with the present

digital technology, we can monitor any DES located at any place from our office or home using the communication and information technology. We should thank, persons behind the evolving technologies that could transform the energy sector into digital. One can recognise from these technologies that plant performance can be optimized from any location as per the needs and demands. ICT has rapidly transformed the energy sector and embraced many benefits like real-time performance monitoring, preventive maintenance and in-depth data analysis related to energy, economics, and emissions.

So called IoT and Blockchain has given a digital look for DES enabling wide range of services in easier way making the global energy transition. Today DES adapted to the reality with globally conneted devices using IoT. DES are become truly intelligent and more secure with the IoT and Blockchain technology formed out of a hardware and software gathering. Many say that, in IoT the security, data losing, hacking friendly issues are more and if the same happen in the energy utility that could cause manipulation in the tariff, and netmetering reports, financial flows, emission inventory credits etc. In such cases, ledger based BCT could help the DES to have highly secured data flow between the energy producers, energy traders, emission traders, operating and maintaining staff etc. With BCT, todays DES can go fully digital with high security giving a scope for the processing and decision making as per the real time conditions. This analysis would become more difficult when a large number DES's are feeding energy to one single electric grid, or multiple conumers at local community level. In such cases there is a need for having the relevance, control, and supervision over the energy network with the consideration of energy feeding and energy delivering. As said by Stefan Degener, IoT functions as data collector, and data visulaizer enabling the real time performance with appriproate decisions and actions. The continous monitoring of imports and exports data could be tampered. BCT allows this data to flow without any tampers allowing them to flow through ledger based distributed networks by duplicating each energy data transaction with time lable as per the aceesing protocol. Blockchain with its special features such as "smart contract, decentralized characteristics, anonymity, collective maintenance, three consensus trust mechanisms (Proof of Work, Proof of Stake, and Delegate Proff of Stake) and reliable database" (Jianchao Hou et al., 2017, <https://doi.org/10.1002/er.3984>) has proven to show few implications in DES.

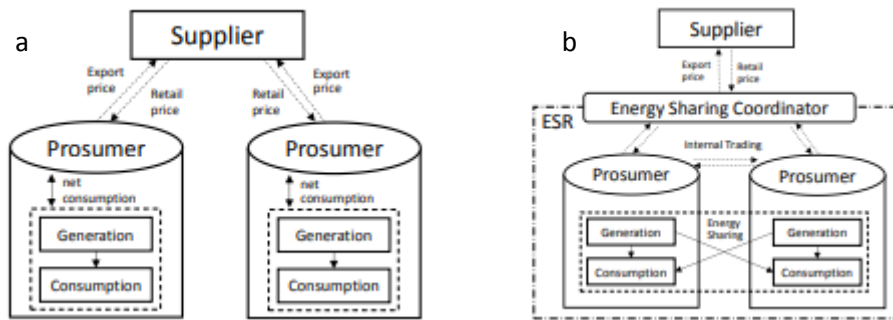


Fig. 3. (a) Energy sharing in conventional practice (b) Peer-to-peer energy sharing (Source: Yue Zhou et al., 2017, <https://doi.org/10.1016/j.egypro.2017.12.768>)

BCT+DES will help the owner of the DES to have the complete control over the energy generation. Allows to have peer-to-peer sharing depending on the condition of self use requirements, grid purchase limits etc. The peer-to-peer energy sharing in BCT enabled DES is more convenient than to the conventional DES. In such cases block chain would benefit the DES owner to have paybacks sooner. BCT with its base functionality can provide the tamper proof digital energy trading platform for export and imports of energy with continuous monitoring of electricity flow and maintains its trace with time stamping. This sought of digital transaction allow the owner to have transparency in the energy trading as well as in the energy metering and monitoring. We use to have many stakeholder in the development of DES projects, but to certain most of the stakeholder might have difference of opinion due to lack trust between each other. But blockchain could overcome this and provides best solution in building a trust between all the stakeholder who involved in the DES projects giving a control over the DES in accessing the data that is modified or traced by the other stakeholders. BCT could be best asset in DES in the financial and developmental activities.

BCT with ledger based decentralized network makes the DES a truly intelligent and smart DES by providing a wide range of services in development stage, operating stage, energy trading stage, energy metering stage etc. This could even give a better solution in maintaining the every record of DES without tampering.

5. Conclusion and The Future of Blockchain Enabled DES

The future of DES could even grow higher than the present levels of acceptance. Present and in near by future, we mostly have digitalized life. No wonder to have digitalization in energy networks also. Days are near by using a electricity with fully digital control. Also the DES is having more applications reaching every corner of the industrial and domestic sectors

including the remote islands. Blockchain enabled DES could play a major role in the energy services like satisfying the business needs of the energy producers and consumers, providing fully controlled and secure energy monitoring platform on residential and commercial buildings and industrial energy plants, provides easy access and transparency in the electricity prices, supply, and demand levels. Could also help in the energy security while trading energy.

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Highlights

- Blockchain technology (BCT) concept is introduced in distributed energy system (DES)
- Possible implications of BCT in DES is identified.
- Various services BCT+DES were discussed.

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