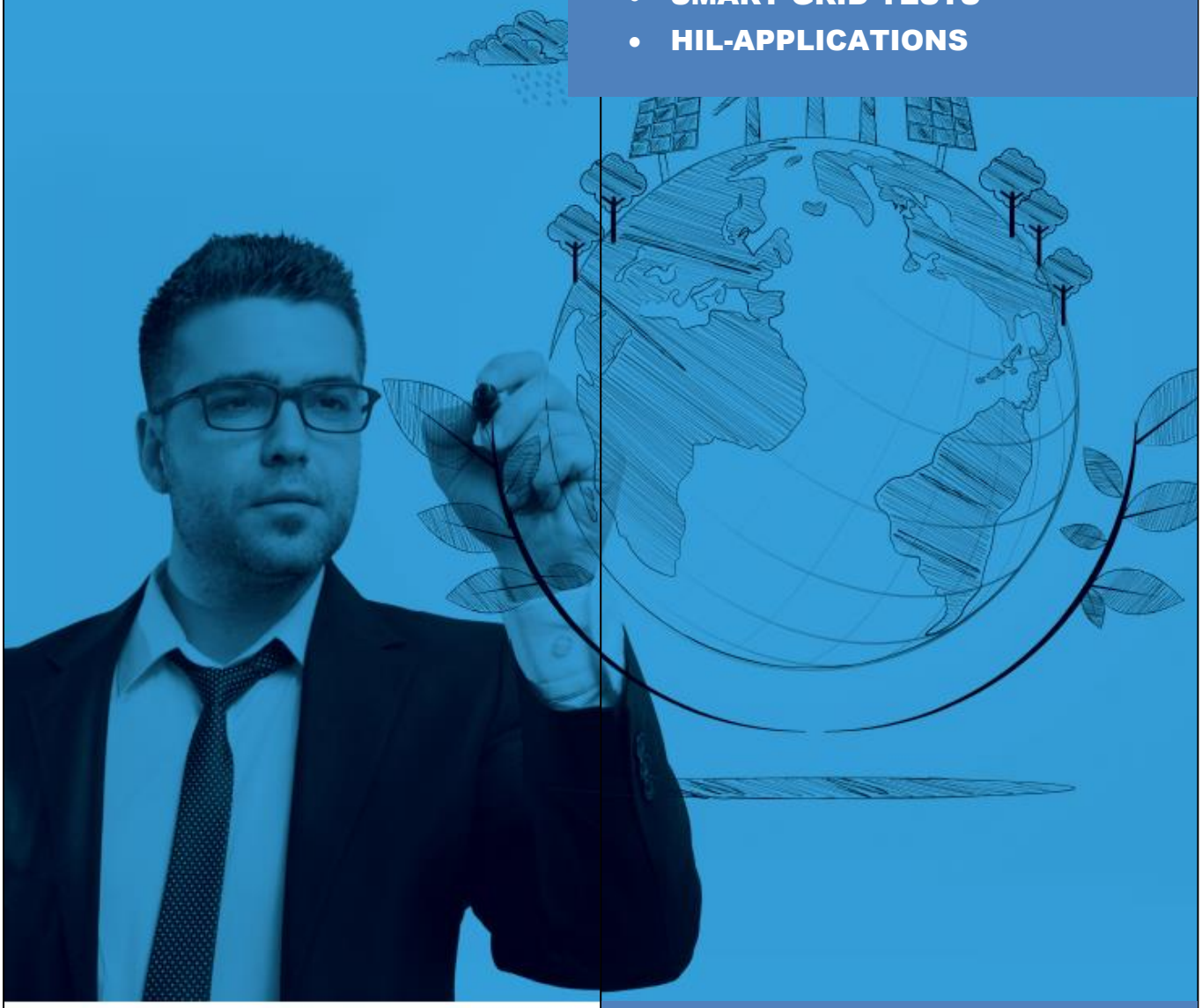
YOUR ENTRY TO:

THE WORLD OF

- SOLAR ARRAY SIMULATION
- E-STORAGE SIMULATION
- E-STORAGE TESTING
- E-CONSUMERS SIMULATION
- SMART GRID TESTS
- HIL-APPLICATIONS



REGATRON
programmable power supplies

1. Abstract

Today's solar systems range up even to the MegaWatt region and are feeding the public grid as well as so called island applications. In most cases, energy is being stored at site to ensure a day and night power availability as also to have energy reserves for extraordinary situations.

Operational safety and uninterrupted operation are often of highest priority. Within such systems, several high power subsystems are working closely together, so each component has to follow specific rules of operation, be it under normal conditions or – to a much greater extent – in extraordinary situations.

It stands to reason that such systems have to be tested intensively under all reasonable conditions in order to avoid 'painful' and expensive surprises in the practical field application.

2. Why specialised component and system tests

State-of-the-art energy components like solar panel fields, solar inverters, energy storage components and related safety equipment do not stand on its one, but have to work together within a wide range of external conditions. Therefore, safe operation under all possible conditions has to be tested intensively in order to ensure the envisaged safety of operation.

A second important reason for component testing is the mandatory need to fulfil national and international regulations with respect to:

- Feeding energy into public grid
- Feeding energy in so called island applications
- Regulations for the safety of operators and service personnel
- Regulations of local/regional supplier companies
- Safety and emergency precautions
- EMI test certificates (Electro-magnetical interference)

System behaviour in extraordinary situations needs particular attention in order to protect expensive secondary equipment from damage and - not least - to safeguard operators from injury.

3. What to test

Below, some component related test procedures are listed to give a raw survey about general test work to do. The list might easily be extended by adding further national and local regulations and test procedures.

a) Solar inverter equipment tests with the **Solar Array Simulator**

- Check of general DC input behaviour as wake-up, overload, leaking current to earth
- Check and verify the Maximum Power Tracking and efficiency (MPPT)
- Check and verify behaviour in the case of partial shadowing
- Test of long term full load at maximum ambient temperatures
- Test patterns as e.g. SANDIA LABs test for dynamic scenery response

b) Solar inverter test on AC grid side with **Grid Simulator**
(Tests following international conventions and regulations)

- Response of the inverter to grid under-/overvoltage and related AC frequency
- Ability of the inverter to support the grid in the case of a brown-out or short voltage drops
- Ability of the inverter to handle grid irregularities like phase asymmetries, harmonics
- EMI considerations
- Ability to detect 'Islanding conditions' of a public grid

c) Electrical storage system tests with programmable **bidirectional DC power source**

- Test for bidirectional constant charge/discharge current handling of charger interface
- Tests of system over-/under voltage protection (very important for batteries)
- Storage capacity tests at high/low ambient temperatures
- Cycling tests of storage system to determine thermal behaviour
- Test of system protection plane (temperature, overload, deep discharge, voltage limits)
- Functional tests of emergency cut-off chain under different operational conditions

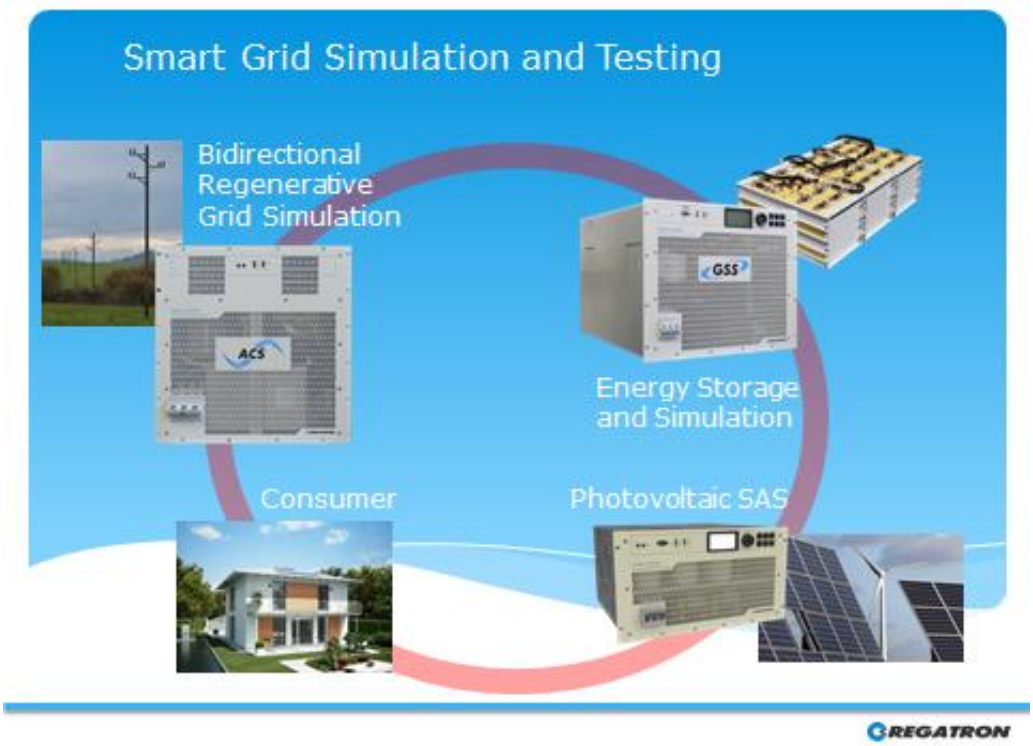
4. Why REGATRON test laboratory equipment

REGATRON represent more than 45 years of experience in the field of Electrical Engineering and was first on the world market offering fully programmable Solar Simulators and full digital programmable bidirectional DC power supplies.

Customers benefit from an in deep experience in the field of high quality DC and AC power sources for all imaginable test situations. Due to the high degree of modularity, test equipment can be accurately tailored to the customer's needs, always open for future adaptions and power extension.

5. Integral system testing

Today tests on whole energy systems are an important key aspect for electrical engineering laboratories. Refer to picture 1 for a typical 'smart grid' situation including the building blocks solar energy, electrical energy storage, consumers as also an energy grid network feed-in.



Picture 1: Typical energy grid situation / Smart Grid

6. The individual REGATRON laboratory components

6.1 REGATRON Solar Array Simulation

Modular well proven SAS (solar array simulation) components ranging from low power spacecraft simulators up to systems with several MegaWatt are at the customers' disposition.

TC.P.LIN: 2.2kW/200V Specialized SAS system for low power and spacecraft onboard equipment

TC.P.20/32kW, modular SAS from 10 kW up to the MegaWatt range and up to 1500VDC

TC.P.SYS: SAS-systems in the range up to several MW and 1500VDC

Picture 2: REGATRON Solar Simulation components

6.2 REGATRON Grid Simulation systems

Testing of modern solar inverters calls for 3-phase AC simulation systems able to generate all grid situations claimed by international regulations. Due to restrictive rules, this implies full four quadrant operations and a very high degree of programmability, fast step response and high modulation bandwidth.

REGATRON TC.ACS Grid simulators were developed to meet these requirements in an ideal manner. An exceptional high efficiency makes the TC.ACS a first choice even for long term full load system tests. TC.ACS offers additionally the unique ‘Amplifier Mode operation’ enabling the operator to run 1 to 3-phase patterns from an external low power source. This is an ideal feature for so called ‘hardware-in-the-loop’ operation (HIL), providing the system to behave like an electrical 2- or 4-pole network computed by an external Real Time computer. Even a 3-phase R/L-load mode is provided featuring full energy recuperation into the grid.

Picture 3:
TC.ACS Grid Simulators
30/50 kVA,
Wide range grid input
(On top air cooling unit TC.LAE)

Picture 4: Big scale 800kVA Grid Simulator system for an international Test Facility in Europe

The powerful application software GridSim supports the operator within all of the three operation modes:

- Grid simulation inclusive storage and recall of even complex test procedures
- Amplifier mode for connection to external signal sources -> HIL applications
- 3-phase electronic R-L-loads with energy recuperation back into grid

6.3 Simulation and testing of e-storage systems

As mentioned above, e-storage systems need highly specialized bidirectional DC power sources for test and evaluation work.

REGATRON TC.GSS series offers a modular, fully programmable and bidirectional DC power source ideally suited for e-storage purposes.

Starting with a single unit of 20 or 32 kW DC power, systems up to the MegaWatt range may be built up using a very fast domestic MACbus system for networking.

Picture 5:
TC.GSS 20/32 kW
Bidirectional DC Power module

Picture 6:
TC.GSS in a 768 kW DC power system
Equipped with additional switch boards

TC.GSS units/systems are controlled either by HMI/TopControl software or by external commands by means of a multitude of control interfaces. The operator is further supported by specialized application software as:

- BatSim software to simulate the behaviour of battery stacks of different cell types
- CapSim software dedicated to simulate capacitive storage stacks
- SASControl software for multifunctional simulation of Solar Arrays
- A customer API interface for customer made external software

7. REGATRON Test- and laboratory equipment – powerful, reliable, versatile!

TopCon TC.P. Series: Uni-directional programmable DC power supplies

Voltage classes	52VDC to 1200VDC, up to 1500V in series connection
Power classes	10/16/20/32kW
Circuit types	serial, parallel, mixed mode, Multiload
System power	up to several MegaWatt

TopCon TC.GSS. Series: Bidirectional programmable DC power supplies

Voltage classes	65VDC to 600VDC, to 1500V in series connection
Power classes	20/32kW
Circuit types	serial, parallel, mixed mode, Multiload
System power	up to several MegaWatt

TopCon TC.GXS. Series: Programmable recuperative electronic load (sink)

Voltage classes	65VDC to 600VDC, to 1500V in series connection
Power classes	20/32kW
Circuit types	serial, parallel, mixed mode, Multiload
System power	up to several MegaWatt

TopCon TC.ACS. Serie: Programmable full 4-quadrant Grid Simulator

Sim output voltage	3 x 0 to 305 Vrms against voltage controlled Neutral
Output current	3 x 72 Arms
Operation modes	4Q-Grid Simulator system 4Q-power amplifier for external control signals; HIL mode 3-phase electronic RL-load, recuperation into grid
Unit power	30kVA, 50kVA
Output frequency range	16Hz to 1000Hz; DC to 16 Hz with current derating
Modulation bandwidth	5 kHz
Power factor	0 to 1.0
Voltage accuracy	0.1% F.S.

Appendix A

Examples of REGATRON Full Functionality smart grid LAB systems

Excerpt

AIT - Austrian Institute of Technology, Test and Verification Institute

1.35 MW Precision Solar Simulation
320 kW Battery simulation
800 kVA Grid Simulation

- 36x TC.P.32.320.400.S with linear post-processing units
  - 5x 192 kW / 640 V / 300 A or 5x 192 kW / 960 V / 260 A or 8x 128 kW / 1280 V / 130 A or 6x 160 kW / 1500 V / 130 A 1x 1344 kW / 640 V / 1800 A or 1x 1344 kW / 960 V / 1560 A or 1x 1024 kW / 1280 V / 780 A or 960 kW / 1500 V / 780 A
- 8x TC.GSS.32.600.4WR.S for battery simulation
- 2x TC.GSS.32.130.4WR.S for battery simulation
- 16x TC.ACS.50.480.400.S with GridSim for grid simulation

Picture A1 : Part view on the AIT power supply section

ENEL - Italian Electricity Supplier

30 kW DC Solar Simulation
40 kW DC Battery Simulation
200 kVA Grid Simulation

- 3x TC.P.10.1000.400.S with SASControl for PV simulation
- 2x TC.GSS.20.600.4WR.S with BATSim for battery simulation
- 4x TC.ACS.50.480.400.S with GridSim for grid simulation

University New South Wales – Sydney

58 kW DC Precision Solar Simulation
40 kW Alternative Solar Simulation System / Battery Testing System
150 kVA Grid Simulation

- 1x TC.P.10.1000.400.S with linear post-processing unit TC.LIN with SASControl for PV simulation
- 2x TC.P.16.1000.400.S with linear post-processing unit TC.LIN with SASControl for PV simulation
- 1x TC.P.16.600.400.S with linear post-processing unit TC.LIN with SASControl for PV simulation
- 2x TC.GSS.20.600.4WR.S for PV Simualtion and BATControl for testing and cycling batteries
- 40 kW / 600 V / 80 A or 40 kW / 1200 V / 40 A
- 3x TC.ACS.50.480.400.S with GridSim for grid simulation

Pictures A2 – A4: Equipment at University New South Wales

- left: Mobile TC.P. TopCon DC power supply for Solar Array Simulations
- mid: Mobile TC.ACS 50 kVA Grid Simulator
- right: Mobile TC.GSS bidirectional power supplies for Battery Simulation and Tests

EPRI - China State Grid: Test and Verification Institute

1.35 MW Solar Simulation
1.35 MW Battery simulation
Split operation Solar/Battery simulation on discretion

- 42x TC.GSS.32.500.4WR.S with BATSim for battery simulation and SASControl for PV simulation within the same system
- 7x 192 kW / 500 V / 480 A or 192 kW / 1000 V / 240 A or 192 kW / 1500 V / 160 A
  1x 1344 kW / 500 V / 3360 A
  or 1x 1344 kW / 1000 V / 1680 A
  or 1x 1344 kW / 1500 V / 1120 A

Picture A5: System components before shipment

FRONIUS - PV inverter manufacturer in Austria

> 1 MW DC power sources for Inverter Tests
196 kW Bidirectional Power Sources for Battery/Fuel Cell Test and Simulation
50 kVA Grid Simulation

- few hundreds TC.P for PV simulation
- 5x TC.GSS.32.500 for battery and fuel cell simulation
- 1x TC.GSS.32.130 for battery and fuel cell simulation
- 1x TC.ACS.50.480.400.S with GridSim for grid simulation

LUXCO - Solar Energy, Korea

32 kW DC Solar Simulation
64 kW DC additional Solar Simulation or
64 kW Battery Simulation/Testing
50 kVA Grid Simulation

- 1x TC.P.32.1000 with SASControl for PV simulation
- 2x TC.GSS.32.600.400.S with BATSim for battery simulation
- 64 kW / 600 V / 132 A or 64 kW / 1200 V / 66 A
- 1x TC.ACS.50.480.400.S with GridSim for grid simulation

Picture A6: REGATRON System components within LUXCO Research Laboratory

Aalborg University – Denmark

32 kW DC Solar Array Simulation
240 kW Bidirectional DC power sources, Battery Testing and Simulation
50 kVA Grid Simulation

- 1x TC.P.32.1000 with linear post-processing unit with SASControl for PV simulation
- 12x TC.GSS.20.500.4WR.S with BATControl for testing and cycling batteries
- 1x TC.ACS.50.480.400.S with GridSim for grid simulation

UPC - Politechnical University Barcelona, Spain

96 kW Precision Solar Simulation
40 kW Additional DC Solar Simulation by TC.GSS components
40 kW Bidirectional Power sources for Battery Simulation and Tests
30 kVA Grid Simulation

- 3x TC.P.32.1000 with linear post-processing precision unit with SASControl for PV simulation
- 96 kW / 1000 V / 120 A
- 2x TC.GSS.20.500.4WR.S with BATSim for battery simulation and SASControl for PV simulation
- 1x TC.ACS.30.480.400.S with GridSim for grid simulation

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