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Short-Circiut Current Limiter for Electric Network Based on the Magnetic-Coupled Reactor and Fast-Operating Switch

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SUMMARY

The progress of electrical power systems causes the steady growth of short-circuit (SC) currents in the network and substations. Sometimes SC currents can exceed the permissible levels of the standard electric equipment such as the circuit breakers, power and measurement transformers etc. Thus the main problem for high voltage network is the fast limitation of SC current including the transient component i.e. limiting actuation at the first current rise. So the speed of the limiter should be not more than 1-2 ms. The possible decision of the problem is described.

The new device for deep limitation of SC currents is realized on the base of the magnetic-coupled reactor and the fast-operating switch. This short-circuit current limiter (SCCL) corresponds the step-down transformer with primary winding connected in series to transmission line or between bus sections and the secondary winding shunted by the normally closed switch. The fast-operating switch consists of two parallel components: the main conductor with special charge installed in the explosion–proof insulating tube and the fuse installed in the box filled by the quartz sand. The fuse parameters determine the form of the current decreasing curve and the level of the overvoltage which takes place during the current limitation process.

Actually SCCL devicies with rated voltage 20 kV, 110 kV and 220 kV are developed and the drafts of magnetic-coupled reactors based on the transformers with and without magnetic limb are carried out.

KEYWORDS

Sort-circuit current limiter, magnetic-coupled reactor, fast-operating switch.

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The main reasons of short circuits currents growth

Electric power industry development – the building of new power stations and enlargement of existing ones, increasing of transmission capacity of electric networks, all that causes a steady growth of short circuit (SC) currents. Maximum levels of SC currents take place on the buses of large power stations and on the buses of substations with powerful electromagnetic coupling at high density of electric networks and generating sources.

The reasons of SC currents growth are the followings:

- increase of the generation capacities connected in parallel operation in power system;
- growth of power consumption density and loads where synchronous motors are used;
- tendency to increase the reliability of power supply systems at modernization and development of electric networks.

In networks of 220 kV and more, on a number of objects of UES of Russia, the interrupting capacity of the installed circuit breakers does not correspond to the existing levels of SC currents.

To make the interrupting capacity of the circuit breakers in compliance with the steady growing levels of SC currents can be carried out in two ways:

- by enhancement of existing circuit breakers or by replacing them with more powerful;
- by taking the particular measures limiting SC currents.

The interrupting capacity of HV circuit breakers is limited because of constructive reasons and under modern conditions don’t exceed 63 кА.

The development of electric networks is accompanied with the increase of their sectioning depth. In nearest outlook that will lead to decrease in reliability of the grid operation if the special equipment is not applied. This equipment should to relieve an electric network only in emergency operation when short circuit occurs.

The consequences caused by the growth of SC currents levels:

- damages of windings of the generators, synchronous compensators, transformers, reactors etc;
- damages of switching devices (circuit breakers and disconnectors);
- fires in power objects.

Possible measures to avoid the negative consequences from SC currents

- Development of electric machines and devices which can withstand the higher loadings (mechanical and thermal) without damages. *This way is expensive and ineffective as it does not eliminate the problem of SC currents growth.*
- Division (sectioning) of electric network in several independent power districts. The disadvantage of such stationary sectioning of the network is slackness capacity of the network redundancy and relevant decrease of reliability of the electrical power supply to consumers. *Therefore the depth of stationary sectioning should be limited.*
- Introduction in the network scheme of the elements which limit the values of SC currents and the time of their existence (SC currents interruption). *This is the most perspective decisio*n but it demands the coordination of the current limiter parameters and protection relay and automation (PRA) devices to provide the sensitivity and selectivity of PRA operation.

The usage of the fixed current limiting reactors causes the voltage drop and additional active losses therefore the possibility of their application and the depth of the current limitation are limited particularly in the high voltage systems.

At the moment the various types of current limiting devices are developed. They are based on power electronics application, use of high-temperature superconductivity, explosive elements, DC links etc.

General technical requirements to the short circuit current limiter (SCCL)

- Limiting the surge and steady-state SC current with action time no more than 0.002-0.003 sec.
- Maintenance on possible higher level of voltage in the network in normal conditions.
- Implementation of automatic operation and recovery after elimination of SC current. The recovery time and the connection circuit of current limiter should provide the possibility of the autoreclosing procedure.
- Not to affect essentially on a normal operating mode of network.
- Not to bring essential nonlinear distortions in network mode parameters, especially at its normal operation mode.
- To have the stable parameters at change of the network configuration.
- Limiting level of SC current should provide the functioning of all exiting network elements.
- To have the high operational characteristics from the point of view of safety and reliability.

The structure of new device for deep limitation of SC currents is realized on the base of the magnetic-coupled reactor and the fast-operating switch (FOS) is shown on Fig.1.

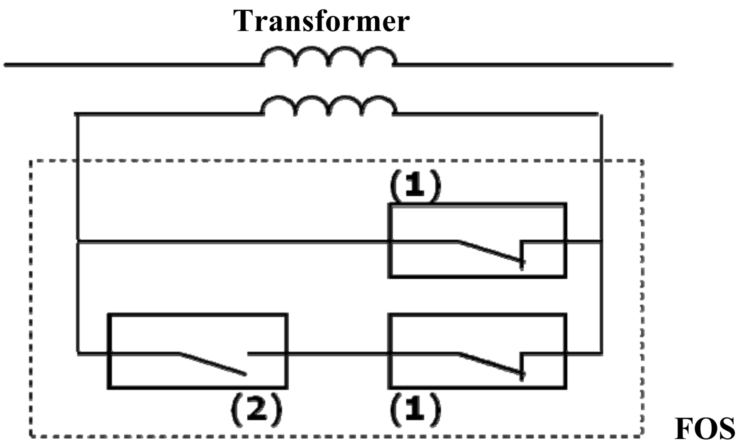


Fig.1. Current limiter based on the magnetic-coupled reactor and fast-operating switch

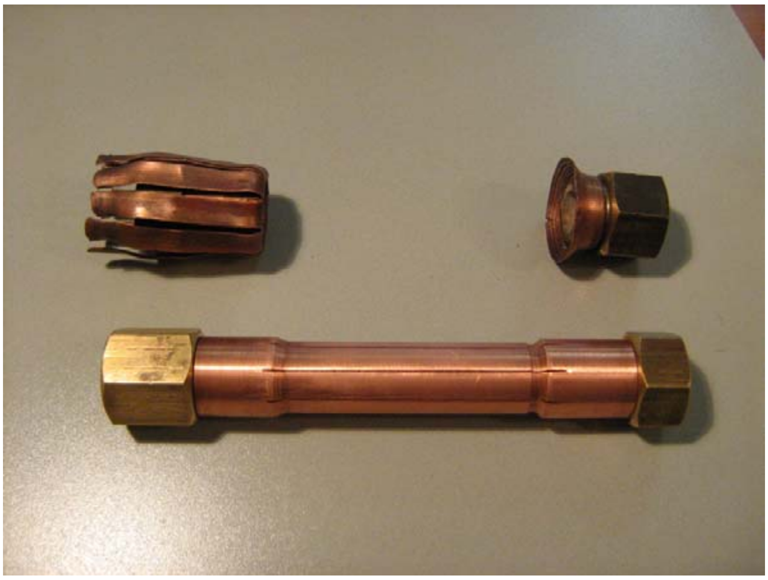
Special transformer (magnetic-coupled reactor) with switching device of explosive type in secondary winding connects in series to transmission line or between bus sections and has small impedance in normal mode. When the short circuit springs up it automatically increases the impedance and provides the deep limiting of surge and steady state SC currents.
The important part of the current limiter is fast operating switch which consists of three basic elements:

- fast operating interrupting device (1);
- fuse connected in parallel;
- fast operating circuit closing device (2),

and the control unit with current transformer.

The normally closed (1) and normally opened (2) contacts are located in the special unattended cartridge. The quantity of FOS in one current limiter is defined by maintenance conditions. It is expedient to establish in each current limiter two cartridges each of them contains four FOSs.

a)



b)

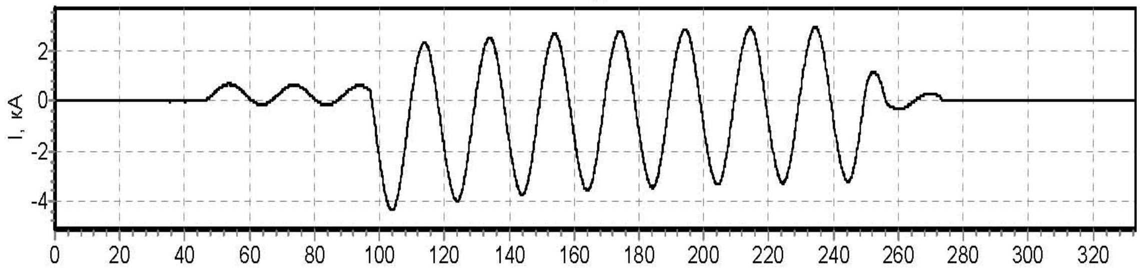
Fig. 2. Switching devices

a) Current bus of fast operating circuit closing device after operation,
b) Current bus of fast operating interrupting device before and after the operation

In normal mode the current runs through the copper bus located in the cartridge of the switching device. The current in fuse is about 0.1% from the current transmitting through the current limiter.

During SC the control unit, at certain instant value of current, produce the signal which provide the exploder action and destruction of the copper bus then the current completely goes to the fuse that practically excludes commutation overvoltage. After SC interrupting PRA produces the command of current limiter state recovery, its control unit generates the signal for actuation of fast operating circuit closing device and thus the limiter comes back in initial condition.

The prototype of this SCCL with rated voltage 20 kV was successfully tested a real power supply system.
The tests have confirmed the working capacity of the currents limiter inductive type with a switching element. The current tail occurs on the first half-cycle within 1 ms (fig. 3-4).



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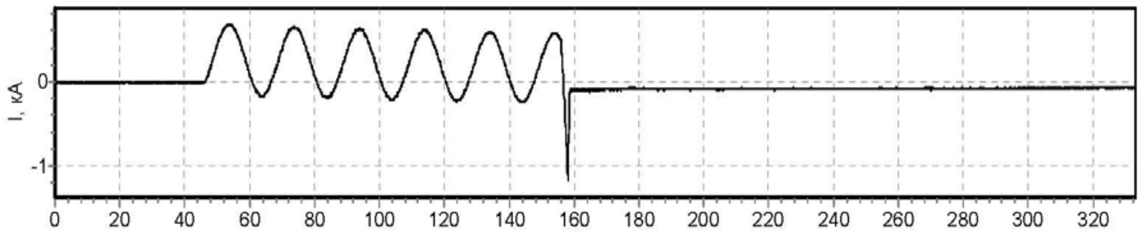

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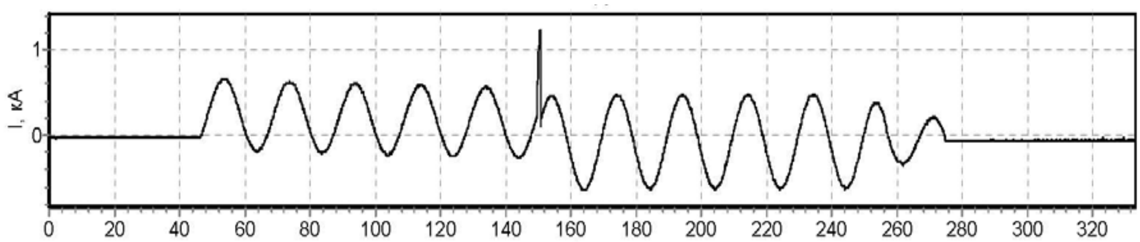
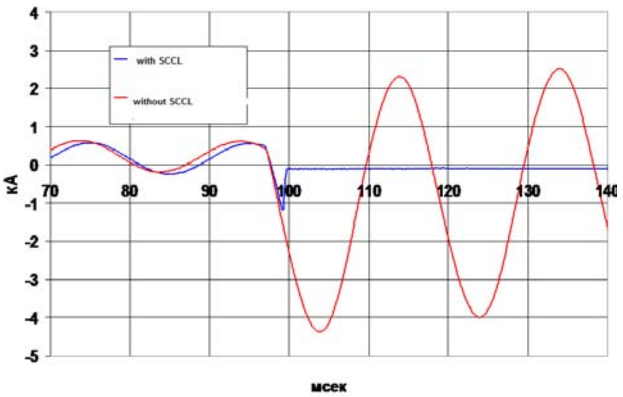
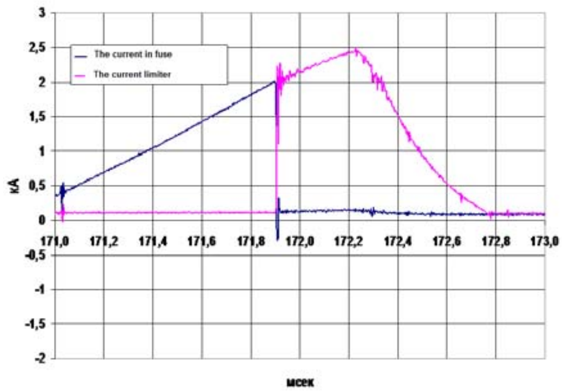


c)

Fig. 3. Oscillograms of short circuit processes during the tests
a) without SCCL, b) with SCCL without additional reactor,
c) with SCCL and additional reactor





a) b)

Fig. 4. The transient processes of SCCL
The time of FOS operation is 0,3 ms, current decay time is 0,5 ms.
a) Load current, b) SCCL current.

Actually SCCL devices with rated voltage 20 kV and 110 kV are developed and the drafts of magnetic-coupled reactors based on the transformers with and without magnetic limb are carried out. The device for 220 kV is now being elaborated. The transformer without magnetic limb is designed for the current limitation in the transmission lines and the transformer with magnetic limb is designed for the deep current limitation on the substation bus.

Technical parameters for electromagnetic part of SCCL for the lines of 110 kV ROMК-110 type (magnetic system with limb)

Parameters	Value
Voltage of primary winding, kV	110
Voltage of secondary winding, kV	35
Continuous operating current, A	1000
Reactance in transformer mode (secondary winding is closed), Ohm	3,2
Reactance in reactor mode (secondary winding is opened), Ohm	15000
Steady state SC current in reactor mode, no more, A	5
Steady state SC current in transformer mode, A	17100
Total losses in nominal conditions, kW	110+15%
Gross weight, kg	175000
Transport weight, kg	150000
Gross weight of oil, kg	23000
Dimensions (LxBxH), mm: - in transport conditions - ready-assembled	 5500×3400×4200 6200×6000×6500

Technical parameters for electromagnetic part of SCCL for the lines of 110 kV ROMК-110 type (magnetic system without limb)

Parameters	Value
Voltage of primary winding, kV	110
Voltage of secondary winding, kV	35
Continuous operating current, A	1000
Reactance in transformer mode (secondary winding is closed), Ohm	3,2
Reactance in reactor mode (secondary winding is opened), Ohm	12,6
Steady state SC current in reactor mode, no more, A	5000
Steady state SC current in transformer mode, A	17100
Total losses in nominal conditions, kW	110+15%
Gross weight, kg	130000
Transport weight, kg	110000
Gross weight of oil, kg	20000
Dimensions (LxBxH), mm: - in transport conditions - ready-assembled	 4500×3200×4200 6000×5000×6500

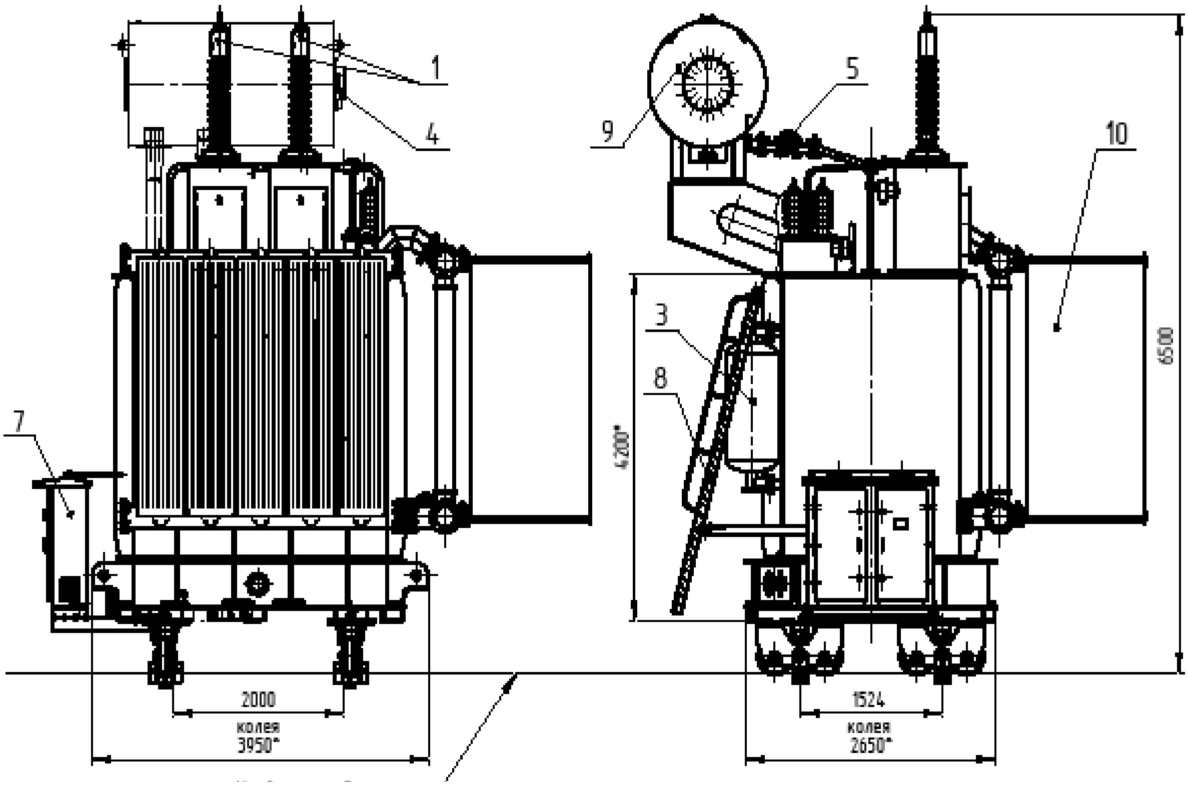


Fig.5. The drawing of electromagnetic part of SCCL for the line of 110 kV ROMK-110 type (magnetic system without limb)

Conclusion

Application of the current limiter on the base of the magnetic-coupled reactor and the fast-operating switch is the most effective from the technical and economical points of view as compared with another types of current limiters.

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