Blockchain: An Enabling Technology for Decentralized Grid Management

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Abstract

Smart and innovative solutions are required to foster the penetration of renewable energy sources (RES). Blockchain has been identified as an enabling technology to provide such a platform with capabilities for decentralized operations, like local energy transactions, while handling other problems associated with complex grid management at large.

Situation Overview in 21st Century Electricity Grid Operation

Advancements in Information and Communication Technology (ICT) is enabling the growth and development of smart grids, with increased contribution of RES in grid generation mix and improved energy efficiency, thus contributing to decarbonizing our societies and leading to a more sustainable development. For example, in Portugal, in May 2020, RES consisting of hydro, solar, wind, and biomass constituted over 70% of electricity generation mix according to (APREN, 2020) report. The country has also consistently maintained RES percentage of over 60% of the electricity generation in 2020. Unfortunately, with increased RES penetration comes complexities in grid management and control, demanding for higher flexibility of power systems. This is attributed to a number of reasons such as:

- **Intermittent nature of some RES:** is a long and widely known reason as explained by (Houseman, 2009) and (IEA ETSAP and IRENA, 2015). Some RES like wind and solar are intermittent and difficult to forecast in the long run which makes them non-dispatchable. In addition, large contribution of RES may lead to the absence of inertia, causing the grid to respond more nervously to events. Besides, often exists mismatch between available RES and demand hence requiring support from other technologies.
- **Active participation of consumers:** is another reason as described in (Mollah et al., 2020) report while emphasizing the need for decentralization. In smart grid, the number of end-users participating in electricity generation increases (prosumers) and as such the typical centralized grid control system fails to accommodate the peculiarities of each prosumer and generation group in real-time or near real-time.
- **Data privacy and security:** is also a well-known concern from the beginning of widespread adoption of smart grid according to (Cavoukian, Polonetsky and Wolf, 2010) and (Miglani et al., 2020). Data privacy and security concerns arises from risk associated with the unavoidable data exchange among smart grid components and stakeholders.

All of these reasons influence grid operation planning and hampers RES adoption. The solution to these is in the application of novel and innovative solutions for which blockchain has identified as being supportive of. Blockchain is an enabling technology that enables decentralized operation and control in near real-time, the exchange of large volumes of data and seamless automation of processes. These features of the technology provide it with capabilities that makes it useful for developing and implementing solutions for decentralized grid and RES management.

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Blockchain as an Enabling Technology

Blockchain technology is a system of nodes characterized by decentralized data storage system, decentralized transaction, peer-to-peer (P-P) data exchange, integrity and verification. The technology uses a distributed ledger system that is trustless and capable of managing large volume of data exchange. Every node in the blockchain system maintain a copy of data or references a trusted node that maintains a copy. Blockchain uses a trusted consensus mechanism system to validate data and implements different network protocol to achieve data privacy. (Wang *et al.*, 2019) reports that the first version of blockchain technology, the blockchain 1.0 was mainly for cryptocurrency trading but blockchain 2.0 provides integration with other technologies like the smart contract. Smart contract is a self-executing set of code blocks of digital transaction protocol.

The rise of RES in decarbonized economies changes the dynamics of transaction processes. In such economies, direct interaction can occurs between prosumers and consumers in local communities and in micro-grids. In more complex scenarios, interactions may transverse across several micro-grids. These interactions which may be simple or complex includes energy contract negotiations, energy trading for various purposes, data exchange for grid management and energy settlement transactions. Seamless interaction in such system is key to foster RES and management of grid operations.

Many blockchain based projects already exist but most are particular seeking to explore the technology to improve energy trading. Typically, energy transaction processes are characterized by many inefficiencies which includes:

- **Bureaucracy:** resulting from the presence of intermediaries, need for concessions and approvals which constitute delays in many energy trades.
- **Transparency, trust and standardization problem:** because many energy trades involve series of internal processes to reach agreement and many of the time these processes are not known to all parties involved in the trade.
- **High investment and transaction costs:** emanating from intermediary cost, investment collateral cost and transaction execution cost.
- **Commitment, risk and error concern:** because of error associated with manual trade execution coupled with investors trust, shares payout and profitability concerns.

Energy trade solutions are leveraging on smart contract to provide solutions to these inefficiencies. Blockchain integration with smart contract provides automation of data and transaction processes. This integration provides decentralization, data security and privacy control, automation and trust. The solution eliminates the need for an intermediary and automates the trading process.

However, despite the possibilities that blockchain has to offer, its adoption in the energy operations has been slow having experienced several setbacks. The report by (World Energy Council and PwC, 2017) identifies uncertainties in the viability and reliability of applications on blockchain, security and regulations as responsible for some of these setbacks. As such governments, private companies and research organizations in many developed countries are actively involved in funding and stimulating research in this area in order to tap into the full potential that the technology has to offer.

Blockchain Trend in Energy Operations

There are a number of blockchain based energy projects in the pipeline with some records of already successfully implementation.

In the area of energy investment, Sun Exchange developed a system for solar assets such that investors can invest in solar PV generation and a smart contract system is used to ensure automated transaction and payment to investors without delays (Sun Exchange, 2019). The system has helped develop several solar powered businesses and schools in South Africa. Similarly, a different project, Impact PPA uses a blockchain based system to provide investment for micro grid power projects (Impact PPA, 2018). The system which is equipped with automated payouts to investors, owners and the government also uses a smart meter connected to blockchain to monitor consumption and allows consumers in the micro-grid pay for electricity via their mobile devices. Impact PPA has successfully deployed the technology in Haiti, Ghana, India, Somalia and others.

In the area of security, Electron in the UK is working on a blockchain based encryption system for gas and electricity smart meters to solve cyber-security and privacy problems associated with registering consumers. The system will also allow consumers switch from one energy provider to the other with ease. Similarly, Guardtime in the US has a number of developed and on-going energy projects on blockchain to resolve scalability problems in public ledger technology.

In the area of energy trading, (Khatoon *et al.*, 2019) proposes the use of blockchain based technology in Italian White Certificate Scheme (IWCS) aimed at promoting energy efficiency. In the report it expresses that blockchain technology with smart contract can used in handling complex processes in verification, monitoring and trading of certificates. Similarly, Power Ledger in Australia has also developed a wide range of blockchain based application. One of such is the peer-to-peer (P-P) local community trading system between prosumers and consumers in a micro grid system with a successful pilot test for solar photovoltaic (PV) producers (Andoni *et al.*, 2019).

In Spain and Portugal, blockchain use in the energy industry is receiving numerous attentions. Iberdola in 2019 reported the deployment of blockchain based platform using technology from Energy Web Foundation (EWF) to track and monitor supply of RES. The system provided transparency and authenticates the source of energy supply. Similarly, (Enterprise *et al.*, 2020) EDP Portugal in 2018 began deploying blockchain based solution in the Brazil using low cost crypto tags for solar energy production tracking in order to provide transparency and authenticity of energy data. Generally, the Portuguese government is exploring at different levels and stimulating the development of blockchain based innovative solutions (Madeira A., 2020).

In Germany, project DENA was commissioned at the beginning of 2020 by the German government. This project led to the establishment of a Future Energy Lab to explore energy solutions on Artificial Intelligence (AI) and blockchain with focus on energy asset registration, carbon emission tracking and smart contract utilization. Also in October of 2020, Siemens demonstrated Pebbles, a demo project for P-P energy trading that enables prosumers sell energy directly to local consumers without interference of intermediaries.

Conclusion

Fostering RES penetration in decarbonized economies requires innovative solutions to manage complexities and difficulties posed by such dissemination. Blockchain has been identified as an enabling technology to drive such innovation. It is widely believed that the future of many energy solutions for decentralized management will rely on blockchain. Consequently, in recent times the technology has received more attention, with governments of many developed nations providing funding and seeking private-public partnership to provide regulatory framework to encourage research and implementation.

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