RG3 - T4
Transistorized Excitation Systems for Synchronous Generators
Operating Characteristics

- Reliability
- High availability
- Digital control facilities
- Very good control characteristics
- Low maintenance
- Outstanding flexibility
- Compact design
- Small space requirements

![Image: Internal Assembly]

Standard circuitry

RG3 - T4 is a static excitation system for synchronous generators with exciters and rotating-rectifier diodes. It can also be connected directly to the sliprings of the generator. Thanks to its high degree of flexibility and modular design, this excitation system is suitable for use in industrial power plants and in steam and hydro-electric power stations and lends itself especially to the modernization of existing plant.

The power part exists of a transistorized chopper and is connected to the field winding of the exciter or the generator sliprings.

The excitation power of the standard excitation systems is supplied either from a permanent-field pilot exciter, from a separate excitation transformer or from an auxiliary winding. The clamping bolts of the laminated stator core form the auxiliary winding, e.g.. The excitation transformer may be connected either to the terminals of the synchronous generator or to the station service system. Further redundant incoming feeders are possible, e.g. through station battery or an uninterrupted power supply.

The outstanding flexibility of the standard system and the low mounting space requirement make the RG3 - T4 system particularly suitable for the modernization of existing excitation systems.

Especially for new power plants we can specifically consider the customer requirements.

Mechanical Design

The RG3 - T4 excitation system is installed in a standard cubicle specially designed for equipment comprising open loop and closed-loop controls and power electronics devices. Modular design and easy accessibility of all components facilitate all setting and optimizing operations. The cubicle is 900 mm wide by 600 mm deep, at a height of 2200 mm. The adaptability to all kinds of local conditions and existing plant may necessitate deviating cubicle dimensions, especially in the case of modernization projects.
The main components are:

Transistor chopper (1) and using redundancy there is a second Transistor chopper (2).

Automatic voltage regulator (3) for controlling the voltage at the generator terminals and the field current regulator (4) for the manual channel.

The station battery can provide the excitation power (E) by the station service system, by an auxiliary winding, by a separate excitation transformer or by a permanent-magnet pilot exciter.

Optional redundant feeders, e.g. from the station battery to the excitation system ensure high availability of the excitation system. The excitation system RG3 - T4 is suitable for various types of engines: brushless exciter with rotating-rectifier diodes (5) and (7), direct current exciter (6) and for direct excited engines (8). The input power for the transistor chopper regulator comes from a rectifier and DC link.

De-excitation of the generator is by means of the integral field discharge resistor.
Mode of Operation

Closed-loop control
Automatic Voltage Regulator
(Automatic control system)
The actual value of the generator voltage is compared with an adjustable generator voltage setpoint. The resulting signal is compared with the output of the excitation limiter and taken to the input of the PI voltage controller. The PI voltage controller with adjustable gain and time response provides an output signal which is applied to the setpoint input \( I_{ref} \) of the secondary field current controller. The output of this controller governs the generation of the frequency-modulated driving pulses for the power transistors of the associated output stage, which is operated with a clock frequency of about 2.5 kHz. The DC current flows through the phase U and W of the transistor power circuit.

Automatic \( \cos \phi \) or reactive power regulator at the generator leads
(Automatic control system)
The \( \cos \phi \) regulator compares the actual value with an adjustable \( \cos \phi \) reference value. In case of a deviation the reference value of the voltage regulator is adjusted until the deviation is reduced to zero. In isolated or no-load operation of the generator the operation mode of the automatic control system is switched over from \( \cos \phi \) regulation to voltage regulation.

Manual control system
(Excitation current regulator)
The P-action control amplifier of this regulator receives a filtered setpoint signal that is compared with the actual value of the field current. The output signal controls the frequency-modulation drive circuit for the power transistors of the associated output stage.

Of the three control systems the automatic one is normally in operation, even during starting and stopping of the electric set. The automatic control system includes the measuring and setpoint devices and the control and monitoring circuits for the following functions:

- Generator voltage regulation
- Fast secondary control and limitation of the output current of the field current chopper regulator and/or field-forcing limiter
- Limiting controller for the under-excited range (under excitation limitation)
- Delayed high limiting control for the over-excited range (over excitation limitation)
- Delayed generator current limiter (stator current limitation)

Options
- V/Hz-limiter (over fluxing limiter)
- Failure detection of rotating diodes
- \( \cos \phi \)- or reactive power regulator at the supply point
- VAR joint control of several generators

Commissioning mode
The manual control system is designed as excitation current regulator which permits generator characteristics to be recorded during commissioning and inspections, and also short-circuit operation of the generator to be carried out for setting the protective relays. When the automatic voltage regulator is faulted, it can also be used for the operational adjustment of the generator excitation.

Follow-up control
The setpoint value of the field current controller is continually updated during operation on the automatic control system, thus ensuring rapid and nearly bumpless changeover to manual control in the event of a fault. Automatic switchover takes place when certain fuses or protective circuit breakers operate or in case of failure of the automatic control system.
Limiting Controllers

When operating a synchronous generator, it is necessary to observe the permissible combinations of active and reactive power, which can be seen from the capability diagram.

LMO  Limit characteristic of the underexcited range
OP   Limit set by the stator temperature rise
PQ   Limit set by the rotor temperature rise

Similar characteristics with reversed active-power flow apply to motor operation of the generator.

The underexcitation limiter corrects the reactive power by raising the machine voltage as necessary to ensure that, in case of an excursion beyond the limit characteristic L-M-O, the operating point is returned to that characteristic before the machine is tripped by the underexcitation protection.

The overexcitation limiter ensures that, in the overexcited range, the operating point always keeps within capability curve section P-Q of the generator. In response to system voltage drops caused by high reactive power requirements, switching manipulations or faults, the voltage regulator raises the excitation level so as to keep the generator voltage constant. The overexcitation limiting device acts as a safeguard against thermal overloading of the rotor.

The overexcitation limiter admits excitation current values between the maximum continuous current and the maximum excitation current (field forcing) for a limited period of time so that the generator can back up the system in response to short-time system voltage dips.

The secondary excitation current limiter (field-forcing limiter), in contrast, has the task of limiting the excitation current to the maximum permissible value as quickly as possible.

The stator current limiter ensures the delayed limitation onto working points, within the N-P range of the generator power diagram. The main task of the stator current limiter is to prevent the generator stator from thermal overload, which can be caused by a high reactive power at increased active power. The stator current limiter also permits increased excitation values for a limited period so that the generator can back up the system.
Automatic Control

Each operating condition of the excitation system are all supervised and indicated.

The internal monitoring routine makes the following signals available at the cubicle terminals:
- Fault with Protective Off command
- Fault in automatic control system and switchover to manual control system
- Group alarm triggered by various internal fault signals causing starting lockout.

Additionally following operating signals are available for external indication.
- Excitation is on
- Excitation is off
- Automatic Voltage Regulator is on
- Excitation Current Regulator is on
- Cos Φ – or VAR Regulator is on
- Limiters are active

Further more detailed signals are optionally possible.

Overexcitation and field-forcing limiter

When driven to maximum output, the chopper regulators provide a voltage higher than required for exciting the generator to its ceiling current. This overvoltage on the field winding shortens the time required for reaching the ceiling current in that it substantially accelerates the excitation build-up.

The output current of the chopper regulator for the manual control system is limited by the maximum value of the setpoint setter.

The output current of the chopper regulator for the automatic control system is influenced by the integration limit of the PI voltage controller. This reference variable corresponds to the voltage that gives the required field current.

Driving the transistor chopper to a high output voltage in order to obtain faster exciter response.

- $U_E$ = Chopper output voltage (equivalent to excitation voltage)
- $I_E$ = Chopper output current (equivalent to excitation current)
- $I_{EO}$ = No-load excitation current
- $I_{EN}$ = Rated-load excitation current
- $I_{Emax}$ = Ceiling current
- 1 = Output current without field-forcing limitation
- 2 = Output current without overdriving
**Power circuit**

The power circuit uses transistor chopper regulators, which provides the necessary excitation power via a DC link. The field voltage is adjusted by varying the pulse/pause ratio and the field circuit resistance causes the field circuit to vary accordingly. The field current is measured in the output stage and the signal is converted for the field current controller.

**De-excitation**

De-excitation of the synchronous generator is necessary for shutdown and when a protective device of the machine itself or of the unit transformer operates. Therefore the transistor chopper is blocked. The magnetic energy stored in the field is returned to the DC link via the diodes in the chopper circuits. This ensures very rapid de-excitation of the generator.

Principle connection of the transistor power part

Clock frequency about 2,5 kHz. Variable pulse/pause ratio. Chopper output voltage as affected by the driving pulses. Excessively high voltages are prevented by parallel-connected varistors.
The operator friendly software tool SIMOVIS/DriveMonitor guarantees simply commissioning of the RG3. Through a serial interface the voltage regulator can be connected with the PC for easy configuration.

Customer friendly Configuring

The SIMOVIS/DriveMonitor software for Microsoft Windows 9x/2x/NT allows the complete parameterization of the power circuit. Actual values can be monitored in the parameter list and parameters can be changed easily by selecting the corresponding parameter in the parameter list. It is possible to choose between a complete parameter list, pre-defined parameter lists with selection of parameter for a special application (e.g. input/output) or a user defined parameter list by entering the interesting parameter numbers. A complete upread of parameters allows easy documentation.
Trace

Trace is an add-on for SIMOVIS/Drive Monitor that permits visualization of recorded data. You can also store the data read out of the device and open it again later. It is also possible to import such data into text processing programs, such as Microsoft Word, or into spreadsheet programs, such as Microsoft Excel.

You can perform simple measurements of amplitudes and instants using two moveable cursors.

The trace recording function contains following features:

- Monitoring of up to 8 analog signals
- Monitoring of 16 binary signals per unused analog signal (e.g. 32 binary and 6 analog signals)
- Maximum recording time of 280s at a maximum sampling rate of 280ms or 1.4s at minimum sampling rate of 1.4ms
- Freely adjustable sampling rate between 1.4 and 280ms in steps of 1.4ms
- Fault recording is automatically triggered by programmable fault signals (triggered by binary signals e.g. faults or by comparing an analog value (condition: <>) with a predefined value)
- Adjustable pre-trigger between 0% (no pretrigger, only future) and 100% (only past, no future)
Configuring with D7-ES

The complex voltage regulator with its limiters and calculations as well as control functions such as interlocking is integrated inside the programmable T400 circuit board. The T400 can be configured with the graphic D7-ES configuring tools, based on Windows 95/NT.

Thus, it is very easy to implement even complex customized supplementary functions inside the RG3. Complete standard software packages are available for functions and applications which are frequently required.

The picture below shows an example of a software structure and a selection of available functions out of the function block library.
### RG 3 - T4

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<th>Feature</th>
<th>Specification</th>
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| **Auxiliary power up to 250 V from the station battery** | For power circuit controls  
Power consumption:  
< 0.1 kW continuously  
< 0.2 kW short-time  
For signal and controller power supply (24V DC)  
Power consumption:  
< 0.2 kW continuously |
| **Instrument transformers:**                 | Potential transformers:  
connected to 3 phases of the generator voltage.  
Power consumption < 5 VA per phase;  
Secondary voltage rating 100 V to 120 V.  
Current transformers:  
Two-phase (L1, L3), for measuring the generator current.  
Secondary current rating 5 A or 1 A,  
< 3 VA (plus CT cable losses).  
The transformers are not included in the scope of supply of the voltage regulator. |
| **Standards:**                               | The RG3 - T4 excitation system is rated and designed according  
Service and maintenance of the excitation system RG3 - T4 can  
executed according the VGB4- instructions. |

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*Niederaussem, lignite-fired steam turbine power plant, Rheinbraun, Germany: two RG3 systems for Units A and B, 2 x 214 WVA.*