

**SC A Transmission & distribution equipment**  
**PS 2 / Lifetime management of transmission & distribution equipment**

**Overvoltages research in switching modes of cable and mixed overhead-cable lines, power transformers, shunt reactors and capacitor banks of 110-750 kV and development of a controlled switching device for the above electrical equipment**

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Switching of electrical equipment can be accompanied by unacceptably high overvoltages, throws of switched currents which are comparable in magnitude with short-circuit currents, and the appearance of aperiodic components in the switched current with parameters [magnitude and duration] exceeding the breaking possibilities of switching equipment.

Despite the short duration, overvoltages are characterized by a high ratio to the operating voltage and can be dangerous both for the main electrical equipment and for secondary circuits.

The presence of an aperiodic component in the breaking current can lead to the impossibility of interrupting such a current during the operation of the circuit breaker delaying the breaking process and, as a consequence, to a severe emergency of the circuit breaker.

Methods and means of controlled switching of power equipment, non-reacted and reacted power lines, shunt reactors, capacitor banks and power transformers have been widely introducing in the world energy sector over the last years.

In the last 14 years CIGRE WG A3.07 issued a number of basic documents concerning the mentioned subject, and also prepared the extensive review of application of the controlled switching in a world practice.

Research works carried out in Russia on the study of overvoltage and the development of domestic controlled switching device (CSD) allowed us to offer a number of technical solutions to ensure:

- versatility of the proposed device for SF<sub>6</sub> circuit breakers of different companies, different voltage classes and different years of production;
- the possibility of using the device with both individual phase and three-phase control circuit breakers;
- availability of control algorithms for switching various types of electrical equipment [capacitor banks, shunt reactors, power transformers] and power lines [overhead, cable and mixed overhead-cable] realized in one device;

- the presence of the diagnostic function of 110-750 kV circuit breakers on the results of monitoring of normal and emergency modes (switching life, mechanical life, synchronism of drives, etc.);
- universal interfaces of information exchange both for the internal purposes of the device and for external circuits of SCADA supporting IEC 61850;
- the possibility of embedding into the "digital substation" technology to control the operation of electrical equipment at substations 110-750 kV;
- reducing the cost of the developed device by 15-25% compared to imported analogues due to the versatility and the use of domestic production capabilities.

The following works have been carried out under the mentioned research:

- the efficiency test of the developed structural scheme and algorithm of CSD with the use of specially designed "CSD algorithms testing real-time emulator";
- switch resource saving estimation during operation in individual phase and three-phase (with phase interchange) switching modes in comparison with the three-phase switching without CSD.

#### **Basic switching scenarios:**

1) switching on by a command from a dispatcher power lines without reactors, capacitor banks (the "star with neutral" connection) under voltage and under load, series capacitor banks and power transformers under load without arc between contacts of the circuit breaker;

2) switching on by a command from a dispatcher power lines without reactors, capacitor banks (the "star with neutral" connection) under voltage and under load, series capacitor banks and power transformers under load with the minimum time of arc burning between contacts of the circuit breaker;

3) switching on by a command from a dispatcher capacitor banks ("star without neutral" or "delta" connection);

4) switching on by a command from a dispatcher power lines with reactors (including auto-reclosing) under voltage, shunt reactors;

5) switching on by a command from a dispatcher unloaded power transformers;

6) switching off by a command from a dispatcher power lines without reactors, capacitor banks and series capacitor banks;

7) switching off by a command from a dispatcher power lines with reactors, shunt reactors and power transformers;

8) switching off by a command from a dispatcher capacitor banks ("star without neutral" or "delta" connection);

9) transfer of the switch-off command from relay protection to the circuit breaker without time delay.

Testing of the algorithms was carried out with the simulation of various external conditions:

- Drive temperature change from -40°C to +40°C
- Deviation of the network frequency 50 Hz from 40 Hz to 60 Hz
- Supply voltage change of circuit breaker control circuits from 70 % to 110 %
- Change of gas temperature in the circuit breaker from -40°C to +70°C
- Circuit breaker poles with different RDDS
- Invalid scatter of the circuit breaker poles operation time

The test showed the proper operation of the proposed device while implementing these switching scenarios under the changing external conditions.

#### **Circuit breaker switching life saving**

The essence of the research was to determine the number of the circuit breaker switch-off operations of nominal currents (4 kA) and short circuit currents (50 kA) resulting in the switching life consumption over the specified threshold for each of the modes described above.

Using the controlled switching technology when the rated currents are switched off the circuit breaker switching life saving up to 23 % can be achieved at three-phase control with phase interchange and up to 17 times at individual phase control.

In the case of switching off heavy currents up to 50 kA the advantage of the controlled switching is significantly increased, the switching life saving can reach up to 34 % at three-phase control with phase interchange, and up to 40 times at individual phase control.

The carried out researches allow to raise the question of the controlled switching expediency both at planned switching of the equipment and at breaking short circuit currents at least on power lines.