# Blockchain enabled Smart Grid 2.0

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***Abstract*—Smart Grid 2.0 (SG 2.0) architecture is envisaged to revolutionize the next generation of electricity networks. Further, it is identified as a key role player in realizing Industry 4.0, which is striving towards cyber-physical systems. Blockchain integration in next-generation smart grids has proven to be beneficial in catering to the requirements of SG 2.0, which are challenging to be achieved with the existing context. Blockchain integrated smart grids have room for improvement, in which 5G and beyond networks have great potential yet to be explored. This paper presents avenues available for blockchainized smart grids that would cater to distributed power generation and delivery with higher consumer discretion.**

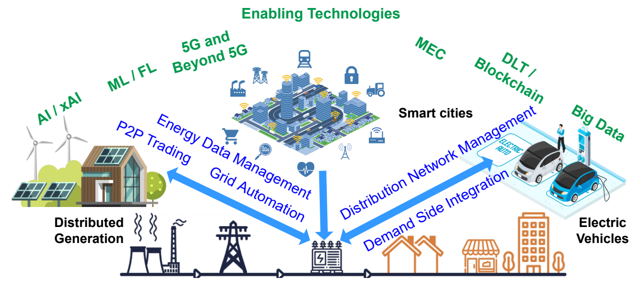


Fig. 1. Smart Grid 2.0 architecture.

## I. Introduction

Smart grids are facilitating proper coordination and management of electricity distribution, with improved reliability and integration of green energy technologies. Conventional electricity has been overlooked due to environmental, social, and economic impacts. Developments in Internet of Things (IoT) technologies have enabled the Distribution System Operator (DSO), acting as an intermediary to interconnect with each energy user through smart meters installed at their premises. Energy profiles are monitored and feedback is provided to the user to encourage efficient consumption patterns and increase the utilization of renewable energy generation [1], [2]. Further, accumulated data can be utilized to improve the quality of service delivered by these networks and help to minimize the impact on environmental, social. and economic paradigms.

Smart grid 2.0 (SG 2.0) is the next generation of smart grids, which aims at intelligent and autonomous electricity distribution [3]. It is a versatile aspect, where the applications and possibilities are endless [4]. Key applications can be categorized as 1) Peer-to-Peer (P2P) energy trading, 2) seamless grid integration of renewable energy generation, 3) demand-side integration, 4) distribution network management, and 5) energy data management. A schematic of the SG 2.0 architecture with applications and its enabling technologies are illustrated in Figure 1. Envisaged grid architecture operates in a distributed manner, enabling the integration of heterogeneous energy sources, irrespective of their geographical location. However, the main challenge identified is ensuring coordination, trust, security, and privacy in delegated operations [5].

Blockchain is a distributed ledger having collective characteristics including immutability and transparency offering inbuilt security, pseudo-anonymity to protect user and date privacy, and decentralization enabling autonomy [6]. Blockchain can be further identified as the game-changing technology to overcome the challenge of trustworthy distributed operations of future smart grids.

Blockchain integration in envisaged SG 2.0 will create new avenues in achieving sustainable energy generation goals. Consumer participation in this effort is equally appraised with processes gaining the autonomous approach. 5G and beyond networks would further accelerate this transformation process [7]. Edge processing, edge intelligence, fast and reliable communication with broader coverage, massive machine-type communication, and low latency are key characteristics of these technologies, which can facilitate blockchainized smart grids in communication, data transfer, and processing aspects. [8]. Artificial Intelligence (AI) and big data and Machine Learning (ML) techniques have prospects in the management of large densities of accumulated data and their effective analysis for decision-making purposes.

This paper explores the blockchain integration in SG 2.0, aiming at operations independent from an intermediary and maximized consumer contribution towards supply-demand management through renewable installations.

## II. Smart Grid 2.0 applications

This section summarizes each SG 2.0 application and how blockchain will be integrated to facilitate intermediary-free operations of the related functionalities.

### A. P2P energy trading

Consumers are liberated from the monopoly market structure with the introduction of the consumer-centric SG 2.0 implementation. Energy exchange is possible at user discretion in the proposed smart grid structure. Price signals can be adjusted in a real-time manner considering the impact to the voltage profile of the distribution network, upon connection of renewable installations [9].

*Importance of blockchain:* Blockchain facilitates intermediary-independent authentication, which would enable seamless integration of consumer surplus generation. Transparent and immutable record management related to measured voltage profiles helps establish a reputation-based scoring scheme for prosumers.

### B. Seamless grid integration of renewable energy generation

Aligning with the sustainable development goals, rapid growth in grid integration of renewable energy generation is envisaged. This would distort the main grid supply with uncoordinated interconnections [10].

*Importance of blockchain:* Blockchain will enable remote data processing and transparent storage at edge nodes [8]. Smart contracts will facilitate access authorization, prevention of double-spending and energy theft, and privacy-preservation of user data, energy profiles, in an autonomous operating environment.

### C. Demand Side Integration

Consumers can further contribute through voluntary participation in efficient energy consumption, which is coordinated through DSI approaches. Incentive and penalty mechanisms are established in a manner that would encourage consumers to adapt to less energy-intensive life styles [11].

*Importance of blockchain:* Blockchain can act as the trustless mediator, facilitating distributed storage of energy consumption data. Data security against modification and fraudulent interpretation along with privacy preservation against unauthorized sharing is enabled through in-built cryptographical approaches [12]. This would guarantee the transparency of the adapted incentive policy.

### D. Distribution network and grid management

Fault isolation, periodic maintenance, and breakdown recovery of distribution networks are envisaged to be operated with a third-party independent approach. Supply-demand mismatch adjustments are enabled through real-time information exchange [11].

*Importance of blockchain:* Blockchain integration could address trust issues related to edge nodes that are providing diagnostic services for fault recovery [12]. Further, incorporating a transparent scoring mechanism maintained using a blockchain, for diagnostic services and distribution network maintenance will improve the reliability of the power supply.

### E. Energy data management

Energy data, parameter measurements of the grid status, and control signals are the drivers of the SG 2.0 architecture. Integration of millions of nodes will accumulate large densities of data, which a single entity will not be capable of handling. Accumulated grid relevant information requires unprejudiced analysis for uninterrupted operations of autonomous grids.

*Importance of blockchain:* Applications of big data, AI, Machine Learning (ML), and FL are envisaged to be implemented in analyzing energy data, for the improved accuracy of decision-making purposes. These technologies can be secured with blockchain platforms to ensure the integrity of the data set and obliterate unauthorized information sharing.

## III. Conclusion

This study highlights the applications of the envisaged SG 2.0 architecture with the capabilities of the blockchain platform to facilitate its realization. Blockchain, with its inherent features, is expected to establish secure, transparent, self-maneuvering distributed energy delivery operations, with minimal involvement of a central authority. Further, through reliable communication with ultra-low latency and broader coverage by connecting across billions of nodes; 5G and beyond networks including 6G will enable the realization of blockchain integrated, intelligent smart grids catering to sustainable energy management.

## Acknowledgment

This work has been performed under the framework of University Research Grant (grant ASP/01/RE/ENG/2022/85) of University of Sri Jayewardenepura.

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