State-of-the-Art Exciter Systems: Enhancing the Reliability of Generator Operation

To meet today’s demand for power system reliability in highly competitive power generation markets, we leverage our 136 years of OEM (original equipment manufacturer) experience and knowledge to deliver proven, highly reliable and efficient technological products and intelligent service solutions. Our extensive range of excitation systems SIPOL®, RG3, THYRIPART®, THYRISIEM® and THYRIPOL® ensures reliable generator operation and excellent coordination with generator protection and sequence control. Their flexible component design and wide-range performance can be applied for the full range of new and retrofit applications, e.g. hydro, industrial, nuclear, biomass, steam and combined-cycle power plants and emergency generators.

Each excitation system can be customized into an individual system solution via standard design plus optional add-ons in order to deliver cost-effective, optimized systems. Every excitation system is fully function-tested for rapid and easy on-site commissioning. The standard design incorporates proven digital technology for dependable voltage regulation, monitoring and system control, which includes:

- Automatic Voltage Regulator (AVR)
- Excitation Current Regulator (ECR)
- Over- (OEL) and Under-Excitation Limiter (UEL)
- Reactive Power (VAR) or Power Factor (PF) control
- Reactive current compensation.

With appropriate options, it can be easily adapted to various project-specific requirements:

- Power System Stabilizer (PSS)
- Stator current limiter
- Volts per Hertz limiter (U/H)
- Rotor temperature calculation
- Joint reactive power control
- Redundancy
- Local and remote control for commissioning and operation.

The Benefits are Easy to See:

- Increased power output
- Improved efficiency
- Extended service life
- Increased reliability and availability
- Improved operating flexibility
- Minimized losses.

These benefits result in reduced operating and maintenance costs.

Covering the Entire Spectrum

<table>
<thead>
<tr>
<th>Excitation System</th>
<th>Application Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIPOL® IE ≤ 20 A</td>
<td>Small industrial and hydro power plants/nuclear plants</td>
</tr>
<tr>
<td>RG3 IE ≤ 130 A</td>
<td>Hydro, steam and industrial power plants/retrofits</td>
</tr>
<tr>
<td>THYRIPART® IE ≤ 1000 A</td>
<td>Station service and emergency generators for hydro and nuclear power plants/nuclear plants</td>
</tr>
<tr>
<td>THYRISIEM® IE ≤ 225 A</td>
<td>Static excitation system with compounding source</td>
</tr>
<tr>
<td>THYRIPOL® IE ≤ 8000 A</td>
<td>Hydro, steam, combined-cycle and nuclear power plants/nuclear plants</td>
</tr>
</tbody>
</table>

We offer an excitation system solution for every synchronous generator, whether they are our products or made by someone else.

Bugok, combined-cycle power plant, South Korea: 3 THYRIPOL® systems, 2 x 205 MVA and 1 x 207 MVA.

All systems comply with ISO 9001: 2000 quality standards and IEC, EN, DIN, VDE, IEEE 421 requirements. They can be safe-guarded throughout their life cycle with our full scope of services:

- Spare parts
- Commissioning and maintenance assistance service
- On-site customer training carried out by our engineers
- 24-hour on-site engineering support
- Customer accessibility to the system software
- Rapid assistance via a 24-hour service hotline
- Trace function and self-monitoring to save time and money
- Simulation of closed-loop and certain operating conditions
- Service for electrical machines: erection, commissioning and maintenance.

System technologies delivered worldwide have been operating, for example, since 1975 in over 2000 excitation systems, show our experience and achieved a world-class availability of nearly 100%.

Our service can assist you in minimizing maintenance costs and maximizing availability.

Amortization calculation: The new excitation system saves costs due to lower power losses. We calculate the time period for amortization of the purchasing costs of a new excitation system. A typical example: By installing a new static THYRIPOL® system in a hydro power plant in India, an efficiency enhancement of more than 0.5% points was achieved with a return on investment shorter than 5 years.
State-of-the-Art Exciter Systems: Enhancing the Reliability of Generator Operation

To meet today’s demand for power system reliability in highly competitive power generation markets, we leverage our 136 years of OEM (original equipment manufacturer) experience and knowledge to deliver proven, highly reliable and efficient technological products and intelligent service solutions.

Our extensive range of excitation systems SIPOL, RG3, THYRIPART®, THYRISIEM® and THYRIPOL® ensures reliable generator operation and excellent coordination with generator protection and sequence control. Their flexible component design and wide-range performance can be applied for the full range of new and retrofit applications, e.g. hydro, industrial, nuclear, biomass, steam and combined-cycle power plants and emergency generators.

Each excitation system can be customized into an individual system solution via standard design plus optional add-ons in order to deliver cost-effective, optimized systems. Every excitation system is fully function-tested for rapid and easy on-site commissioning. The standard design incorporates proven digital technology for dependable voltage regulation, monitoring and system control, which includes:

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The Excitation Systems

- SIPOL: IE ≤ 20 A, small industrial and hydro power plants/nuclear plants
- RG3: IE ≤ 130 A, hydro, steam and industrial power plants
- THYRIPART®: IE ≤ 1000 A, station service and emergency generators for hydro and nuclear power plants
- THYRISIEM®: IE ≤ 225 A, steam and nuclear power plants
- THYRIPOL®: IE ≤ 8000 A, hydro, steam, combined-cycle and nuclear power plants

We offer an excitation system solution for every synchronous generator, whether they are our products or made by someone else.

Bugok, combined-cycle power plant, South Korea: 3 THYRIPOL® systems, 2 x 205 MVA and 1 x 207 MVA

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All in all, our comprehensive spectrum of excitation system solutions for synchronous generators promoting reliable generator operation producing reliable and economical power.
The System Solution for Low Power Output
Up to 20 Amps Excitation Current

**Features and Benefits:**
- Compact design and easy installation
- Short delivery time
- Failure monitoring through digital display
- Actual value displayed on digital display or as analog value
- User-friendly operation
- Spare parts support* within 24 hours
- Fully digital system stands for lower maintenance and better noise immunity
- Compatible with generator types of all manufacturers.

**Software:**
Easy parameterization of standardized software functions.

**References:**
The two projects below are highlights of typical retrofit projects.

**Project:** Langweid, Germany  
**Customer:** Bayerische Elektrizitätswerke GmbH  
**Application:** Retrofit  
**Plant type:** Hydroelectric power plant

**Project:** Garda Paper Factory, Italy  
**Customer:** Cartiere del Garda  
**Application:** Retrofit  
**Plant type:** Industrial power plant

* Applies to standard system devices

**Applications:**
Thanks to its compatibility with all manufacturer types, this excitation system is suitable for use in small industrial and hydroelectric power plants and lends itself especially to the modernization of existing plants.

**Application Range:**
The power supply of the SIPOL excitation system can be supplied from an auxiliary exciter (DC 50...300 V or AC 0...400 V up to 400 Hz), an uninterruptible power supply or a station service system.

SIPOL is an excitation system for synchronous machines with an exciter set and rotating diodes. It can also be connected directly to the slip rings of the generator. In this way, the SIPOL excitation system rounds out the power range of the well-proven RG3 excitation system.

Gersthofen hydroelectric power plant;  
Lech-Elektrizitätswerke AG, 5 x 3-MVA generators. Although space was very restricted, the SIPOL technology was integrated without any problems into the existing facility.

For the hydroelectric power plants  
Volkach and Kitzingen on the river Main in Germany we delivered 3 SIPOL 1.6 MVA.

SIPOL assembled in a Rittal cubicle 1200 x 600 x 400 mm.

SIPOL mounted on a mounting plate.

Generator output

<table>
<thead>
<tr>
<th>Power Ratings</th>
<th>MVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
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<tr>
<td>0.1</td>
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<td>1</td>
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<td>100</td>
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<tr>
<td>1000</td>
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</tbody>
</table>

Small industrial and hydro power plants/retrofits.

For the hydroelectric power plants

Schwandorf, waste incineration plant, Germany: 1 SIPOL 12.5 MVA.

5
4
5

For the hydroelectric power plants

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**Customer:** Cartiere del Garda  
**Application:** Retrofit  
**Plant type:** Industrial power plant

* Applies to standard system devices.
SIPOL
The System Solution for Low Power Output
Up to 20 Amps Excitation Current

Applications:
Thanks to its compatibility with all manufacturer types, this excitation system is suitable for use in small industrial and hydroelectric power plants and lends itself especially to the modernization of existing plants.

Application Range:
The power supply of the SIPOL excitation system can be supplied from an auxiliary exciter (DC 50...300 V or AC 0...400 V up to 400 Hz), an uninterruptible power supply or a station service system.

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**RG3**

The System Solution for Low/Medium Power Output
Up to 130 Amps Excitation Current

<table>
<thead>
<tr>
<th>Generator output</th>
<th>0.01</th>
<th>0.1</th>
<th>1</th>
<th>10</th>
<th>100</th>
<th>1000 MVA</th>
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</thead>
<tbody>
<tr>
<td>Hydro, steam and industrial power plants/</td>
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<tr>
<td>retrofit</td>
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</table>

**Applications:**

RG3 is an excitation system for synchronous generators with exciters and rotating-rectifier diodes. It can also be connected directly to the slip rings 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 hydroelectric power stations, and lends itself especially to the modernization of existing plants.

**Application Range:**

The excitation power of the standard excitation systems is supplied either from a permanent-field pilot exciter, a separate excitation transformer, an auxiliary winding or the clamping bolts of the laminated stator core form the auxiliary winding. The excitation transformer may be connected either to the terminals of the synchronous generator or to the station service system (DC 50...300 V, AC...400 V up to 400 Hz). The power part consists of a transistorized chopper and is connected to the field winding of the exciter or the generator slip rings.

**Features and Benefits:**

- Uninterruptible automatic transfer through diode decoupling via redundant power input facility
- Redundant manual channel or redundant AVR with separate power converter available through redundant power circuit facility
- Local and remote control for commissioning and operation
- Special solution for industrial purposes including Profi-Bus™
- The interfaces can easily be adapted to customer requirements, especially for refurbishment
- Rotating-diode monitoring
- Power system stabilizer (PSS)
- Joint reactive power control
- Volts per Hertz limiter and stator current limiter
- Compatible with generator types of all manufacturers.

**Software:**

Easy adaption by standardized software with an open structure and function block libraries.

**References:**

The two projects below are highlights of typical retrofit projects in fossil-fired power plants with medium output:

- **Project:** Elgin, Unit 1–4
  - **Customer:** Ameren, Illinois
  - **Application:** New system
  - **Plant type:** Gas power plant

- **Project:** Weisweiler Block C+D, Germany
  - **Customer:** RWE Rheinbraun AG
  - **Application:** Retrofit
  - **Plant type:** Steam power plant
RG3
The System Solution for Low/Medium Power Output
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Customer: RWE Rheinbraun AG
Application: Retrofit
Plant type: Steam power plant
THYRIPART®
The System Solution for Medium Power Output
Up to 1000 Amps Excitation Current

Applications:
This excitation system is suitable for use in industrial and nuclear power plants, for retrofits and for emergency generators.

Application Range:
The THYRIPART® excitation system is a load-dependent static excitation system. The compound excitation is fed from the generator voltage (max. 11 kV) as well as from generator current (max. 2000 A) and supports load steps or short circuits on the generator line side. It supplies the energy required to excite the generator directly via slip rings.

Its functional principle is based on a "Harz'sche circuit", which uses an oscillating circuit to convert a voltage source into a current source.

Features and Benefits:
- Load-dependent: the compound excitation is fed from generator voltage as well as from generator current and supports load steps or short circuits on the generator line side.
- Black start capability: during start-up, the internal oscillating circuit delivers a voltage rise and builds up the field from the remanence voltage of the generator.
- High availability and reliability: the fundamental excitation is still supplied through passive components (transformer, reactor, capacitor, uncontrolled rectifier) even if the regulator is out of order.
- Small voltage gradient: normally the controlled thyristor rectifiers create relatively high voltage gradients dU/dt. The THYRIPART® excitation system uses an uncontrolled rectifier, so the dU/dt is low. The strain on the field windings insulation is then lowered.
- Compatible with generator types of all manufacturers.

Software:
The programmable digital control circuit allows easy adaption of the excitation system to meet special demands.

References:
The two projects below are highlights of typical retrofits in nuclear and industrial power plants with high output:

- Project: Bohunice, Slovakia
  - Customer: Slovenske Elektrarne a. s.
  - Application: Retrofit
  - Plant type: Nuclear power plant

- Project: Ludwigshafen, Germany
  - Customer: BASF
  - Application: Retrofit
  - Plant type: Industrial power plant

Isar 2, 1475 MW nuclear power plant, Germany: four THYRIPART® systems for emergency generators with 7.3 MVA each (also installed one THYRISIEM® system with 1640 MVA). With top ranks in terms of cumulative output in every year since commissioning (several times rated number one), it is one of the most successful nuclear power plants in the world.

Camanche Peak nuclear power plant, USA: THYRIPART® systems qualified to American standard 1E.

Comanche Peak nuclear power plant, USA: THYRIPART® systems qualified to American standard 1E.

Current- and high voltage transformer belonging to the THYRIPART® excitation system.
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The hydroelectric power plants Trunoy, Argentinia: four THYRIPART® systems for emergency generators of Atucha 2.

Comanche Peak nuclear power plant, USA: THYRIPART® systems qualified to American standard 1E.

Current- and high voltage transformer belonging to the THYRIPART® excitation system.

THYRIPART®

The System Solution for Medium Power Output
Up to 1000 Amps Excitation Current

Generator output

Station service and emergency generators for hydro and nuclear power plants, retrofits, industrial power plants.
**THYRISIEM®**
The System Solution for Medium/High Power Output Up to 225 Amps Excitation Current

**Application**
This excitation system is suitable for use in steam and nuclear power plants.

**Application Range:**
THYRISIEM® is an excitation system for synchronous generators with rotating exciters. The power supply is supplied from the pilot exciter (150–420 Hz) and/or from the station service supply (400 V, 50/60 Hz).

**Features and Benefits:**
- Complete redundant structure
- Two independent controller channels including manual and automatic mode
- Two independent rectifier sections (2 x 100 % concept)
- Rectifiers can be replaced during operation of generator
- Complete digital controller from real-value detection up to the thyristor firing stage
- Complete set of limiters to ensure safe operation even at the limits of the generator
- Local operation panel including fault indications
- Power system stabilizer (PSS).

**Software:**
Open- and closed-loop control in 32-bit technology based on Siemens SIMADYN®D technology.

**References:**
The two projects below are retrofits in one of the oldest and most successful nuclear power plants in Germany and the most advanced steam power plant in China:
- **Project:** Biblis A, Germany
  - Customer: RWE
  - Application: Retrofit
  - Plant type: Nuclear power plant
- **Project:** Wai Gao Qiao, China
  - Customer: Shanghai Municipal Electric
  - Application: New power plant
  - Plant type: Steam power plant

**Generator output**

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<thead>
<tr>
<th></th>
<th>0.01</th>
<th>0.1</th>
<th>1</th>
<th>10</th>
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<th>1000 MVA</th>
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<tbody>
<tr>
<td>Steam and nuclear power plants</td>
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Suiza steam power plant, Egypt: 1 THYRISIEM® system 420 MVA.

Niederaussem lignite-fired steam power plant, Germany: 2 THYRISIEM® systems, 2 x 780 MVA for Units G and H, 1 THYRISIEM® system 1223 MVA, for the most advanced and powerful lignite-fired power plant of the world, Unit K.

Paiton II, 5+6, Jawa Power, Indonesia: two THYRISIEM® systems, 2 x 789 MVA.

Suez steam power plant, Egypt: 1 THYRISIEM® system 420 MVA.

Schwarze Pumpe, 2 x 1000 MVA, Germany, one of the most advanced lignite-fired power plants of the world: 2 THYRISIEM® systems.
THYRISIEM®
The System Solution for Medium/High Power Output
Up to 225 Amps Excitation Current

Generator output

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Schwarze Pumpe, 2 x 1000 MVA, Germany, one of the most advanced lignite-fired power plants of the world: 2 THYRISIEM® systems.
**THYRIPOL®**

The System Solution for High Power Output
Up to 8000 Amps Excitation Current

Generator output

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<tr>
<th>0.01</th>
<th>0.1</th>
<th>1</th>
<th>10</th>
<th>100</th>
<th>1000 MVA</th>
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Applications:

THYRIPOL® is a static excitation system for synchronous generators and synchronous condensers. It is equally suitable for hydro, steam and nuclear power plants and for rotary converters or synchronous condensers in substations.

Application Range:

Excitation of the synchronous machine is controlled directly by a thyristor converter equipped with a voltage regulator, i.e. the converter supplies the excitation current to the rotor of the synchronous machine without any interposed rotary exciters being required.

There are two standardized THYRIPOL® excitation systems:

- Feeding from the generator terminals or station supply (medium voltage)
- Feeding as a compound excitation system by additionally using a stator current-dependent component from a series reactor.

**Features and Benefits:**

- Power system stabilizer (PSS)
- Higher level closed-loop and open-loop controls
- Volts per Hertz limiter, stator current limiter
- Local operator panel including fault indications
- Redundancy (e.g. 2 AVRs)
  - fully controlled thyristor rectifier
  - fully digital system from actual-value detection up to firing pulse generation
- Compatible with generator types of all manufacturers.

**Software:**

- Modular open- and closed-loop control with components from the SIMADYN® family
- Multiprocessor system with 32 bit CPUs (RISC processors)
- Watchdog
- Floating-point arithmetic.

**References:**

The two projects below are two of approximately 650 references that are supplied for one of the numerous retrofits in Eastern Europe, and for one out of a series of steam power plants which Siemens has erected or equipped in China:

- **Project:** Sostanj 4, Slowenska Republica
  - **Customer:** Termoelektrarwa Sostanj d.o.o.
  - **Application:** Retrofit
  - **Plant type:** Steam power plant

- **Project:** Hanfeng, China
  - **Customer:** Hebei Electric Power Corp.
  - **Application:** New power plant
  - **Plant type:** Steam power plant

Hanfeng steam power plant, China: 2 x 765 MVA THYRIPOL® systems with up to 10,750 A
Connection of excitation system to generator lead with single-phase transformer (3 x 7910 KVAR).

Sanxia, Three Gorges, China, China Yangtze Three Gorges Project; with 26 x 840 MVA it will be the most powerful hydroelectric power plant of the world: Siemens will deliver 14 THYRIPOL® systems.

Tucurui hydro power plant, Brazil: 23 x 390 MVA. Siemens is delivering 11 THYRIPOL® systems.

Combined-cycle power plant, Santa Rita, Philippines: 4 x 298 MVA THYRIPOL® systems.
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Software:
Modular open- and closed-loop control with components from the SIMADYN® family
• Multiprocessor system with 32 bit CPU's (RISC processors)
• Watchdog
• Floating-point arithmetic.

References:
The two projects below are two of approximately 650 references that are supplied for one of the numerous retrofits in Eastern Europe, and for one out of a series of steam power plants which Siemens has erected or equipped in China:

Project: Sostanj 4, Slovenska Republika
Customer: Termoelektrarna Sostanj d.o.o.
Application: Retrofit
Plant type: Steam power plant

Project: Hanfeng, China
Customer: Hebei Electric Power Corp.
Application: New power plant
Plant type: Steam power plant
Additional Services

We also offer the following additional services to provide a comprehensive package for your plant:

- **Technical support for excitation systems**
- **Excitation systems for other manufacturers**
- **Power system stabilizer / simulation of generator and excitation system / control engineering and consulting**
  - **Power system stabilizer (PSS)**
    Design and optimization of PSS, calculation of damping performance, on-site measurement and analysis of performance.
  - **Simulation of generator and excitation system**
    Testing of voltage regulators using a digital real-time simulator for a hardware-in-the-loop-test, i.e. for a comprehensive check of existing voltage regulators and for new excitation systems (functional performance test, support of commissioning).
  - **Control engineering and consulting**
    Analysis and optimization of control loops in power plants, computer presentation of excitation systems.
- **Grid and system stability calculations**
  Engineering and consulting for the design, coordination and adaptation of AVR parameters and PSS parameters to all system constellations and conditions. Using modern system simulation techniques, system dynamics and system stability are taken into account. In addition, coordination of parallel operating generators and reactive power contribution can be designed together with the setting of block transformer tap changers. The review of grid code conditions and the check of fulfillment are also included in our services.
- **Technical services for electrical machines, hydro and diesel power plants**
  - **Erection and commissioning (start-up)**
  - **Diagnostics and maintenance**
  - **Repairs**
  - **Modernization, extension and retrofit**
  - **Consulting service**

We also offer maintenance contracts, on-call and hotline services.

- **Technical services for fossil and nuclear power plants worldwide**
  Specific know-how constitutes the basis for successful service. We are focused on high-end competences for support of any erection, reconstruction and operation phases of your plant:
  - **Project site management**
  - **Engineering**
  - **Erection and commissioning (start-up), training**
  - **Maintenance and repair.**