Implementation of Blockchain-Based Security and Privacy in Energy Management

A. D. Dhass, S. Raj Anand, and Ram Krishna

Abstract Digital infrastructure can be used to help communities to meet their energy needs by exploiting the community-based power generation network. The present scenario of power generation can be seen in industries, educational establishments, and other organizations, where these installations are using industrial solar panels in their buildings. The ability to control access of energy with two or more resources has not been convinced by authentication. Commonly, the implementation of an individual solar panel system in each resource is very sensitive and expensive. Hence, it is very important to provide accuracy of the grid environment for social communities, so that they can be benefited with minimal cost for accessing the shared distributed energy and authenticating the access control. Each energy resource is authenticated by the consensus mechanism using the proof of work once connected to the first block as a genesis block. Such energy resource supports web chained database architectures and links to encrypt the large volumes of energy-driven data with blockchain-based distributed cloud storage design. This chapter aims to examine the significance of blockchain technology in accessing its role to date in enhancing energy protection and performance based on its technological advantages. The blockchain technology will be implemented in energy management to secure and understand the consumption and utilization of energy levels to reduce the overburden and waste. In addition, a case study based on energy resource management in educational institutions is provided to demonstrate how well implementation of blockchain technology can be offered alternatives for community-oriented energy security to increase the quality of service.

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1 Introduction

Sustainable energy sources have undergone monstrous improvement since the inception, which has been empowered by privatization, the unbundling of the energy division, and motivating the activities through budgetary encouragement and energy strategy [1]. The energy area has a characteristic—power is hard to store for a huge scope as a physical product. The principle issue is that power should be generated on a scale that all individuals need. In any case, this is perfect and it is important to know in advance how much power individuals can accomplish it [2]. The producers of sustainable energy source systems have begun to bring down the expenses for generating power with proficient systems by expanding the financial intensity of sustainable power source assets. Most of the decentralized energy reserves are sustainable power sources which are discontinuous, rendering it hard to predict their capacity yield [3–6]. Throughout the customary power industry, there is a proximity of fundamental lattice to which both the distribution lines and small matrices are associated. The energy stream occurs in one way and the exchange takes place in the other way of the energy stream, demonstrating that the system is brought together. The latest measure for the unified power system is the idea of transactive energy, where the disseminated vitality is regulated directly by its creator. The Distributed Energy Exchange Model is a part of this transactive vitality component [7]. In addition, in this paradigm, residents and partners are progressively becoming a partner in the so-called sustainable power source networks and are partaking in the energy change by investing resources through, creating, selling, and conveying a sustainable power source [8].

Blockchain's invention continues with Bitcoin, standing in as the basis for the cash issuance and flow. The idea of Bitcoin is a disseminated and decentralized accounting innovation dependent on cryptography, with the plan to take care of the decentralization accord issue in the computerized world. Numerous ventures are dealing with how to adapt blockchain technology to their own organizations [9]. Blockchain technology additionally has an essential role in managing energy supply, transportation, storage, usage, and power, including validation of carbon outflow rights, the security of the digital-physical framework, sharing of virtual power assets, and preparation of a multi-energy system network. In any case, the set up focal administrator can be expected to guarantee confidence in the direct prosumer-to-prosumer exchange models. The blockchain stores information obtained from savvy meters and exchanges, while increments are ultimately performed consequently utilizing keen agreements [10]. Moreover, it will likewise encourage the capacity of vitality buyers to monetize their abundance vitality which may have originated from either age or vitality investment funds [11].

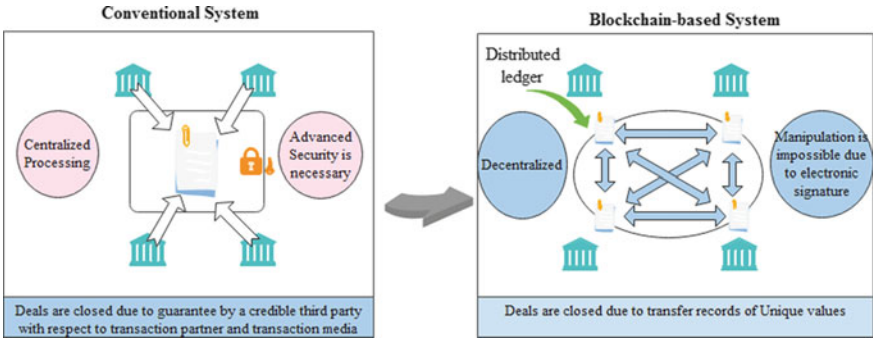

Fig. 1 Conventional and blockchain-based applied systems [12]

Blockchain innovation likewise called conveyed record innovation, is an administration system for the common check, endorsement, control, and sharing of the substance of exchange records among hubs dispersed at numerous center points on a PC arrange, as shown in Fig. 1 [12, 13]. As an independent and solid system innovation, blockchain has significant hypothetical and reasonable worth. It is a safe and self-governing shared system to work and guarantee the successful transmission of energy internet esteems. A settlement strategy is put in place to help with the last reviews and to improve the believability of exchanges, such as the power installment. The framework guarantees the security and validity of Internet of Things (IoT) gadgets and information from source to information sharing, underpins the improvement of vitality internet account, and recognizes the capacity of information on network exchanges dependent on blockchain [14].

Blockchain-based vitality involves exchanging the market stage for private networks with the goal of diminishing by and large network top interest and family power bills. Keen homes inside the network place vitality offer for its accessible, appropriated vitality assets (DERs) for each discrete exchanging period during day, and a twofold closeout instrument is utilized to clear the market and process the market-clearing value (MCP) [15]. Because of blockchain innovation, unalterable information age is conceivable and is for all intents and purposes illustrated. This safe and solid information as a keen agreement, P2P exchange, clean vitality endorsements, service bills without a dispersion system can bring a factor of trust among prosumers and customers [16]. The energy area is an undeniable case of an industry with the possibility to incorporate blockchain innovation and related technology. Power is led at the speed of light and is difficult to follow between two focuses in a power arrangement. Therefore, power markets can be brought together on exchanging stages like stock trades [17].

Decentralized vitality frameworks have been broadly examined in the scholarly community. It is also essential to talk about further progress in the dissemination of frameworks that blockchain innovation may encourage. Figure 2 shows the simplified approach to centralized and decentralized move in power and data streams are emerging. It brought together frameworks where the cause of a partner intended

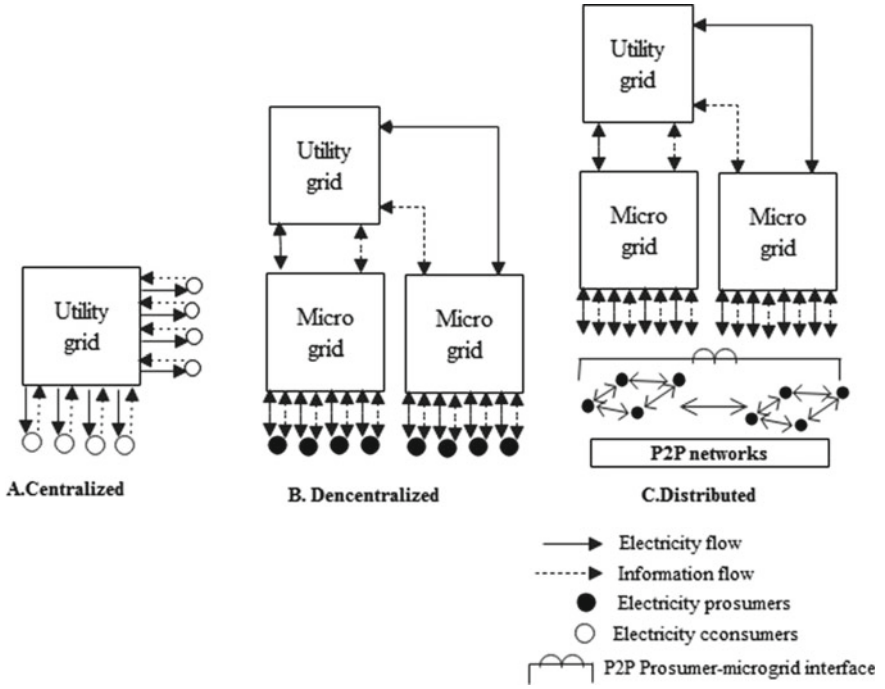

Fig. 2 Simplified model of **a** Centralized, **b** Decentralized, **c** Distributed energy systems with microgrids and Peer-to-Peer (P2P) networks

for the progression of power from high voltage to low voltage downstream loads. Microgrids have progressively added to the decentralized vitality frameworks, with the development of a private, small, and medium-scale sustainable power source age. Power makers, prosumers, and customers can easily purchase and sell power with each other in P2P systems, for which blockchain plays a key role in the development and empowerment of the power distribution innovation depicted in Fig. 2b, c. A few creators likewise suggest power-sharing by the microgrids in multi-microgrid network systems [18].

In fact, the diverse agreement systems are additionally utilized for the approval of squares and after accord, the square turns into the piece of the chain. The characteristics of various blockchain types are listed in Table 1.

Table 1 Types of blockchain and its characteristics [19]

Category	Directness	Decentralization	Write	Read
Open	Any person	Absolute	Any person	Everybody
Personal	Individuals	In part	Specific	Specific
Group	Specific	In part	Specific	Any person

The base of every other sort of agreement systems is Proof of Work (POW). Today's blockchain technology is utilized in various ideal models such as well-being checking, information sharing, customer criticism, decentralized exchange. To limit the odds of single point disappointment, unapproved people are not part of the system to forestall pernicious assaults [19]. Although wireless local area networks (WLAN) and Zigbee technologies are sufficient to manage home area network (HAN) and home automation, large power line access must be used for charging electric vehicles, grid operation, and automatic meter reading.

In an Internet of Energy (IoE) network, electricity delivery among nodes (electric cars, microgrid, smart grid, and smart homes) includes electricity consumption payment bills that are further used for services such as demand estimation, dynamic price estimation, and optimum energy use scheduling [20]. The routing, which satisfies the permission verification criteria and decreases the service center load; when storing the data in the blockchain data system, the hash pointer is used to maintain data access validity and complexity, and database protection is achieved [21]. The blockchain technology was operated by the P2P network, and each node is defined using a public key (PK). Node transfers are authenticated using PKs, and then sent to the network. That node is able to validate the source of the transaction through its digital signature [22]. The central smart contract is responsible for naming the participants and maintaining all the required data relevant to all purchases, P2P smart contract is responsible for handling local market exchange and the P2 G smart contract handles grid energy purchases for the prosumer [23]. Blockchain has been a competitive and quick increasing field of study as a groundbreaking technology. Now, this technology became a lucrative and fast-growing area since it incorporates centralized data management, peer-to-peer sharing, consensus processes, and encryption algorithms to allow verifiable documentation of data and transactions [24].

Key findings from the aforementioned studies have shown that blockchain technology provides secured information of energy data stored and it is expected to be used not only in cryptocurrency and fintech but also in the power and energy system fields. This is revealed that it examines the significance of blockchain technology in accessing its role to date in enhancing energy protection and performance in energy management based on its technological advantages.

2 Blockchain Technology

Blockchain technology is a decentralized process of a distributed ledger. It produces a set of rules for making mutual understanding between the producer and consumer called a smart contract. A smart contract can be applied in many industries, educational institutions, and other organizations for marketing the products and reflecting the information irrespective of buying and selling the procedures. This is an automatic process until it is stored in the blockchain. Each process will be verified by the techniques called a consensus mechanism. When a number of resources are added to the

current chain, the POW mechanism has confirmed the authentication. No resources can alter and tamper, once it has been updated in the shared ledger.

Blockchain creates trust because every resource confidently makes a transaction to authorized resources. Hence, it increases confidentiality, authentication, and integrity to improve efficiency and transparency. Proof of Stake (POS) and Proof of Authority (POA) in the consensus technique could be authorized without tampering any transaction data. In the recent scenario, blockchain and photovoltaic are both popular cutting-edge sectors for industries, agriculture, and other organizations. It is optimized the existing security mechanism and produce the combination of a new energy revolution. A decentralized sharing peer-to-peer blockchain-based network to share the energy and particularly it is eliminating the middleman that is the centralized distribution system. Hence, blockchain technology is a very emerging technology to store the accuracy of data and efficiency.

3 Blockchain Architecture

The proposed blockchain technology model used with the photovoltaic system consists of three categories: blockchain smart contracts, consensus, and energy storage in the cloud using a peer-to-peer network. The decentralization of the overall architecture of the blockchain is shown in Fig. 3. In the primary building of educational institutions, the photovoltaic panel should become a genesis block. The smart contracts should be executed automatically for making the mutual agreement between prosumer and consumer. Here, the first block, the genesis block is acted as a prosumer when the new resources are connected with the primary building. Each resource acts as a consumer to consume energy levels locally.

The verification will be approached to each consumer when connecting to a new building with the existing energy level transaction by a consensus mechanism. Each individual consumer is verified the authentication process is called proof of work (POW). In Fig. 3, the photovoltaic panel resets the energy transmission to the maximum value for other buildings. Then the energy process verified in blockchain consensus mechanism to consumer 1 whether it is authenticated or not by POW. This sequence is processed for each consumer (i.e., consumer 2, consumer 3…consumer n). Then the subsystem of the peer-to-peer network has consumed the energy from the respective consumers either in a centralized or decentralized network. Consumption of power in terms of voltage is stored in the cloud. The data is stored rapidly to the cloud for the utilization of total threshold values. Overall efficiency will be monitored in mobile devices through a connected network. It also controls the access of energy between prosumer and consumer which is described in Fig. 3.

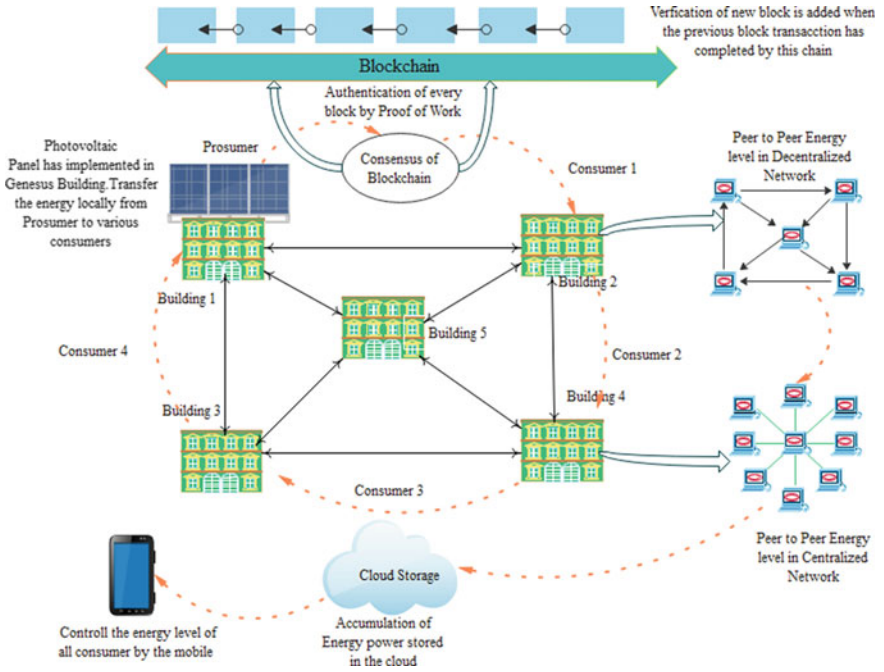

Fig. 3 Performance of blockchain using smart contracts in the photovoltaic panels

4 Energy Management and Blockchain Technology for Educational Institutions

In recent trends, the solar energy level is very popular and common to implement in day-to-day life. It helps the community to implement in the rural sectors. Many educational institutions are facing difficulty in utilizing the electricity in particular transmission time. Moreover, power failures are causing the education of all the students' communities to deny the concentration in order to improve their knowledge.

Therefore, in this portfolio, the entire educational institution will be switched over to the photovoltaic panel to implement the acquisition of more energy consumed throughout the buildings. In order to focus on the solar energy system, the advent of blockchain technology has dramatically increased the capacity of power utilization when the number of buildings in the institutions is increased. This technology can improve the security and authentication of decentralized network connections established in all buildings. This process attempts to clarify the Quality of Service (QoS) to all classrooms without the intervention of any learning methodologies. The solar system will drastically change the power process of all the educational institutions that have emerged in rural sectors. The consumption of energy is much lower in cost and reduces the power discrepancies.

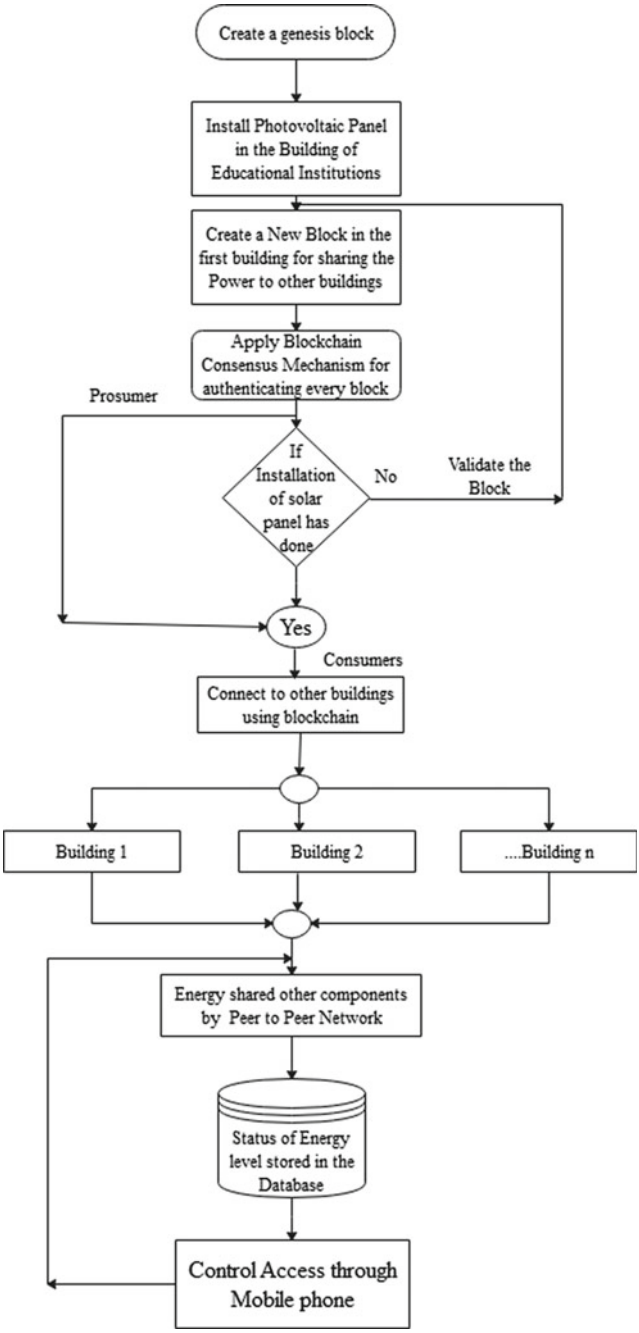

Fig. 4 Block diagram of prosumer and consumer agreement for smart contracts and a consensus mechanism

Figure 4 shows the simple block diagram of blockchain technology that could be adopted in a photovoltaic panel using smart contracts and a consensus mechanism. It shows that the genesis block will be built in the main building of the institution. The photovoltaic panel will then be installed in the main building of the institution for sharing the energy with other buildings. If the number of buildings is connected to the primary block, it should first be authenticated by a consensus mechanism. The POW only verifies all buildings for the accumulation of energy by those blocks. Using the smart contract system of blockchain, the prosumer shares energy to all consumers. Each consumer has to store the energy level in the cloud database.

This mechanism is very sustainable for the collection of a large number of energy levels. Other accessories utilize the power to communicate with peer-to-peer networks. The rural community people could implement these techniques by using blockchain technology to improve electrical energy efficiency and reduce the electricity utilization cost. However, peer-to-peer network sharing is controlled by mobile phones to monitor how power is to be used between the buildings.

India has a milestone in achieving the 20GW power capacity trading target for another two years in the year 2022. The survey of solar power capacity has been shown in Fig. 5, to be established at 6 MW in the year 2009. Then the solar power installed capacity has been increased every year. In Fig. 5, it is described 20 MW capacity of energy power is identified in India in the year 2018. In view of this, the Government of India has planned to implement the solar panel capacity to be implemented with 20GW instead of MW in 2022. Security is also a major factor in the implementation of the solar panel in all industries and other organizations.

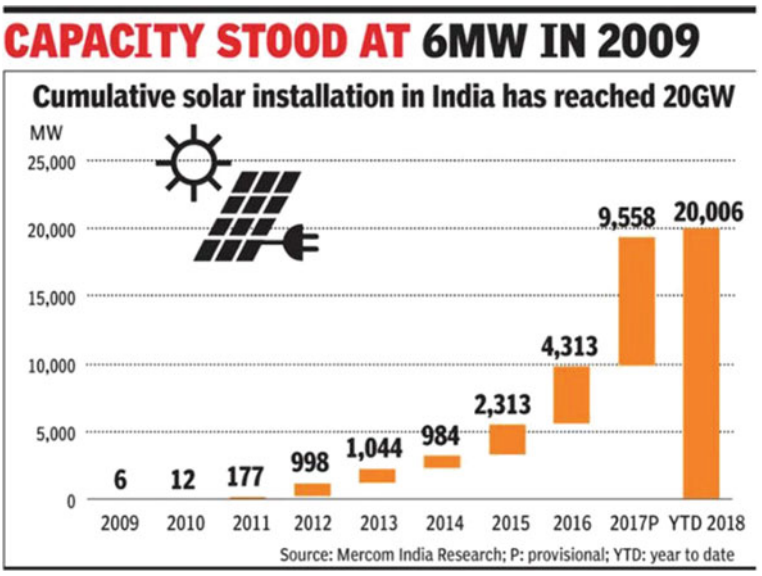

Fig. 5 Survey of solar installation in India [25]

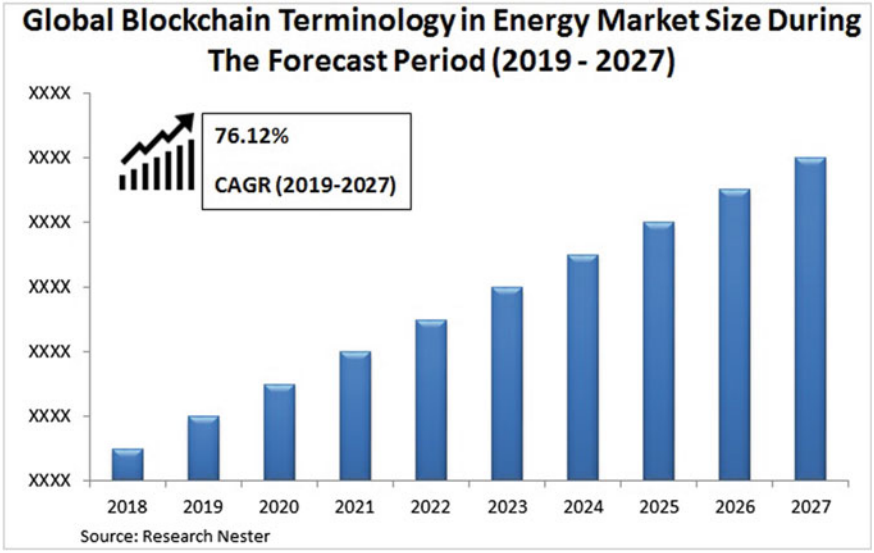

Fig. 6 Energy market size during the Period (2019–2027) using blockchain technology [26]

Figure 6 has depicted how blockchain technology has improved every year for producing security and privacy in the energy market. The survey mentioned in Fig. 6 revealed the energy level using the blockchain at a rate of 76%. There will be a greater manufacturing rate of up to 10 years (2018–2027). Hence, from both the Figs. 5 and 6, the market survey of blockchain technology using solar energy would be more scalable.

In worldwide business, blockchain technology has been implemented smoothly for decentralized mechanisms. The various activities carried out by the businesses, industries, and educational institutions are registered. Figure 7 illustrates the various aspects of security level research behind the blockchain technology. For automation and asset management, peer-to-peer activities will be validated using the energy level consensus algorithms through peer-to-peer transformation, wherever information has been made publicly available such as Proof of Authority (POA), Proof of Capacity (POC), and so on. In Fig. 7, the proof of work (POW) is defined as a major concentration for the verification of all the peer-to-peer network connections with security level up to 55% for the accumulation of solar energy to be connected to other buildings or locations. It is used to verify when a block has been created. At the same time, POA and POC have been establishing the transactions with 13% and 2%, respectively. In order to view Fig. 7, the scalability of every transaction would be increased by using the blockchain technology.

Figure 8 has demonstrated that the plan of action taken to consider every transaction in the business activities. The measurement of the percentage in IoT, smart devices, automation, and asset management by 11% and 19% of the total use of cryptocurrency cases for making the transactions, but 33% will be generated in the

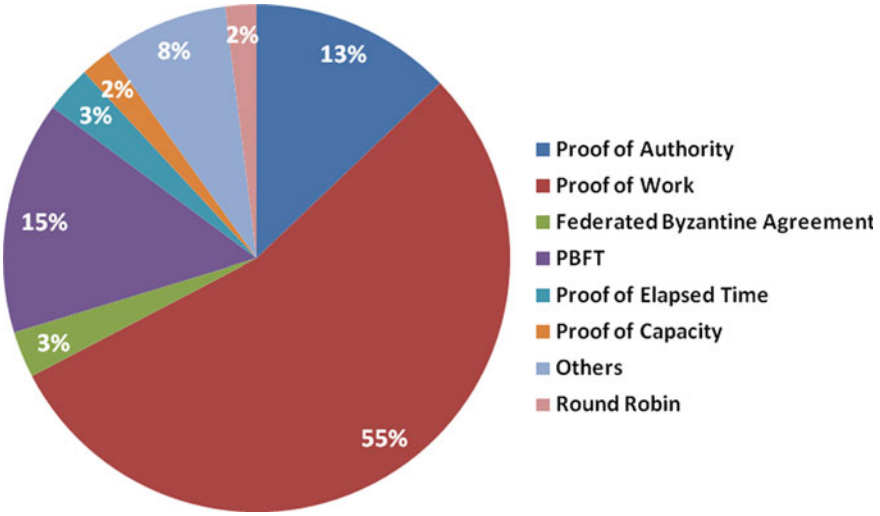

Fig. 7 Security of blockchain using POW in Solar Energy

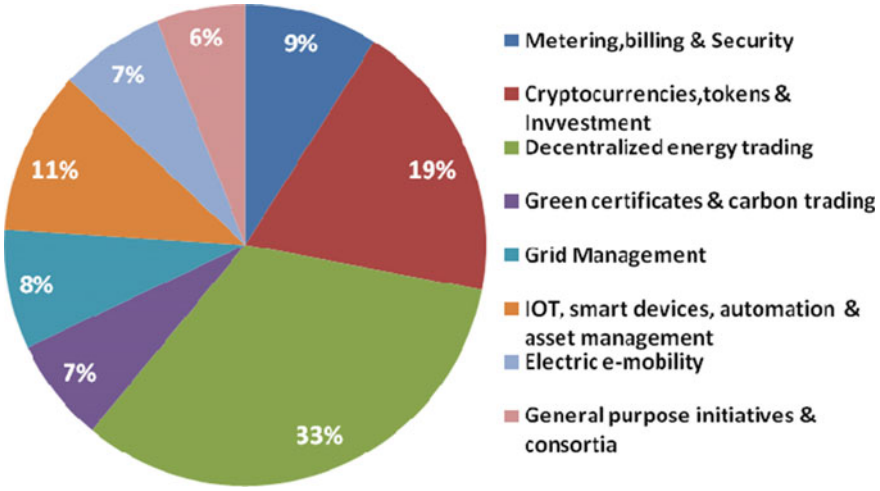

Fig. 8 Percentage level of decentralized energy trading using smart contracts [27]

case of decentralized energy trading. The purpose of this mechanism has been to provide a more secure transaction for various asset management activities. Hence, blockchain is more powerful than a centralized system for producing more accuracy in a decentralized network.

5 Conclusion and Future Outlook

Blockchain technology allows for more efficient and secure data storage while addressing the energy needs of emerging cities. Thus, the scalability of photovoltaic energy levels can be utilized efficiently with blockchain technology using consensus and smart contract mechanisms. Based on the above survey, this technology benefits the rural communities from a peer-to-peer network system with decentralized access to all the energy levels. Such communities will use electricity without any mind to raise electricity costs. The significance of blockchain technology in accessing its role to date in enhancing energy protection and performance in educational institutions on the basis of its technological advancement. It ensures that this technology is more powerful in order to protect energy consumption for the production of quality of service. Moreover, energy production using a photovoltaic panel in the future from all educational institutions, industries, and other organizations would be very scalable to reduce the cost of electricity usage.

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