Development of the Test Bed for Experimental Investigation of Autonomous Current Supply System

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Abstract. The test bed is intended for investigations of autonomous current supply system and its individual units and testing of the correspondence of the system to the demands of the wind power alternator with high-temperature superconductive field winding. The test bed configuration is based on module principles thus accelerating the adapting of experimental equipment for quite definite tasks. The test bed contains serial equipment and a number of units specially developed for the definite test program. Some of specially developed modules are presented in the paper.

1. Introduction

The development of wind power alternators with high-temperature superconductive (HTSC) field windings [1] needs an independent regulated current supply source to feed the winding. The test bed is intended for experimental investigation of individual units and assembled autonomous current supply system presented in figure 1. The system is based on the general scheme [2] with specific features, reflected in [3], and is supposed to feed the excitation winding of wind power generator with a varying DC current via a 3-phase rotating rectifier. In this definite case the high-current low voltage supply is intended for a high-inductance low electrical resistance field winding, manufactured of HTSC. The HTSC field winding operates with a 1 MVA wind power alternator. But the investigated current supply system in principle may be used as a brushless exciter of any wind power alternator.

It comprises two alternators:
- a sub-excitator representing a self-excited disc generator with Nd-Fe-B magnets excitation and the armature with circular 3-phase copper winding and magnetic shield of metallic glass tape;
- an exciter representing a reversed design synchronous generator with stationary excitation winding fed from the sub-excitator armature winding via a 3-phase rectifier.

For the exciter manufacturing a DC generator was used. The armature winding was disconnected from the commutator and re-soldered into a three-phase armature winding of a synchronous alternator. Special attention is therefore paid to the individual unit investigation due to their original design.

The developed system, operating at ambient temperature, needs further modification to be a part of cryogenic rotor. Therefore experimental investigations, forming the base of new developments, are of prime importance.
2. Main parameters of the test bed
The current supply system is to be fixed on the rotor shaft of the main generator and its exit bars are connected to the current leads of HTSC field winding. In our case the system has its own shaft and we use a drive motor to test the equipment under rotation. Therefore the test bed configuration includes the drive motor control elements. To check the ability of the current supply to provide the low volume of high-harmonics contents and smooth regulation of excitation current the system was equipped with temporary contact rings and brushes. It fed a stationary simulator of excitation winding, which is an element of the test bed as well.

The test bed is to provide the following technical data:
- maximum output DC current 200 A;
- AC voltage up to 380 V;
- DC voltage up to 24 V.

The test bed configuration is based on the block-modular principle, thus simplifying the adaptation of the equipment for a certain experimental task, including individual investigation of the sub-exciters, the exciter, rotating rectifier and of the assembled current supply system.

The test bed equipment comprises the following main modules:
- the unit responsible for regulation of the power supply, indication and control of the main operating parameters of the equipment;
- adjustable power supply for 200 A, 10 V;
- power supply microprocessor control unit;
- scanning and visualization of magnetic flux distribution;
- drive motor with the control system;
- data collecting system with a computer access.

![Figure 1. Principal scheme of the current supply system and a wind power alternator.](image-url)
3. Test bed power supply
To provide experimental investigations conditions the power supply system is to correspond to the test
tasks and the equipment is to be placed conveniently. The principal scheme of power supply for the test
bed is shown in figure 2, with T1B160 – contactors with current protection; automatic protection C125,
C100; connection terminals HA 25-35; zero bus and earth bus.

![Figure 2. Test bed power supply principal scheme.](image)

To improve the reliability of the modules and to extend the service life of the rectifier and of the
condensers of DC unit filter there is installed an entrance choke. It is responsible for the decrease of
harmonic distortion of the network AC voltage and for the removal of consequences of AC line low
impedance (≤1%). The signal cables are spatially separated from main cables and power supplies.

4. Examples of the equipment for individual unit tests and assembled system tests
There was developed a power supply unit based on a regulated inverter with microprocessor control. It
is intended for investigation of the system of rotor field winding current measurement. A simplified
scheme of the power source is shown in figure 3.

Basing on a step-down transformer, diode bridge VD1 and integrated stabilizer, a power source to
feed the microcontroller DD1 (ATMega32) was assembled. It controls the exit signal form. Variable
resistors R1 and R2 as well as buttons SB1 and SB2 are intended for configuration of the device
operation mode. The information about time, voltage and signal form is transferred to digital indicator.
Resistors R3 - R10 and R11 - R18 are transforming the digital signals of the microcontroller into the
analogue ones. The latter are being sent to high-rated transistors VT1 and VT3. Transistors VT2 and
VT4 operate in a key mode. As a result the voltage of any selected form and polarity may be obtained
on the excitation winding L1. Diodes VD2 - VD5 protect the transistor from the induced heavy currents.
Electric voltage value, proportional to the magnetic flux density and current in the rotor winding, is
obtained on the transverse leads of the Hall sensor and is transmitted to oscilloscope and millivoltmeter.
To investigate the units and the assembled current supply system an auxiliary drive motor was used. Its control system is intended for investigation of the current supply in dynamic modes of operation. It is based on a microprocessor module MR40M. The module comprises a three-phase bridge inverter with IGBT transistors operating as a function of the rotor position angle. The inverter regulates the voltage value to obtain the shaft torque, providing the specified value of the angular velocity of the motor frequency of rotation. The components and elements of the developed motor control module are presented in figure 4.

The developed control module may be used for regulation of any AC or DC motors with a rated current around 50 A in case they are equipped by the rotor position angle sensor and a tachogenerator.
5. The system of information registration
The system of information registration represents a universal measuring complex for control, registration and subsequent processing of the test results. Its functional scheme is given in figure 4. The system comprises a module of meters, amplifier-converter module, analog-digital module and a computer. Module of meters provides the information about the values of phase and linear voltages and currents, magnetic flux density and temperature of the units. The amplifier-converter module is intended for the agreement and normalization of signals obtained from sensors and measuring shunts with the modules of analog-digital converter. The analog-digital module enforces the interface of the computer with test bed equipment. As a result there was developed a convenient instrument for high-performance system of signal processing in a real-time scale based on personal computer.

![Functional diagram of the information collection system](image)

**Figure 5.** Functional diagram of the information collection system.

6. Alternator field winding simulator
To carry out experimental investigation of the assembled autonomous current supply system the test bed was equipped with a field winding simulator (figure 6).

![Inner part of the field winding simulator](image)

**Figure 6.** Inner part of the field winding simulator.
It contains eight race-track copper coils fixed on a rotary but non-rotating shaft and positioned in a magnetic screen. Exciter exit was equipped with temporary contact rings with brushes electrically connected to the inductance coil. The simulator parameters are: electrical resistance – 0.96 Ohm, inductance – 25.5 mH. It was fed by a varying DC current with very low high-harmonic contents (figure 7) and provided a smooth current variation with the pre-determined rate.

Figure 7. Rectified output voltage of the exciter.

This stage of investigations approved the developed design of the current supply system as well as the reliability of the developed test bed equipment.

7. Conclusions
1. Development of independent power sources (like wind power generators) suggests the development of autonomous current supply system in case the alternator has a field winding.
2. The system comprises two non-conventional electrical machines and the investigation program includes individual unit tests and the tests of the assembled device.
3. The test bed configuration is based on module principle and permits to adapt its equipment easily to each new test task.
4. The assembled autonomous current supply system was tested in no-load and was connected to the alternator field winding simulator via the temporary sliding contact.
5. During the test bed development some new elements were introduced thus improving the quality of the experiments.

8. References
[1] Yuanyuan Xu*, Lian-Tong An, Bao-Zhu Jia, Naoki Maki, Mitsuru Izumi 2020 Physica C: Superconductivity and its applications 578 1353767
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