On issue of reconstruction at central distribution substation by example of one of plants of Chelyabinsk region

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Abstract. The article considers the issues of increasing the reliability and economy of the distribution substation. The result is found due to the reconstruction of the central distribution substation and one of the plants of Chelyabinsk region. The reasons for the reconstruction are explained. A comparison of oil and vacuum circuit breakers is made. The advantages of vacuum circuit breakers are shown. Alternative replacement of cables is offered. The basic technical characteristics of the cable brands are shown. The results of reconstruction are proved.

1. Introduction

Machine-building production is the main branch of the world production [1, 7]. The world machine-building complex accounts for about 35% of the cost of all products manufactured in the world. In the Russian Federation, the share of machine building accounts for 20% of the country's total industrial complex (Figure 1) [2-6].

Distribution substations are an integral part of any machine-building enterprise. Therefore, the quality of the output production of any plants directly depends on the level of their equipment and the efficiency of functioning [1, 6].

To date, most of the equipment of many substations put into operation dozens of years ago exhausted its operational life. Therefore, the reconstruction of enterprises is an urgent task and requires a solution; it includes the replacement of auxiliary equipment and cable products.

In the article, some results of reconstruction are reviewed, and recommendations are given by the example of the central distribution substation of one of the plants.

2. The supposed changes

A part of the plant is powered by a central distribution substation (CDS). The switchgear of unilateral maintenance (SUM) was reconstructed: several connections were added; oil circuit breakers of the VMG-10 series are replaced with vacuum ones of BB/TEL type; instead of the protection made on electromechanical relays, microprocessor relay protection blocks (hereinafter referred to as MRPB) are installed.

This decision was made due to the fact that existing cameras have been in operation for 34 years and during this time the equipment has completely exhausted its operational life.

In addition, it is proposed to replace the cables feeding the busbar sections of the transformer substation (TS). This is due to the prolonged operation of the supply cables, so in the case of unsatisfactory indicators during the preventive tests, their replacement is required [3, 7]. The cables
supplying the TS substation are laid in earthen trenches, therefore instead of existing ones it was proposed to lay in the PvBP brand. PvBP cables are designed for laying in the ground (trenches) with low, medium and high corrosive activity. The cables supplying the substation TP are laid in earth trenches; therefore instead of existing ones, it is proposed to lay cables with XLPE insulation of APvBP and PvBP grades. The choice of cables with copper conductors is due to the greater capacity.

**Machine-building in Russia**

![Pie chart showing distribution of machine building in Russia]

3. **Comparison of switches of different types**

Oil switches for such parameters as total shut-off time, own switching time, switching wear resistance, non-uniformity of contact closure, current consumption by the drive are much inferior to vacuum switches.

Vacuum switches BB/TEL are intended for work in complete switchgears and stationary single-sided maintenance cabinets of internal and external installation of voltage class up to 10 kV three-phase alternating current 50 Hz for systems with isolated and earthed neutral.

Vacuum switches BB/TEL are switching devices of new generation. At the heart of the constructive solution of the switch, there is the use of phase-by-phase electromagnetic drives with a "magnetic latch" mechanically connected by a common shaft.

The main types of circuit breakers and their brief description are given in Table 1 [8-10].

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**Figure 1.** A structure of machine building in Russia.
Table 1. A comparison of existing disconnect switches

| Type of disconnect switch | Arc extinguishing method | Advantages | Disadvantages | Appliance |
|---------------------------|--------------------------|------------|---------------|-----------|
| Oily                      | Pairs of gas; the contacts are in the container with oil. The oil in these tanks mainly serves as arc-quenching medium, and only partly, it is the insulation between the open contacts. | 1. Simplicity  
2. Low cost  
3. High breaking capacity | Tank:  
1. Explosion and fire hazard.  
2. Large oil reserves are needed.  
3. Use only outdoors.  
4. Continuous monitoring of oil level is required. | Nowadays, tank switches are not produced; low-oil switches are widely used in closed and open distribution devices of all voltages. |
| Air                       | Under pressure of 2-4 MPa in the blow channels (nozzles) which are constructively in conjunction with the final part of the contacts of the arc chute form the blowing system. | 1. High breaking capacity.  
2. Fire safety.  
3. High speed.  
4. The ability to commute short-circuit currents with a large percentage of the aperiodic component (up to the commutation of direct current circuits). | 1. Increased air for ventilation during rain.  
2. The need for electrical heating in switchgears and control cabinets of poles at a temperature of less than 41 °F.  
3. High cost of components.  
4. High sensitivity to the speed of the recovering voltage in case of unsuccessful faults. | Used in high voltage distribution devices for indoor and outdoor installation. |
| Vacuum                    | When the contacts are opened in vacuum, immediately after the first passage of the current in the arc through zero, the insulation is restored and the arc does not light up again. At the moment of opening contacts in the vacuum gap, the commutated current initiates the occurrence of an electric discharge - a vacuum arc, the existence of which is maintained by a metal evaporating from the contact surface into the vacuum gap. | 1. High speed.  
2. Full explosion and fire safety.  
3. Ecological cleanliness.  
4. Wide temperature range (from 392 to -94 °F).  
5. Reliability.  
6. Minimum operating costs.  
7. The minimum overall dimensions.  
8. Increased resistance to shock and vibration loads.  
9. High wear resistance in commutation of rated currents and load currents.  
10. Arbitrary operating position of the vacuum. | 1. Relatively small rated currents and tripping currents.  
2. The possibility of switching overvoltages when switching off small inductive currents.  
3. Small resource arcing devices to disconnect short-circuit currents. | In recent years there has been an intensive use of vacuum switches in the voltage range of 6-35 kV to create vacuum contactors, load switches, vacuum switches for switchgear. |
| SF6 circuit breaker        | As well as in air circuit breakers with intensive cooling of the arc by the flow of gas. Unlike air switches, when the arc is extinguished, the gas escapes through the nozzle not into the atmosphere, but into the closed chamber volume filled with SF6 gas at a small excess pressure. | 1. Ease of the arc chute  
2. High resistance to the effects of electric current.  
3. Reliability at a relatively low cost;  
4. Reduced noise level. | 1. Not environmentally friendly - SF6 gas causes a "greenhouse effect";  
2. A danger to human health. | Currently, in foreign power systems, most of the high-voltage switches are used SF6-type. Unfortunately, in the domestic energy sector, switches of this type have not yet found wide application. |
The main advantages of vacuum circuit breakers, which determine their wide application, are:
- high wear resistance in commutation of rated currents and rated breaking currents. The number of cut-offs of rated currents by a vacuum switch (hereinafter referred to as VV) without replacement of the vacuum arc chute (hereinafter referred to as VDC) is 10,000 – 20,000; the number of trips of the rated breaking current is 20,000 – 200,000, which is 10-20 times higher than the corresponding parameters of low-oil switches;
- a sharp decrease in operating costs compared to low-oil switches. Maintenance BB/TEL is reduced to greasing of the mechanism and a drive, a check of deterioration of contacts on labels once in 5 years or through 5,000 - 10,000 cycles “inclusion - switching-off”;
- full explosion and fire safety and the ability to work in aggressive environments;
- a wide range of ambient temperatures, in which the work of the VCD is possible;
- increased resistance to shock and vibration loads due to small weight and compact design of the device;
- an arbitrary working position and small dimensions, which allows the creation of various layouts of switchgears;
- noiselessness, cleanliness, serviceability due to low energy release in the arc and the absence of gas emissions when switching off short-circuit currents;
- absence of environmental pollution;
- high reliability and safety of operation, shortening of installation time.

Use for installation of vacuum switches is offered in existing SUM cells. To do this, a set of adaptation of the vacuum switch to the cell of this series is used, which is supplied with the switch.

At present, relay protection based on microprocessor units is widely used. The use of digital terminals makes it possible to increase the sensitivity of the protection and significantly reduce the time of their operation, which, combined with high reliability, can significantly reduce the amount of damage from interruptions in power supply [9, 10].

4. Cable production
The existing cables of the brands PvBP and APvBP, offered as replacement, are made using interfacial filling from a chemical chalk-filled unvulcanized rubber compound. The use of filling from the non-vulcanized mixture in the cables makes it possible to give them a round shape and to facilitate the conditions for cutting the cables during installation, and due to the additional inclusion of the core in the center of the cable core, moisture resistance of the cables is ensured.

Design features of cables of PvBP and APvBP grades, on the basis of which it is planned to perform the reconstruction, are given in Table 2.

It should also be noted that many important characteristics depend on the material and the structure of the cable cores. In particular, the copper conductors of the cable have less electrical resistance than the aluminum wires, therefore, the power losses in such cables (for the same cross section and current value) will be lower and the current carrying capacity will be higher (with the same cross section). In addition, copper wires have better mechanical properties than aluminum ones. One can also say about multi-wire veins in comparison with single-wire wires. Such veins (copper and multiwire) perceive the bending and tensile forces affecting the cable during operation better. However, a cable with copper cores is more expensive and has a greater mass than a cable with aluminum conductors.
| Type of cable  | PvBP – 35 kV                        | APvBP 35 kV                        |
|---------------|------------------------------------|------------------------------------|
| Current-carrying conductor | cooper                             | aluminic                           |
|                | round multiwire compacted          |                                    |
| Conductor screen | from extruded electrically conductive cross-linked polyethylene |                                    |
| Insulation     | of cross-linked polyethylene       |                                    |
| Insulation screen | extruded from an electrically conductive peroxide crosslinkable polyethylene composition. | from extruded electrically conductive cross-linked polyethylene |
|                | Combined screen:                   |                                    |
|                | - a layer superimposed by a winding made of electrically conductive paper or an electrically conductive polymer tape with a thickness of at least 0.2 mm; | A screen made of copper wires fastened with a copper tape: |
|                | - wiring from copper wires with a nominal diameter of 0.7-2.0 mm, over which a copper tape with a thickness of not less than 0.1 mm is spirally superimposed. The minimum width of the tape is 8 mm. | - section not less than 16 sq. mm for cables with cross-section of conductors 35-120 sq. mm, |
|                | Standing                           |                                    |
|                | shielded by copper wires, round conductors are twisted into the core around a bundle of unvulcanized rubber or polyvinyl chloride plastic. | central filling of harness. |
| Interfacial filling | from a non-vulcanized rubber compound or a highly filled polyvinyl chloride resin | from a non-vulcanized rubber compound or a highly filled polyvinyl chloride resin |
| Inner shell    | from polyethylene                  |                                    |
| Armor          | of two steel zinc-coated tapes superimposed so that the upper band overlaps the gaps between the edges of the lower band. |                                    |
| Appliance      | Cables are designed for transmission and distribution of electrical energy in stationary installations for a rated alternating voltage of 35 kV with a nominal frequency of 50 Hz for networks with earthed and isolated neutral; For laying in the ground (in trenches), with the exception of abrasive and subsidence soils; Are intended for operation at a lining in the ground irrespective of a degree of corrosion activity of soils. It is allowed to lay these cables in air, incl. in cable structures, provided that additional fire protection measures are provided, for example, the application of fire retardant coatings. Cables are designed for laying on the tracks without limiting the difference in levels. Class of fire hazard according to the classification of airbags is 248-97 O2.7.1.3. | Cables are used for stationary laying in cable structures and production facilities. |
5. Conclusion
At the moment, due to the increase in capacity at the plant, there is a reconstruction of the plant substations, in particular the Russian Electrical Code, where a replacement for the BB/TEL cell type has already been made. The relay protection has been replaced by an open switchgear-35, 110 kV, a new 35 kV cell with an oil transformer S = 16000 kVA has been installed in comparison with the old cell transformer S = 6300 kVA. A program for the incorporation of a new 35 kV cell is being prepared and is being agreed.

The cables feeding the substation bus sections are recommended to be replaced by the brands PvBP and APVBP. This will ensure the best anti-corrosion and conductive properties, and losses will decrease. The proposed reconstruction will affect the reliability of the electricity supply system as a whole and reduce operating costs.

6. Acknowledgments
The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0011.

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