Development and Application of Triangular Main Transformer On-load Tap Changer Hoisting Equipment for Overhaul

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Abstract—On-load tap changer is an important part of transformer. It is playing an important role in voltage regulation, and its safe and stable operation affects the reliability of power supply of the power grid. The tap changer has to maintenance after a certain number of operations. In the maintenance process, there are problems such as long time consumption and low efficiency. On this basis, this paper proposes a development on the main transformer on-load tap changer hoisting equipment. It has been verified in practice that the equipment can significantly shorten the working time and improve the working efficiency under the premise of ensuring the work safety.

1. Introduction

Main transformer is one of the key equipment in substations. It is a transformer used to transmit power to the power system or the user. On-load tap changer is a switching equipment that provides constant voltage for transformers when the load changes. The tap changer changes the number of turns in the winding by switching between taps in the transformer winding. This ensures that the load current is not interrupted and the voltage ratio of the transformer is adjusted to achieve the purpose of voltage regulation [1-5].

During the operation of an on-load tap changer, it often switches the number of turns to adjust the voltage of the main transformer. In the process of turns ratio adjustment, it will cause wear on the contact part. This can increase the chance of malfunctioning of the device and even cause damage to the contacts, which can lead to the device not being able to complete its regulating work properly [6-7]. Therefore, the on-load tap changer must be overhauled when the electrical contacts have operated more than a certain number of times. The on-load tap changers of several main transformers are maintained annually. This can ensure the reliability of voltage switching and power supply and meet the needs of various customers for voltage quality [8-10].

Since the on-load tap changer is built into the main transformer body, traditional maintenance relies on a crane to hoist the on-load tap changer out of the transformer. As the crane is not easy to finely control the lifting object, it may cause wear and bruising of the on-load tap-changer contacts and components such as the equalizing ring. Damage to the equipment body can seriously affect the overall maintenance schedule [11-13]. Meanwhile, the on-load tap changer overhaul process is time-consuming and inefficient in terms of crane permits, entry and other preparatory work [14-15].

Based on the above maintenance status, this paper developed a main transformer on-load tap-changer overhaul hoisting equipment. The equipment can shorten the overhaul time and improve the efficiency on the basis of fully guaranteeing the quality of the overhaul work.

2. Analysis of the current situation

The maintenance process of the on-load tap changer is displayed in Figure 1.

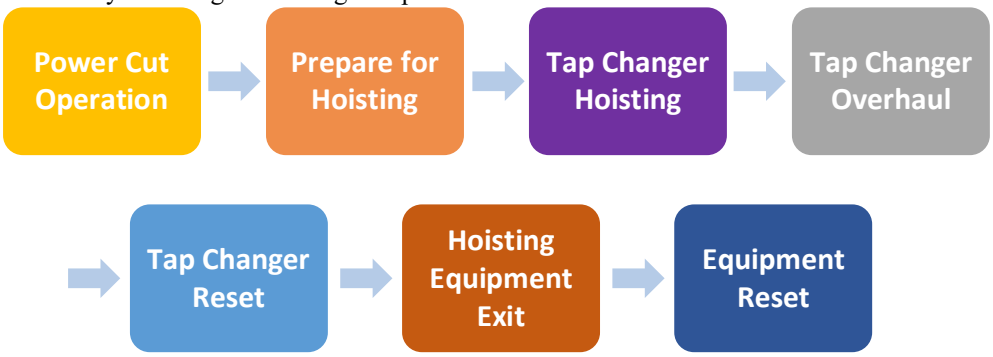

Fig.1 The maintenance process of on-load tap changer

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According to the actual situation, the maintenance process of the main transformer on-load tap changer is divided into seven parts: power cut operation, prepare for hoisting, tap changer hoisting, tap changer overhaul, tap changer reset, hoisting equipment exit, equipment reset. These seven parts take different time, and the specific time used is shown in Table 1.

Table.1 On-load tap changer maintenance time

Maintenance process	Time (minutes)	Percentage(%)
Power cut operation	77	15.5
Prepare for hoisting	241	48.4
Tap changer hoisting	12	2.4
Tap changer overhaul	95	19.1
Tap changer reset	12	2.4
Hoisting equipment exit	18	3.6
Equipment reset	43	8.6

According to the statistical results, it can be seen that the preparation time before hoisting is too long. If this process can be optimized, the overall maintenance efficiency can be greatly improved. Also, since the remaining six phases are already highly optimized, it is not possible to make them efficient. Therefore, this paper chooses to research and optimize the pre-hoisting preparation stage.

3. Develop solution

In this paper, according to the principle of stable load-bearing of triangular legs of hoisting triangle bracket and related technical requirements, a specific module decomposition scheme is proposed. The scheme divides the delta-type main transformer on-load tap changer hoisting equipment into six modules: hoisting hook, support frame, protection chain, supporting foot, segmentation legs and protection shield. Also, different options to be chosen for each module were selected for comparison, as shown in Figure 2.

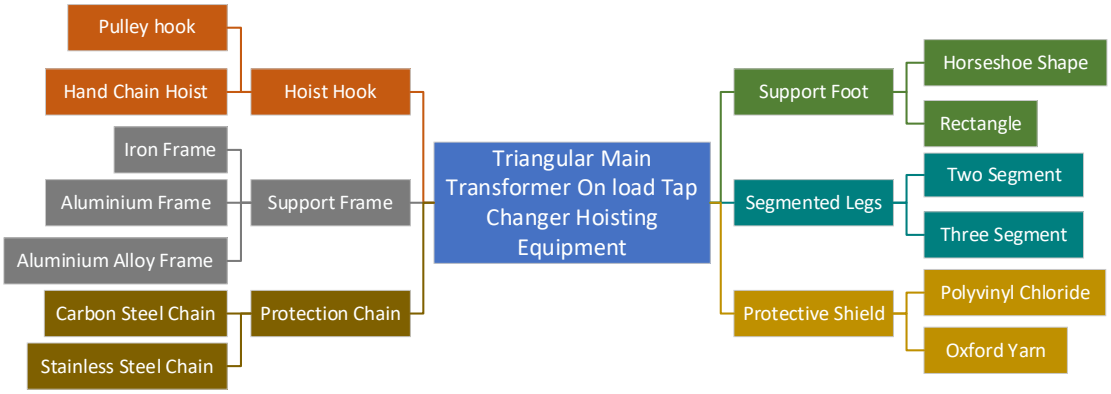


Fig.2 Triangular main variable on-load tap-changer maintenance and hoisting device

3.1. Hoisting hook module

In the selection of hoisting hook module, it is mainly based on the single installation time to compare, and after multiple test operations, the pulley hook that meets the requirements is finally selected for implementation. The comparison of hoisting hook modules is shown as figure 3(a).

3.2. Support frame module

In the selection of the support frame module, the comparison is mainly based on tensile strength conditions. After testing several test samples, the aluminum alloy with better performance was finally selected for implementation. The comparison of support frame modules is shown as figure 3(b).

3.3. Protection chain module

In the selection of protection chains, the performance is mainly based on the tensile strength of the material. After testing several test samples, the stainless steel chain with better performance was finally selected. The comparison of protection chain modules is shown as figure 3(c).

3.4. Support foot module

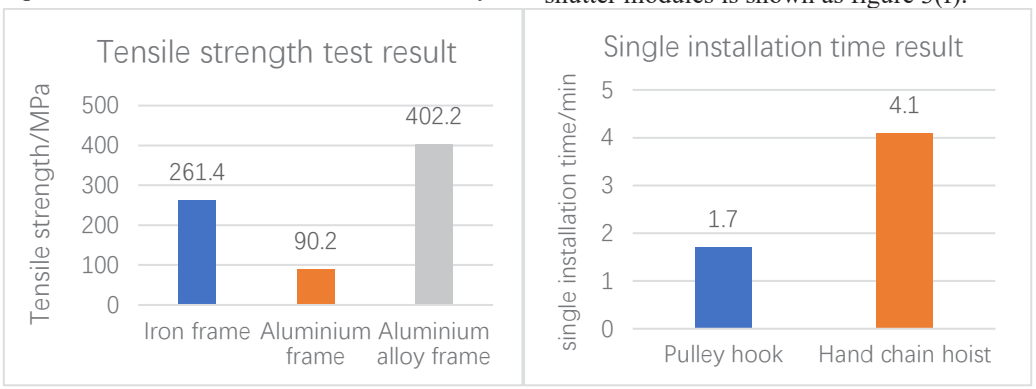
In the selection of the support foot module, the main choice is based on the effective force area of the foot. After testing several test samples, the rectangular foot was finally selected with data meeting the requirements. The comparison of support foot modules is shown as figure 3(d).

3.5. Segmented leg module

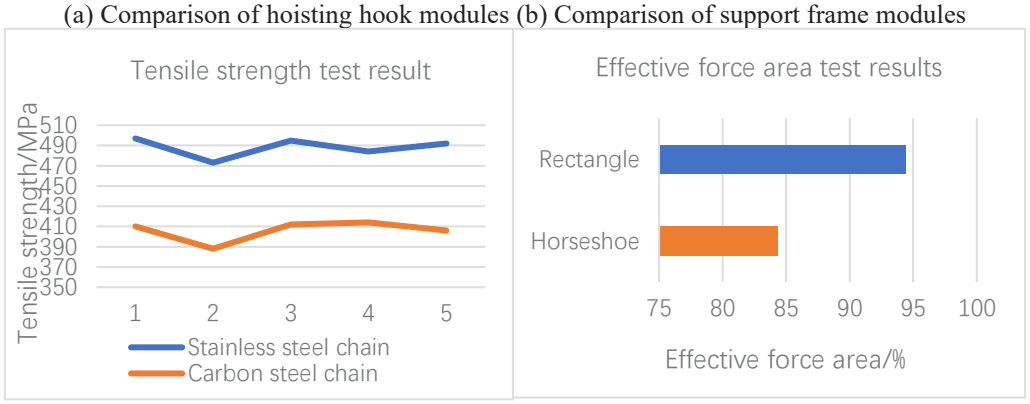
In the selection of modules for segmented legs, the main selection is based on the 100 kg shape variables. After testing several samples, the final choice was a two segment structure. The comparison of segmented leg modules is shown as figure 3(e).

3.6. Protection shutter module

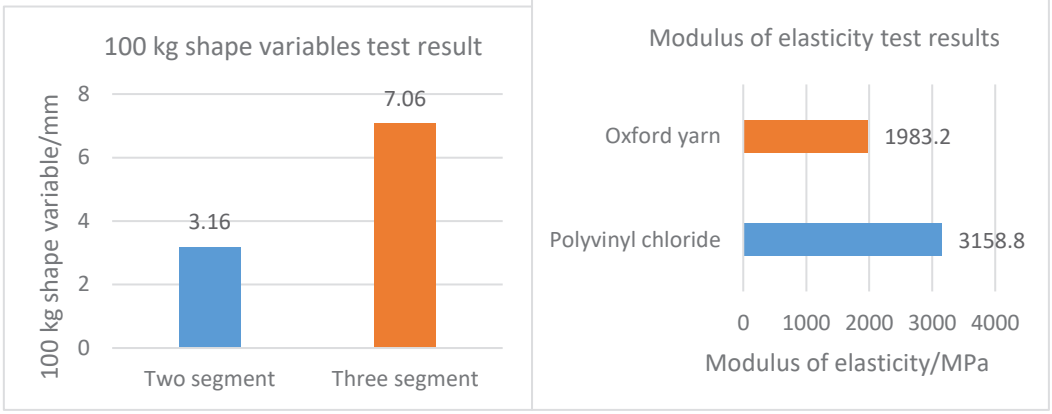
In the selection of the protection shield module, the main basis is the experimental data on the modulus of elasticity of the protection shield. After testing several test samples, polyvinyl chloride material was finally selected as the protective shield module. The comparison of protective shutter modules is shown as figure 3(f).



(a) Comparison of hoisting hook modules (b) Comparison of support frame modules



(c) Comparison of protection chain modules (d) Comparison of support foot modules



(e) Comparison of segmented leg modules (f) Comparison of protective shutter modules

Fig. 3 The options test result

3.7. Final solution determination

According to the actual needs of the site, what kind of winch is used for the pulley hook and what shape is used for the polyvinyl chloride shield are further selected. Through experimental comparison and data selection, the final scheme is shown in Figure 4.

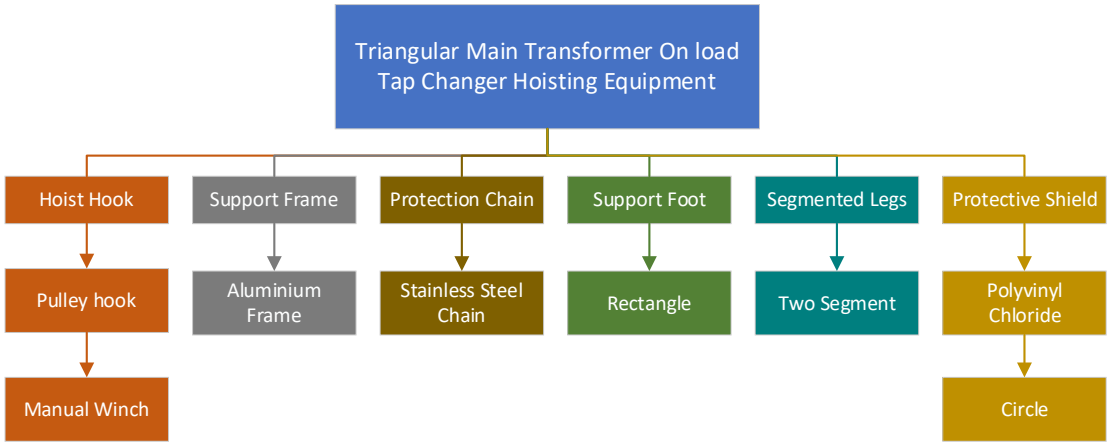


Fig.4 Final solution

4. Solution implementation

According to the selection results of the modules in the final scheme, the design and production of manual winch pulley hook, aluminum alloy support leg frame, stainless steel protective chain, rectangular support foot, two segmented leg and round PVC protective shutter were completed.

4.1. Design and production of manual winch pulley hook

This part is implemented through three parts: pulley hook drawing design, manual self-locking winch design and manual winch pulley hook physical production, which requires a hoisting speed ≤5m/min when lifting 130kg objects, and the goal is achieved after the effect inspection.

4.2. Design and production of aluminum alloy support leg frame

This part is implemented through three parts: aluminum alloy leg drawing design, aluminum alloy leg production and anti-corrosion treatment. The frame requires the thickness of the anti-corrosion coating to be ≥0.5mm, and the goal is achieved after the effect inspection.

4.3. Design and manufacture of stainless steel protective chain

This part is implemented by selecting the stainless steel chain of suitable length chain buckle, the production of stainless steel protective chain and the verification of stainless steel protective chain length. It is requiring 3m ≤chain length≤ 3.1m, and the goal is achieved after the effect inspection.

4.4. Design and production of rectangular support feet

This part is implemented through three parts: the design of the support foot drawings, the production of the support foot and the design and production of the foot anti-slip mat, which requires the critical angle of the foot anti-slip tilt to ≥ 10°, and the goal is achieved after the effect inspection.

4.5. Design and production of two segmented legs

This part is implemented through three parts: selection of appropriate type of connecting plug, design and production of connecting plug, and debugging of connection parts combination. It is requiring the adjustment time to be in place before hoisting ≤ 18min, and the goal is achieved after the effect inspection.

4.6. Design and production of round PVC protective shutters

This part is implemented through three parts: circular PVC protective shield drawing design, circular PVC protective shield production, on-site comparison and verification, and the installation time of the protective shield is required to be ≤1min, and the goal is achieved after the effect inspection.

Subsequently, the designed and produced components are combined and processed, assembled and run-in and debugged. The results of debugging are sent to the professional testing department for qualified verification. After verification, the results are operated in the actual main variable on-load tap changer maintenance work, as shown in Figure 5.

Fig.5 Triangular main transformer on-load tap changer hoisting equipment

In the subsequent maintenance work of the main transformer on-load tap changer of each substation, the tap changer maintenance is carried out by the triangular main transformer on-load tap changer hoisting equipment, and the maintenance time is greatly shortened, and the statistics are shown in Table 2.

Table.2 Maintenance time after using the developed hoisting equipment

Main transformer name	Main transformer 1	Main transformer 2	Main transformer 3	Main transformer 4	Main transformer 5
Single interval maintenance time/min	295	296	291	298	295
Average maintenance time/min	295				

Through the actual application, it can be seen that the developed hoisting equipment greatly shortened maintenance time. The maintenance time is shorted from 498min to 295min, which is 203min less than that of each main transformer before application The maintenance time effect of the main transformer on-load tap changer before and after the use of the equipment is shown in Figure 6.

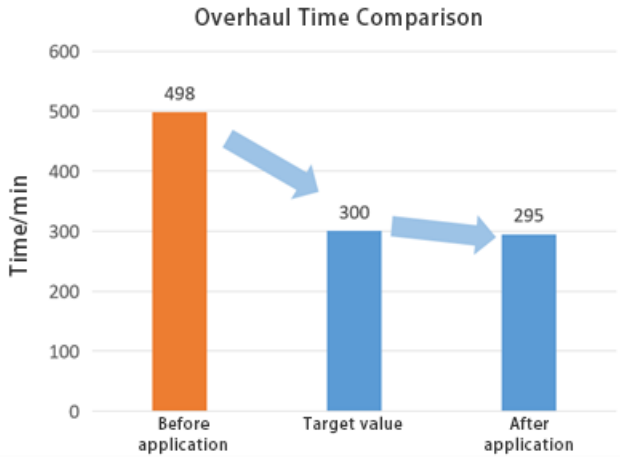


Fig.6 Comparison of maintenance time of main transformer on-load tap changer and cost.

5. Effectiveness test

5.1. Security

In order to ensure that the results are safe and reliable for use, this paper sends the device to a third-party professional testing organization for testing and certification. The test results of each data of each device are qualified. The equipment works well in practical application in the site. As certified by the relevant departments of the company, this equipment has no negative impact in terms of safety, quality, management

5.2. Economic

The application of the triangular main transformer on-load tap changer hoisting equipment improve the comprehensive maintenance efficiency of the main transformer. Meanwhile, the equipment has the advantages of convenience, safety and efficiency. The equipment saves a lot of labor and material costs and improves power supply reliability. From January 2022 to July 2022, the total investment of this project is 16,000

yuan. In September, the main transformer on-load tap changer hoisting equipment was applied to 5 main transformer on-load tap changers in several substations. The results show that the application of the equipment can significantly reduce the outage time. With the use of developed equipment, the tap changer maintenance time is greatly reduced. Based on a single important customer interval load of about 3MW, at 0.62yuan per kWh, the total additional electricity charge is 157,000yuan. After deducting the cost of activities, the project has generated economic benefits of 141,000yuan.

5.3. Promotion

The project staff hoped that the equipment could be better promoted and applied subsequently, and that the scope of promotion and calculation of economic benefits could be documented. After a statistical study of all substations under Jiaxing's jurisdiction, the team found that the developed equipment could be perfectly applied to main transformers of different voltage levels. The equipment is suitable for different manufacturers and different voltage levels of the main transformer on-load tap changer maintenance. The developed equipment has the characteristics of easy replication and wide range of promotion.

6. Conclusion

This paper conducts research on the hoisting equipment of the main transformer on-load tap changer in the substation, mainly focusing on the following three technical points:

1. Using the principle of triangle stabilization, the triangular main transformer on-load tap changer hoisting equipment is developed. The research optimizes the main transformer on-load tap changer overhaul process, reducing the overhaul process time from 498 min to 295 min.

2. By using segmented legs for hoisting, the preparation time before lifting can be reduced. At the same time, the segmented legs can effectively adjust the lifting height in the field, which is convenient for operation. The equipment can be quickly disassembled and stored after hoisting, making it easy for the operator to carry.

3. The bottom of the triangular main transformer on-load tap changer hoisting equipment adopts a protective shield, which can effectively prevent rainwater, dust and even work tools from falling in the tap-changer. This prevents dirt from clogging the oil circuit and reduces the failure rate of main transformer.

The triangular main transformer on-load ta -changer hoisting equipment can effectively shorten the maintenance time of the on-load tap changer. This provides a strong guarantee for the quality and reliability of power supply to the grid.

Acknowledgments

This work was financially supported by the Mass Innovation Project of State Grid Jiaxing Power Supply Company (5211JX22000Q).

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