1) Introduction

The RT2DB excitation system was developed for excitation and voltage regulation of synchronous generators equipped with rotating exciters (brushless or DC exciters).

In the case of brushless exciters it will result in a maintenance free power generation system.

The system can be used not only in hydro but also in thermal power plants, in new projects or as an excellent alternative for refurbishment of old regulators.

The RT2DB excitation system can take the necessary energy either from the terminals of the generator being excited, through a three-phase dry type excitation transformer in this case, or from a permanent magnet exciter (PMG). If a PMG is used to supply the system, its frequency should be at most 100 Hz.

The voltage regulation is achieved by actuating on the field winding of the exciter machine.

For the field flashing auxiliary energy is taken from the auxiliary power supply (DC or AC).

The voltage and current regulation, the setpoint generation, the actual value measuring, the control of the field flashing and shutdown processes, as well as the excitation system monitoring are fully digital. These functions are carried out by a 32 bit processor module, which is plugged in a three-phase fully controlled converter of the series Simoreg DC Master.

2) Power stage

The current rectification is carried out by the self cooled Simoreg DC Master unit. The thyristors are protected by monitored ultra-fast fuses. The Simoreg converter is designed taking into account the most severe overload conditions of the generator.

In the cases where the excitation system takes its supply voltage from the generator terminals it may be necessary to sustain the excitation current during a short circuit on the generator terminals in order to guarantee the actuation of protection relays or protection selectivity. For that reason the RT2DB excitation system can also include a special circuitry for sustaining the stator current of the generator at a certain level in the case of near short circuit.

Fig. 1: The Simoreg DC Master converter unit.
3) Configuration of the electronics

The voltage regulation, the control and the monitoring functions of the excitation system are carried out by the processor module T400 plugged in the Simoreg converter. The thyristor gating and monitoring are implemented by the converter itself. The power supply for the electronics is taken in a redundant way from the excitation transformer and from the station battery.

Fig. 2: The generator voltage regulation is carried out by the T400 technological board, which is plugged in the Simoreg unit.

There are two regulating channels: AUTOMATIC (automatic voltage regulator) and HAND (field current regulation).

Both regulating channels (AUTOMATIC and HAND) act on the same power stage. The bumpless channel change-over is carried out by software.

3.1) Automatic channel

The automatic channel corresponds to the automatic voltage regulator (AVR), which compares the generator voltage actual value with the reference value (voltage setpoint) adjusted by the power plant operator.

The actual values of the active and reactive power are measured directly on the generator terminals through 3 potential transformers with secondary voltages of 110, 115 or 120 V as well as 2 current transformers with secondary current of 1 or 5 A.

The generator voltage setpoint is digitally generated and can be adjusted in the range 90% to 110% of the rated generator voltage.

During the operation of the synchronous generator attention must be paid to its capability diagram. For this reason the following limiters act on the AVR:

1. Quick acting excitation current limiter (field forcing limiter)
2. Overexcitation limiter
3. Underexcitation limiter
4. Volt/Herz limiter
5. Stator current limiter

When a limiter intervenes an indication signal is released.

The software routines for the limiters run on the T400 module.

The AVR possesses an underordinated excitation current regulator. This configuration ensures the system an excellent dynamic behavior and simultaneously allows limiting the excitation current at its maximum values.

A power factor (or reactive power) regulator is also included. This additional regulator allows the generator to operate at any desired power factor regarding its capability diagram. The setpoint value is digitally generated by the T400 module.
4

Fig. 3: By means of the Drive Monitor parametering software it is also possible to record oscillograms of analogical signals.

3.2) Hand channel

This control channel corresponds to the excitation current regulator. It is extremely useful when performing tests on the generator. In addition the hand channel works as a stand-by regulator allowing continuing of the operation even at failures in the AVR.

The setpoint of the excitation current ranges from about 10% up to 110% of the rated excitation current of the exciter. By taking an independent power supply for the excitation system the setpoint range stretches from zero to 110%.

3.3) Channel switch over and follow-up control

A bumpless channel change-over from AVR to excitation current regulator and vice-versa can occur at any time.

This is possible thanks to the follow-up routine, which ensures that the selected control channel follows up the settings of the other channel. This way both channels outputs always the same firing angle for the thyristors, what guarantees a bumpless channel change-over at any time.

Certain failures involving the AVR cause an automatic change-over to the hand channel. A trip signal is released if failures occur in the hand channel being selected the hand channel.

Fig. 4: The regulation and control software is user friendly, what makes the programming and understanding very easy.

3.4) Operation

The excitation cubicle is delivered with provisions both for local control (from the cubicle door) and for remote control (from a central control room).

In the standard version of this cubicle the local operation is carried out by means of push buttons on the cubicle door. Alarms and status indications are made by LED signalizations.

A man-machine interface (MMI) is optionally available to make the operation of the system easier. This optional device is equipped with keyboard and display (LCD). Through this device commands can be entered and actual system parameters (excitation current and voltage, generator active and reactive power, generator voltage, setpoints etc) can be read out.

Fig. 5: In order to make die operation easier a man-machine interface can be
Additionally ordered. The figure shows one of the available models (OP17).

There are two standardized types of MMI: a simple one (OP1S) and a more comfortable one, which can display alarm messages of the excitation system in clear text with indication of the time in which the alarm occurred.

The RT2DB cubicle can be connected to the superordinated control system by means of normal cabling because all of the input and output signals are available on terminal strips as potential-free contacts.

The optional board CBP2 allows the system to be connected to a communication network using the PROFIBUS DP protocol. This communication link can be optionally built using optical fiber. In this case the optional module OLM has to be ordered.

Other communication protocols are optionally available.

4) Instrumentation and operation

In the standard version of the system the following instruments are installed on the cubicle door: reset push-button, signaling LEDs to indicate operational statuses and grouped alarms and push-buttons to enter commands for the local operation.

In the case the optional MMI is ordered neither push-buttons nor signaling LEDs are supplied.

5) De-excitation and overvoltage protection

At normal conditions de-excitation is carried out by forcing the thyristor bridge to operate as inverter. The field polarity inversion causes thus a very quick reduction of the excitation current towards zero. About 5 s after introducing inverter operation the controller opens the field contactor. Since the excitation current at this time will have already reached zero, the main contacts of the field contactor open at no load condition, what increases the lifetime of the device.

Additionally the RT2DB excitation cubicle is also equipped with a linear field discharge resistor. It is used to dissipate the stored energy of the exciter field winding in emergency situations, where inverter operation cannot be ensured any more.

The RT2DB excitation system has a suppressor device in parallel to its DC output, in order to protect the thyristors and the field winding against induced overvoltages.

6) Mechanical features

The excitation cubicle has the following approximate dimensions:
The cubicle has only front door. Cables inlet and outlet are made from the bottom.

The cubicle is constructed with 1.9 mm thick steel sheets. The supporting frames are made of 2.5 mm thick steel sheets.

The cubicle wiring uses self extinguishing copper conductors insulated for 750V. All conductors have identification rings at both ends.

Each one of the devices has identification tags with the device symbol according to the electrical diagrams. Each device can be easily accessed.

The protection degree is IP41.

7) Optional frame assembly

As an economical alternative all the low voltage parts of the RT2DB excitation system can be supplied assembled on a steel sheet (frame) sized 800 x 1200 mm (see Fig. 8). This way the system can be installed in a client's existing cubicle saving thus the costs of an additional cubicle.

8) Optional features

The following devices can be additionally ordered:

- Man-machine interface;
- Rotating diode monitoring (for brushless generators);
- Communication board for PROFIBUS DP link;
- Communication port for other protocols;
- Redundancy in the power stage (in this case two automatic channels are supplied, each one with its own rectifier bridge, i.e. two independent Simoreg DC Master units are supplied);
- Compounding circuitry for sustaining the generator current during near short circuit.

Fig. 7: The Simoreg DC Master converter includes the electronics for controlling and monitoring the fully controlled three-phase rectifier bridge.

Fig. 8: As an economical solution the RT2DB excitation system can also be supplied on a steel sheet to be housed in a client's existing cubicle.
Fig. 9: General diagram of the RT2DB excitation system
General technical data of the RT2DB digital excitation system

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum excitation current</td>
<td>Up to 20 A DC</td>
</tr>
<tr>
<td>Maximum ceiling voltage</td>
<td>Up to 600 V DC</td>
</tr>
<tr>
<td>Voltage for control and interfacing</td>
<td>From station battery</td>
</tr>
<tr>
<td>Auxiliary voltage for field flashing</td>
<td>Power plant auxiliary power supply (AC or DC); current consumption: 2 A typ. during max 10 s (depends on generator data)</td>
</tr>
<tr>
<td>Connection to potential transformers</td>
<td>3 x PT’s; secondary voltage: 110, 115 or 120 V (“V connection” is allowed); power consumption: 10 VA per phase</td>
</tr>
<tr>
<td>Connection to current transformers</td>
<td>2 x CT’s; secondary current: 1 or 5 A; power consumption: 10 VA per phase</td>
</tr>
<tr>
<td>Regulator</td>
<td>Fully digital; double channel configuration: Auto Channel (AVR) and Hand Channel (excitation current regulator)</td>
</tr>
</tbody>
</table>
| Limiters                                     | • Quick acting excitation current limiter  
• Overexcitation limiter  
• Underexcitation limiter  
• Stator current limiter  
• V/Hz limiter |
| Power supply for the regulator electronics   | Redundant configuration: from the excitation transformer and from the station battery |
| Setpoint range                               | • Generator voltage: 90% ... 110% (typical)  
• Excitation current: 10% ... 110% |
| Rectifier                                    | Fully controlled thyristor bridge (6 pulses), self cooled, continuous DC output current: 30 A DC |
| Power requirements from the station battery  | Interfacing and control circuits: max. 100 W  
Regulator redundant power supply: max. 250 W |
| Dimensions                                   | 600 x 800 x 2200 mm (W x D x H)                                           |
| Approximate weight                           | 300 kg                                                                 |
| Protection degree of the cubicle             | IP 41                                                                  |
| Finish color                                 | Grey Munsell N6.5 or according to customer’s specifications.            |
| Dimensions of the steel sheet in the case of frame assembly | 791 x 1200 mm |
| Standard interfaces                          | Conventional wiring (potential-free contacts)                          |
| Output signals (4 ... 20 mA) for remote indication | • Excitation current  
• Voltage setpoint |

For more information please contact:
Siemens Ltda.
Rua Werner Siemens, 111
05069-900 Lapa São Paulo, SP
Tel: (11) 3833-4052 / 4106 / 4098  FAX: (11) 3833-4189
Internet:  www.siemens.com.br/excitacao
E-mails:  sebastiao.carpi@siemens.com  jorge.humberto@siemens.com

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