THYRISIEM® DD
The Digital Voltage Regulator for Large Generators with Brushless Exciters
THYRISIEM® DD is a fully digital excitation system for synchronous generators with rotating exciter units, e.g. exciters with rotating diodes. The THYRISIEM® DD excitation system is designed for excitation currents of up to approximately 200 A. The excitation system has the following features:

- Great reliability
- High availability
- Good control characteristics
- High response speed
- Robust design
- Low maintenance

The user-friendly design of the hardware and software in conjunction with the associated system of matched input/output devices provide the user with new enhanced options for the following activities:

- Operator input (parameter setting)
- Monitoring
- Logging
- Testing
- Trouble shooting
- Commissioning

Standard equipment can be supplied to obtain the excitation power from an pilot exciter, an excitation winding of the synchronous generator or an excitation transformer. This excitation transformer can either be connected to the terminals of the synchronous generator or supplied from the unit auxiliary power system (refer to picture 2).

The regulator has a two-channel structure and is implemented entirely with a configurable digital control system. This system is especially suitable for fast closed-loop and open-loop control and calculation with sampling rates that can be as fast as once per millisecond. The power sections used are full fired thyristor bridges.

The voltage regulator THYRISIEM® - DD consists of two independent regulator channels and two thyristor bridges. Each of the regulator channels has a dedicated power section. Each power rectifier can feed the field winding of the main exciter. The second channel runs in standby mode. In this way, if one channel fails, the other can take over the full excitation power.

The system also feature interfaces for analog and binary inputs and outputs. These are implemented using standard analog and digital modules. Special interface modules permit the system to be linked to and operated from the plant. For selection, a bus connection to I+C can be provided.

The software required for the system is configured using an user-friendly configuring language based on familiar function diagrams. This permits modification or expansion of the THYRISIEM® DD excitation system simply by adapting the software without any significant changes to the hardware.

The THYRISIEM® DD excitation system is mounted in standard cabinets designed especially for electronic open-loop and closed-loop control systems and their power electronics. The modular design and the accessibility of all components facilitates handling of all important functions and parameters for the optimization of the regulator both during commissioning and service.
Main Components

The power sections are mounted in separate cabinets. De-excitation is normally performed electronically, i.e. rapid rundown of the current in the field winding of the main exciter is implemented by the regulator, with the power relay opened to interrupt the power supply to the controllers.

The power controllers can be powered via an auxiliary exciter, an auxiliary winding in the generator or via a separate feeder transformer. The over voltage protection and the de-excitation equipment are integrated in the power controllers.

Control Equipment

Both channels are installed in separate racks. The automatic control of the generator voltage including all necessary limitations for a secure operation of the generator within the acceptable limits is integrated in each channel. The inactive channel is updated constantly and takes over if the first channel fails. (Pic. 2)

Each channel can be switched over to manual mode (excitation current control) locally, but also from I&C.
Method of Operation

The excitation system is supplied with two completely redundant voltage regulators as a standard.

**Automatic channel 1 (Automatic channel 2) (Automatic Voltage Regulator)**

In the automatic voltage regulator, the actual value of the generator voltage is compared with an adjustable generator voltage reference value. After comparison with the outputs of the excitation limiter the signal is sent to the input of the digital voltage regulator. The digital voltage regulator has PI characteristics, its gain and dynamic response can be set and it provides an output signal that is passed to the lower level excitation current regulator as I_set. The output of the power thyristors is set by the output of this current regulator.

In normal operation and during start-up and shutdown one automatic channel is in operation.

The second channel is in standby mode. It contains measured-value acquisition functions, set point functions, control and monitoring loops for:

- regulating the generator voltage
- lower level rapid regulation and limitation of the output current of the power controller
- (excitation current regulation) or maximum current limitation
- excitation limiter for the under excited range (under excitation limitation)
- delayed excitation limitation for the overexcited range (over excitation limitation)

**Manual Channel (excitation current regulation)**

Here a smoothed set point from a set point adjuster is compared with the excitation current actual value. The output signal sets the output of the power thyristors via the current regulator (P-controller). The manual channel is included in the automatic channel.

For the configuration with two redundant automatic channels, one channel functions as the master, the second is a slave synchronized with it. The power sections are each designed to provide the full excitation power if the other power rectifier is shut down with a fault (100 % redundancy).

Continuous synchronization and synchronism monitoring of the voltage regulator channels is achieved by making the stored generator voltage set point for the slave controller track the actual value. Internal calculated variables are also corrected and all parameters entered are compared with the measured variables for the controlled system.

Correct functioning of the voltage regulator channels is monitored both by scanning the input/output area as e.g. monitoring the power supply and by measures taken in the area of the hardware and software of the digital control system. These include self-monitoring functions of the system with standardized diagnostic software and checking input, output and internal calculated variables.

The manual channel permits recording of generator characteristics and short-circuit operation of the generator to make protection settings for the purposes of commissioning and inspection. This channel can also be used to set the generator excitation if automatic voltage regulation is defective.

During operation of automatic channel 1 the set points of the 2nd channel and the manual channels are continuously tracked to permit rapid bumpless switchover in case of a fault. Switchover is performed automatically on response of defined fuses protective circuit breakers, or if the automatic channel fails. Control can be switched back to the regulator channel manually once the fault has been remedied.

**Options:**

- power system stabilizer (PSS)
- second under excitation limiting curve
- U/I limitation
- Q / Cos φ - control

**Niederasseh lignite-fired steam power plant, Germany:**

2 THYRISIEM® systems, 2x780 MVA for Units G and H, 1THYRISIEM® system 1223 MVA, for the most advanced and powerful lignite-fired power plant of the world, Unit K.
Control Structure

The control structure of the digital voltage regulator is shown in Figure 2. The voltage and current transformers of the generator output the two stator variables VG and IG from which all required quantities can be calculated in real time using the “actual-value processing” function. The generator voltage regulator takes account of the following influences:

- Drop compensation
- Over excitation limitation
- Under excitation limitation
- Field current limitation
- Stator current limitation

The function “ΔV generation” yields the voltage deviation. “Droop” is taken into account at this point. The “under excitation limitation” is included as a second deviation via “maximum evaluation”. For test purposes the characteristic can be mirrored in the under excited range “characteristic 1/2”, so that it is possible to check the functioning and setting of this important limitation without risking a protection trip. In automatic mode, with the function field current limitation the maximum for the voltage regulator is set. In manual mode the field current is controlled.

The set point of the voltage regulator is either formed from Raise/Lower commands or using the “Reference value V mains” and, if necessary, modified by the functions “Q/cos φ regulator” or “stator current limiter”. This corrected voltage reference value is input to “Reference value limiter” and, if necessary, also “V/Hz limitation”. The “voltage regulator” can also be influenced using the (optional) function „PSS“.

Image: Software structure of the digital voltage regulator

Figure 4: Software structure of the digital voltage regulator
Limitations

Under excitation limitation:
By increasing the generator voltage, reactive power is being corrected in a way, that with exceeding the limiting curve in the under excited area, the operating point is traced back to the limiting curve before the unit is shut down by the under excitation protection system.

Over excitation limitation:
The over excitation limitation allows excitation currents with values between equalising current of excitation system (I_E = factor * I_N) and maximum excitation (field forcing, app. 150%) over a preset time to enable the generator acting as grid support when grid voltage breaks down.

The duration of exceeding and the following reduction to a value that excepts a thermal overload of the field winding, is realised according to the following method:
- Fixed, characteristic curve controlled over excitation limitation

Field current limitation:
The function of the field current limitation is to restrict the excitation current to the maximum allowable value.

Stator current limitation
This limitation affects on operation points within the power diagram (refer to pic. 5). It is responsible for prevent the thermal overload of the stator due to reactive power at increased active power. The stator current limitation also allows higher excitation values for a preset time, in order to let the generator act as grid support.

Picture 5: Typical power diagram

Response time (s)

Field current I_F / I_F rated (%)
**U/f-Limitation**

Due to high frequency deviations in the grid, big transformers can fail because of thermal overloads, caused by eddy currents.

To hold the unit connected to the grid even in cases of big frequency collapses, the voltage is being reduced together with the frequency (U/f limitation).

This limitation protects the main transformer against saturation.

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**Cubicle Assembly**

As standard, excitation equipment of type THYRISIEM® DD consists of 3 cubicles with 600mm width each. In first cubicle, the two racks for the control system Simadyn D and terminal strips are mounted, in the second and third cubicle, the power sections with power relays and fuses are installed.
### Technical Data

<table>
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| **Supply voltage** | From medium voltage busbar:  
| | 400V ± 10%  
| | 50 / 60 Hz ± 2%  
| | Permanent magnet generator:  
| | 240V +0 / -20%  
| | 400 / 420 Hz or 150 / 180 Hz ± 10%  
| **Weight:** | 1200kg with redundant power section (standard)  
| | 800kg with non-redundant power section (option)  
| **Permissible ambient temperature:** | During operation: 0°C to +40°C  
| | During storage / transport -25°C to +70°C  
| **Permissible humidity:** | 85%  
| **Installation altitude:** | ≤ 1000m above sea level  
| | for altitudes above 1000m above sea level the rated current must be reduced by 5% for each 300m. Above 2000m above sea level, the voltage must be reduced.  
| **Degree of protection:** | IP31  
| **Norm:** | The THYRISIEM® excitation system is rated and designed according to IEC, VDE, DIN standards.  

*Schwarze Pumpe, Germany, one of the most advanced lignite-fired power plants of the world: 2 THYRISIEM® excitation systems 2x1000-MVA.*

*Steam power plant Paiton II, 5+6, Jawa Power, Indonesia: two THYRISIEM® systems, 2x789 MVA*
Excitation Systems

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The information in this document contains general descriptions of the technical options available which do not always have to be present in individual cases. The required features should therefore be specified in each individual case at the time of closing the contract.