

## Synchronous machines excitation systems

Synchronous machines excitation systems are designed to feed the excitation winding with rectified adjustable current.

Our company manufactures the following modern digital quick-response excitation systems, intended for installation at synchronous generators of synchronous compensators and synchronous motors:

- Static excitation systems,
- Excitation control system for machines with brushless high-frequency inductors and cross-field exciters.

These excitation systems are microprocessor-based, which enabled to implement the following:

- To substantially improve accuracy and reliability of conventional solutions for excitation systems,
- To simplify execution of management, diagnostic and protection functions,
- To ensure early access to information about the current state of the system,
- To keep a record of emergency processes,
- To minimize the size of excitation systems.

The static generator excitation system

KVsgOS- RA-XXX-XXX- DXX-UHL 4

Excitation system of KVsgOS- RA-XXX-XXX- DXX-UHL4 type is designed to feed generator excitation winding with rectified adjustable current. The system is implemented on the base of automatic excitation regulator ARV-SG. ARV is implemented on the base of the control module SINAMICS DCM (SIEMENS) with built-in measuring board PTB. ARV-SG have been tested with the electrodynamic model NTTs UES for compliance with the requirements STO 5912820.29.160.20.001-2012.

Thyristor converters are installed separately in power cabinets.

The excitation system can be implemented both as self-excitation scheme and independent excitation scheme.

The excitation system can be implemented as single-channel version, double-channel version for control and power segment with 100% redundancy, as double-channel version for control having three bridges for the power segment working in parallel (N + 1 circuit).

**The excitation system provides the following modes of operation:**

- The initial excitation of the generator to the desired setting,
- Generator voltage adjustment to the mains voltage,
- Operation in united and autonomous systems with the loads ranged from idle to rated ones,
- Operation in automatic or manual modes of control with seamless transfer between the modes,
- Seamless transfer between the channels for the double channel scheme
- Control statism in the range of  $-30\%$  to  $+30\%$ ,
- Excitation boosting in case of voltage reduction on the generator buses,
- Limitation of minimum excitation on power generator diagram,
- Limitation of boosted value of motor excitation current value at the set level and duration,
- Limitation of excitation winding overload with inverse time characteristic,
- Suppression of the generator field in emergency conditions and normal shutdown,
- Communication with the upper level automatic control system.

**The main specifications of the static excitation system:**

<b>Parameter name</b>	<b>Value</b>
Rectified rated voltage, V	115 – 600
Rectified rated current, A	125 – 5,000
Voltage boosting ratio	2.5
Current boosting ratio	2.0
Boosting duration, s	10÷50
Rise time of the excitation voltage from the rated value to 0.95 of the limit for quick-response excitation system, ms	20
Accuracy of bus voltage maintenance at the turbine generator buses relative to of the static characteristic, %	0.25
Operating frequency range, Hz	23÷110
The main power of the excitation system equipment, V	-85÷265
Standby power of the excitation system equipment, V	=130÷350

**The main elements of the generator excitation system.**

- The transformer rectifier (TE) is designed to feed the thyristor rectifier.
- As a thyristor rectifier dry 3-phase transformer with natural cooling for indoor installation is used.

- Managed thyristor converter (A1): is designed to feed the generator rotor winding with rectified current.
- Type of thyristor converter cooling: forced air or water.
- Automatic excitation regulator (AV) controls excitation according to the set law. As a digital controller the microprocessor controller is used.
- The system of initial excitation (contactor KM1, transformer TL, rectifier VD) provides initial excitation of the generator.

The initial excitation can be carried out both from the battery of the plant, and from the AC voltage source ~ 380V through a matching transformer and uncontrolled rectifier VD.

- The field suppression system (switches QF, arrester A2, resistor R1).

During normal shutdown of the generator, converter is transferred in the inverting mode, During emergency shutdown of the generator, control pulses are taken from the inverter and automatic field-suppression AGP on the side of rectified current is switched off. In this case excitation field is suppressed through this discharge resistor connected with additional advancing normally-closed contact AGP.

#### **Protective functions of the excitation system:**

- Rotor protection against overvoltage,
- Protection against short-circuit on the rings of the rotor,
- Undervoltage protection of the stator,
- Overvoltage protection of the stator,
- Protection against loss of excitation,
- Protection from insulation reduction of excitation circuit,
- Overcurrent protection of the rectifier transformer,
- Overload protection of the rectifier transformer,

Structurally, depending on the parameters of the generator excitation, the excitation system equipment is located in four or more cabinets equipped with automatic temperature control fans.

Cabinet protection degree: IP54.

#### **Generator excitation control system with brushless high-frequency and cross-field exciters ARV-SG-RA-XXX-XXX-DX-8 UHL4**

Digital Excitation Control System (automatic excitation controller) is designed to control excitation current of brushless cross-field exciter or high-frequency exciter of the synchronous generator with exciter current up to 315A. It is implemented on the base of digital converters SINAMICS DCM with power segment with built-in measuring board PTB (Power Transducer Board). This type of excitation control system can be used to upgrade the control systems of generator excitation and synchronous compensators.

**Basic technical characteristics:**

<b>Parameter name</b>	<b>Value</b>
Rectified rated voltage, V	36 - 125
Rectified rated current, A	4 - 315
Voltage boosting ratio	4-5
Current boosting ratio	2
Boosting duration, s	60
Rise time of the excitation voltage from the rated value to 95% of the rated value in case of voltage reduction of the generator of 5%	No more than 20ms
Accuracy of bus voltage maintenance at the turbine generator buses relative to the static characteristic, %	Not worse than 0.25
Operating frequency range, Hz	23 ÷ 110
The main power supply of the excitation system control circuit	~85 ÷ 264 V
Standby power supply of the excitation system control circuit	=(110 ÷ 350) V

**The excitation control system provides the following modes of operation:**

- The initial excitation of the generator to the desired setting,
- Generator voltage adjustment to the mains voltage,
- Operation in united and autonomous systems with the loads ranged from idle to rated ones,
- Operation in automatic or manual modes of control with seamless transfer between the modes,
- Control statism in the range from -30% to +30%,
- Excitation boosting in case of voltage reduction on the generator buses,
- Limitation of minimum excitation on power generator diagram,
- Limitation of boosted value of exciter excitation current value at the set level and duration,
- Limitation of excitation winding overload with inverse time characteristic,
- Suppression of the generator field in emergency conditions and normal shutdown,
- Communication with the upper level automatic control system.

**Protective functions of the excitation system.**

- Protection against excitation winding overloading,
- Undervoltage protection of the stator,
- Overvoltage protection of the stator,
- Protection against loss of excitation,
- Protection against valve breakdown of rotating rectifier

**Static exciter of the synchronous motor of KBsdOS-RA -XXX-XXX-DX-8 UHL4 type.**

Static exciter of KVsdOS-RA-XXX-XXX-DX-8 UHL4 type is designed to feed the synchronous motor excitation winding with rectified adjustable current. Static exciter is implemented on the base of the thyristor converter with digital control SINAMICS DCM with built-in measuring board PTB (Power Transducer Board).

**Static exciter provides the following modes of operation:**

- Direct and reactor start of electric motor with automatic determination of the excitation initial moment upon achievement of subsynchronous speed,
- Motor operation with loads from zero to nominal,
- Stable parallel operation of electric motors,
- Operation in automatic or manual modes of control with seamless transfer between the modes,
- When operating in automatic mode, the predetermined level with predetermined voltage statism are maintained as well as cos phi and reactive current for user-selected motor,
- In manual mode, the exciter provides the excitation current stabilization with the adjusting capability within 0-1,2 of the rated current in accordance with the operator task,
- Excitation boosting at preset ratio in case of voltage reduction down to the set level,
- Limitation of minimum excitation according to given diagram of permissible regimes,
- Limitation of boosted value of motor excitation current value at the set level and duration,
- Overcurrent limitation of the motor excitation with the inverse characteristic of time,
- Suppression of the motor field in emergency conditions and normal shutdown,
- Communication with the automatic control system of the upper level.

**Basic technical characteristics:**

<b>Parameter name</b>	<b>Value</b>
Rectified rated voltage, V	36 - 300
Rectified rated current, A	125 – 1,000
Voltage boosting ratio	1.75
Current boosting ratio	1.4
Boosting duration, s	up to 60
Operating frequency range, Hz	45 ÷ 65

**The main elements of a static exciter of the synchronous motor.**

**Matching transformer (TE).**

Matching transformer provides power to the power segment of the exciter from switchgear buses, it is a dry 3-phase transformer with natural cooling for indoor installation.

**Managed irreversible digital thyristor converter (A1):**

Made as per three-phase bridge circuit.

Structurally, the bridge is made up of three modules each of which includes two thyristors. The modules are removable, which allows their quick replacement. For

protection from switching surges occurring during rectifier operation, RC-circuits are used connected in parallel to each thyristor.

**Automatic excitation regulator (AV).**

Controls excitation according to the set law.

As a digital controller the microprocessor controller ARV-CD-RA is used, which is integrated into thyristor converter SINAMICS DCM.

**The system of rotor protection against overvoltage and field suppression.**

Thyristor arrester FV with control unit A2 and starting resistance R is used:

- To control excitation supply in slip and rotor frequency curves, during direct start of the synchronous motor,
- For rotor protection against overvoltage,
- For fast suppression of the field during emergency shutdown of the motor,
- Normal suppression is performed by inverting.

Circuit breaker is designed to eliminate the short circuit in case of valves' breakdown and short circuit on the rings of rotor.

**Protective functions of the excitation system**

- Maximum current protection of thyristor converter,
- Protection from the asynchronous motor,
- Overheat protection of the starting resistor,
- Protection from a long start-up,
- Undervoltage protection of the electronic components,
- Phase loss of power supply,
- Lowering of the power input voltage,
- Lowering of the power input frequency,
- Protection of I2t motor rotor,
- Protection against earth faults in the circuits of the rotor.

Structurally, the above listed elements except transformer TE are located in the cabinet that provides IP54 degree of equipment protection according to GOST 14254 and is equipped with a fan.

**Motor excitation control system with brushless exciters ARV-CD-RA-XXX-XXX-DX 8-UHL4.**

Digital Excitation Control System of ARV-CD-RA-XXX-XXX-DX 8-UHL4 type is designed to control excitation current of brushless exciter of the synchronous motor with exciter current of up to 20A. The system is performed on the basis of converters SINAMICS DCM with power part with built-in measuring board PTB (Power Transducer Board).

**Excitation control system provides the following modes of operation:**

- Direct and reactor start of electric motor or compensator with automatic determination of the moment of initial excitation upon achievement of subsynchronous speed,
- Motor operation with loads from zero to nominal, Stable parallel operation of motors,
- Operation in automatic or manual modes of control with seamless transfer between the modes,
- When operating in automatic mode, the predetermined level with predetermined voltage statism are maintained as well as cos phi and reactive current for user-selected motor,

- In manual mode, the exciter provides the excitation current stabilization with the adjusting capability within 0-1.2 of the rated current in accordance with the operator task,
- Excitation boosting at preset ratio in case of voltage reduction down to the set level,
- Limitation of minimum excitation according to given diagram of permissible regimes,
- Limitation of boosted value of motor excitation current value at the set level and duration,
- Overcurrent limitation of the motor excitation with the inverse characteristic of time,
- Suppression of the generator field in emergency conditions and normal shutdown,
- Communication with the upper level automatic control system (if required by the Customer).

**Protective functions of the excitation system.**

- Protection against excitation winding overloading,
- Mains undervoltage protection,
- Protection against loss of excitation,
- Protection against valve breakdown of rotating rectifier.

**Basic technical characteristics:**

<b>Parameter name</b>	<b>Value</b>
Rectified rated voltage, V	36 - 125
Rectified rated current, A	4 - 20
Voltage boosting ratio	4-5
Current boosting ratio	2
Boosting duration, s	60
Rise time of the excitation voltage from the rated value to 95% of the rated value in case of voltage reduction of the generator of 5%	No more than 20ms
Accuracy of bus voltage maintenance at the turbine generator buses relative to the static characteristic, %	Not worse than 0.25
Operating frequency range, Hz	23 ÷ 110
The main power supply of the excitation system control circuit	~85 ÷ 264 V
Standby power supply of the excitation system control circuit	=(110 ÷ 350) V

## Examples of completed projects

### 1. Oil and Gas

Supply of the three excitation systems of KBcrOC-BE-250-2100-D22- UHL4 type for turbogenerators TTR-110 with converter transformers 1,600 kVA, manufactured by Trafotek firm. Supply of the system is carried out for a totally new facility of "Ivanovo PGU" branch. Excitation systems are designed on the base of regulators with PSS DECS400 produced by Basler Electric. Excitation systems with 100% redundancy of power and control segments.

### 2. Novokuibyshevsk Refinery

Supply of the excitation control system of the ARV-CG-UN-24-6.3-D2- UHL type for the turbogenerator of T-12-2UZ type. Excitation systems are designed on the base of regulators UNITROL1000-15 produced by ABB. Excitation system with 100% redundancy of power and control segments.

### 3. Cherepovets SDPP

Supply of one standby excitation system KBcrOCP-RA-460-2000-D11- UHL4 for turbogenerators of the type TGB-200M with converter transformers 1,600 kVA, manufactured by Trafotek firm. Excitation systems are designed on the base of regulator SIMOREG CM produced by Siemens.

### 4. Petropavlovsk CHP

Supply of one excitation system of KBcrOC-RA-230-1600-D22- UHL4 type for turbogenerators of the TGB-200M type with converter transformers 1,250 kVA, manufactured by the JSC Electrofizika. Excitation systems are implemented on the base of regulator SIMOREG CM with PSS produced by Siemens. Excitation system with 100% redundancy of power and control segments. The system is equipped with a device to transfer to standby excitation without stopping the turbine generator.

### 5. Arkhangelsk PPM

Supply of one excitation system KBcrOC-RA-125-315-D11- UHL4 for turbogenerators of the type T2-6-2 with converter transformers 125 kVA, manufactured by Trafotek firm. Excitation systems are designed on the basis of regulator SIMOREG DC MASTER



manufactured by Siemens. The system is equipped with a device to transfer to standby excitation without stopping the turbine generator.

b. Severstal

Supply of one excitation system KBcrOC-RA-230-315-D22- UHL4 for turbogenerators of the T2-12-2 type with converter transformers 200 kVA, manufactured by Trafotek firm. Excitation systems are designed on the base of regulator SIMOREG DC MASTER produced by Siemens. Excitation system with 100% redundancy of power and control segments. The system is controlled via Profibus by means of SCADA system.