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Revolutionizing domestic solar power systems with IoT-enabled Blockchain technology

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ABSTRACT

Solar power systems in homes have become the need of the hour due to the crisis of fossil fuels. Also, it is a useful way of rural electrification and cutting down on running electricity costs. This paper discusses a 26-kW solar power system for powering homes along with IoT-based monitoring. The proposed system is expected to be low in cost and highly efficient. The system can also be used as a battery backup without solar power. The emergence of Blockchain technology is poised to revolutionize the sharing of information by providing a means of building trust in decentralized settings without the reliance on intermediaries. This technological breakthrough has the potential to transform several industries, including the internet of things (IoT). In addition to Blockchain, IoT has also been able to address some of its limitations by utilizing innovative technologies like big data and cloud computing. For security, Blockchain as a decentralized application will be used. Each block typically contains the transaction data, and power consumption data which can't be tampered with even if changing all subsequent blocks, which is expensive to do so.

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1. INTRODUCTION

Electricity has become a basic requirement of every individual. Fossil fuels being a nonrenewable source of energy have the risk of depletion. Also, they pose severe environmental and health hazards. Hence alternate sources of energy such as solar energy need to be brought into the picture [1], [2]. This paper discusses a domestic solar power system that may be beneficial for rural electrification as well [3]. Also, installation can be done by consumers themselves. Most appropriate components such most suitable fuse, batteries, and grounding have been chosen [4]–[7]. Since this will be used for domestic purposes fault monitoring plays an important role. This will be done via the Blockchain [8], [9]. It is a new technology and has been improving rapidly [10]. It is a type of database that operates in the collections of nodes with decentralization. It means that the data will be synchronized to all the connected nodes and it will be verified each time by using some algorithm to check its legitimacy which can harness the power of immutability and efficiency [11], [12]. It will be used with the internet of things (IoT) to reduce the consumption of electricity with the help of Blockchain logic we can reduce the logical embedded system as well as maintain the same efficient power management and reduce the cost. The usage of Blockchain with the solar power system is because of the network management and recording of each piece of information and sending it to Blockchains. After the complete transaction, the energy can be traded with fellow neighbors and can be returned back using the Blockchain which in turn has more usability and trust on the side of the domestic power system.

Consensus algorithms should be considered during the creation of a Blockchain network [13]. Suliyanti *et al.* [14] discusses the deployment of smart contracts. Yusoff *et al.* [15] discusses key problems and precautions in the Blockchain. Monrat *et al.* [16] shows the different perspectives of Blockchain, including applications, challenges, and opportunities that should be considered when deploying such a large project. The prevention against DDoS attacks and end-to-end encryption is presented in [17]. The plug and play communication is presented in [18]. Awan *et al.* [19] discusses Blockchain with a futuristic approach in agriculture and the food supply chain. Some intriguing examples of machine learning and cloud-based solutions for better insight into the problem are presented in [20]. Rahmani *et al.* [21] presents the addition of Blockchain in smart grids.

This paper discusses a domestic solar power system that may be beneficial for rural electrification as well. Some of the problems with the existing domestic solar power systems that this paper overcomes are high initial costs, complex installations, maintenance, and lack of proper fault monitoring procedures and security. Installation of the proposed system can be done by consumers themselves. Appropriate components such as fuse, batteries, and grounding have been chosen. Since this will be used for domestic purposes fault monitoring plays an important role. This will be done via Blockchain. It is a new technology and has been improving rapidly. It is a type of database that operates in the collections of nodes with decentralization. It means that the data will be synchronized to all the connected nodes and it will be verified each time by using some algorithm to check its legitimacy which can harness the power of immutability and efficiency. It will be used with the IoT to reduce the consumption of electricity with the help of Blockchain logic we can reduce the logical embedded system as well as maintain the same efficient power management and reduce the cost. The usage of Blockchain with the solar power system is because of the network management and recording of each piece of information and sending it to Blockchains. After the complete transaction, the energy can be traded with fellow neighbors and can be returned back using the Blockchain which in turn has more usability and trust on the side of the domestic power system.

2. DESIGNING DOMESTIC SOLAR POWER SYSTEMS WITH BLOCKCHAIN-BASED FAULT MONITORING

2.1. Algorithm 1: User verification

The main initialization of this system involves checking the user's private key for existence before any transactions or installations can be carried out. The system employs a Blockchain network [22], [23], a smart contract, and an IoT device that can be used for contactless verification using a physical object or card. Together, these components enable secure and efficient user verification, ensuring the trust and reliability of transactions. In Figure 1, the algorithm during installations is shown. First, it is checked whether the user is existing or if it is a new connection. If it exists, then the owner's identity is fetched with a key. Then the owner hash ID and owner solar grid specifications are fetched [24]. The power stored in the power bank is estimated and hence the system is ready to operate.

The step-by-step approach of this Algorithm 1 is explained below:

- Step 1: Create a function user_defind
- Step 2: Get the user hash id
- Step 3: Get the user new solar grid id
- Step 4: If the user hash id is not present
    Push hash id to the new node
  Else
    Push solar grid id to exist user hash id
- Step 5: Return success and user hash id

It's for establishing the device on the Blockchain network, the user can either be an existing one or a new one. Using the generated public key, the system will verify and register the new user or simply add the existing user, awaiting the installation of the new solar equipment. This grants access to the existing user for updating the information, which can only be accessed by the user and cannot be altered until the user makes the changes.

2.2. Algorithm 2: Power sharing

The proposed autonomous power-sharing system is designed to operate only after the initialization of phase 1, which is outlined in Figure 1. This phase is essential for the system to focus on monitoring the battery health and remaining power of connected devices, which is done using IoT sensors. By gathering this information, the system can determine which devices require charging and which devices can share power.

Once this phase is complete, the system can initiate the power-sharing process using its autonomous behavior, aided by wireless devices [25], [26]. With the help of IoT sensors and wireless devices, the system can efficiently check and initiate power sharing among connected devices, ensuring that power is utilized effectively and efficiently. Overall, this system provides a solution to the ever-increasing demand for energy management systems.

In Figure 2, it is shown that in ideal conditions total energy remaining in the power bank is checked. The data is sent to the Blockchain at an interval of 10 minutes. If power consumption and charging both take place simultaneously, then the interval will be increased to 20 minutes if it is below 50%. On the other hand, if the battery is fully charged, then the 10 minutes mark is followed to send the data. If the power consumption is very sudden, then the notification will be deemed [27]. Every instant, the power consumption and battery status will be saved. If no issues are found, the process is repeated.

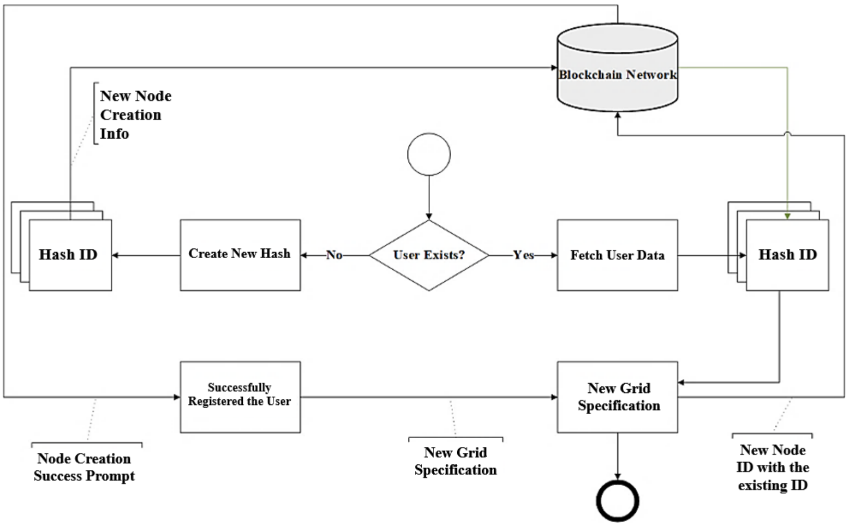

Figure 1. User verification algorithm during installations

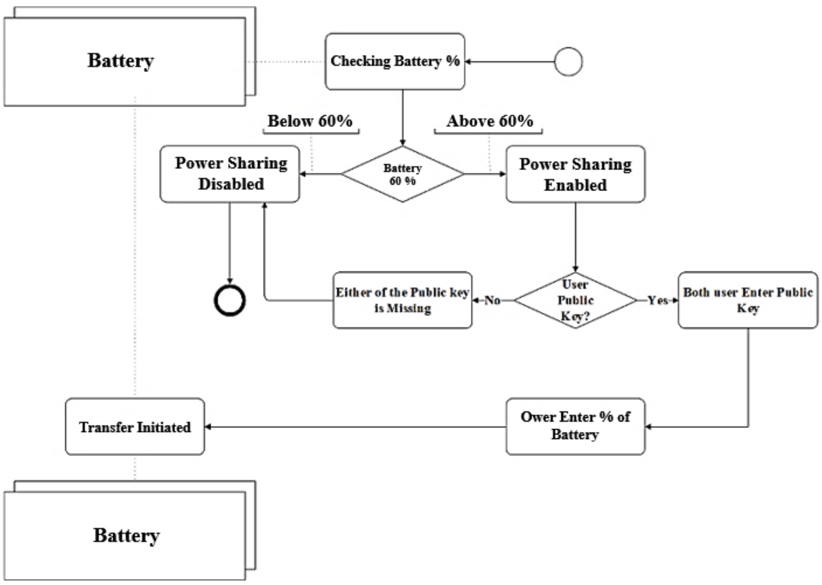

Figure 2. Power sharing algorithm

The step-by-step approach of this Algorithm 2 is explained below:

- Step 1: Create a function grid_ER_share
- Step 2: If user_defind returns success

  Get the remaining battery percentage

- Step 3: If the remaining percentage > 60%
  Get user hash id input
  Getower_hash_id input;
- Step 4: If user hash id and owner_hash_id is not present
  Return invalid transaction
  Break
- Step 5: Set battery percentage input
- Step 6: Initiate a transaction

One of the functionalities is to maintain the connection and transfer battery power to another specified battery using the grid system. This capability is made possible due to the technology employed. In this process, the transaction is initiated using the owner's and owner's hash_id, and the percentage of battery to be maintained is set. This ensures that the battery is not excessively drained.

2.3. Algorithm 3: Fault checker

This system is essential for the whole working of this model where it checks for fault and battery percentage simultaneously for any abrupt changes which can harm the IoT device or the battery health in any way. The use of middleware and IoT devices here is necessary but the logic used here should be tested for more as it is a safety feature so it has to be in top condition to handle such unconditional events with the synchronous between the IoT and Blockchain network to tackle the fault in quick succession in worst case scenarios [28]. In Figure 3, transfer permission is granted only if the owner's battery level is above 60%. In case of urgency, the owner can override the transfer permission using their public key. A new hash ID is generated temporarily for the connection between the owner and the user. The owner sets the reserved power percentage for power sharing, and the user establishes a mutual connection using their public key. Once the reservation threshold is reached, power sharing ceases [29], [30]. The contract expires, but the connection hash ID is saved on both accounts. If a power failure occurs, the batteries are compared, and the transfer is reinitialized.

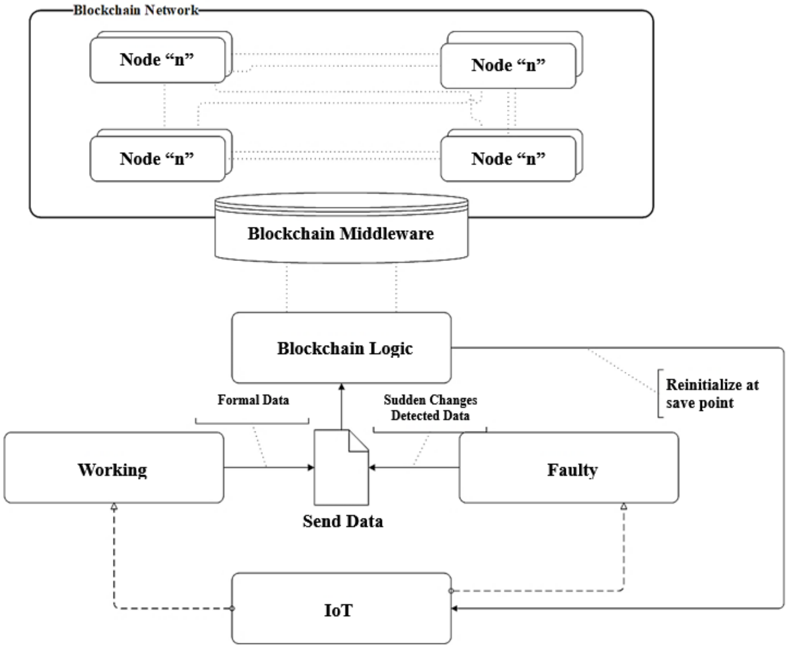

Figure 3. Working algorithm-fault checking

The step-by-step approach of this Algorithm 3 is explained below:

- Step 1: Create a function fault_search
- Step 2: Get fault threshold // set by the engineer according to the appliances
- Step 3: Get power usage
- Step 4: If power_usage > fault threshold
  Return and reinitiate the grid
  Break

- Step 5: Refresh power usage
- Step 6: Loop power usage every 10 min
- Step 7: Return no issue found

The main purpose of this program is to address any faults arising from IoT devices or technical issues. It monitors both power usage and application health simultaneously, allowing it to restart itself promptly in the event of any fault [31]. Due to its operational methodology, it is possible to configure an alert system that can notify the user or save relevant information in the log for future reference in case of any accidents.

2.4. Connections and design

This solar power system aims to be used mainly for rural electrification and energy saving [1]. While developing this paper, we learned about energy availability in various areas, power systems, electrical components, communication systems, grounding, IoT, Blockchain, and the software Visio. PV conductors capable of giving an AC output of 6500 W each are used for designing the system. Thus, 4 units are used hence the AC output obtained is 26000 W. They are connected to a 250 A busbar. Necessary circuit breakers and fuse are used including solar disconnect. LiFePO4 batteries are used. The fault monitoring will be done via the Blockchain. In Figure 4, the PV conductors are initially mounted at a certain distance between them in order to prevent heat dissipation [2], [3]. The AC output is taken in series. However, the battery connections are made in parallel. The inverters are connected to the battery bank. The busbars need to be rated 500 A or above. The solar input by the system is 32000 W and the AC output is 26000 W. The inverters used are high-frequency single phases having high efficiency. Devices such as mobile phones can be charged from the grid directly. It uses plug and play communication [20] mode in order to reduce the need for labor and hence labor costs [4], [32].

Positive terminals of the battery are connected to a K1 class fuse [5]. Solar PV disconnect circuit breakers are added. The inverters are connected to the main panel. LiPe04 batteries will be used [6]-[7]. Grounding electrode conductors will be used for grounding and the residual current device will also be used for the safety of homes [8]. The cables used are Pure Arc Copper welding cables [9].

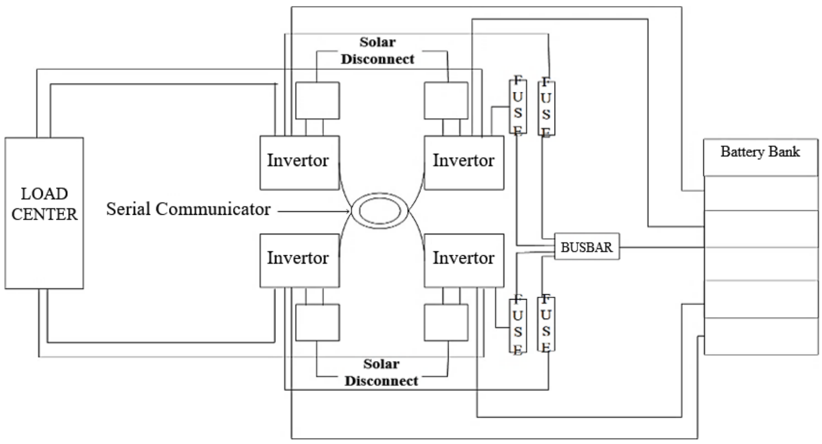

Figure 4. Illustration of circuit diagram

2.5. Blockchain based service

At predefined time intervals, smart meter energy measurements are integrated on a specific Blockchain via IoT modules, and processed using specific technologies in order to be transmitted to the cloud with a high level of security and trust [10]. These files have been cryptographically signed and secured making them auditable and reflecting participants' relationships [11]. Blockchain technology improves cryptography by decentralizing transactions, and consensus algorithms such as proof of work (POW) and proof of stake (POS) have disrupted Bitcoin miners [12]–[14]. A voting or valid tolerance level is used to check for the validity of a node's information or a "Byzantine General Problem". Where about 66% of the nodes will be selected at random to check for validation that the source is the relay. These ensure algorithm stability [15], [16].

2.6. Integration between IoT and Blockchain

With the rapid expansion of miniature and wireless devices, there is an increasing need for integration between IoT and Blockchain technologies with consensus and enhanced connectivity and security of such devices [17]–[19]. This integration can create a more resilient device architecture that allows for seamless connectivity to any wireless device, while also mitigating risks such as DDoS attacks and malware infections through the use of unique ransom addressing [20]–[25]. Furthermore, advanced machine learning algorithms can be employed to detect ransomware attacks and ignore any transaction originating from a compromised node, thereby protecting the entire system [26]–[28]. For lighting, LED lights should be used in domestic solar power systems due to low power consumption. Televisions having LCD displays and fans using brushless DC motors would be preferable [29], [30].

3. RESULTS AND DISCUSSION

The domestic solar power system discussed uses LiPeO4 batteries and has grounding electrode conductors. It is expected to be capable of meeting household electricity requirements however low power consuming devices would be preferred [19]. Also, there can be another disadvantage such as the unavailability of electricity during cloudy days. The plug-and-play mode communication ensures that minimum labor work is needed [20]. The most suitable choices of components have been discussed for meeting the above requirements. Currently, IoT is already in use with machine learning for crop agriculture, internet of medical things (IoMT), and cloud computing for massive network systems and databases. Even if we can draw intuitive information related to certain tasks and store them there it’s hackable and can be manipulated in such a way as to cause more harm to the entire nodes of IoT systems [33]. Figure 5 depicts the time complexity of Algorithms 1, 2, and 3.

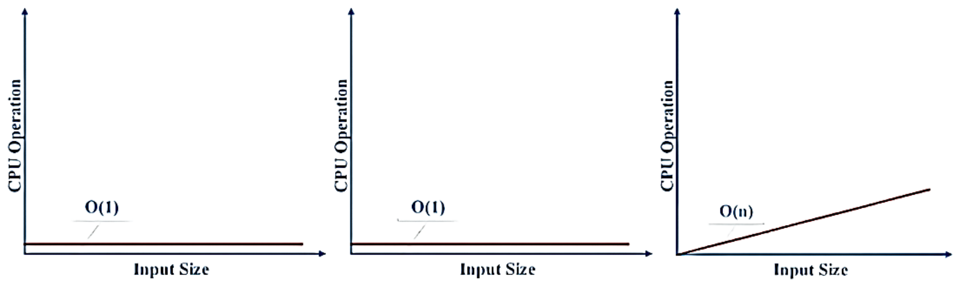

Figure 5. The time complexity of Algorithms (a) 1, (b) 2, and (c) 3

The smart grid system is not currently at a level of maturity that enables its widespread implementation. Therefore, the utilization of Blockchain technology can be explored as a means to verify the existence of users. Peer-to-peer energy trading becomes easier. But with proper security and reliability of the system to be able to use the existing technologies and ideas, the system should have a method of communication, and access information around the globe with more media.

Emerging methods like Chain-link utilize interconnected nodes to gather real-world data, enabling possibilities with APIs, VRF, and automate contracts. This facilitates the creation of random numbers for gaming and NFT projects, improving efficiency. Integrating Blockchain in IoT systems enhances reliability and benefits the growing community. User experience is prioritized, simplifying tasks and transaction processes. Cryptocurrencies can further enhance these technologies, enabling grid maintenance and power supply services. Cluster networks can be formed using collective debt. The algorithm Theo(n) represents an event-driven function reliant on IoT device requests.

4. CONCLUSION

A solar power system for use in homes with IoT with Blockchain-based monitoring has been designed. It is expected to bring about a change in rural areas. Solar photovoltaic is also expected to cut down electricity costs and fossil fuel consumption. The system would require minimal labour work due to plug and play mode. After installation, the working model wouldn’t need to be managed by a third person frequently. In case of any fault, it maintains those faults itself to some extent. For user experience, the only thing a user has to worry about is the public key they use for transactions which have to be protected and used more regularly to get accustomed to the new system more quickly. Blockchain integration for reliability and multi-level security with Blockchain end-to-end protection. IoT can be used with the crop yield prediction supply chain and many more which is related to trust. The tokens and money will be circulated with transparency and with more trust by which the investors will also be more confident in funding these products and issues to resolve quickly. A decentralized system creates an opening for investors to have more reason to invest in these kinds of systems. The transaction will be transparent with the help of Blockchain, so public usage is very much on the side of their benefit.

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