Research on New Scheme of Electric Chassis Vehicle for Switchgear Breaker Handcart

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Abstract. The electric chassis vehicle as a swing-in and swing-out unit of a 10kV centrally installed switchgear vacuum circuit breaker plays a vital role. This article introduces an electric chassis vehicle for 10kV centrally installed switchgear. This electric chassis has all the interlocking functions of the traditional chassis vehicle, and adopts high-precision ball screw, modular integral reduction motor and gear transmission, and the clutch is at the front of the beam. The bottom of the chassis is equipped with guide bearings, which are used in conjunction with special guide plates. This electric mechanism has the characteristics of high precision, low noise, smooth operation, and operation of electric and manual without manual switching, which can be directly operated. This technology can reliably improve the comprehensive technologies such as the reliability and mechanical life of electric chassis vehicle, and improve the reliability of the existing switchgear sequence control operation technology, making it possible to apply one-key sequence control operation, reducing the amount of personnel on-site operation workload and improving operation and maintenance efficiency, and reduce personal safety risks.

1. Introduction

Air-insulated metal-enclosed handcart switchgear (hereinafter referred to as switchgear) equipment is the largest amount of power equipment in the power system, and also the equipment with the largest workload and the most concentrated operation in operation [1]. At present, the total number of 40.5kV and below switchgear equipment in the State Grid Corporation of China system alone is nearly 800,000 units. The switchgear is switched between running, hot standby, cold standby, and maintenance. It usually uses the traditional manual operation mode, which has a large workload, long time consumption, low efficiency, and some operations need to be carried out on site, there are certain personal safety risks [2]. Studying the "one-key sequence control" technology of substation switching operation can solve the above problems to a great extent [3]. "One-key sequence control" technology is to apply advanced automatic control technology, sensing and Internet of things technology, automatic state recognition and intelligent judgment technology to the traditional substation switching operation[4], and the traditional manual filling of the operation ticket is mainly cumbersome, repetitive and error-prone operation mode is changed into pre-manufacturing of operation project software, modular construction of operation content, automatic identification of equipment status, intelligent verification of anti-misoperation interlocking, one-click operation task start, and automatic
sequential execution of operation process, which can help the operator to perform complex operation tasks, transform the traditional operation ticket into a task ticket, and realize the complex operation single-key completion. The entire operation process does not require additional manual intervention or operation, which can greatly reduce invalid labor and greatly reduce the risk of misoperation. Significantly improve efficiency and effectiveness, shorten the power outage time caused by manual operation, and improve the power supply reliability of the substation.

According to State Grid Corporation's "Power Safety Work Regulations (Substation Section)" 7.3.3 [5]: In order to achieve "one-key sequence control", the circuit breaker needs to be able to automatically swing in and out, and it is required that the electric chassis vehicle needs to be able to manually swing out in case of failure, not stuck, and it also requires the circuit breaker to be shaken in and out smoothly and reliably, and has a long life. In addition, it also requires the electric chassis vehicle to have an intelligent protection function. Therefore, one of the most important points to realize the "one-key sequence control" technology of the switchgear is to change the manual chassis vehicle into an electric chassis vehicle to improve the reliability and mechanical life of the electric chassis vehicle, so as to meet the "one-key sequence control" technology’s logic requirements.

In the operation of switchgears in traditional substations, the swing-in and swing-out of circuit breakers rely on manual swing-in and swing-out, which is time-consuming, labor-intensive, and inefficient. However, the current intelligent substations use electric chassis vehicle with a motor and chain transmission method, and the screw is made of hard aluminum and has no guiding function. This type of electric chassis vehicle has a short life span of the hard aluminum screw, the chain is easy to break, and the screw is easy to catch, which makes the chassis unable to withdraw. The clutch is installed on the motor, in the stuck state of the working position, the clutch cannot be disengaged, the chassis cannot be withdrawn, and there is a grounding copper bar at the bottom of the chassis, which is easy to tilt the circuit breaker in and out, reducing the life of the chassis and the circuit breaker. Although the existing schemes already have the basic conditions for sequence control operation, there are defects such as the inability to withdraw from operation and the short operating life, and the advantages of high security and high efficiency of sequence operation are not utilized at all. Therefore, it is of great significance to study a new scheme of circuit breaker handcart electric chassis.

2. Design scheme
In order to solve the above problems, this paper proposes a new solution. As shown in Fig.1, the clutch is installed in front of the crossbeam of the chassis, and the clutch is realized by inserting and pulling out the handle. The clutch mode becomes the key of the manual and electric independent system of the electric chassis vehicle. At the same time, this kind of clutch will not be stuck, preventing the phenomenon that the circuit breaker handcart can not get out of the cabinet; the gear transmission is used between the motor and the screw rod, the transmission force is large and stable, and there will be no chain breakage and stuck phenomenon; the rod is made of 40Gr material after heat treatment, and the ball is added to the end seat to ensure smooth transmission, less wear and long life; two guide bearings are added to the bottom of the chassis, the guide bearing and the partition mounted on the middle cabinet The use of the guide plate can ensure that the circuit breaker is guided correctly, smoothly and with a long life during the swing-in and swing-out process; the design of a special electric chassis vehicle controller can realize the control and protection of the electric chassis vehicle, and truly realize the electric chassis vehicle safe and reliable, easy to operate and long life.
Based on this electric chassis solution, physical research and development, type tests and substation operations have been carried out, all of which have achieved good results. This electric chassis solution can reliably improve the operating state of the equipment and improve the reliability of the existing switchgear sequence control operation technology, making the application sequence control operation possible to reduce the workload of personnel on-site operations, improve operation and maintenance efficiency, and reduce personal safety risks. Through the use of this electric chassis vehicle, the technical bottleneck of the "one-key sequence control" electric chassis vehicle has hidden dangers to be broken. After the substation switchgear equipment is implemented in the whole station sequence control operation, it will greatly reduce the labor intensity of the operation and maintenance personnel and save the cost of the switching operation. Taking a 110kV substation as an example, the annual operation of the switchgear is about 50 times per year. Each operation is calculated according to 4 people and 1 vehicle shift. The annual operating cost of the switch is about 55,000 yuan. If the sequence control operation is widely used, the overall economic benefit will be considerable.

2.1. Working principle of clutch
The working principle of clutch is as shown in Fig.2. After the circuit breaker is pushed into the centrally installed switchgear, the locking plate on the crossbeam of chassis vehicle is inserted into the fixed slot of the centrally installed switchgear, the crossbeam is fixed and can not move, and the chassis 1 and the fixed crossbeam 4 of chassis vehicle are connected together through the screw rod.
During manual operation, the clutch (Fig.1-A) on the chassis is installed in the front middle position of the crossbeam 4, and the gear sleeve (Fig.2-11) is fixed to the screw rod (Fig.1-2) with an elastic pin. The manual operation process is, when inserting the handle into the screw, first press the pressure sleeve (Fig.2-12) in. At this time, the teeth on the gear sleeve and the teeth on the pressure sleeve (Fig.2-12) are disengaged, the screw rod can rotate with the handle, and the motor (Fig.1-17) is connected with the screw nut through the gear transmission, the transmission speed ratio is 5000/50, and the screw nut (Fig.1-6) cannot rotate when the motor is not energized, which is equivalent to fixing the screw nut on the chassis (Fig.1-1), so when the handle turns the screw rod, the interaction of the screw rod and the screw nut pushes the chassis and the circuit breaker forward. When the circuit breaker swings out, the principle is the same. The clutch mounted on the front is disengaged and the screw rod can be used. The handle rotates, and the screw nut does not move. Turn the screw rod, through the interaction of the screw rod and screw nut, the chassis and the circuit breaker are driven to swing out from the working position to the test position together.

This kind of clutch realizes the clutch clutch by inserting and pulling out the handle, thereby realizing a completely independent operating system for manual operation and electric operation, and the clutch jamming phenomenon does not occur between manual and electric switching, which solves the chain transmission chassis In the vehicle, the manual and electric cannot be switched because the clutch cannot be disengaged on the motor.

2.2. Design of screw nut and screw rod

Gear transmission is adopted between the screw nut and the motor, with large power transmission, large torque and stability. Especially for large current circuit breakers, due to the large contact force, when the plum blossom contact and the static contact are just engaged, a huge resistance is generated. The chain transmission is easy to break the chain, and the broken chain is easy to catch the screw, which can not pull the circuit breaker to the test position. The problem can be solved by gear transmission.

As shown in Fig.3, the screw rod of the conventional chassis is made of hard aluminum, and the screw nut is made of brass. Due to the low strength of the hard aluminum, the screw rod is easy to
wear when the chassis is subjected to a strong force. If it is worn to a certain extent, the screw rod cannot drive the circuit breaker. The life of the aluminum screw rod electric chassis is only more than 500 times, and the life of the chassis for high current circuit breakers may be lower. The screw rod of the new electric chassis vehicle is processed with 40Gr material and processed by heat treatment, and the hardness reaches HRC40, as shown in Fig.4, which ensures that the screw rod is not easy to wear. The screw nut is made of bronze, which has self-lubricating effect and the number of screw nut teeth reaches 6, which also guarantees the long service life and wear resistance of the screw nut. Balls are added in the middle of the base of the fixed screw rod to ensure smooth transmission of the screw rod. This design of the electric chassis vehicle has a large transmission force (after verification, the chassis vehicle has a thrust of 4500N), which solves the problem that the screw rod is not strong enough and distorted when the high current circuit breaker is equipped with the cabinet.

2.3. Stability improvement of handcart swing in and swing out

The chassis vehicle of the circuit breaker is equipped with grounding copper bar. The friction between the grounding copper bar and the grounding bar causes great resistance, which causes the circuit breaker to deviate to one side in the process of pushing and shaking out, and even causes the misalignment between the plum contact and the static contact, resulting in the collision of the plum contact. In order to solve this situation, this article takes the use of guide bearings and guide plates to ensure that the fixed electric chassis does not shift when entering and exiting. Install two guide bearings on the chassis vehicle, as shown in Fig.5; install a guide plate on the middle partition of the center cabinet, as shown in Fig.6. The outer diameter of the bearing is 21.98mm, the guide groove size of the guide plate is 22.1±0.1mm, and the maximum angle of inclination is 0.2°.
2.4. Design of electric chassis controller

The electric handcart controller can realize the control and protection of the electric handcart, and has two operation modes of remote and local. The controller includes functions such as segmented overcurrent protection and soft start. The soft start can ensure that the speed of the chassis vehicle gradually increases when leaving the test position, and can prevent the internal structure from vibrating due to the excessive speed at the instant of startup. The segmented overcurrent protection can be set according to the rocking characteristics of the circuit breaker. The controller can brake the motor immediately when the driving motor of the electric handcart is blocked (such as the installation is not in place or the mechanism is stuck in the working position and the shaking out working position). While the protection conditions are met, the motor is braked immediately, and the motor is driven in the reverse direction to remove the jammed vehicle state, and does not affect the manual shaking of the chassis into the working position.

When the handcart is in the non-working position and the non-testing position, the motor is only allowed to shake out. Only when all the interlock signals are satisfied and the controller is not faulty, will the ready light of the controller light up, and does the controller be allowed to operate. When the locked-in process occurs during the roll-in process, the current operation is stopped and the motor is driven back to the test position. During the return process, the locked-up process occurs again to stop the motor operation; when the locked-out process occurs during the roll-out process, the current operation is stopped and the motor is driven in the reverse direction run.

The electric chassis vehicle is used in conjunction with a dedicated electric chassis vehicle controller to achieve the following intelligent protection functions:

1. The electric chassis vehicle has manual operation functions.
2. The clutch for electric chassis vehicle realizes the separation of electric operation and manual operation.
3. The electric chassis vehicle should have manual priority function.
4. The electric chassis is equipped with an intelligent control device, and it has the functions of fault return and alarm during the propulsion process. If a fault occurs during the exit, the chassis will remain motionless and give an alarm.
5. The electric chassis vehicle has remote / local operation functions and can be switched freely.
6. The motor controller of the electric chassis vehicle shall have over-current protection function.
7. The electric chassis controller has reset, self-check and emergency stop functions.
8. The electric chassis controller has RS485 communication function.
9. The chassis is equipped with guide bearings and cooperates with the positioning guide plate to improve the guiding and positioning functions.

3. Effectiveness verification test

The functional and stability tests are carried out on the electric chassis. The circuit breaker handcart equipped with the electric chassis is installed in the switch cabinet. According to the factory inspection rules of relevant products, the manual commissioning is carried out first, and the electric
commissioning is carried out after the commissioning is qualified. The locked rotor test and life running in test are carried out after the electric commissioning is qualified. During the test, the motor current is tested to verify the control The protection function of the device.

Test procedure:

(1) Adjust the circuit breaker to the position of no energy storage, opening and test, and connect with the controller; after the controller is powered on, all signal lights display normally. At this time, the circuit breaker is in the opening, UN stored energy and test position;

(2) Click the "swing in" button of the controller, the circuit breaker will normally move forward to the working position, and the controller signal lamp will switch to "working"; click the "swing out" button, the circuit breaker will normally exit to the test position, without jamming, and the controller signal lamp will switch to "test";

(3) An obstacle is arranged on the guide plate of the middle partition board of the middle cabinet to block the rotation of the circuit breaker. When the circuit breaker operates to the locked rotor position, the controller will give a normal alarm, then the circuit breaker will return to the test position, press the reset button, the controller will return to normal, remove the abnormal locked rotor, and the circuit breaker will swing in normally;

(4) Repeat step (1) and (2) to carry out 7000 life tests on the electric chassis vehicle, and check the parts that are easy to wear every 500 times. After the tests, the mechanical stability of the electric chassis vehicle is good, and the mechanical life is more than 7000 times. The data record is shown in table 1.

| Life times  | 85%Ue | 110%Ue | 100%Ue | Conclusion | Time  | Remarks                          |
|------------|-------|--------|--------|------------|-------|----------------------------------|
| 1~500      | 50times | 50times | 100times | up to standard | April 9th | add lubricating grease to screw rod |
| 501~1000   | 50times | 50times | 100times | up to standard | April 10th |                                   |
| 1001~1500  | 50times | 50times | 100times | up to standard | April 11th |                                   |
| 1501~2000  | 50times | 50times | 100times | up to standard | April 12th |                                   |
| 2001~2500  | 50times | 50times | 100times | up to standard | April 15th | add lubricating grease to screw rod |
| 2501~3000  | 50times | 50times | 100times | up to standard | April 16th |                                   |
| 3001~3500  | 50times | 50times | 100times | up to standard | April 17th |                                   |
| 3501~4000  | 50times | 50times | 100times | up to standard | April 18th | add lubricating grease to screw rod |
| 4001~4500  | 50times | 50times | 100times | up to standard | April 19th |                                   |
| 4501~5000  | 50times | 50times | 100times | up to standard | April 22th | add lubricating grease to screw rod |
| 5001~5500  | 50times | 50times | 100times | up to standard | April 23th |                                   |
| 5501~6000  | 50times | 50times | 100times | up to standard | April 24th |                                   |
| 6001~6500  | 50times | 50times | 100times | up to standard | April 26th |                                   |
| 6501~7000  | 50times | 50times | 100times | up to standard | April 27th | end                              |
4. Conclusion and prospect
This paper studies and designs a new scheme for the electric chassis and controller of the circuit breaker handcart. By redesigning the clutch clutch mode, improving the structural materials of the motor, screw nut, and screw rod, improving the variable transmission mode, and adding guide bearings and guide plates, design a special controller to realize electric chassis control and protection functions, effectively improve the reliability, strength and mechanical life of electric chassis vehicle. Through the locked-rotation test and mechanical life test of the electric chassis, the test shows that the locked-rotor function is good and the mechanical life has reached more than 7,000 times, which proves the effectiveness and reliability of the electric chassis. This technology can reliably improve the comprehensive technology of electric chassis vehicles, improve the reliability of the existing switchgear sequence control operation technology, reduce the workload of personnel on-site operations, improve the efficiency of operation and maintenance, and reduce the risk of personal safety. In the follow-up research work, the reliability of the electric chassis can be further judged by recording each time the handcart is shaken in and out, and statistical analysis is performed.

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