Template

1.

**Improvement and Application of Blockchain Consensus Algorithm for Distributed Power Energy System**

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2023

**Abstract**

This article focuses on the application of blockchain consensus algorithms in the power energy trading system and the comparison of these algorithms such as PBFT(Practical Byzantine Fault Tolerance), Raft and IBFT(Istanbul Byzantine Fault Tolerance). The article introduces the concept of blockchain consensus algorithms and its application in power energy trading system. It then provides a brief overview of the three algorithms and their underlying structures. The comparison of the algorithms is done in terms of features such as scalability, reliability and security. The article also provides an overview of the advantages and disadvantages of each algorithm and its application in power energy trading system. We examine the blockchain partition algorithm improved by the integration of Raft consensus and IBFT consensus, with a special focus on the advantages of using a hybrid algorithm in distributed networks. We discuss the need for consensus algorithms that are well-suited to blockchain networks and the improved security provided by a consensus algorithm incorporating both Raft and IBFT.We also discuss the implications of incorporating Raft and IBFT into a blockchain partition algorithm and its potential scalability. In conclusion, we provide a synthesis of our research, with potentials for further studies and contributions in this field.

**Problem Formulation**

Blockchain technology could not be applied in power systems due to the lack of consensus algorithms needed for proper operation and management of the system. potential solutions for improving the consensus algorithms for electric energy management is discussed.

**Solution/Method**

A permissioned blockchain based 2-layer architecture.

The blockchain node receives the transaction block request sent by the client. The blockchain network starts a new round of block consensus. The blockchain network groups all nodes and elect’s leader nodes within each group. As shown in Figure 3, the blockchain consensus approach for the power energy system includes:

1. Out-of-group consensus stage: The leader node of the group where the node receiving the client request belongs, as the block proposer node, broadcasts to the leader node of other groups; The block proposer node enters the pre-prepared state; The leader nodes of other groups also enter the pre-preparation state after receiving the pre-preparation message; Each leader node sends the preparation message to other leader nodes, and all leader nodes enter the preparation state from the preparation state; Each leader node sends the submission message to other leader nodes, and then all leader nodes enter the submission status from the preparation status.
2. Intra-group consensus stage: leaders in the group broad-cast their log contents to the group so that the consensus nodes in the group can copy the current log entries; A new leader node is elected in the group, and the consistency of master and slave node logs is maintained in the group; The leader node in the group completes the submission process and feeds back the results to the client.
3. In order to ensure the security of the consensus process, each group has an observer node to solve the problem that the Raft consensus cannot fight against Byzantine malicious acts. The group determines whether the leader of the real-time dynamic group is down according to the heartbeat mechanism of Raft algorithm, and the group uses the periodic restart mechanism to resist the non-Byzantine problem of the system. Fig. 2 shows the node structure of the IBFT consensus and Raft consensus of the improved algorithm.

## **Conclusion**

In this paper, we discussed the blockchain partition algorithm improved by the integration of Raft consensus and IBFT consensus, and we discussed the advantages of using a hybrid consensus algorithm in distributed networks. We then looked at the processes involved in the integration of the two consensus algorithms and analyzed the results. We also discussed the potential applications and implications of the improved algorithm and how it could be used in blockchain networks. This partitioned consensus strengthening method can make the blockchain process faster and safer. A multi-node consensus method and system perform well in terms of time consumption, consensus success rate, transaction throughput and scalability.2

2**.Power log partition collection and storage system based on alliance blockchain**

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2021

**Abstract:**

The power system log is used to record the operating data of power equipment, and it has a pivotal position in the management of power equipment. Green development is an inevitable requirement for building a modern economic system and an important part of the high-quality development of power companies. Aiming at the problems of the authenticity, validity, and security of the information in the power system, as well as the requirements of decarbonization and emission reduction, a power system log partition collection and storage system based on alliance blockchain technology is proposed. The system uses blockchain technology's distributed storage, decentralization, data resistance to tampering, consensus authentication, and traceability characteristics to store power system data, avoiding artificial attacks and tampering of information, and ensuring the authenticity of information, Traceability and safety, provide effective guarantee for later use.

**Problem Formulation**

Inability to predict operating conditions or trace back to the source of operating failures. Need of Transparency and better security.

**Solution/Method:**

The power system log partition collection and storage system structure

Is divided into four parts: power source-end alliance chain collection log

distributed database, administrator, and partition storage.

A master-slave multi-chain structure of power source alliance is made.

This system collects log data in different districts by constructing alliance

chains at different power sources. The alliance blockchain is a special

blockchain, which is built on a certain number of pre-selected

authentication nodes. The consensus algorithm of the blockchain

executed by these pre-selected nodes. A main-chain is selected.  the main

chain node is responsible for the sending and receiving of all information

on the source-end alliance chain, and the slave chain node is responsible for

uploading and reading the information generated by the node.

the log information of the specific device user is temporarily stored Local

storage is performed on the main chain node and on the slave chain node.

## **Conclusions**

This paper analyzes the principles of blockchain technology and the deficiencies in power system log management, and proposes a power system log partition collection and storage system based on alliance blockchain technology, which integrates blockchain technology into power system log management. Not only improves the informatization level of power equipment information management, but also ensures the authenticity, traceability and security of power system log information, and improves the value of power system logs. The classified collection and storage method enables administrators to review. Accelerated speed will help obtain data analysis results faster, find faults faster, reduce a lot of manpower and material loss and carbon emissions, and contribute to the realization of China's future low-carbon development. At the same time, in the process of power log management, the method of multi-party participation and multi-party maintenance is adopted, which is also multi-party mutual supervision, which improves the real safety of the power system.

3.

# Vulnerability Analysis and Evaluation of Nodes in Cyber-Physical Power System under the Framework of Blockchain

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**Problem Formulation**

The coupling connection between power system and communication system has improved the operation efficiency of cyber-physical power systems, but it also introduces the threat from cyber side. Further, the failure occurring in one side of systems can propagate another side, and iterates between power system and communication system, forming cascading failure and causing catastrophic damage on social production and life.

**Solution/Method**

In this paper, we detail the model for cyber-physical power systems consisted of power system and communication system, and the mechanism for cascading failure propagating between power system and communication system. we employ IEEE Standard Bus Test system to generate power system, and employ random network model, including ‘ER’ network model, Newman-Watts (NW) network model, Barabasi-Albert (BA) network model to generate communication system.To reach the aim of fast and safe transmission, the 5G network based on blockchain is employed to strength communication system. By means of `one-to-one correspondence' model, the model for cyber-physical power systems is established.

**Tool**

We simulate the state of cyber-physical power systems after certain attack, and the survival nodes after attack.

The detailed process is as follows,

**Step (1):** Generate topologies of power system and communication system, and establish the ‘one-to-one correspondence’ power and control connection between nodes;

**Step (2):** Given certain failure on nodes in power system to simulate aging failure or attacked;

**Step (3):** Delete failure nodes in power system, and analyze isolated clusters in power system;

**Step (4):** If isolated cluster in power system has generator node, the cluster survives the failure, turn to Step (5); Else, the cluster is considered as failure. Calculate isolated clusters without generator node, turn to Step (3);

**Step (5):** Analyze support nodes correspondent to nodes in power system. If the node in communication system has no support node, the node is considered as failure, turn to Step (6); Else, turn to Step(8);

**Step (6):** Delete failure nodes in communication system, and analyze isolated clusters in communication system;

**Step (7):** Analyze support nodes correspondent to nodes in communication system. If the node in power system has no support node, the node is considered as failure, turn to Step (3); Else, turn to Step(8);

**Step (8):** End the cascading failure in cyber-physical power systems, calculate survival nodes in power system and communication system.

**Test System**

Vulnerability Analysis

Simulation Ananlysis

The proposed hybrid attack can effectively locate the vulnerable nodes in cyber-physical power systems through modulating adjustable parameters in. This also illustrates that to hybrid attack, the 5G network can be seriously disintegrated, thus the attack methods proposed can help guide the strengthen of cyber-physical power systems.

## **Conclusion**

In this paper, we propose the isolated clusters-based model for cascading failure and hybrid attack method for vulnerability nodes analysis under the framework of blockchain. First, considering that traditional systems model neglects the distribution of clusters after attack, thus survival clusters and electrical characteristics are mixed together into systems modeling. To overcome the difficulty of that traditional searching methods, neglect the nodes characteristic of coupling system, we propose the hybrid attack method, and the adjustable parameter can be revised to better mini the vulnerability of systems, to better locate vulnerable nodes.

Further, employing 5G network to strengthen communication system can make information transmission faster and stable, avoiding the drawbacks of delay and package loss in traditional communication system. Moreover, based on the framework of blockchain, the security of information transmission can be guaranteed, due to the encryption transmission of information in traditional communication system. However, the hybrid attack method proposed in this paper also illustrates the vulnerability of 5G network, which can guide the research on protection strategies to various attack.

# 4.

# A Power Market Transaction Management System Based on Blockchain

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# 2022

# *Abstract:*

# With the continuous development and improvement of smart grid systems, related services such as the power market transaction management system power system will also increase in the future, resulting in a large amount of data analysis, processing, and management, and high storage costs. Database solutions, the decentralization and transparency of blockchain technology, and the concept of the energy Internet express their demands. This paper proposes a new blockchain-based power transaction storage system to improve service capabilities in a large-scale system.

# *Problem formulation*

# Based on energy domain data market model and the interactions, the security and safety of data in power transactions real-time sharing presents new challenges. Decentralization of data storage, access control, information transparency and privacy are essential.

# *Solution/Method:*

# This paper proposes a new blockchain-based electricity transaction storage certificate system, which greatly improves the service capabilities of the system. Build a basic blockchain platform module to realize a complete blockchain basic functional system such as consensus module, distributed ledger, P2P network, smart contract engine, encryption module, privacy protection, data management, member management, and blockchain governance. The upper application system provides standard, efficient, and scalable blockchain basic services.

*Tool:*

### Building aBlockchain general basic technology platform

### Application of electricity trading based on blockchain

#### 1) Power market alliance chain construction

#### 2) On-chain storage of business data

#### 3) Transaction traceability and energy use certification

#### 4) Transaction traceability and energy use certification

#### 5) Docking the upper-layer business system

This project intends to use 4 blockchain consensus nodes.

The core organization serves as a consensus node, and other non-core structures serve as non-consensus nodes. By adopting a partition consensus method, different partitions are formed according to business data for data synchronization. Real-time electricity transaction data is on the chain, and the Energy Bureau and the Municipal Supervision Bureau are included in the electricity transaction alliance chain, and the data on the chain can be viewed in real time. Write the algorithm for generating green energy use certificates into smart contracts. The smart contract automatically obtains the data on the chain according to the set period, and generates green energy usage certificates. The certificate is stored on the blockchain for users to obtain and use. use blockchain as the underlying technology to establish a power trading system, with transaction centers, dispatch centers, regulatory agencies, etc. as consensus nodes, and marketing centers, credit institutions, etc. as non-consensus nodes, forming a multi-level large-scale Power trading alliance chain.

*Test System:*

All the following test scenarios use the same servers configuration, each server deploys a blockchain node, and *N* nodes form a blockchain cluster. In each round of testing, one set of clusters and two presses were redeployed. The transaction used in the test is ordinary transfer, account *a* is transferred to account *b* 0 value 0 extra. The error is within 5%.

## *Conclusion*

In view of the difficulty of data analysis, processing and management, and the high storage cost of the traditional power market transaction management system, this paper proposes a new blockchain-based power transaction storage certificate system, which greatly improves the system’s service capabilities. Experiments show that compared with traditional methods, data synchronization performance has been significantly improved.

# 5)Case Study of Direct Communication based Solar Power Systems in Sub-Saharan Africa for Levelled Energy Cost using Blockchain.

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2020

**Abstract:**

Smart grid (SG) is an information technology-enhanced power grid, which provides a two-way communication network between energy producers and customers. Also, it includes renewable energy (RE), smart meters, and smart devices that help to manage energy demands and reduce energy generation costs. However, SG is facing inherent difficulties, such as security-based reliability issues and energy inadequacy. In addition, existing energy planning models like levelized cost of energy (LCOE) that evaluate the cost of RE do not measure the impact of reliability on energy cost. LCOE is a method used to compare the economic costs of RE and non-RE. However, the main problem of evaluating RE based on LCOE is that it does not consider the fill rate (FR) and service level (SL) effect. This paper proposes a direct communication-based LCOE (BLCOE) model as the least-cost solution that measures the impact of energy reliability on generation cost using FR and SL. The model also considers daily variations in the cost of solar modules and battery storage across sub-Sahara Africa (SSA). Furthermore, Quasi-Newton's method is employed to optimize the capacity of solar module and battery storage. Simulation results show the reduction of energy costs by approximately 95% for battery and 75% for the solar modules. The future BLCOE varies across SSA on an average of about 0.049 /kWhascomparedto0.15/kWh of an existing LCOE used in the literature.

**Problem Statement:** the main objective is to propose a secure framework that leverage blockchain technology for decentralized electrification in SSA. A blockchain-based methodology that estimates the cost of solar modules, which is comparable to the cost of battery storage is designed.

**Solution/Method:**

The problem can be solved by adopting these methods:

This paper uses proof-of-authority that depends on a highly reputable node, and only a highly reputable node can add the block to the chain.

Use of SHS. Solar home system is a household standalone PV system, which offers a cost-effective way of meeting the household energy demand. It also provides rural electricity in the absence of main grid.

Consumers pay their electricity bills through cash, debit cards at the start of each month, or in arrears by quarterly account.

Blockchain’s smart contract is a computer script that provides terms and conditions, which binds participants and also transfers digital currencies or assets between participants. Smart contract provides enforcement, and minimizes contract signing and regulatory costs.

Smart meters installed in the residential homes of all prosumers and consumers provide the first proof of their work for energy consumed or sold.

With blockchain, prosumers can sell their excess generations to neighboring prosumers or consumers via peer-to-peer (P2P) trading mode. Blockchain technology has a high degree of adopting decentralized SHS. Blockchain creates a trustless environment and establishes P2P trading market without the trust endorsement of a third party. Therefore, it reduces the difficulty of unifying industrial standards.

**Tools:**

This paper calculates the energy generation mix of solar and battery storage, which is vital to supply electricity for the whole day. Solar and Storage optimization Problem is solved using Quasi-Newton’s Method.

The solar insolation data used in this paper is obtained from the national aeronautic and space administration.The proposed scheme is implemented using MATLAB, and blockchain is implemented using the Ethereum platform.

**Test System:** This paper builds the blockchain with the following dependencies, using the ethereum platform: Truffle v5.0.8 (core: 5.0.8), Solidity v0.5.0 (solc-js), Node v10.13.0 and Web3.js v1.0.0-beta.37. The hash operations are carried out using the keccak256 solidity library, and some of the data used are generated randomly, if not specified. The hardware platform is a Dell i5, with a processor speed of 1.60 GHz and 8 GB RAM.

## **Conclusion**

The proposed framework in the paper efficiently resolves the possible security challenges of SG for the decentralized electrification in SSA, such as lack of trust and privacy of prosumers’ data. This paper proposes a BLCOE mechanism that compares the energy cost of solar module and battery storage for standalone SHS in SSA. In the proposed mechanism, the impact of energy reliability on generation cost is measured based on FR and SL. BLCOE is minimized by approximately 95% for battery and 75% for the solar module. Future energy costs vary across SSA on an average of 0.049 /kWhFRagainstexistingcostmodelof0.11/kWh. The impact of reliability premium is as low as 0.05 $/kWh in the anticipated blockchain scenario using the least-cost system. The low impact of reliability premium observed from the simulation results enables prosumers to make upfront curtailment decisions in real-time. The coefficient of variation is used to compare the distributions of the proposed cost model with the existing model. Results from the coefficient of variation of the proposed model confirm the accurate estimate for future energy cost. Also, it reflects the prediction of solar and storage costs for the year 2022.

In future, this study intends to analyze the possible security threats that may confront the proposed framework and offer the required remedies. In addition, this study intends to examine the impacts of the increasing number of prosumers and consumers on the performance of the proposed framework, for example throughput, computational cost and storage.

6.

# Research on Consensus Algorithm of Hierarchical Partition Blockchain for Virtual Power Plant Transactions

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**Abstract:**

With the construction of new power systems, the proportion of new energy power generation will gradually increase, and the energy transaction of virtual power plants will become more complex and challenging. With the increase in the number of energy entities involved in virtual power plants, the traditional centralized dispatching method can no longer meet the needs of the development of virtual power plants. The decentralization, tamper resistance and smart contracts of the blockchain can improve the transaction efficiency of virtual power plants. However, with the increasing number of distributed users participating in transactions, the consensus delay of the blockchain in completing transactions hinders the expansion of the blockchain network..This paper first proposes a blockchain-based virtual power plant system architecture, and expounds the relationship and role of each level. Later, a blockchain partition consensus algorithm for virtual power plant transactions was proposed, namely Partition Practical Byzantine Fault Tolerance (PPBFT). Finally, using OMNET++ to simulate the algorithm in this paper, it is concluded that when the number of nodes increases, the algorithm can effectively reduce the consensus time and improve the fairness and timeliness of transactions.

**Problem statement:**  Developing a blockchain-based VPP model based on the energy Internet under the condition of real-time electricity price, combining the security, transparency, and decentralization of blockchain. This paper first proposes a blockchain-based VPP system architecture, and expounds the relationship and role of each level. Later, a blockchain partition consensus algorithm for virtual power plant transactions was proposed, that is, the Partition Practical Byzantine Fault Tolerance (PPBFT). Finally. the performance of the algorithm is simulated.

**Solution/Method:**

In the structure of this paper, each response layer node partition is a relatively independent consensus group. Each partition processes transactions in parallel and then generates sub-blocks. The traditional PBFT consensus efficiency is low, in order to increase the consensus efficiency and reduce the communication complexity between nodes. This paper proposes Partition Practical Byzantine Fault Tolerance(PPBFT).

Each partition selects a leader node (leader), this leader node is responsible for the verification of a certain VPP internal transaction in this partition, and packs various transactions obtained from terminal devices into sub-blocks. Then, the sub-blocks packaged after the consensus are sent to the main chain layer. The selection of the leader node follows the principle that whoever pays the most deposit will serve as the leader node.

There are five stages: 1)Transaction stage -hash of the transaction is sent to the leader node and leader node sends it to the rest of the blocks 2)prepare stage - The signature of the leader node on the block is recorded in the Signature section 3)Endorsement stage-correctness of the blocks are checked. If it is correct endorsement is sent to leader node otherwise by 2/3rd of nodes leader is declared malicious. 4)If leader node is found correct, node signatures are sent to main chain node. 5) The main chain node now attaches it’s own signature and sends it to main node. 6) After the leader node receives the message, it sends the response message of the main chain layer node to other nodes, and then each node of the partition adds sub-blocks to its own local blockchain. Main code does not use PPBFT protocol.

**Tools:** The simulation uses OMNET++ to simulate the simulation of VPP blockchain node**.**

**Test System:**  To evaluate PPBFT performance, this experiment tests the consensus latency in different network scales. From the simulation results, it is concluded that the traffic complexity of TDH-PBFT is O(n2), and this algorithm makes the traffic increase linearly and enhances the scalability of VPP based on blockchain.

## **Conclusion**

Aiming at the shortcomings of the current VPP blockchain research, this paper first proposes a blockchain-based VPP system architecture, and expounds the relationship and role of each level. Later, a blockchain partition consensus algorithm for VPP transactions was proposed: Partition Practical Byzantine Fault Tolerant (PPBFT). Finally, the performance of the algorithm is simulated. The experimental results of OMNET++ simulation show that when the number of nodes increases, the algorithm can effectively reduce the consensus time, reduce the number of communications, and enhance the scalability of the VPP blockchain.

**7.**

# Seal-bid renewable energy certification trading in power system using blockchain technology

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2020

**Abstract:**

As the problems of existing fossil fuels are raised, the importance of renewable energy as a substitute energy is getting more emphasized. In order to solve this problem, various attempts have been made to expand the penetration rate of renewable energy based on various monetary support polices under government initiative. Therefore, we analyze the renewable energy certificate, which is a compensation system for renewable energy generation facility, and discuss the rational decision of consumers based on the mathematical perspective. In addition, based on the combination of the second price seal-bid auction and the blockchain technology, the overall system was developed so that the transactions between the market participants could be rationalized and the superior it of the performance was verified by comparing with the existing technology.

**Problem Formulation:** Developing a blockchain technology based REC trading market which make it possible to record whole of transaction and derive user’s truthful bidding in the market.

**Solution/Method:** A seal-bid auction method using blockchain technology to maximize the profit of each participant with the consideration of existing security problem in the REC transaction market. There are participants and auctioneers, market *participants* offer an initial bidding price than the seller confirms the transaction according to it’s reference value of REC.

**Tools**: Simulation

**Test System**:

*Case*1, 2, and 3 show the cases where the REC holding amount is 30%, 60%, and 90% respectively. The percentage refers to the current rec holding amount. we could see that in whole of cases, the longer the remaining period, the lower the bidding price in *Participant*’s perspective. Based on the results, it is possible to examine the decision method of each market participant, and possible to predict market operation and overall bidding price.

## **Conclusion**

In this paper, we propose an REC trading market in actual environment with the proper blockchain technology. With the proper auction based trading mechanism, it is possible to store transaction results while minimizing the exposure of personal information. In addition, by analyzing the utility of buyers considering the actual situation, we could derive a reasonable bidding price of market participant.