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Research on the Informatization Management System of Hazardous Waste in Power Grid Based on the Virtual Warehouse

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ABSTRACT. As the environmental protection policies become increasingly strict, hazardous waste disposal is a noteworthy issue for power grid companies to achieve clean production. Based on the radio frequency identification devices (RFID) and internet of things (IoT) technology, a virtual warehouse theory, and informatization management system was introduced in this article, which consists of waste identification and tracking, full-chain of IoT, trade matching, production forecast, and visual display. This study offers a new thought for grid companies to develop other management methods to promote environmental protection and management works.

Keywords: Informatization Management; Hazardous Waste Disposal; Power Grid; Virtual Warehouse

1. Introduction

With the severe environmental protection situation, a series of policies have been promulgated to promote the reduction, reuse, and harmless treatment of hazardous waste. Hazardous waste management has become a new hotspot of environmental supervision, which directly affects the environmental protection tax and has an impact on the economic and social benefits of the power grid companies. Since the 18th National Congress of China, the government has attached great importance to environmental protection and stressed the importance of cracking down on illegal acts of hazardous waste emission [1]. At present, the disposal of waste batteries and waste oil still cannot meet the regulatory requirements, which induced a greater risk of environmental protection. There is no clear technical path, implementation plan, and management standard for recycling and harmless treatment of waste oil and waste battery [2]. In addition, there are many shortcomings in the management of power grid hazardous waste. The disposal and management works involve many departments, including construction, science, information, materials, transportation, inspection, etc. At present, the disposal process of power grid hazardous waste is basically in accordance with the collection, temporary storage, transfer and transportation, and hazardous waste disposal. The division of responsibilities at all levels and departments of the company is not clear and the working procedure is indistinct. Therefore, the disposal process and management of power grid hazardous waste are chaotic, the buck-passing phenomenon always exists. Each unit is lack corresponding management standards for grid hazardous waste ledger, personnel allocation, and environmental protection funds.

Therefore, in order to achieve the high-efficiency disposal of the power grid hazardous waste, it is urgent to establish a scientific and effective management system, which contains operation, decommissioning, recovery, storage, transportation, and treatment processes. Based on the “virtual warehouse”, in this study, an implementation case of an informatization management system was introduced to systematically and comprehensively dispose of the power grid hazardous waste, which can provide a new insight for power grid companies and other hazardous waste disposal institutions.

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2. Present situation of power grid hazardous waste disposal

2.1 Power grid hazardous waste

In the power grid system, waste mineral oil is mainly generated in the process of overhaul, technical transformation, retirement, and scrapping of power transmission and distribution facilities (transformers, capacitors, reactors, transformers, bushings, etc.). These waste mineral oils are mainly composed of long-chain hydrocarbons and aromatic compounds, which are hard to be biodegraded [3]. Once leaked or directly dumped into soil or water, they will cause serious damage to the ecological balance, then human health and animal growth are under threat. At present, the company's waste oil reserves are divided into two parts: one is recovered and temporarily stored by the maintenance department, and the other is stored in the decommissioned equipment at the distribution network which will be disposed of together with the equipment. However, a large number of the oil cannot be separated from substation equipment in the distribution network during material disposal, the equipment was directly auctioned as a whole and common waste by companies. Statistically, in 2017, Zhejiang power grid company scrapped 13916 oil-bearing substation equipment and the waste oil content is estimated at 2000 ~ 5500 tons, however, the reported waste oil reserves by each unit are only 244.458 tons. Thus, after centralized scrapping and disposal by the company, it can be found that the waste oil which generated benefits is less than 10% of the total content, and the disposal of power grid waste oil is far from achieving its actual economic benefits.

The waste battery is another important part of power grid hazardous waste. Power grid waste batteries include lead-acid batteries and lithium batteries. Among them, lead-acid batteries are in the majority, which can be generated in the scrapping process of information, communication, automation, and standby power sources of substation secondary equipment. Lead-acid batteries contain a large amount of lead sludge and waste sulfuric acid. Once the shell is damaged, the leaking of lead and electrolyte will cause soil and water pollution. These contaminants can eventually enter the human body through the food chain, endangering human health [4]. The power grid companies generate a large number of used batteries every year. In 2017, the Zhejiang company produced a total of 34013 waste batteries, and 20846 waste lead-acid batteries were produced in the first nine months of 2019. Among them, 10593 waste lead-acid batteries were sold through unified bidding, and the destocking rate was only less than 51%. A large number of waste lead-acid batteries can only be temporarily stored in the material warehouse until the scrap life, which consumes manpower and material resources, and also has environmental risks and safety hazards.

2.2 Problems in the hazardous waste disposal

In terms of collecting temporary inventory, due to the restrictions of capital, personnel, and site, all departments of the power grid company have not established professional hazardous chemical warehouses, which cannot meet the "Hazardous Waste Storage pollution Control Standards" provision. There are three reasons: first, the established standard of the dangerous chemical warehouse has not been stipulated; second, there is no appropriate project and expenditure; third, some warehouses in cities are leased and it is difficult to set up dangerous chemical warehouses due to the limited space.

The waste disposal process of the power grid shall be reported by the material department of the city and county company to the provincial company and processed by unified bidding. Hazardous wastes (waste mineral oil, waste storage batteries) will be processed by unified bidding through specific hazardous waste batches, and the frequency is twice a year. However, according to the “Guidelines on Environmentally Harmless Disposal and Resource Utilization of Power Grid Waste of the State Grid Corporation”, the maximum amount of waste lead-acid batteries temporarily stored is not allowed more than 30 tons, and the maximum storage time is not more than 90 days, thus it is easy to exceed the deadline. If the temporary stock is small, the recycler may be reluctant

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to recycle and the bid might be lost. The scrap auction process of oil-bearing substation equipment cannot separate the equipment from the waste oil, and most of its recyclers lack the qualification of the comprehensive hazardous waste operation license, resulting in environmental risks and hidden dangers.

For the ledger management, in the power grid, the management system of waste materials planning, statistics, and reporting is usually irregular, and a complete and unified basic information database has not been established. The contents and formats of the hazardous waste management ledgers (in and out of storage) of most units vary greatly, and some management ledgers are unclear or missing. Therefore, the reliability of the ledger is relatively low.

2.3 Hazardous waste management patterns

Developed countries such as the United States, Japan, and Germany started relatively early in the hazardous waste disposal and have accumulated certain technological capital and institutional capital [5]. In May 2016, the Ministry of Commerce of China and other six ministries jointly issued “Opinions About Promoting Renewable Resources Recovery Industry Transformation and Upgrading”. From a macro perspective, the paper puts forward four basic principles and guarantee measures for the transformation and upgrading of the renewable resource recycling industry, defines the “Internet & Recycling” model, and innovates and explores a new mechanism for cooperative development of the two networks. "Internet & Recycling" and the IoT (Internet of Things) is one of the important means to promote the transformation and upgrading of the traditional recycling industry.

The intelligent garbage classification system of the Internet of Things provides innovative ideas and tools for waste classification and resource recycling, gradually changing the situation of "small, scattered and poor" traditional recycling patterns, and promoting the intelligent development of garbage classification. Because of the huge potential of the renewable resource industry and the advantages of the Internet model, environmental protection companies such as Greenmei and Qidsander have set foot in Internet recycling, and a large number of start-up companies such as “Love recycling”, “Life again” and “Money exchange” have emerged.

Nowadays, environmental waste disposal of power grid enterprises has become a new hot spot of power grid environmental protection work under the new situation. In the future, the top priority of the company's power grid environmental protection work is to adhere to the principle of “reduction, harmless and resource recovery”, strengthen and standardize the management and disposal of power grid waste, promote the continuous improvement of environmental harmless disposal and resource utilization level of power grid waste, and promote the clean and green development of power grid.

3. The informatization management system of hazardous waste in power grid based on the virtual warehouse

Herein, based on the virtual warehouse, a full-chain IOT power grid hazardous waste information management and control system is introduced. This system aims at promoting the “reduction and recycling” of hazardous waste of power grid, optimizing the hazardous waste management mode with scientific evaluation system and information control technology, and striving to achieve “harmlessness” and “no waste” of the power grid. Waste oil and battery information will be stored uniformly, and disposal suggestions will be directly issued by the supervision platform after path optimization and transaction matching. The system is beneficial to completely solve the hazardous waste disposal problem, save the site and human resources, significantly improve the company's environmental management technology level. This design has a great significance for promoting circular economy, building a new-type power grid with sustainable development as the goal of resource-saving, ecological environmental protection, standard specification, and economic efficiency, and promoting the green development of power industry and society. In detail, the implementation plan of this system can be divided into 6 parts.

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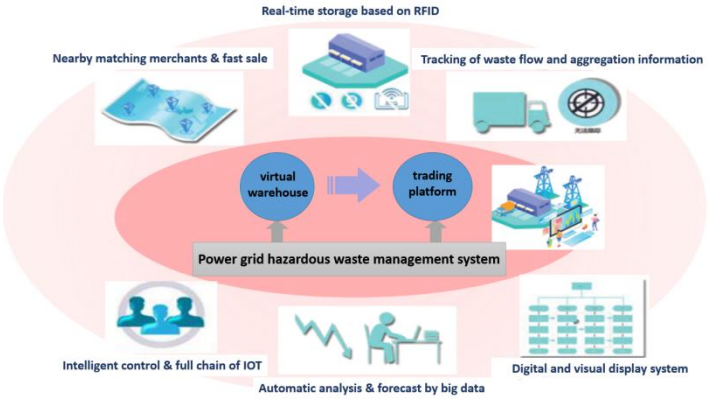

Figure. 1 Power grid hazardous waste information management system based on the virtual warehouse

3.1 Waste identification and real-time storage based on RFID

The detailed implementation plan of the power grid hazardous waste management system was shown in Fig. 1. The design specification of uniform material code identification for lead-acid batteries and lithium batteries was studied based on the RFID (radio frequency identification devices) technology [6]. The coding rules of power grid waste batteries were formulated by fully considering the information of power grid battery suppliers, application scenarios, types of equipment in service, service life range, types of failure reasons, and decommissioning status rating. The unique identification method of waste battery RFID tag was studied, the implementation scheme of RFID data such as feature extraction, multi-feature fusion, and unique coding authentication was clarified, and the RFID data acquisition scheme is definite.

3.2 Tracking of waste flow and aggregation information

The tracking information management system of the power grid hazardous waste (flow and aggregation) was significant to master the running track of solid waste. The collect mode of the location information of the spent battery RFID tag has to be clarified. The intelligent oil tank with liquid level and temperature monitoring is researched to replace the existing temporary storage oil tank. The uniform identification specification of the oil tank code is designed, and the waste oil storage tank is used as the RFID tag identification object, and the real-time collection of waste oil generation location, time and production amount, and other information. The RFID-based waste battery Internet of Things identification technology and information security protection scheme is of great importance [7].

3.3 Intelligent control & full chain of IoT

The key pieces of information of the recovery methods of hazardous wastes have to be collected, such as transformer oil and waste lead batteries, qualified agents or recycling manufacturers with environmental protection certification, resource-based technologies and recycling scenarios, recycling technologies, and economic feasibility. According to the analysis of key information of waste battery recycling, combined with the calculation of recovery cost accounting model and the evaluation of reuse business model, a power grid waste battery recycling control system scheme based on RFID unique identity tag was designed. The main information of the whole IoT chain in the service stage can be learned from the code label of the waste battery in the power grid, as shown in Fig. 2.

Based on the waste battery and waste oil recovery reuse control system design, the virtual warehouse of power grid hazardous waste was constructed, and the business demand module of the virtual warehouse was defined [8]. A detailed technical implementation plan of hazardous waste management system information platform was designed including research entity entry and exit process, transaction declaration and approval process, waste material operation process, process

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management, and monitoring process. In addition, intelligent storage tanks for batteries and intelligent storage tanks for mineral oil are designed and constructed for store and disposal of waste lead-acid batteries and waste oil in a standard manner, and to configure environmental emergency supplies according to standards, which was shown in Fig. 3.

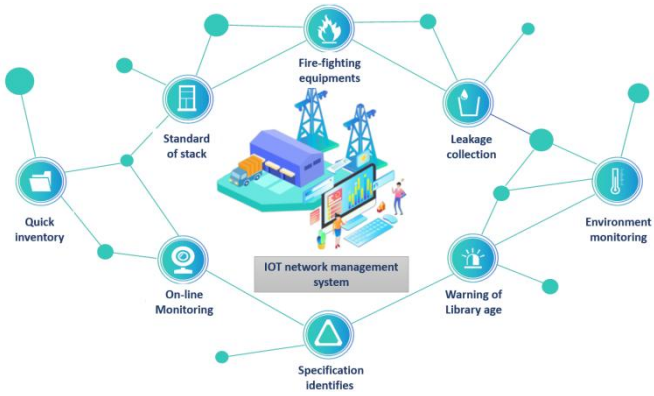

Figure. 2 IoT network management system of the power grid hazardous waste

3.4 Trade matching and fast-sale based on model

The growth rate of waste lead-acid batteries and waste oil was analyzed by forecasting the model of power grid waste production. According to the capacity of transport vehicles and the appropriate number of a single transaction, the existing temporary storage points of municipal companies are divided into blocks within the provincial region [9]. The best trading point with low transportation cost and convenient trading were modeled and calculated (i.e. centralized temporary storage point), and appropriate recycling merchants was selected to push trading information. According to the transportation cost from the temporary storage point to the best trading point, the bargaining range was established and the online bargaining and trading were completed. The intelligent management of hazardous waste information was realized, such as status, source, transportation location, and disposal direction.

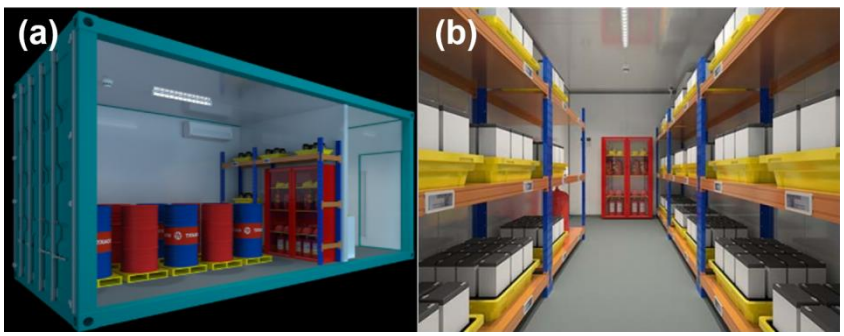

Figure. 3 Intelligent temporary storage tanks for (a) mineral and (b) batteries

3.5 Production analysis & forecast by big data

Utilizing the existing material management system and transportation inspection management system of the power grid, the historical time information, service conditions, failure causes, and corresponding quantities of hazardous wastes, such as transformer oil and lead-acid batteries in the company's provincial cities, can be analyzed and collected. The information database of the transformer oil and waste battery was first studied and designed based on a full-chain IoT technology [10]. The performance deterioration of the original manufacturer of hazardous waste in the power grid and its products was analyzed, and the evaluation method of the service life of each battery product in the power grid was formulated. Based on material procurement, transportation, and inspection data, the time series prediction method was used to make a historical extended prediction, and the time axis and corresponding quantity of waste oil and lead-acid batteries were

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estimated. Moreover, BP neural network, grey theory, and other forecasting model methods were used to study the forecasting model of power grid hazardous waste production.

3.6 Digital and visual display system

The time dimension ("history-present-future") display system was introduced to supply and improve the intelligent management system of the state, source, disposal direction, and other information of waste oil and battery in the virtual warehouse of hazardous waste in the power grid. Furthermore, relying on the "four-dimensional" information data analysis, the digital and visual display system scheme of power grid hazardous waste was established.

4. Conclusion

In conclusion, this article systematically describes the new type of power grid hazardous waste information management system based on the virtual warehouse. The main classification of power grid hazardous waste (waste mineral oil and waste battery) was introduced and the existing problems of hazardous waste disposal were analyzed. More importantly, the detailed implementation plan of the power grid hazardous waste management system was introduced with the aid of RFID, IoT technologies, which supported the virtual warehouse technology. This study provided a theoretical foundation and an implementation example for grid companies to establish a sustainable and reliable management system for hazardous waste disposal. Meanwhile, this work also provides new insight for grid companies to design other management models to promote the environmental protection supervision and energy green transformation works.

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