Design and Research of Power Grid Equipment Supply Chain Based on Blockchain Technology

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Abstract. The comprehensive construction of the ubiquitous power Internet of Things has been determined to the current core task by the State Grid Company. Power equipment supply chain is an important part of ubiquitous power Internet of things. Its operation efficiency is directly related to the operation efficiency of ubiquitous power Internet of things. In order to solve a series of problems in the operation of power equipment supply chain, such as lower efficiency of equipment supply chain, higher supply cost and poor stability of supply chain, due to the characteristics of information asymmetry, incompleteness and time lag. The block chain technology is introduced into the supply chain of power grid equipment. A multiple linear regression model is established to analyze the economic value of the system, and the stability of the system is analyzed by combining the basic characteristics of block chains. The feasibility of the theory is verified by case analysis. The results show that the supply chain of power grid equipment based on block chain technology can reduce the equipment purchase cost of power grid enterprises and improve the stability of equipment supply chain.

1. Introduction

In 2019, the State Grid Corporation of China made the strategic deployment of comprehensively building "three types and two networks" at the "Two Sessions", and pointed out that the construction of ubiquitous power Internet of things is the core task to implement the strategic goal of "three types and two networks and world-class" [1]. "Ubiquitous" refers to the information connection and interaction in any time, any place, any person and any thing. The ubiquitous Internet of things connects power users and their equipment, power grid enterprises and their equipment, suppliers and their equipment, as well as generates shared data to serve users, power grid, suppliers and government [2]. As an important part of ubiquitous power Internet of things, power network equipment supply chain is the link between power grid enterprises and suppliers, and its operating efficiency determines the efficiency of ubiquitous power Internet of things.

Meanwhile, with the continuous development of Chinese science and technology, the quantity and types of electrical equipment continue to increase. State Grid Corporation of China expects that the installed power grid capacity in China will reach more than 700 billion KWH in 2020 [3]. In order to achieve the goal of nearly doubling the installed capacity, it is imperative to build a huge infrastructure in the power grid industry, among which the main power grid construction links, such as transmission,

transformation and distribution all rely on some power grid equipment [4]. Normal supply of equipment is the basis of the normal operation of enterprises, due to the features of the production or sale [5]. Power grid equipment supply chain is different from other supply chains, which involves more equipment specifications, quantity. Once there is an incident in the supply chain, it will not only affect the normal operation and maintenance, delay the power grid infrastructure period, and also affects the normal production of other enterprises, normal operation of institutions, causing unnecessary economic loss, even casualties. Therefore, how to mitigate risk of the supply chain power grid equipment and reduce the economic loss is the basis to ensure the normal operation of the power grid.

At present, relevant domestic scholars have made achievements in the research of power grid equipment supply chain, including conceptual analysis, risk identification and assessment, and the establishment of risk response mechanism. Literature [6] classified and analyzed the identified risks according to the procurement quality of power equipment, and proposed corresponding risk response methods. Literature [7] studies the risk management of power grid equipment supply chain with specific examples; Literature [8] analyzes the problems existing in the power grid equipment supply chain, identifies the risks, and proposes corresponding preventive measures based on the identification results. Literature [9] listed different risk management methods of supply chain.

To sum up, domestic and foreign scholars' researches on power network equipment supply chain mainly focus on risk identification, risk assessment, establishment of risk response mechanism and other aspects of power grid equipment supply chain, but not essentially eliminating uncertain factors that cause the risk in power gird equipment supply chain. This article will propose the application of blockchain technology in the power grid equipment supply chain. Basing on retaining the original operating mode of the internal enterprises in supply mode, it can realize the transition from the simple monopoly model to complex network model of the grid industry supply chain, eliminated endogenous risks brought by the factors such as information asymmetry, incompleteness and time lag, eventually to reduce power grid enterprise equipment acquisition cost and enhance the stability of the supply chain.

2. Applicability analysis of blockchain in power grid equipment supply chain

This paper analyzes the applicability of block chain in the supply chain of power grid equipment based on the risk and characteristics of blockchain, and provides certain theoretical support for introducing blockchain into the supply chain of power grid equipment.

Supply chain risk refers to various unexpected events and uncertainties that cause the supply chain to fail to operate normally or be inefficient [10]. According to sources, supply chain risks are mainly divided into endogenous risks and exogenous risks [11]. Endogenous risks mainly include moral risk, information risk, intellectual property risk and risk arising from corporate culture differences. Exogenous risks mainly include uncertainty risk of market demand, policy risk, legal risk and accident risk. The endogenous risks of the supply chain mainly come from the production activities of individuals or organizations, with inevitability and certainty. In addition, as a virtual organization, the supply chain itself lacks the corresponding supervision and control mechanism, which indirectly promotes the occurrence of endogenous risks. Exogenous risk mainly refers to the environmental disaster, policy change, the risk of uncontrolled factors such as the financial crisis, because of its contingency and uncertainty, companies cannot avoid the occurrence of exogenous risk. Therefore, the effective implementation of risk warning and establish good risk coping mechanism, is the key to reduce the loss due to exogenous risk [12].

It can be seen from the above analysis that, in order to substantially reduce the probability of equipment supply chain risk, it is necessary to focus on the endogenous risk of supply chain. Endogenous risks of power grid equipment supply chain mainly include:

(1) Moral risk

Internal enterprises in the equipment supply chain are independent economic entities with the main purpose of obtaining economic benefits. In order to maximize their own interests, enterprises will damage the interests of other enterprises, such as cutting corners and shoddy products [13]. Moral risk

is essentially caused by the self-interested behavior of enterprises. Adding the corresponding regulatory system in the equipment supply chain can effectively avoid the occurrence of moral risk.

(2) Information risk

Information risk mainly includes bullwhip effect and information distortion. Among them, bullwhip effect refers to the phenomenon that demand is amplified step by step when downstream enterprises transmit demand information to upstream enterprises in the operation of supply chain. The fundamental reason of information distortion is that there is no real sharing of demand information between upstream and downstream enterprises. Information distortion refers to the phenomenon that enterprises are unwilling to share some information with other enterprises or pass on false information in order to maximize their own interests. Information risk is essentially caused by information asymmetry and incompleteness.

(3) Intellectual property risk

Enterprises in the equipment supply chain have both competitive and cooperative relations. In the process of competition and cooperation, inevitably, the core technologies of enterprises will leak out, making enterprises lose competitiveness and reduce market share, and finally forced to withdraw from the equipment supply chain [14]. The withdrawal of one enterprise will have a certain impact on the overall structure of the equipment supply chain, and ultimately affect the stability and reliability of the equipment supply chain.

(4) Enterprise culture differences

Power grid enterprises need a large number and variety of equipment. Also the equipment supply chain operation process is complex, and needs multiple departments to coordinate with each other to normal work, which leads to the equipment supply chain involved in more enterprises. In the communication and cooperation among many enterprises, due to the differences in enterprise culture, there are many unnecessary misunderstandings and frictions in the cooperation process, which ultimately leads to the reduction of the efficiency of the entire equipment supply chain.

From the analysis above, it can be seen that the endogenous risk of power grid equipment supply chain is mainly caused by information asymmetry, incompleteness, time lag and other factors. Whether it is the self-interest of enterprises, or the generation of "bullwhip effect" or "information distortion", all of them take information as the carrier of generating and spreading risks. However, blockchain is a new application mode based on distributed data storage, consensus mechanism, asymmetric encryption, intelligent contract and other computer technologies [15], which has the characteristics of decentralization, trust removal, information tamper ability, openness and transparency, collective maintenance and so on. Based on the characteristics above, block chain provides a network-level solution to avoid endogenous risks of supply chain for power grid equipment supply chain, and verifies the applicability of block chain in power grid equipment supply chain.

Meanwhile, State Grid Corporation of China regards the construction of ubiquitous power Internet of things as its current core task, and the power network equipment supply chain is an important part of ubiquitous power Internet of things. Therefore, the introduction of block chain into the supply chain of power grid equipment can enable power grid enterprises to directly participate in the decision-making of the supply chain, enable power grid enterprises to grasp the design and production process of equipment, and then realize the interconnection of decision-making information and equipment production, so as to promote the research and construction of ubiquitous power Internet of things.

3. Power grid equipment supply hain based on Blockchain

In this paper, blockchain is proposed to be applied in the power grid equipment supply chain to avoid endogenous risks caused by factors such as information asymmetry, incompleteness and time lag, in order to improve the efficiency of supply chain, reduce costs and promote the development of ubiquitous power Internet of things. The topology of the power grid equipment supply chain system based on blockchain is shown in Figure 1:

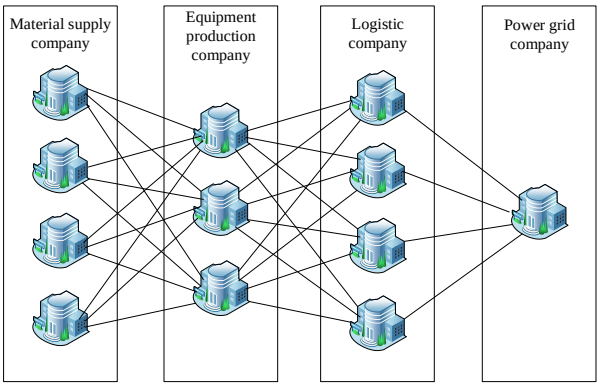

Figure.1 Material supply chain system topology of grid industry based on blockchain

In the power grid equipment supply chain network, participants mainly include material supply enterprises, equipment manufacturing enterprises, logistics enterprises and power grid enterprises. All enterprises in the equipment supply chain will exist as an independent node in the blockchain network. The power grid chain supply network based on the blockchain adopts the P2P network protocol for data transmission, which is beneficial to solve the problems of information asymmetry, incompleteness and time lag, improve the efficiency of the equipment supply chain and reduce equipment acquisition costs. The equipment supply chain adopts distributed consistency algorithms, consensus mechanisms and intelligent contracts to solve the problem of "General Byzantine", that is, when the business content is verified and confirmed, if more than 51% of the nodes in the whole network can reach a consensus, then the whole network can be considered to reach a consensus. After the establishment of the cooperative relationship, the asymmetric encryption technology is adopted to transmit the detailed information of the scheme, in order to ensure the security of the data.

The blockchain-based power grid equipment supply chain operates as follows:

(1) The equipment demand information is released by the demand node (the power grid enterprise) and broadcasted throughout the network;

(2) If other nodes (material supply enterprises, equipment manufacturing enterprises, logistics enterprises, etc.) have doubts about the demand information, the content of the questions needs to be broadcasted throughout the whole network, waiting for the demander to respond. If there is no doubt, go to the next link;

(3) Each node designs or provides a corresponding technical solution (the equipment manufacturing enterprises provide equipment design and production plans according to actual conditions, and each material supply enterprise provides the performance of materials that may be used according to the preliminary plan provided by the equipment manufacturing enterprise and logistics companies provide logistics solutions, etc.), and then broadcasts the corresponding information throughout the network;

(4) If other nodes are suspicious of the scheme information, the content of the question needs to be broadcasted throughout the whole network, waiting for the node to respond. If there is no doubt, go to the next link;

(5) Each node votes to select the best solution for each link (the best solution for material supply, equipment design and production, and logistics solution);

(6) The node that can complete the best solution broadcasts the information such as the time and cost required to complete the solution;

(7) Each node will vote for the best completion node of each link (the best enterprise for material supply, the best enterprise for equipment design and production, and the best logistics enterprise);

(8) The demand node establishes a cooperative relationship with all the best completion nodes, and broadcasts throughout the network;

4. Value theory analysis of power grid equipment supply chain based on blockchain

The application of blockchain in the power grid equipment supply chain will affect the supply speed V, precision A, quality Q, price P, logistics cost C, cooperation integrity L and other parameters of the

equipment supply chain. Among these parameters describing the equipment supply chain, some are correlated with each other, such as V and Q; V, Q and P.

In general, when the production capacity of the business department remains the same, there is an inverse relationship between V and Q, that is, the faster the speed is, the worse the quality will be, and vice versa. Therefore, it is assumed that the following relationship exists between V and Q:

$$X = V * Q \tag{1}$$

X represents the supply capacity, which reflects the supply ability of the business departments.When X increases, V is improved under the condition that Q remains unchanged. If the demander requires fast supply speed and high supply quality, the final supply price will also be relatively high. Therefore, it is assumed that the following relationship exists between V, Q and P:

$$P = \omega * V * Q = \omega * X \tag{2}$$

ω is the price coefficient, which reflects the relationship between supply capacity and supply price. When X remains unchanged, the smaller ω is, the lower the price will be.

In order to simplify the research process, this paper constructs a multiple linear regression model between the equipment acquisition cost Z and various parameters of power grid enterprises, which is as follows:

$$Z = \frac{k}{\theta A + \alpha VQ + \frac{\beta}{P} + \frac{\gamma}{C} + \delta L} + \varepsilon_E \tag{3}$$

ε_E is the disturbance term of uncertain factors. Substitute equations (1) and (2) into equation (3) and we will get:

$$Z = \frac{k}{\theta A + \alpha X + \frac{\beta}{\omega X} + \frac{\gamma}{C} + \delta L} + \varepsilon_E \tag{4}$$

The application of blockchain in the power grid equipment supply chain can avoid the loss caused by the “bullwhip effect” and improve the supply accuracy of enterprises. There is a competitive relationship between each enterprise of each link, which helps enterprises improve their supply capacity and reduce the supply price. Group decision making is helpful to improve the transparency of the process of the supply chain, making enterprises supervise each other and enhance the integrity of cooperation. With the analysis of multiple linear regression model, we can know that improving supply accuracy and capacity, enhancing the integrity of cooperation and reducing supply price are all beneficial for power grid equipment supply chain to reduce the equipment acquisition cost.

In the environment of mutual competition and restriction, enterprises are more inclined to provide real and effective business information to avoid being eliminated by the supply chain, which makes the supply chain avoid the risks caused by information asymmetry, incompleteness and time lag, and improves the stability of the supply chain. At the same time, the application of blockchain enables power grid enterprises to directly participate in the decision making of the supply chain, which is beneficial for power grid enterprises to find the weak links in the supply chain, so as to adjust their own operation strategies and achieve the purpose of improving the efficiency of equipment supply chain and transmission efficiency.

The table of comparative analysis between the power supply chain based on blockchain proposed in this paper and the traditional power supply chain is as follows:

Table 1. Comparison Analysis Table of Euipment Supply Chain of Power Grid Industry Based on Blockchain and Traditional Euipment Supply Chain of Power Grid Industry

Category	Equipment Supply Chain in this paper	Traditional Equipment Supply Chain
Delivery speed	Fast	Slow
Accuracy of supply	High	Low
Supply quality	Good	Poor
Supply price	Low	High
The logistics cost	Low	High
Cooperative integrity	Good	Poor
Stability	Good	Poor
Difficulty level	Difficult	Easy

Based on the comparative analysis, it can be concluded that the supply chain of power supply chain based on blockchain is superior to the traditional equipment supply chain in terms of supply speed, accuracy, quality, price, logistics cost, cooperation integrity and stability. Only in terms of the difficulty level, the traditional equipment supply chain is better.

In conclusion, the power supply chain based on blockchain has the value of being researched and applied.

5. Case Analysis

Using the case that a power grid enterprise purchases transformers, this paper respectively makes two flow charts that are before and after optimization, and analyzes, with specific data, the feasibility and the economic value of the application of Blockchain in the power equipment supply chain. The brief flow charts of the supply chain that are before and after optimization showed as Figure.2 and Figure.3.

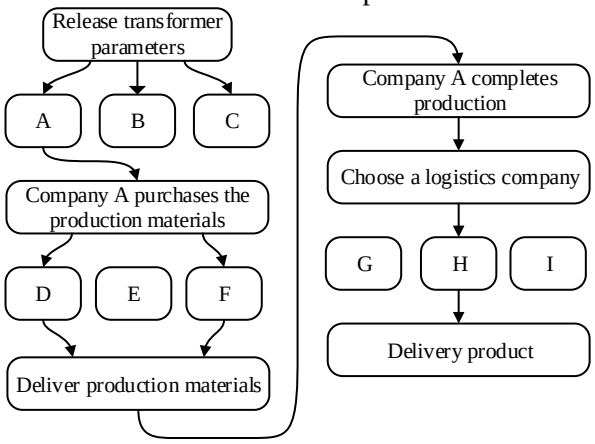

Figure.2 Traditional Transformer Supply Chain Brief Flow Chart

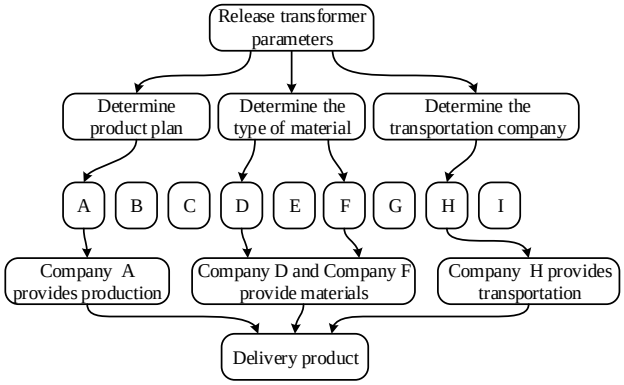

Figure.3 Brief Flow Chart of Transformer Supply Chain Based on Blockchain

After analyzing the flow charts, by the transformer supply chain based on Blockchain, such participators of the equipment supply chain as the transformer manufacturers, the material suppliers, the logistics enterprises and so on can directly participant in the decisions of the transformer supply chain, which realize the group decision-making, foster the transparency of the operation flow, avoid risks brought by the asymmetry, incompleteness and time lag of the information and furthermore enhance the reliability of the supply chain. Meanwhile, within the network environment based on Blockchain, there exit the competitions among different material suppliers, different transformer manufacturers and different logistics enterprises, the relationship that contributes to the improvement of the speed, the quality and the precision of the transformer supplying. Also, among the participators of the equipment supply chain including the transformer manufacturers, the material suppliers, the logistics enterprises and so on, there exist the relationship of mutual supervision and restriction conducing to the avoiding of the moral risks. In conclusions, it is viable to introduce the Blockchain into the power equipment supply chain to evade the risks caused by the asymmetry, incompleteness and time lag of the information.

A power grid enterprise purchases two batches of transformers of the same specification and quantity before and after the optimization of transformer supply chain, and calculates the delivery cycle and purchase cost of two purchases, as shown in Table 2. By analyzing the data in the table, it can be seen that the application of blockchain to transformer supply chain reduces the delivery cycle and purchase cost of transformer. The analytical results are the same as the theoretical ones, which verify the correctness of the theory.

Table 2. Comparison Analysis Table of Transformer Supply Chain Based on Blockchain and Traditional Transformer Supply Chain

	Pickup Circle (Day)	Acquisition Cost (10k Yuan)
Supply chain based on Blockchain	60	12.4
Traditional Supply Chain	66	16.8

6. Conclusion

This paper first analyzes the causes of the endogenous risks caused by information asymmetry, incompleteness and time lag in the power grid equipment supply chain. It is proposed to apply the Blockchain to the power grid equipment supply chain, which is conducive to avoiding the occurrence of endogenous risks and at the same time achieving the goal of reducing costs and improving efficiency. Then this paper establishes the multivariate linear regression model, verify the economics of applying the Blockchain to the power grid supply chain and meanwhile analyze the stability of the equipment supply chain combined with the characteristics of the Blockchain. Finally, through the case analysis, this paper expatiates the specific operation process of the power grid equipment supply chain after the introduction of the Blockchain technology and the feasibility is also verified.

It can be seen from the analysis that it is reasonable and viable to apply the Blockchain to the power grid equipment supply chain. By combining the Blockchain with the power grid equipment supply chain, objectively speaking, this method realizes the group decision-making of the power grid equipment supply chain without changing the original equipment production strategy and business model, then improves the transparency of the equipment supply chain and effectively avoids endogenous risks caused by information asymmetry, incompleteness and time lag, thereby improving the stability of the equipment supply chain and ultimately improving the stability of the ubiquitous power Internet of Things; essentially, it is said that the power grid equipment supply chain will shift from a simple supply monopoly model to a complex supply network chain model, so that there will be competition between enterprises in the equipment supply chain, and ultimately improve the operational efficiency of the power grid equipment supply chain, reduce the cost of electricity production, and promote The purpose of ubiquitous construction and development of power Internet of Things.

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