

MAGNETICALLY CONTROLLED SHUNT REACTORS





RELIABLE PARTNER
RELIABLE EQUIPMENT



CONTENT:

3

1. Magnetically Controlled Shunt Reactors (MCSRs) - New Type of FACTS Device.....	4
2. MCSR Performance Features.....	6
3. MCSR Field of Application.....	7
4. Principle of Operation.....	8
5. Prospective MCSR Types.....	10
6. MCSR Complex Structure.....	12
7. MCSR Single-Line Flow Chart.....	14
8. MCSR Electric Circuit Diagram 220–500 kV.....	15
9. MCSR Electric Circuit Diagram 110 kV.....	16
10. MCSR-Based Static VAR Compensators.....	17
11. MCSR Operation Experience at Substations of Industrial Consumers.....	22
12. MCSR Operation in Distribution Networks.....	24
13. MCSR as a Solution for a Full-Scale Voltage Stabilization in Transmission Networks.....	27
14. MCSR Operation on Long Distance High Voltage Transits	28
15. MCSR History.....	30
16. MCSR Reference List.....	32



MAGNETICALLY CONTROLLED SHUNT REACTORS (MCSR_s) – NEW TYPE OF FACTS DEVICES

Flexible alternating current transmission systems (FACTS) devices are used for the dynamic control of voltage, impedance and phase angle of high voltage AC lines. FACTS devices provide strategic benefits for improved transmission system management and operation efficiency through better utilization of existing transmission assets; increased transmission system reliability and availability; increased grid stability as well as increased quality of supply. The need for more efficient electricity systems management has given impulse to innovative technologies in power generation and transmission. Worldwide transmission systems are undergoing continuous changes and restructuring. They are becoming more heavily loaded and are being operated in ways not initially forecasted. Transmission systems must be flexible to react to more diverse generation and load patterns. In addition, the economical utilization of transmission system assets is very important for utilities to remain competitive and to survive. Flexible AC Transmission Systems (FACTS) is a technology which meets these requirements. It significantly changes the way transmission systems are developed and controlled together with improvements in asset utilization, system flexibility and system performance.

A magnetically controlled shunt reactor (MCSR) is a new type of FACTS devices which starting from the 1990s is widely used for voltage stabilization and reactive power control in transmission and distribution networks and at the level of industrial consumers. Numerous advantages typical of magnetically controlled transformer equipment allow MCSRs to keep the leading position among other compensation devices. Main competitive advantages of MCSRs are a robust design similar to the conventional transformer design, high operational safety, optimal technical and economical characteristics, easy maintenance and significantly lower price.





Equipped with series capacitor banks MCSR's function as static var compensators (SVC). Unlike a standard SVC which consists of an interconnection transformer, reactors and a thyristor valve (100% of SVC rated capacity) a MCSR is a specifically transformer device, the windings of which act as a SVC reactor while a saturable core acts as a back-to-back thyristor valve. As a result three power elements are replaced with only one.

Field operation and maintenance of MCSR's do not require additional training of maintenance staff or specific operation conditions, i.e. deionized water cooling of thyristor valves and indoor installation. MCSR's can be directly, without using a step-up transformer, connected to high voltage (HV) busbars. This additional advantage makes it possible for MCSR's to provide a full regulating range at voltage levels where regulation is needed according to the network operations requirements.

The high quality of customized MCSR's designs has been totally proved by a decade of successful field operations. Even if only one MCSR is installed at a key substation, continuous automatic control and optimum voltages support for several distribution substations in a large network can be provided. Repair and maintenance costs of transformer and switching equipment used for voltage regulation can be significantly reduced.

MCSR PERFORMANCE FEATURES

6

A magnetically controlled shunt reactor is a three-phase static device operating on the principle of continuous regulation of inductive reactance. MCSRs are designed for automatic voltage stabilization as well as for compensation and regulation of reactive power flows. The use of MCSRs allows to:

- avoid daily and seasonal voltage oscillations in electric networks;
- improve the quality of electric energy;
- optimize and automatize power system operations procedures; rapidly and efficiently respond to changes of electrical parameters by remote control of a MCSR set point from a SCADA/EMS terminal of the relevant Dispatch Center;
- significantly reduce energy losses during transmission and distribution;
- significantly improve network stability;
- improve maintenance conditions of electrical equipment by eliminating the number of switchings of non-regulated reactive power compensation devices;
- increase transfer capability of HV lines and provide secure automatic voltage control when active power flows are close to the thermal or stability limits;
- avoid voltage collapses after network incidents (e.g., load rejections, generator and line outages, etc.);
- provide favorable voltage conditions for operation of power generators.



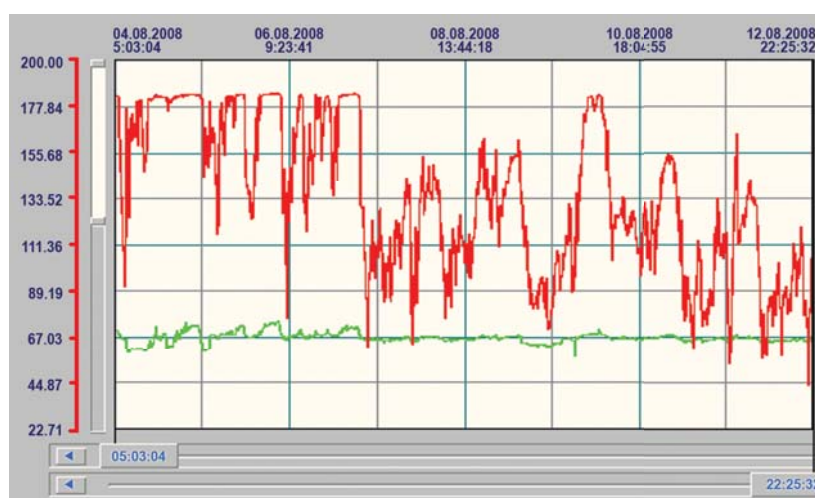


MCSR FIELD OF APPLICATION

7

Based on their advantages and operation experience, MCSRs can be used in power grids including but not limited to the following:

- networks which sustain significant daily or/and seasonal fluctuations in electricity consumption;
- networks with worn-out switching and transformer equipment, which is regularly used for voltage stabilization;
- networks which include long transmission lines prone to frequent changes of loads or power directions;
- networks distributing electric energy to consumers that are highly sensitive to voltage oscillations;
- networks experiencing excess losses of electric energy;
- networks having voltage profiles under which power generators can not operate within permissible reactive power ranges.

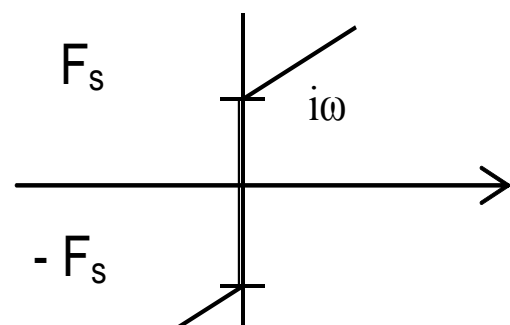
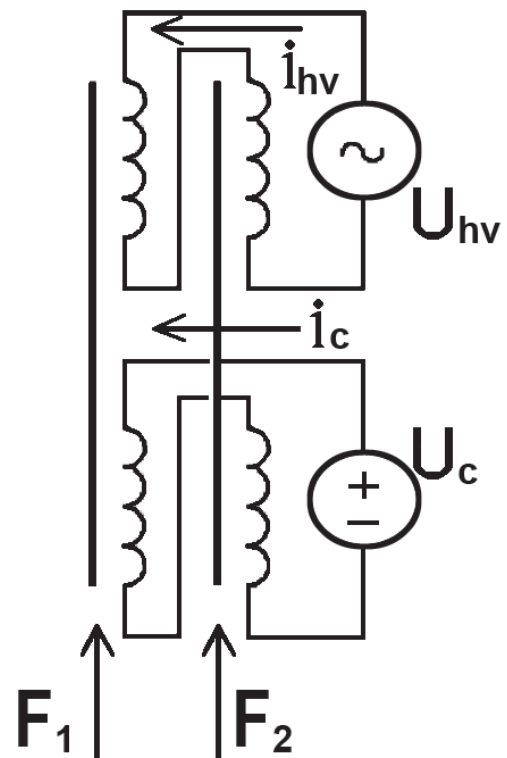


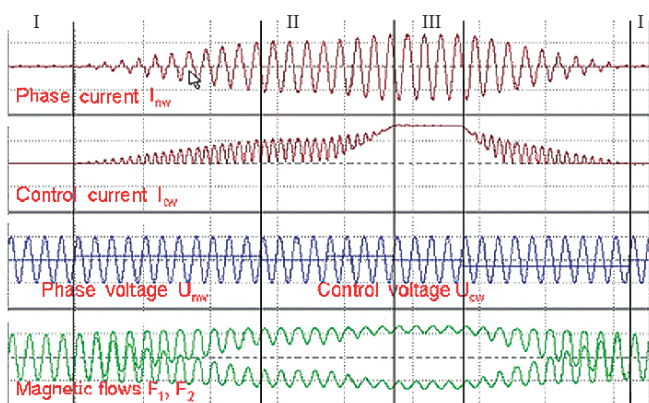
PRINCIPLE OF OPERATION

8

A MCSR is a semiconductor switch transformer device, based on the principle of alternate high saturation of each magnetic core. The magnetic system of each phase includes a control winding and a high-voltage winding. Both windings are placed on two solid cores. When a regulated DC voltage source is connected to the control winding a DC magnetic bias flux appears in the core. The alternating magnetic flux of the HV-winding overlays with the bias flux produced by the DC voltage source and a resulting magnetic flux moves to the saturation range of the MCSR core. Saturation of the MCSR core causes an inductive current flow in the HV-winding. As magnitude of energy in the control system changes, the magnitude of the inductive current in the HV-winding changes respectively. Finally, it causes increasing or decreasing of reactive power consumed by the MCSR.

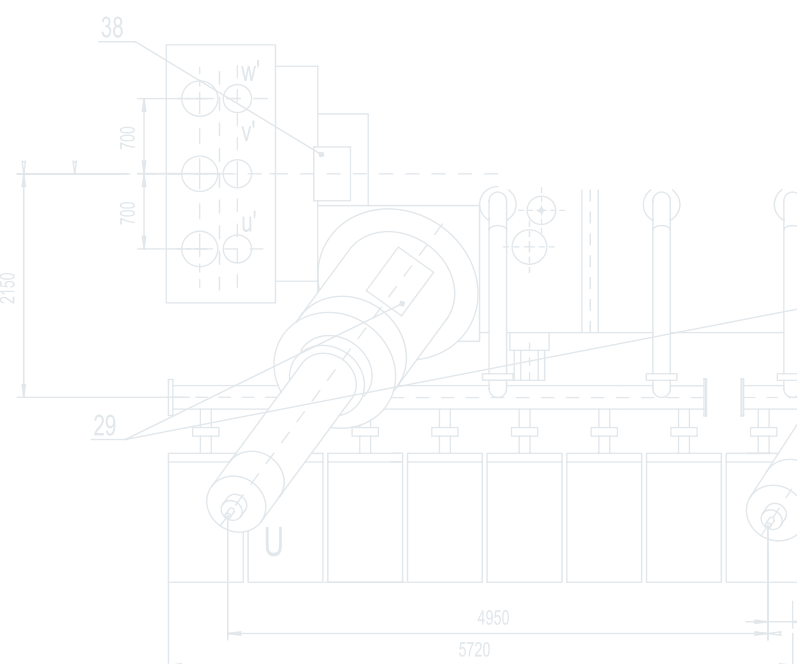
The DC voltage source which produces current in the control winding is fed by a compensating winding of the MCSR. Rectification of the compensation winding alternative current is provided by a small-power thyristor converter. The magnitude of the inductive current in the HV-winding is regulated according to the proportional principle. It means that thyristors' operating angle is defined according to the difference between the MCSR voltage set point and the actual voltage of the bus the MCSR is connected to. In order to achieve a quick change of the MCSR loading from one quasi-steady state to another a super excitation circuit is provided.





MCSRs are designed to allow any required rates of power changes. But the optimum balance between the MCSR's operation speed and the rated capacity of a magnetic bias system was defined during MCSR operation. The recommended time of MCSR loading/unloading is within 0,3-1s. Depending upon the Client's requirements MCSRs can be adjusted so as to either stabilize voltage level or keep the rate of the consumed reactive power or consumed current at a constant level.

Similar to non-regulated reactors magnetically controlled shunt reactors can be of two types: busbar MCSRs and linear MCSRs. Proceeding from the type or upon the Client's request a MCSR design may provide for an additional element to ensure preliminary biasing of magnetic system and subsequent instantaneous loading up to the nominal capacity directly after switching to the network. As any transformer device, MCSRs allow continuous overloading up to 120-130% of rated current and can also be shortly overloaded up to 200%. MCSRs can, if necessary, operate as standard non-regulated reactors having all their functional capabilities including arc extinction during auto reclosing.



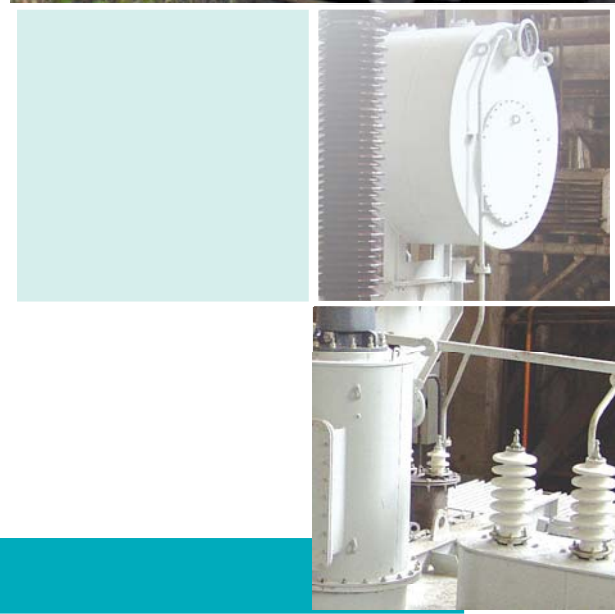
PROSPECTIVE MCSR TYPES

10

In the 1990-s, in cooperation with engineering departments, dispatch centers, system operators from several countries which provided numerous technical data and expertise, ZTR designed and put into production some prospective types of MCSR. At the designing and manufacture of ZTR controlled shunt reactors, the patented technical solutions authored by A.M. Bryantsev, Doctor of TS, Professor, Russia, are employed. Currently, ZTR designers continue working on other types of reactors of different capacity and voltage level. A customized MCSR can be designed and manufactured during 6-9 months including the preparation of design documentation.

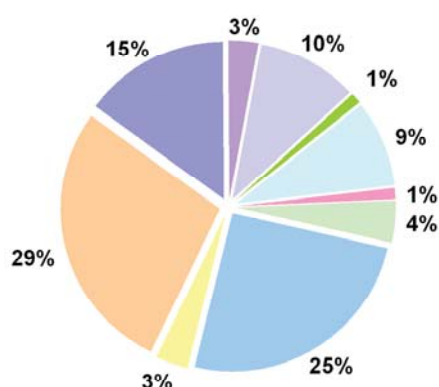
MCSR rated parameters

Type	Rated capacity, kVAr	Rated voltage, kV	Rated current, A
MCSR 25 MVar, 35 kV	25000	38,5 (40,5)	375
MCSR 25 MVar, 110 kV	25000	121 (126)	119
MCSR 63 MVar, 110 kV	63000	121 (126)	300
MCSR 25 MVar, 220 kV	25000	242 (252)	60
MCSR 60 MVar, 220 kV	60000	242 (252)	143
MCSR 63 MVar, 220 kV	63000	242 (252)	151
MCSR 100 MVar, 220 kV	100000	242 (252)	239
MCSR 180 MVar, 330 kV	180000	347 (363)	300
MCSR 100 MVar, 400 kV	100000	420 (420)	138
MCSR 180 MVar, 500 kV	180000	525 (550)	198
MCSR 180 MVar, 500 kV	3x60000	525 (550)	198





Installed capacity of
commissioned MCSR

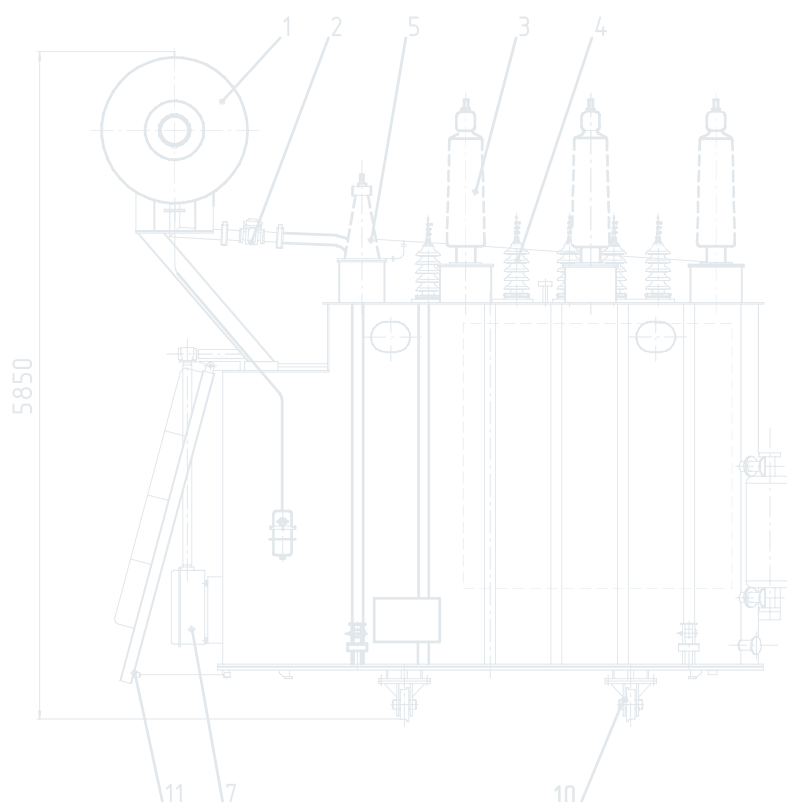


- MCSR 25 MVar, 35 kV
- MCSR 25 MVar, 110 kV
- MCSR 63 MVar, 110 kV
- MCSR 180 MVar, 330 kV
- MCSR 60 MVar, 220 kV
- MCSR 63 MVar, 220 kV
- MCSR 100 MVar, 220 kV
- MCSR 100 MVar, 400 kV
- MCSR 60 MVar, 500 kV
(three-phase MCSR 180 MVar, 500 kV)
- MCSR 180 MVar, 500 kV

The geography and scope of ZTR projects is steadily growing.

Compared to 2001 when only few magnetically controlled reactors were installed in electric networks of the Russian Federation, 90 MCSRs have been delivered to Clients' substations in the Russian Federation, Angola, Belarus, Lithuania and Kazakhstan.

Total installed capacity of MCSRs manufactured by ZTR is over 6000 MVar.





MCSR COMPLEX STRUCTURE

12

A MCSR complex consists of:

- electromagnetic part of a three-phase or single-phase reactor;
- magnetizing system;
- automatic control system.

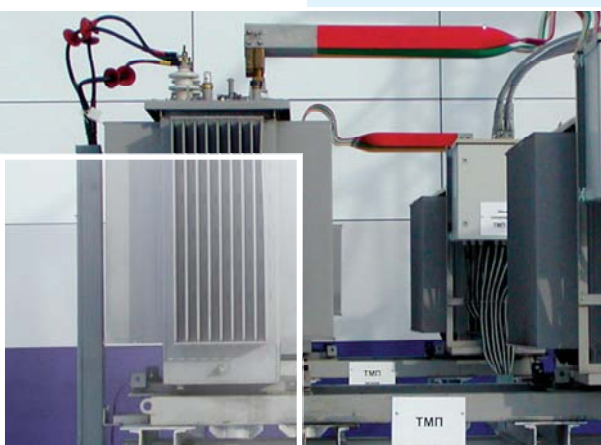
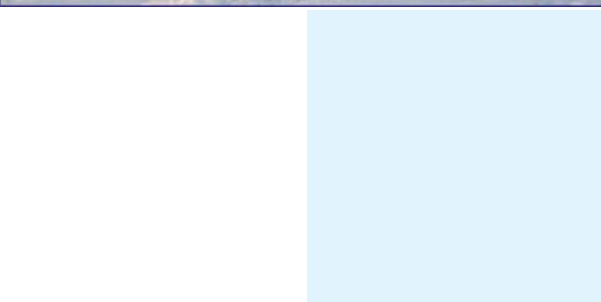
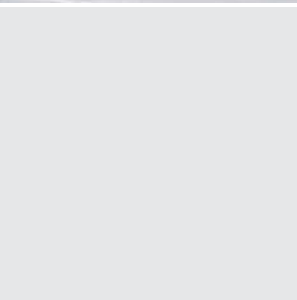
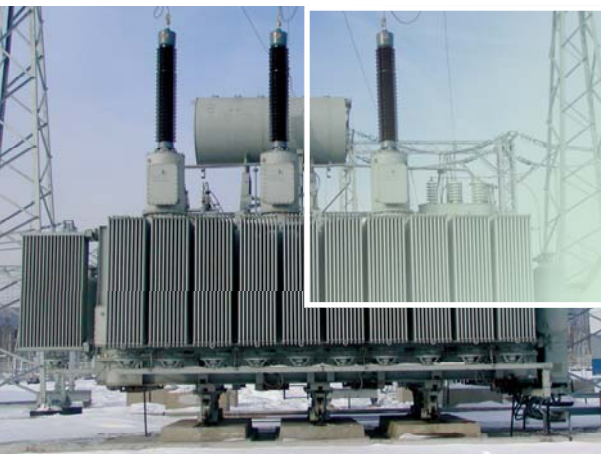
Upon the Client's request a MCSR can include the following additional elements:

- a reserve phase of a single-phase reactor;
- an earthing reactor;
- a monitoring system to control the condition of HV bushings insulation of dangerous oil dissolved gases, moisture content, winding and oil temperature; and to process control instruments signals and protective apparatus monitoring signals.
- a fire fighting system.

An electromagnetic system is the main power element of any magnetically controlled shunt reactor. The electromagnetic system consists of a HV winding which is connected directly to the electric network, a compensation winding and a control winding. In some designs the compensation and control windings are designed as a single winding. The HV winding is used for consumption of reactive power from the network while the control winding is responsible for magnetic biasing of a MCSR core.

The compensation winding feeds a DC voltage source and loops inside the three-aliquot harmonics.



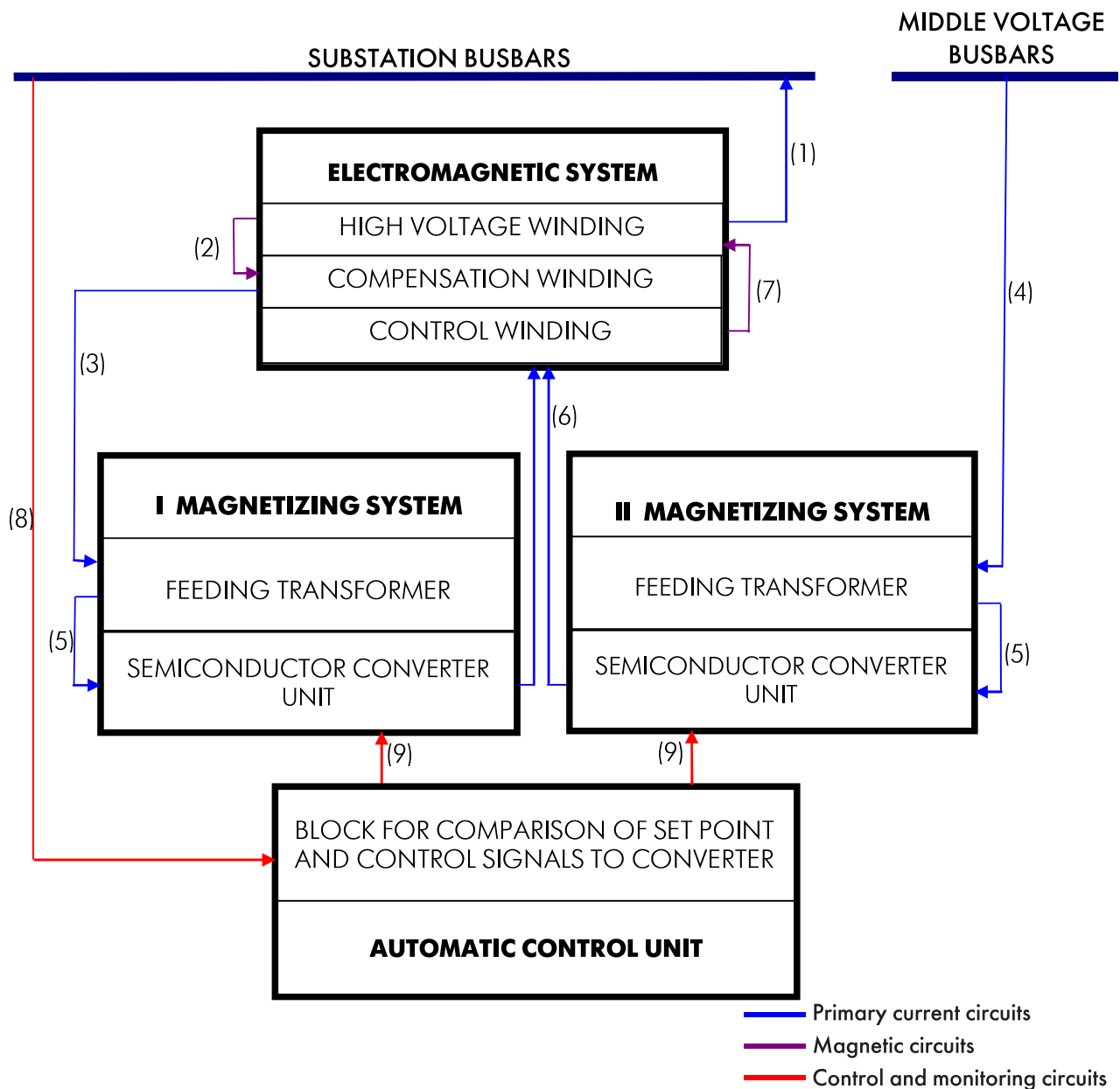


An oil transformer with a converter (OTC) is designed to regulate the magnitude of a direct current in the control winding of the electromagnetic system via changing the magnitude of DC voltage on the terminals of the converter (DC voltage source). The rated capacity of the OTC normally equals to 1-2% of the MCSR's rated capacity. Some MCSR's are equipped with 2 or 3 OTC's connected in parallel. This allows to increase redundancy of MCSR construction and ensure its stable operation even in case of failure of the main OTC. Normally all OTC's (except for those used for preliminary magnetic biasing) are connected to the compensation winding.

An automatic control unit (ACU) generates control signals to thyristor valves of the converter (DC voltage source). According to such signals the converter changes the magnitude of DC voltage in the magnetic biasing system which results in respective changes of MCSR reactive power loading. The ACU is an electronic device mounted in a standard cabinet. Input power of the control system is less than 1kW.

MCSR SINGLE-LINE FLOW CHART

14

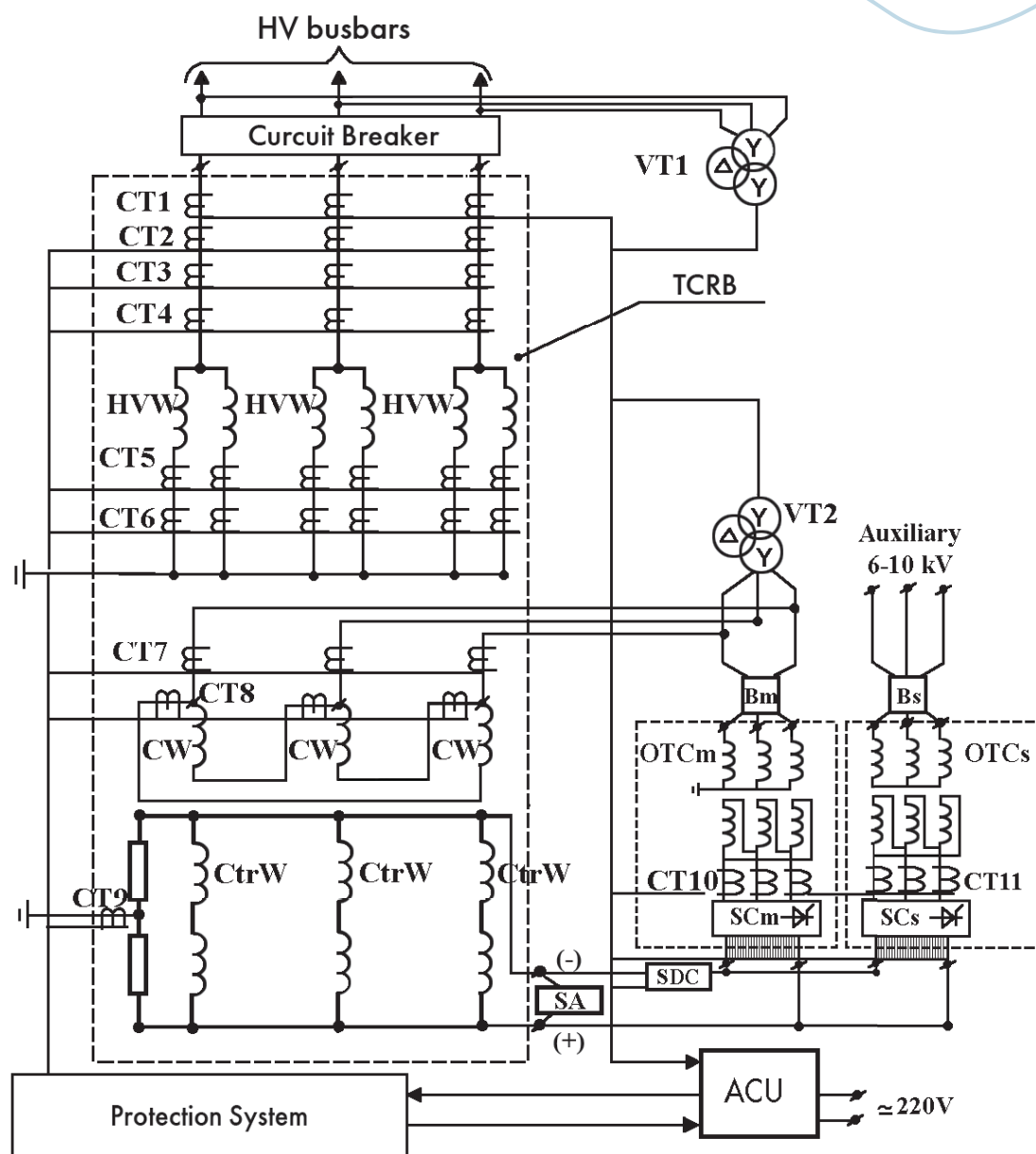


- (1) High-voltage circuits for reactor's connection to the substation busbars
- (2) Electromagnetic coupling of Stabilizing Winding and Compensating Winding
- (3) Connection circuits of feeding transformer
- (4) Power-supply circuits of magnetizing system from substation MV
- (5) Power-supply circuits of converting unit
- (6) Circuits of power intup into controlling winding for magnetizing current alteration
- (7) Circuits of reactor core magnetizing value alteration
- (8) Circuits of control of substation busbars voltage level for comparison with specified setting
- (9) Control circuits for giving instructions to change thyristors' opening angle of transducing current



MCSR ELECTRIC CIRCUIT DIAGRAM 220-500 kV

15

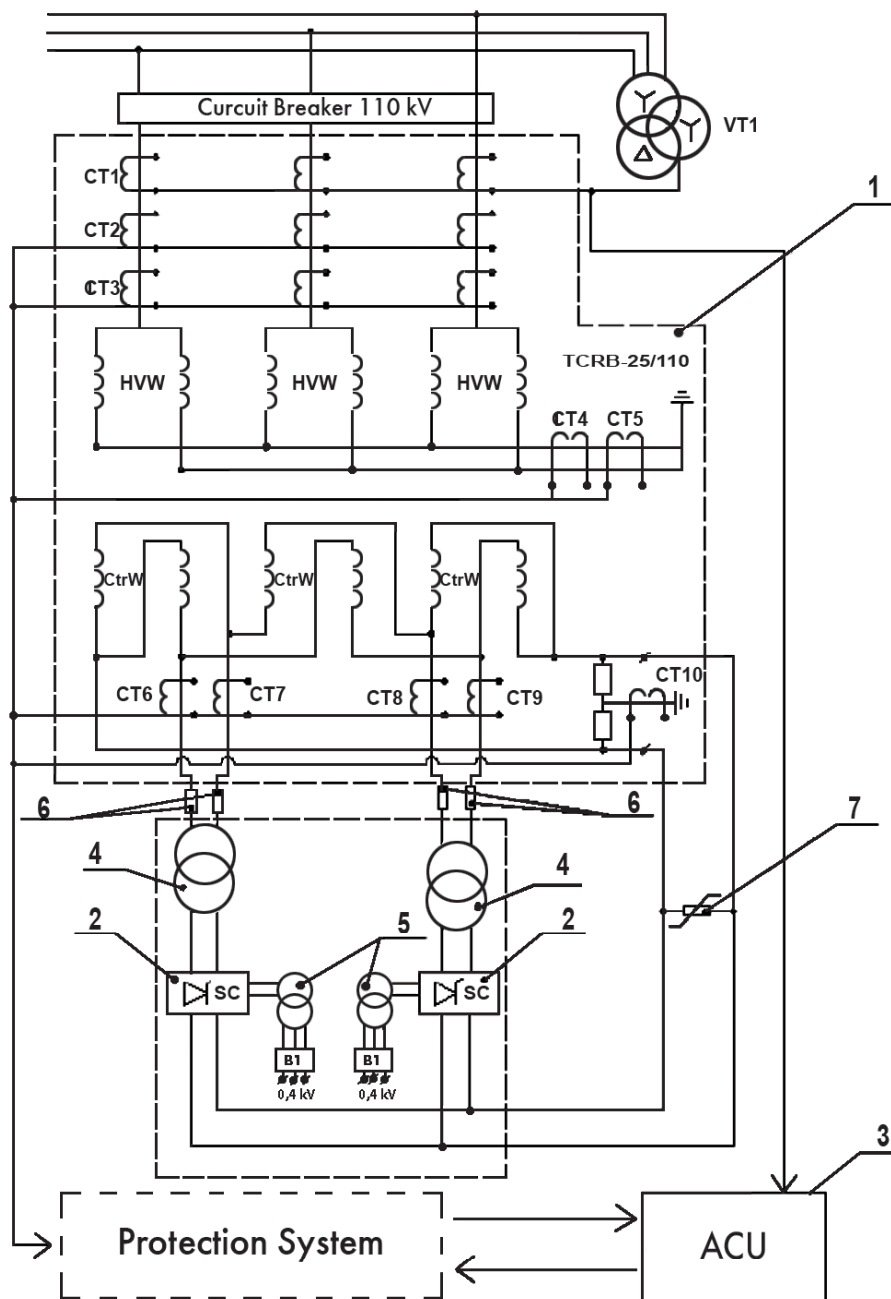


Abbreviations and Definitions:

1. TCRB - Three-phase Controlled Reactor with Blower cooling (electromagnetic system)
2. HVW - High Voltage Winding
3. CW - Compensation Winding
4. CtrW - Control Winding
5. OTC_m - Master Oil Transformer and Converter
- OTC_s - Slave Oil Transformer and Converter
6. SC_m - Master Semiconductor Converter
7. SC_s - Slave Semiconductor Converter
8. ACU - Automatic Control Unit
9. SDC - Sensor DC
10. SA - Surge Arrestor

MCSR ELECTRIC CIRCUIT DIAGRAM UP TO 110 kV

16



Abbreviations and Definitions:

1. Three-phase Controlled Reactor
2. Semiconductor converter
3. Automatic control unit
4. Single-phase magnetizing transformer
5. Initial magnetization transformer
6. Safety device
7. Sensor DC



MCSR-BASED STATIC VAR COMPENSATORS

17

A MCSR-based static var compensator (SVC) consists of a controlled shunt reactor and series capacitor banks (SCB) connected in parallel. Functionally, it is equivalent to a 'classic' thyristor-based var compensator. A controlled shunt reactor functions as a variable inductor, whereas a capacitor bank can include several units to enable the step regulation. The Automatic control unit (ACU) ensures reactive power compensation and sends switch-on/off signals to the capacitor bank circuit breakers as shown in fig.1.

The number and power of capacitor banks are determined in such a way as to minimize circuit breakers (CB) commutations, which, in some instances, allows to totally avoid the capacitor banks switching-on/off or limits them to twice-a-year seasonal operations.

Static compensator based on MCSR flow chart

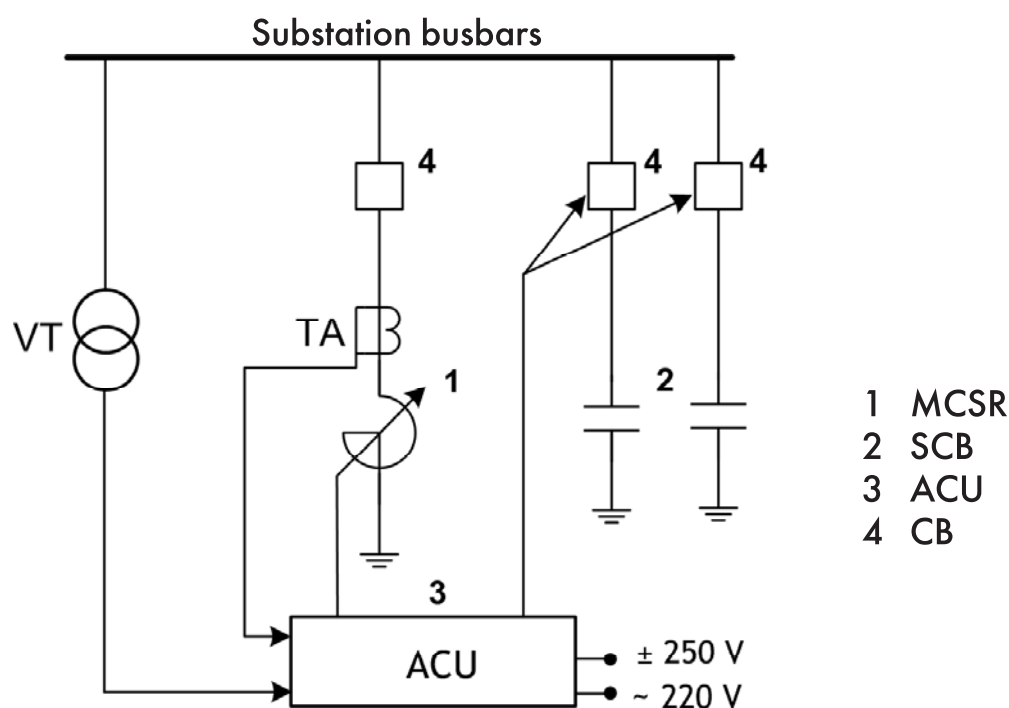


Figure 1



Unlike a classic SVC design, compensators based on MCSR do not contain a HV opposite-parallel thyristor valve for full power. The maximum voltage of currently manufactured thyristor valves does not exceed 35 kV, which necessitates using a step-up transformer to connect a classical SVC to a HV power grid as shown in fig.2.

The absence of a step-up transformer in the MCSR-based var compensator as shown in fig.3 leads to improved voltage regulation and significant cost reduction. The step-up transformer's own resistance leads to partial absorption of SVC power, which prevents the use of such power for regulation of the HV level. Thus, there exists a constant disagreement between a SVC target influence and a real effect of regulation at the HV busbar. Besides, the cost of a step-up transformer adds to the overall cost of the SVC, increasing the payback period of the device.



MCSR based SVC connection

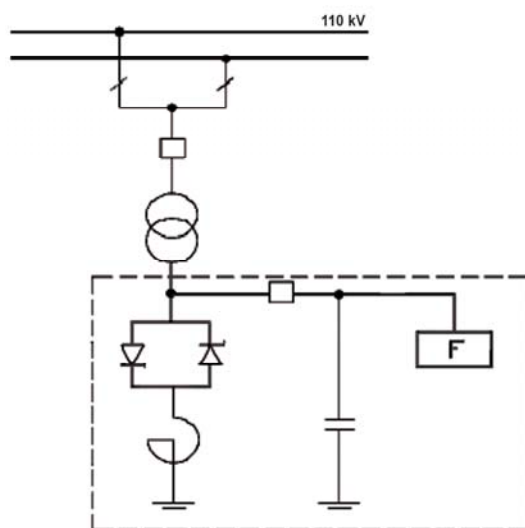


Figure 2



Manufacturers of classic SVCs can sometimes, like in fig.4, connect them directly to the grid through the autotransformer tertiary winding. This does not require using a step-up transformer, but still has its downsides. The SVC connection to the autotransformer tertiary winding leads to its additional reactive power load and as a consequence to decreasing transformer transfer capacity. Moreover, the more is the autotransformer power flow, the more is the voltage loss in it. In order to keep the voltage within prescribed limits, SVC has to generate more reactive power, thus decreasing the autotransformer's transfer capacity. Eventually, it can result in autotransformer overload and reduction of its power transfer capacity. In addition, when regulating voltage in the autotransformer tertiary winding, reactive power from the source is being redistributed both towards HV and MV windings of autotransformer. Therefore the control range of the SVC connected to the autotransformer tertiary winding can not be used in full.



MCSR based SVC connection

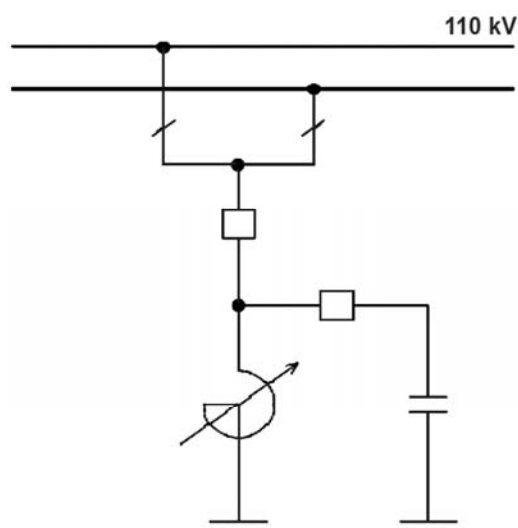


Figure 3

The use of MCSR-based static var compensators allows more flexibility in reactive power compensation and power loss reduction as shown in fig.5. It is not required that all elements of the SVC should be connected to a single point of an electric grid. In certain cases a MCSR and a capacitor bank can be connected to busbars of different operating voltages at the same substation. Normally, the MCSR is connected to HV substation busbars for compensation of excess reactive power in the HV power grid. It can also maintain consistent voltage levels during daily voltage variations. Capacitor banks are connected to LV busbars in order to provide consumers with quality power. Thus, MCSRs meet the system requirements for power transfer reliability of HV backbone transmission lines, and capacitor banks ensure proper operation conditions for consumers.



SVC connection in the autotransformer tertiary winding

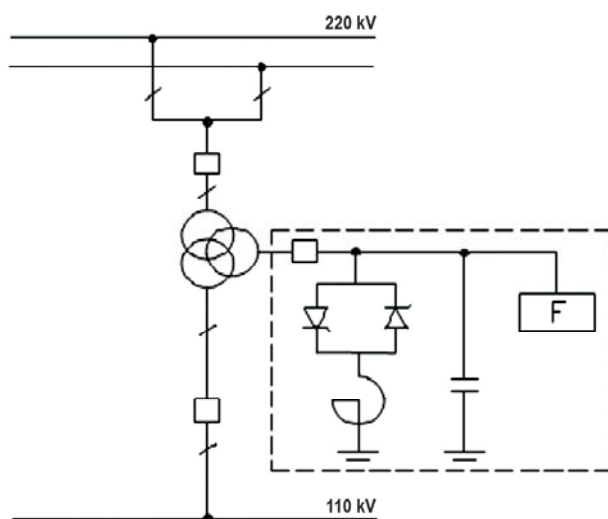


Figure 4



On the condition that the load of consumers connected to LV busbars does not vary the scheme described here allows to reduce the cross-flow through the substation transformer to zero, which results in considerable electric power loss reduction.

Overall, the advantages of MCSR-based static var compensators are as follows:

- high operational safety;
- no need for powerful harmonic filters;
- no need for additional maintenance staff training;
- no need for water cooling of powerful thyristor valves;
- service conditions similar to those of conventional transformer equipment.



MCSR-based static var compensators
switching options

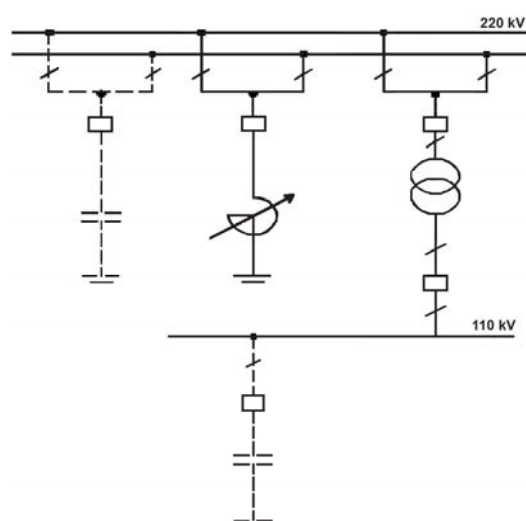


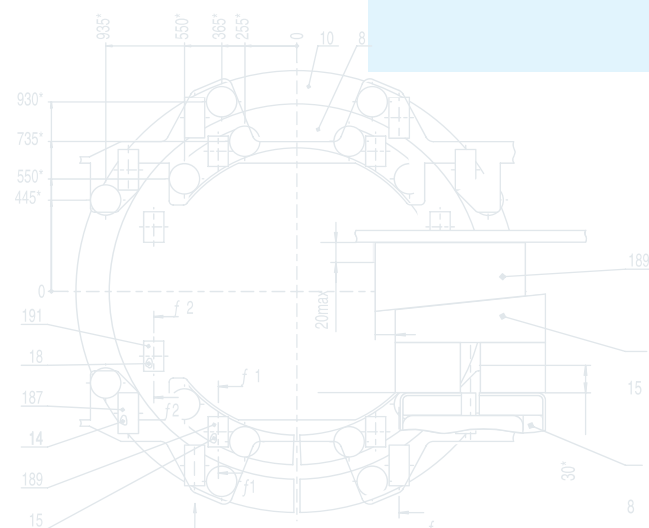
Figure 5

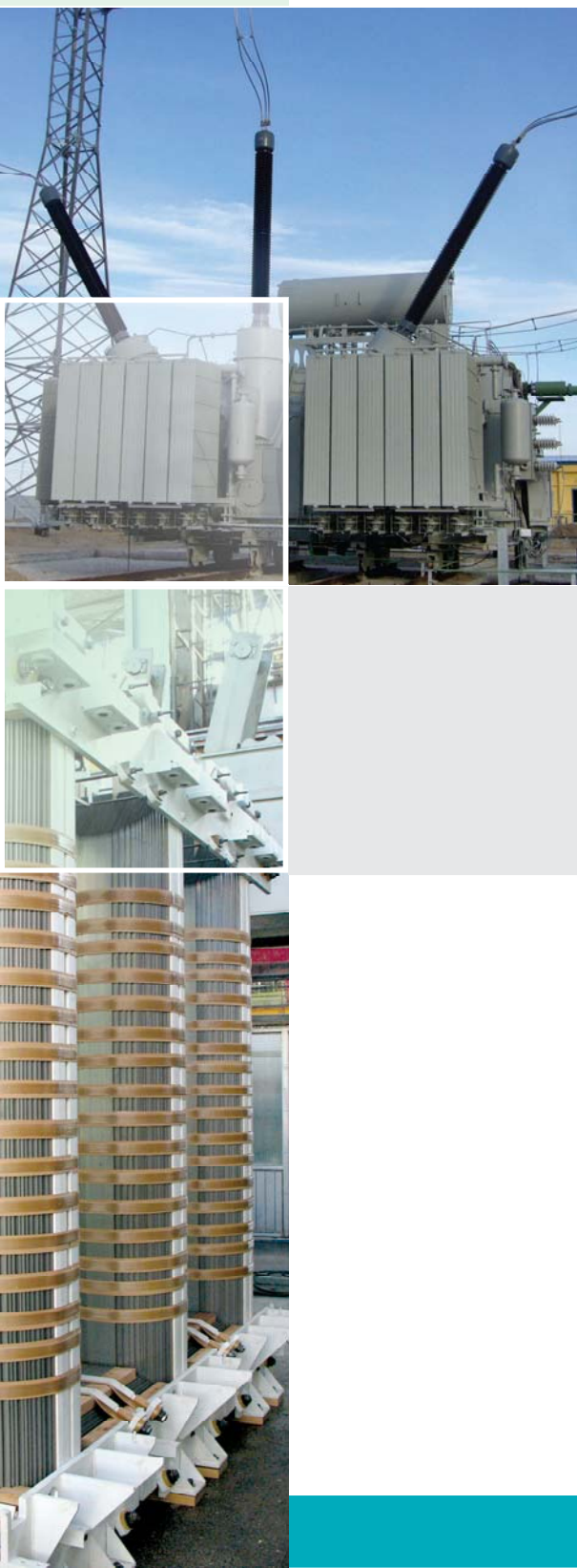
MCSR OPERATION EXPERIENCE AT SUBSTATIONS OF INDUSTRIAL CONSUMERS

22

Beginning from 2004 three MCSRs 25 MVar, 110 kV were installed at 110 kV substations of Dvurechenskaya, Katylginskaya and Igolskaya.

There was a critical situation at Uzhny Vasugan oilfields of Tomskneft' JSC at the end of 2003. Over several years electricity consumption grew steadily due to the industry growth. The total length of the 110 kV distribution network which supplies power to consumers of the region exceeds 700 km. Electric energy from generation sources is transmitted to the deficit region through a backbone 220 kV network. This network was designed and constructed as two closed transits which respect N-1 criteria concerning security of power supply in case of failures. However, due to the big phase difference at the end of each transit, they were forced to operate in an open mode. Under such conditions voltages in the 110 kV network were significantly reduced down to 85% of the rated value (90 kV). As a result, the transmission capacity of electric lines has been totally exhausted. Major consumers of the region are synchronous and asynchronous devices (90% of total consumption) which are very unstable to the voltage oscillations caused by power system disturbances (short circuits, fault clearance, connecting and disconnecting of load, etc.). Any network incident caused a full disconnection of all synchronous and asynchronous devices whereas voltage jumped up to 128-130 kV. Tomskneft' JSC suffered great losses in oil production which resulted both from undersupply of energy and frequent disconnection of electric engines during voltage deviations and unreliable operation of the distribution network. By the end of 2004 the number of emergency outages of oil consumers reached 392 per year (60 times in some months). Oil underproduction rose to 38,5 t per year (more than 7,5 t in some months). Secure level of energy supply was not achieved even after three series capacitor banks of the total rated capacity of 3 x 54 MVar and a gas-turbine unit of the rated capacity of 24 MVar were installed in the 110 kV network. Maintenance staff had to constantly change tap positions of transformers and switched series capacitor banks due to significant voltage oscillations, frequent thunderstorms and complex procedures for equipment connection/disconnection.





Every commutation of a series capacitor bank resulted in 10-15 kV voltage jumps which were still inadmissible for consumers. Cascading disconnections of synchronous and asynchronous devices took place regularly.

Only after three 25 MVar magnetically controlled shunt reactors were commissioned at the Igolskaya, Dvurechenskaya and Katylginskaya substations in August-October 2004 did operation conditions change significantly. Transfer capacity of 110 kV lines increased by 30-50%, voltages were stabilized at 105-110% of the rated value and could be adjusted in a wide range depending on operations conditions. The following advantages were noticed by the Client after a short period of the MCSRs operation:

- the MCSRs equipped with series capacitor banks provide optimum reactive power flows and maximize transfer capacity of electric lines up to the edge;
- enhancement of the distribution network to 220 kV was postponed;
- power losses in the network went down by over 35% (from 11,9 MW to 7,5 MW);
- smooth automatic stabilization of preset voltage rates was provided, the number of series capacitor banks switchings was significantly reduced, using of a transformer's on-load tap changer (OLTC) for voltage regulation was almost avoided.

Cascade load cutoffs were completely eliminated. Emergency disconnection of individual synchronous or asynchronous devices did not lead to voltage jumps and had no influence on other devices.

Commutation procedures for electric grids and other power equipment were significantly simplified which allowed maintenance and repair works without a risk of consumers' power supply interruption.

Losses in oil production were reduced by more than 50 times. The payback period of the MCSRs in question was 1 month.



MCSR OPERATION IN DISTRIBUTION NETWORKS

24

MCSRs were successfully put into operation in 220-110 kV networks at the substations of Kudymkar and Chita in the Russian Federation.

Kudymkar Project

The Kudymkar substation is fed from the Permenergo power system by two 110 kV lines of more than 100 km in length. Regular voltage oscillations within the range 97-120 kV were caused by significant seasonal and daily load fluctuations as well as by Kudymkar's remoteness from the generation source. Available series capacitor banks were switched off/on several times per day (totaling to 800 per year). Continuous voltage regulation via OLTCs was also used. 1800 tap change procedures were registered during a year. When series capacitor banks were switched on/off voltages jumped to 10-15 kV.

Apart from big voltage deviations and worn-out series capacitor banks circuit breakers and OLTCs, the power system additionally suffered from excess losses of electric energy due to non-optimum flows of reactive power.

Following an in-depth feasibility study it was decided to install a magnetically controlled shunt reactor, which together with existing series capacitor banks should act as a standard static var compensator. The price of the MCSR equipped with a series capacitor bank proved to be twice as low as the price of similar SVC devices. Also, commissioning and maintenance costs appeared to be lower because same commissioning and maintenance procedures applied both to MCSRs and to conventional non-controlled shunt reactors and transformers. MCSRs are designed for outdoor installation therefore no additional training for the maintenance staff was required.





9 months after the MCSR was put into operation at the Kudymkar substation the industry experts got together for a seminar to discuss its performance. They stated the following:

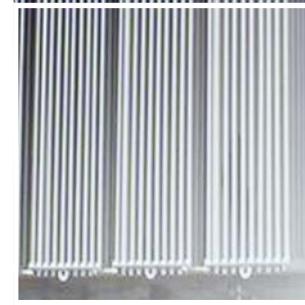
- voltage oscillations at busbars to which the MCSR was connected were within 1,5% of MCSR's voltage set point;
- series capacitor banks and OLTC switchings were reduced by 100 times (to approximately one operation per year);
- at times of peak demand for electricity power losses went down by 2,5 MW reducing the MCSR payback period to 3 years;
- in the automatic mode no maintenance staff involvement is required;
- the MCSR installation ensured no-break power supply of consumers of the Komi-Permyatskiy region and allowed to postpone the construction of a new 220 kV line for 10-15 years.
- during the whole period of the MCSR's operation (since September 1999) neither failures of reactor nor relay protection misoperations have been fixed.

Chita Project

In 2001 a MCSR 100 MVar, 220kV was installed at the Chita substation fed by the Chitaenergo power system and connected to a 220 kV busbar. In the Chitaenergo power system other voltage regulating devices had already been in operation including two non-controlled shunt reactors with rated capacity of 100 MVar connected to busbars at the Heating power station 1 (HPP) and Kharanorskaya Thermal power plant (TPP). In summertime the one installed at the TPP-1 was switched off at least twice a day. A new MCSR allowed to change its own capacity unlimited number of times within the whole regulating range.



- 



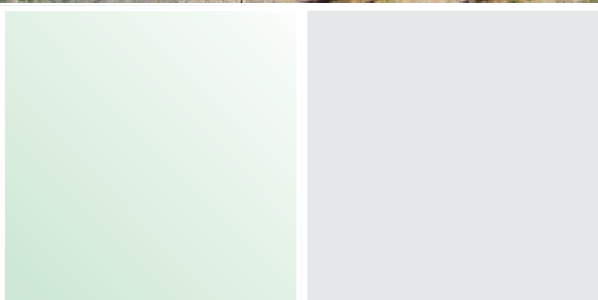


MCSR AS A SOLUTION FOR A FULL-SCALE VOLTAGE STABILIZATION IN TRANSMISSION NETWORKS

27

Since 1991 the power system of Belarus has experienced a sharp decrease in active power load demand. Excessive amounts of reactive power which previously served to ensure long distance active power transfers appeared in the 750-330 kV transmission network. Free surpluses of reactive power caused significant voltage buildup at each voltage level of the power system. Regulating range of all reactive power compensating devices was exhausted. Uneconomical and unsafe measures were taken daily to prevent violations of voltage limits during minimum load periods. The most popular among them were: tripping some 330 kV lines to decrease charging capacity of the network, large-scale disconnection of consumers' series capacitor banks, operation of synchronous generators in the mode of consumption of reactive power, regular autotransformers' OLTC taps changing. These measures led to significant increases in electric energy losses and caused violations of procedures for safe power transmission and supply.

A comprehensive solution for existing voltage problems in the power system of Belarus must have been found. An extensive feasibility study was carried out to define measures to normalize the voltage profile. Finally, it was decided to install four shunt reactors (1 non-controlled shunt reactor and 3 MCSRs) of the rated capacity of 180 MVar and rated voltage of 330 kV. The feasibility study proved that due to a high level of current energy losses the payback period of the installed MCSRs was less than 5 years.



MCSR OPERATION ON LONG DISTANCE HIGH VOLTAGE TRANSITS

28

The Omsk power system includes a long 500 kV transmission line connecting the Russian power system with that of Kazakhstan. Synchronous operations of these systems depend on the reliability of the interconnected 500 kV lines. The Omsk network performance depends on reversible power cross-flows, which results in voltage variations at 500 kV busbars at the Tavrisheskaya substation up to 40 kV per day. After the Kazakhstan and Russian systems were resynchronized in July 2000 the safety of power supply was increased but voltage oscillations increased as well. Before a MCSR 180 MVar, 500 kV was put into operation high voltages and excess losses of electric energy were time after time fixed in the Omsk system. Voltage oscillations directly depended on the magnitude of active power flow on the 500 kV transmission line. Any time the magnitude of active power flow decreased voltages at 500 kV network reached boundary values or even violated upper voltage limits.





In December 2005 a 180 MVar, 500 kV MCSR was installed in the Omsk power system at the Tavricheskaya substation.

The MCSR solved the following problems in the Omsk power system:

- early wear of electric equipment and circuit breakers;
- switching overvoltages of shunt reactors.

The MCSR allowed to maintain voltages in the network at safe and optimum levels irrespective of the magnitude of active power flow and loading demand profile. The MCSR almost instantaneously responds to short circuits and has all functional characteristics of a non-regulated shunt reactor including arc quenching during auto reclosing. For some operational conditions the MCSR keeps voltages at substation busbars close to the highest permissible rates ensuring maximum transfer capacity of the 500 kV transmission line.

MCSR HISTORY

30

1997 • 1st 25 MVA_r, 110 kV three-phase magnetically controlled shunt reactor is designed and manufactured by ZTR, "Energy" Ramensk electrical engineering factory" JSC, FSUE "VEI" named after Lenin and scientific and technical center "VEI" in Toliatti

1999 • 1st 25 MVA_r, 110 kV MCSR is put into operation at Kudymkar s/s, "Permenergo" JSC

2000 • ZTR engineering subsidiary "Electric controllable reactors" ("ECR" JSC) is set up

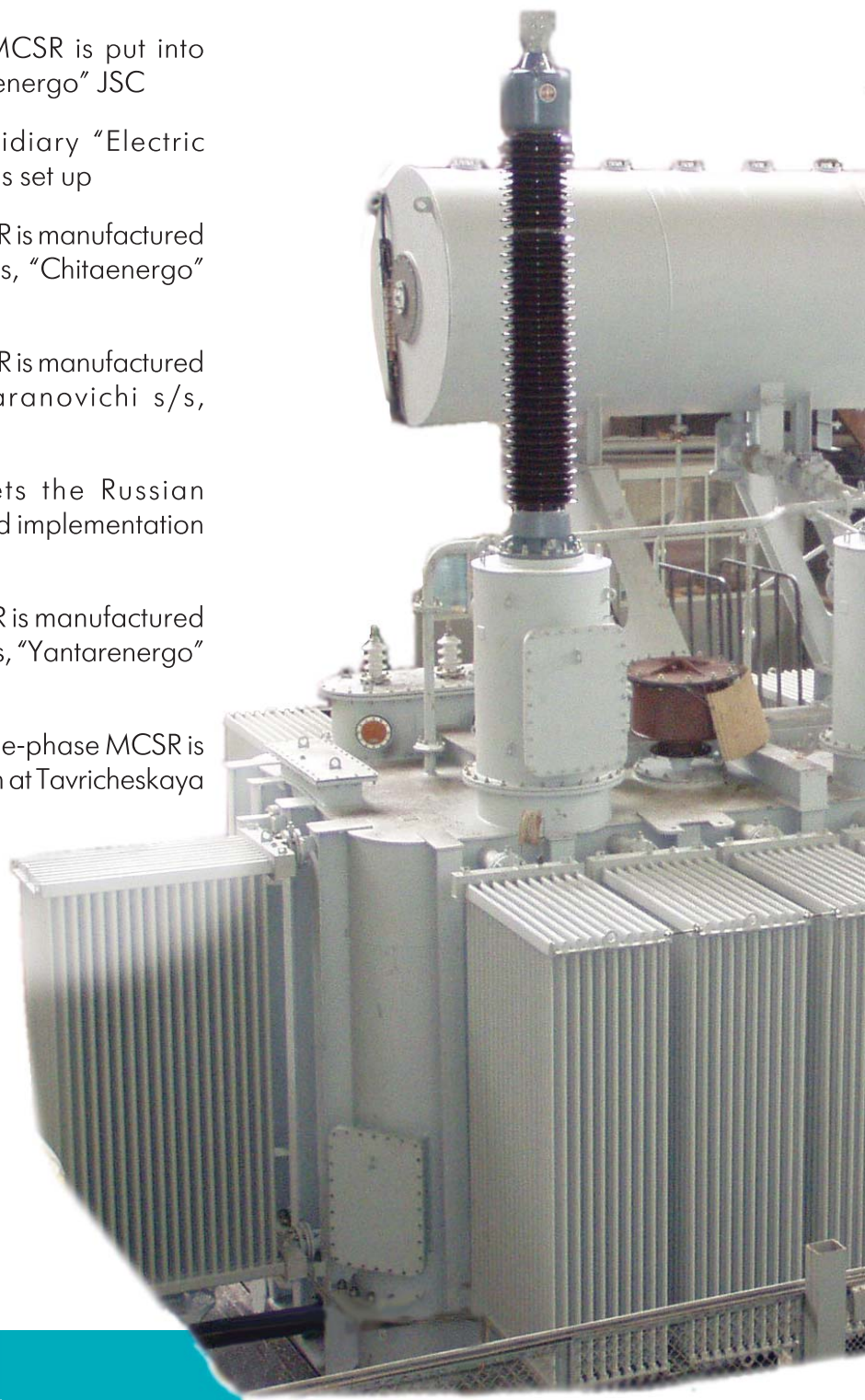
2002 • 1st 100 MVA_r, 220 kV MCSR is manufactured and put into operation at Chita s/s, "Chitaenergo" JSC

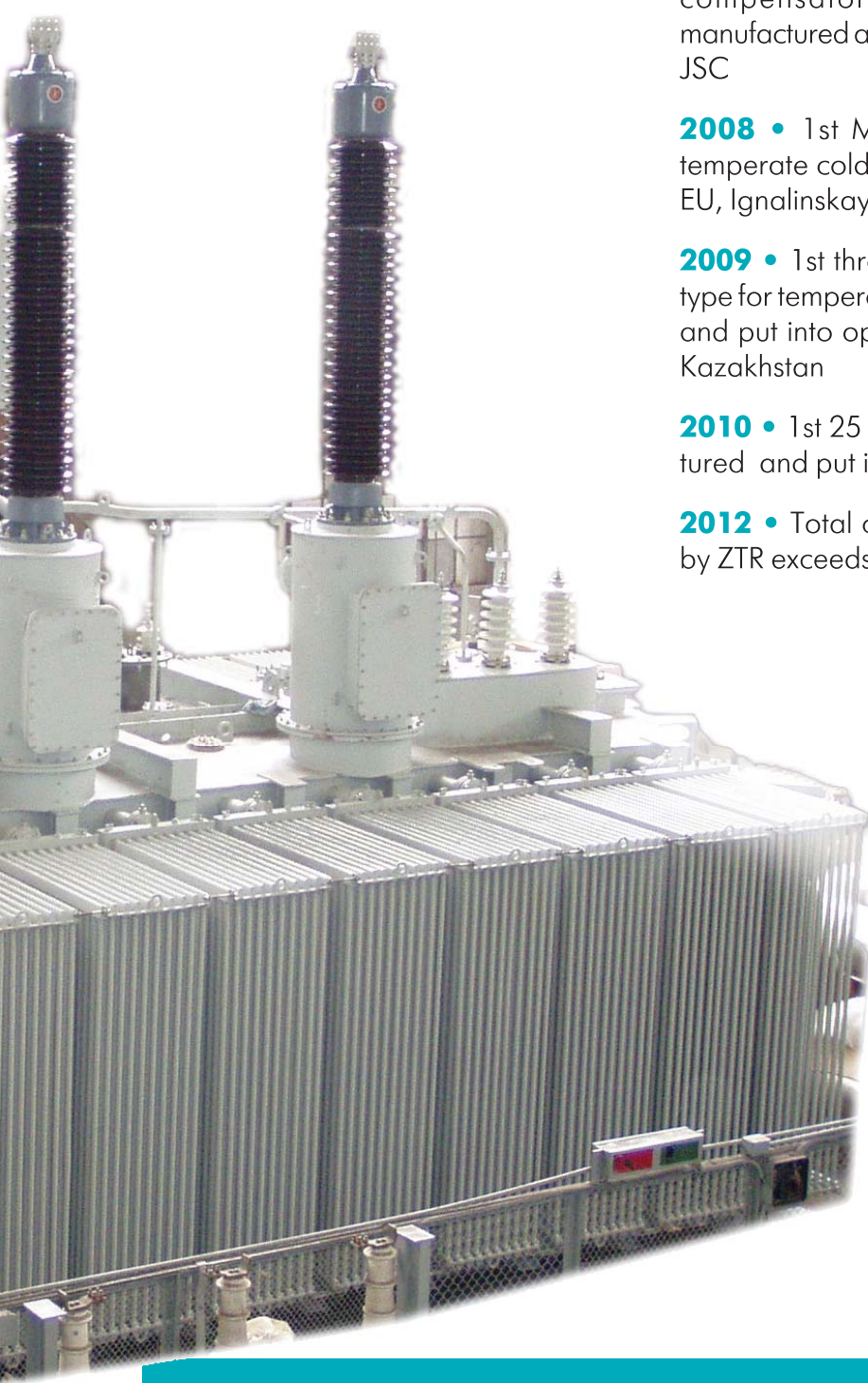
2003 • 1st 180 MVA_r, 330 kV MCSR is manufactured and put into operation at Baranovichi s/s, "Brestenergo" JSC (Belarus)

2003-2004 • "ECR" JSC gets the Russian Government's award for design and implementation of magnetically controlled reactors

2005 • 1st 63 MVA_r, 110 kV MCSR is manufactured and put into operation at Sovetsk s/s, "Yantarenergo" JSC

2005 • 1st 180 MVA_r, 500 kV single-phase MCSR is manufactured and put into operation at Tavrisheskaya s/s, "Omskennergo" JSC





2006 • “Electric controllable reactors” JSC joins “Energy Standart Group”

2008 • 25 MVar, 110 kV MCSR-based static compensator with series capacitor banks is manufactured and put into operation, “Tumenenergo” JSC

2008 • 1st MCSR 180 MVar, 330 kV type for temperate cold climate zone is put into operation in EU, Ignalinskaya NPP, Lithuania

2009 • 1st three-phase MCSR 180 MVar, 500 kV type for temperate cold climate zone is manufactured and put into operation at Agadyr s/s, KEGOC SC, Kazakhstan

2010 • 1st 25 MVar, 35 kV MCSR type is manufactured and put into operation

2012 • Total capacity of all MCSRs manufactured by ZTR exceeds 6000 MVar

MCSR REFERENCE LIST

32

Type	Q-ty	Country	Client	Place of installation	Year of installation
Three phase controlled reactor 25 MVar, 35 kV	7	Russia	Siberia transmission grid company	Selenduma s/s	2010
			Nariyanmarneftegas	Sothorn Hylchyya s/s	2009
			Yakutskenergo distribution company	Olekminsk s/s	2010
Three phase controlled reactor 25 MVar 110 kV	31	Kazakhstan	Aktogaj ore mining and processing enterprise	Aktogaj ore mining and processing enterprise	2007
			Kazakhstan railway	Tassai s/s	2013
		Russia	Vladimirenergo distribution company	Pokrov s/s	2011
			Kubanenergo distribution company	Sochi s/s	2008
			East transmission grid company	Urgal s/s, Elgaugol s/s	2008, 2013
			Western Siberia transmission grid company	Arsenal s/s	2013
			Siberia transmission grid company	Priangarskaya s/s, Razdolinskaya s/s, Kyzylskaya s/s	2009, 2010, 2012
			Sybneft	Fominskaya s/s	2007
			Industrial enterprises	Lysenkovskaya s/s, Technologicheskaya s/s	2013
			Tyumenenergo distribution company	Tavrisheskaya s/s, Sygmytskaya-2 s/s, Vandmtor s/s, Novogodnaya s/s, Vostochnij PP	2007-2008
			Yakutskenergo distribution company	Eldikan s/s	2007
			Megedenenergo distribution company	Pavlik s/s	2012
			Tomskneft	Kudimkar s/s, Dvurecenskaya s/s, Igolnaya s/s, Kupyl'dynskaya s/s	1999-2004
Three phase controlled reactor 63 MVar, 110 kV	1	Russia	North-West transmission grid company	Sovetsk s/s	2005
Three phase controlled reactor 25 MVar, 220 kV	2	Angola	ENE	Kuito S/S	2013
		Russia	Krasnoyarsk regional energy company	Ergaki s/s	2010
Three phase controlled reactor 60 MVar, 220 kV	1	Angola	ENE	Uige s/s	2012
Three phase controlled reactor 60 MVar, 230 kV	2	Angola	ENE	Viana s/s, Camama s/s	2008





Type	Q-ty	Country	Client	Place of installation	Year of installation
Three phase controlled reactor 63 MVar, 220 kV	6	Russia	Far Eastern Energy company	Gorodskaya s/s, Peledys/s	2012-2013
			Siberia transmission grid company	Chadan s/s	2012
Three phase controlled reactor 100 MVar 220 kV	17	Kazakhstan	KEGOC JSC	Shymkent s/s	2013
		Russia	East transmission grid company	Habarovskaya s/s, Hektsyr s/s, Vladivostok s/s, Tynda s/s, Prizeyskaya s/s, Tommot s/s, Majya s/s, Skovorodino s/s	2005-2006, 2008-2009, 2012-2013
			Western Siberia transmission grid company	Urengoi s/s, Mangazeyas/s	2008, 2012
			Siberia transmission grid company	Chita-500 s/s, Angara s/s, Taksimo s/s	2001, 2009, 2012
			Tyumenenergo distribution company	Nadym s/s	2009
Three phase controlled reactor 180 MVar, 330 kV	3	Belarus	Mogilevenergo state power company	Miradino s/s	2006
			Brestenergo State power company	Baranovichi s/s	2002
		Lithuania	Ignalinskaya HPP	Ignalinskaya HPP	2007
Three phase controlled reactor 100 MVar, 400 kV	7	Angola	ENE	Capanda Elevadora s/s, Viana s/s, Kapari s/s, N'Zeto s/s, Soyo s/s	2012-2013
Three phase controlled reactor 180 MVar, 500 kV	6	Kazakhstan	KEGOC JSC	YukGRES s/s, Agadyr s/s	2007
		Russia	Siberia transmission grid company	Ozernaya-2 s/s	2013
			Ural transmission grid company	Ozernaya s/s, Тайшет ПС	2011, 2012
Three phase controlled reactor 180 MVar, 500 kV (formed of single phase controlled reactors 60 MVar, 500 kV)	12 (43)	Kazakhstan	Euro-Asian Energy Company	Aksuskaya TPP	2009
		Russia	East transmission grid company	Lugovaya s/s, Amur s/s	2009-2010
			Western Siberia transmission grid company	Irtys s/s, Lozovaya s/s	2009, 2011
			Siberia transmission grid company	Tavrisheskaya s/s, Barabinskaya s/s, Tomskaya s/s, Angara s/s, Kamala s/s, Voshod, s/s	2005-2006, 2009-2010, 2012
			Ural transmission grid company	Udmurtskaya s/s	2011



"ZAPOROZHTRANSFORMATOR" PJSC

3, Dnepropetrovskoe shosse,
69600, Zaporozhye, Ukraine

tel. +380 61 270 30 33

fax +380 61 270 37 39

e-mail: sales@ztr.ua

www.ztr.ua

«ELECTRIC CONTROLLABLE REACTORS» JSC

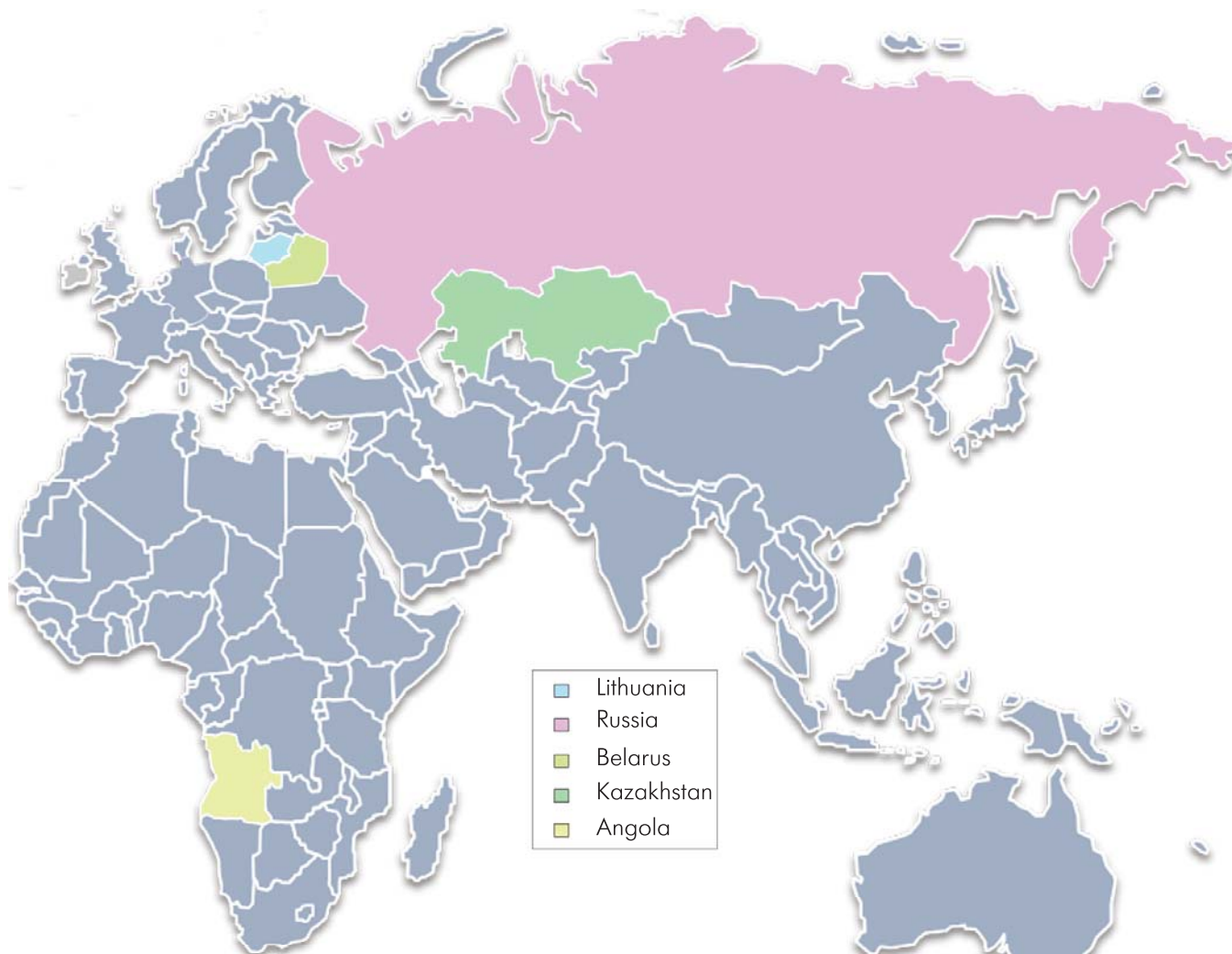
build. 1, 17/2, Bolshaya Yakimanka Str.
119180, Moscow, Russian Federation

tel. +7 495 745 88 49

fax +7 499 230 09 72

e-mail: elur@esgr.ru

www.elur.ru





ZTR
ZAPOROZHTRANSFORMATOR

