BESS® Battery Energy Storage System

Smart Storage System for On-Grid and Off-Grid Applications

March 2014

AccuSol SIEMENS

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1. Project Partners

1.1 AccuSol GmbH, Karlsruhe

AccuSol GmbH has been established early 2012, with the business objective to develop and commercialize battery energy storage systems (BESS®) as a system integrator.
As a small-sized enterprise, AccuSol cooperates closely with SIEMENS and external leading consultants such as the Karlsruhe Institute of Technology. The management and employees, have a strong background as project developers and financial service providers in large scale wind farms (up to 60 MW) and PV park projects (up to 8 MW).

1.2 Siemens AG Sector Industry, Karlsruhe

The Siemens Industry Sector is the world's leading supplier of innovative and environmental friendly products and solutions for industrial customers. With end-to-end automation technology and industrial software, solid vertical-market expertise, and technology-based services, the Sector enhances its customers' productivity, efficiency, and flexibility.
With a global workforce of more than 100,000 employees, the Industry Sector comprises the Divisions Industry Automation, Drive Technologies and Customer Services as well as the Business Unit Metal Technologies.

2. Problem Statement

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2.1 Situation

- Since renewable energy sources with high potential, such as wind and solar, are typically subject to natural intermittency and hence not consumer oriented, there is a need to adapt to real consumer demand.
- The share of electrical power, fed into the electrical grid without destabilizing it, can only be increased if suitable storage technologies are integrated into the system.

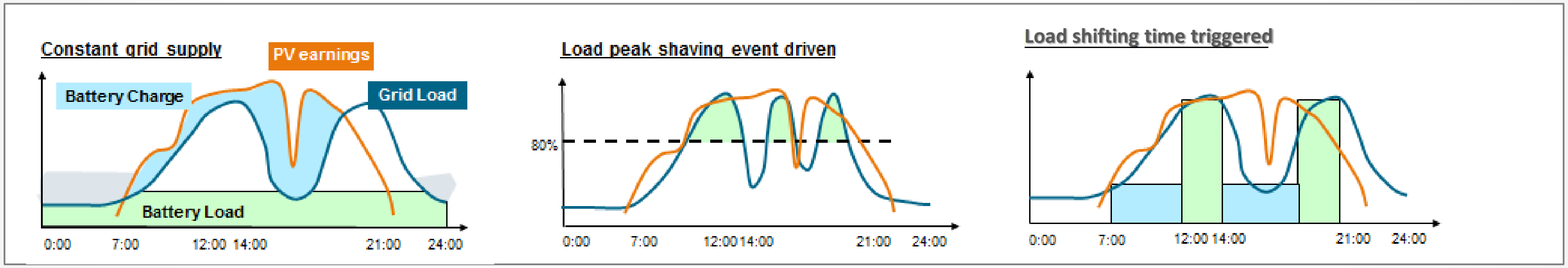

Fig. 1: Required operation modes for an Electrical Energy Storage system (EES)

- Lithium-ion batteries could partially solve the storage problem in some applications due to their high cyclic and electrical power handling capacity.
- The cost of lithium-ion battery technology is still very challenging for the overall system cost.
- It is important to find an optimal balance between renewable energy sources, battery storage technology and consumer demand for each system.

2. Problem Statement

2.2 EES Requirements

Typical requirements for an Electrical Energy Storage system (EES) in connection with the use of energy from renewable sources are:

- Connection to national grid or geographical/electrical island grid
- Handling of erratic energy demand
- Free flow of energy between renewables – generators – storage – grid
- Optimized interaction of energy sources and drains regarding
  - ➢ Operational efficiency
  - ➢ Technical aspects
  - ➢ Load requirements from grid
  - ➢ Balancing of peak production
  - ➢ Balancing of peak loads
  - ➢ Balancing of different energy sources
  - ➢ Forward-looking energy management

… and all that at reasonable energy cost

3. Technical Solution

3.1 BESS® Battery Energy Storage System (I)

BESS® is a battery storage system that is able to handle different grid loads with the objective to increase the portion of renewable energy sources (RES) in an electrical grid. The system mainly consists of a PV generator, Li-ion batteries, power electronics (DC-DC converter/inverter), a control unit and an energy management software.

It can run in a full automatic mode as well as in a manual mode. BESS® is modular und scalable in a range of 0,1 MWh to 2 MWh.
It is possible to operate multiple systems parallel and redundant.

Fig. 2: BESS® system

Unique features:

- **Free combination of renewable energy sources such as PV, wind and others in one system**
- **Only one terminal point to the grid**
- **Free flow of energy between grid, energy sources and consumers**
- **Several operation modes possible as constant grid feeding, peak shaving, peak shifting**
- **Energy management considering all grid and BESS® parameters**
- **Energy management internally on DC level, thus no adjustment control over the grid**
- **Predictive and self-optimizing energy management**

3. Technical Solution

3.1 BESS® Battery Energy Storage System (II)

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BESS® System Components (A)

Battery

- Advanced Li-ion technology
- High level of safety due to ceramic separator
- Modular and redundant architecture
- Capsulated battery module with safety gas
- 4.000 cycles @ 100% DoD

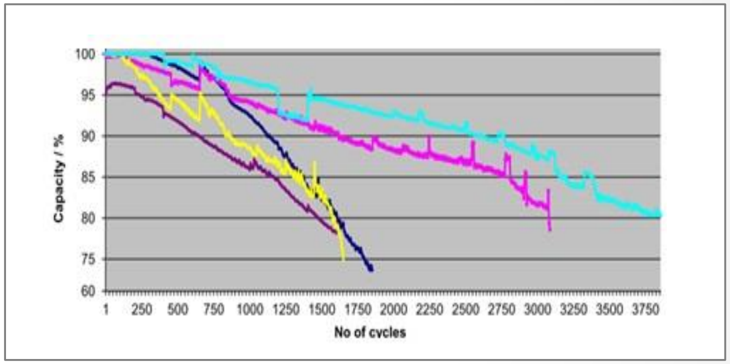

Fig. 3: Cycle trend of different Li ion batteries

BMS

- Intelligent battery management with passive balancing
- Monitoring of Voltage and Temperature of each cell
- CAN/Ethernet interface

3. Technical Solution

3.1 BESS® Battery Energy Storage System (III)

BESS® System Components (B)

EMS

- Considering power grid parameters, geographical parameters and economical conditions as well as BESS® environment
- Energy Management incl. BESS® load and unload algorithm and master functionality for the DC - renewable storage backbone (RSB) unit
- Self-optimizing forecasting

CCU

- Specially developed central computer unit to dynamically and simultaneously control all main parts of the BESS® (PV – battery – power electronics)

3. Technical Solution

3.1 BESS® Battery Energy Storage System (IV)

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DC RSB – Renewable Storage Backbone

The DC renewable storage backbone (RSB) is the innovative solution to equalize the energy flow from solar, wind, battery, and other energy sources and drains on the one hand and the power grid on the other hand according to grid operator demands.

As combination of reliable and proven, standard components from the portfolio of the Siemens Industry Sector, DC-RSB brings together the energy flows of the connected systems through a DC intermediate circuit.

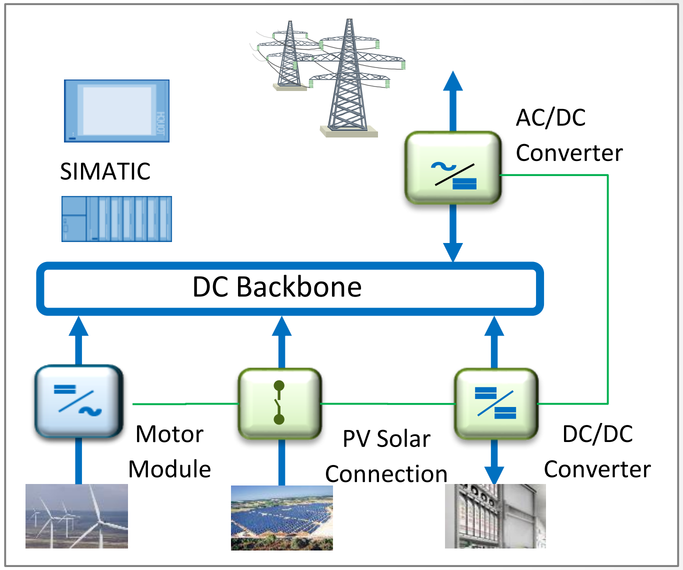

Fig. 4: DC-RSB system overview

DC-RSB Key Parameters:

- SINAMICS AC/DC Converter (16 – 800 kW), DC Intermediate circuit level: 560 – 800 V
- DC/DC Converter 25kW / 50 A / 4 pole: DC/DC Level In = 600 – 700 V / Out: 300 – 800 V
- SINAMICS Active Line Module: 16 – 1.400 kW
- SIMATIC PLC real time controller

3. Technical Solution

3.1 BESS® Battery Energy Storage System (V)

DC RSB System Components

The battery units of the DC-RSB system are connected to the intermediate circuit via DC/DC converters. An intermediate circuit grid offers the advantage of enabling various energy sources with various properties to feed into the grid through a common grid inverter.

Control and regulation within the DC RSB system is performed by a real-time capable local grid controller (LGC). The LGC is equipped with a WinCC operating and control system and is based on the proven automation system SIMATIC S7-300, which has been specially designed for innovative system solutions. All signals relevant for power regulation and component control are acquired and distributed via PROFIBUS and CAN bus.

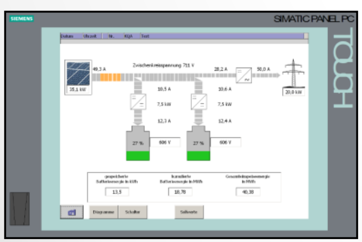

Fig. 5: SIMATIC WinCC Touchpanel

Fig. 6: Inverter and converter unit

DC RSB Advantages:

- Efficient utilization of renewable energy
- Coverage of peak load and peak production
- Higher grid stability through grid support
- High flexibility in the use of energy sources in the grid
- One terminal point to the grid, one converter unit

3. Technical Solution

3.2 BESS® Operation Modes

Enabling free energy flow between energy sources and drains

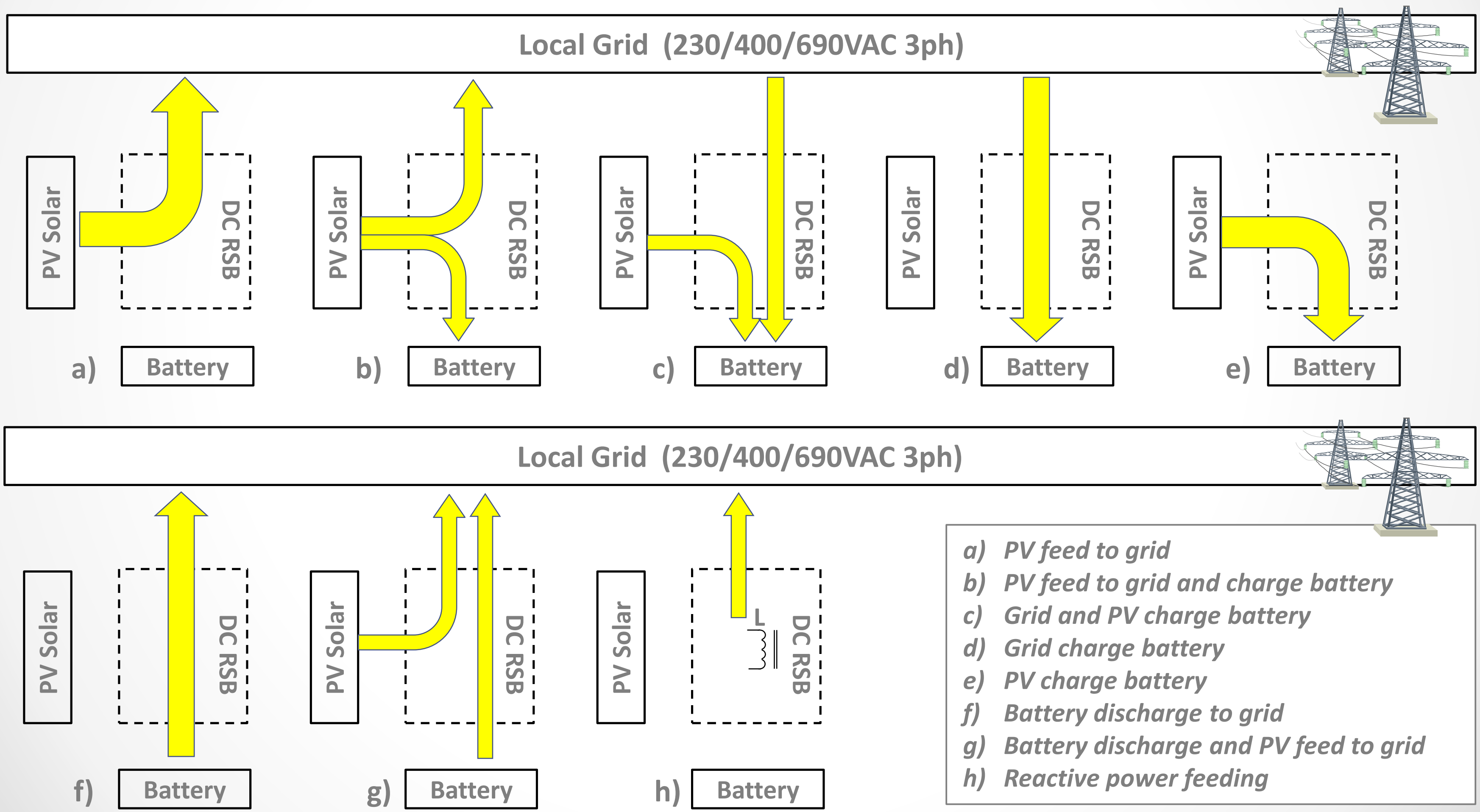

Fig. 7: BESS® Operation Modes

3. Technical Solution

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3.3 BESS® Economical Aspects (I)

An important factor regarding the investment cost for BESS® are the purchase prices for the batteries. The relatively high price level for high grade batteries are leading to a CAPEX share of the batteries of >55% of the overall system. However, considering an increasing use of Li-ion, it is expected that Li-ion batteries will see a similar development as solar modules, i.e. prices are expected to be cut in half by 2017 (source: DIE ZEIT 07/2013).

The leveled cost of energy of BESS can be further improved by increasing the share of renewables (PV/Solar, sun radiation) and optimized utilization of the battery.

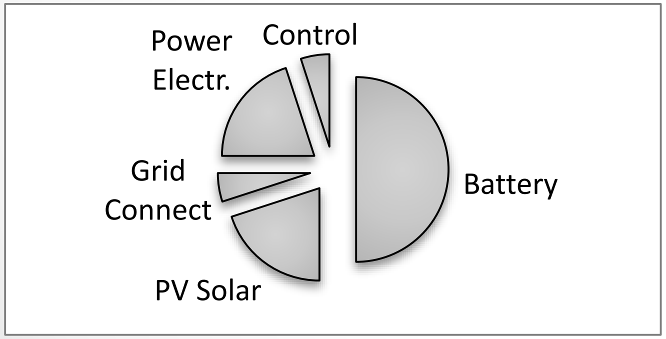

Fig. 8: BESS® CAPEX split

3. Technical Solution

3.3 BESS® Economical Aspects (II)

At the current situation, the most reasonable application for BESS® is the substitution of diesel generators. Later, based on positive development of battery cost and increasing energy cost, the use in other applications will also make sense.

In general:

$$\text{Storage energy cost [€/kWh]} = \frac{\text{Battery invest (+ maintenance etc.) [€]}}{\text{Energy turnover [kWh] until EOL*}}$$

In this case:

$$\text{Energy cost [€/kWh]} = \frac{\text{Invest (PV + battery + power electronics etc.) [€]}}{\text{Profile energy turnover [kWh] until EOL*}}$$

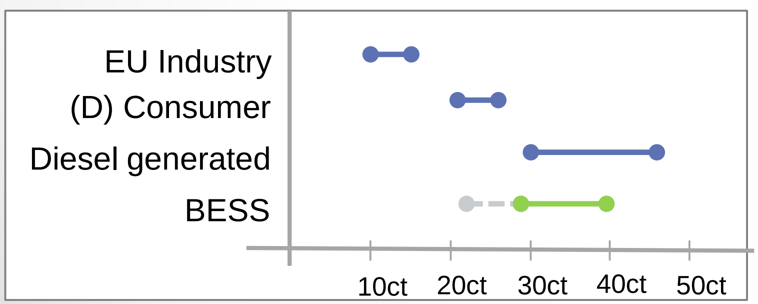

Fig. 9: Energy rates by Ct/kWh

Fig. 9: BESS® CAPEX split

3. Technical Solution

3.4 BESS® Environmental Aspects

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Exhaust emissions from diesel-powered generators includes:

- Nitrogen oxides NO_X
- Hydrocarbons (HC),
- Carbon monoxide (CO)
- Particulate matter as smoke and soot (PM)

In addition a diesel generator emits noise.

BESS® is able to substitute >70% of diesel fuel and hence, an equivalent of emissions could be avoided. Noise emissions are also reduced because most diesel generators could be taken offline. Al components are recyclable.

3. Technical Solution

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3.5 Concept of proof Pilot plant BESS® Karlsruhe

BESS® was designed, built and tested in Karlsruhe, Germany. It is running since May 2013 in full automatic mode and at times in a manual mode according to predefined test profiles for research purposes. After a period of initial troubleshooting and system performance enhancement, it is running since September 2013 without problems

BESS® Pilot Plant System Components:

- PV modules 36 kW
- Battery modules 2 x 50 kWh incl. BMS
- EMS - Energy Management System
- CCU - Central Control Unit
- AC-DC inverter 270 kW
- DC-DC converters 25 kW
- Control panel and PLC
- Container 20” x 2 air conditioning

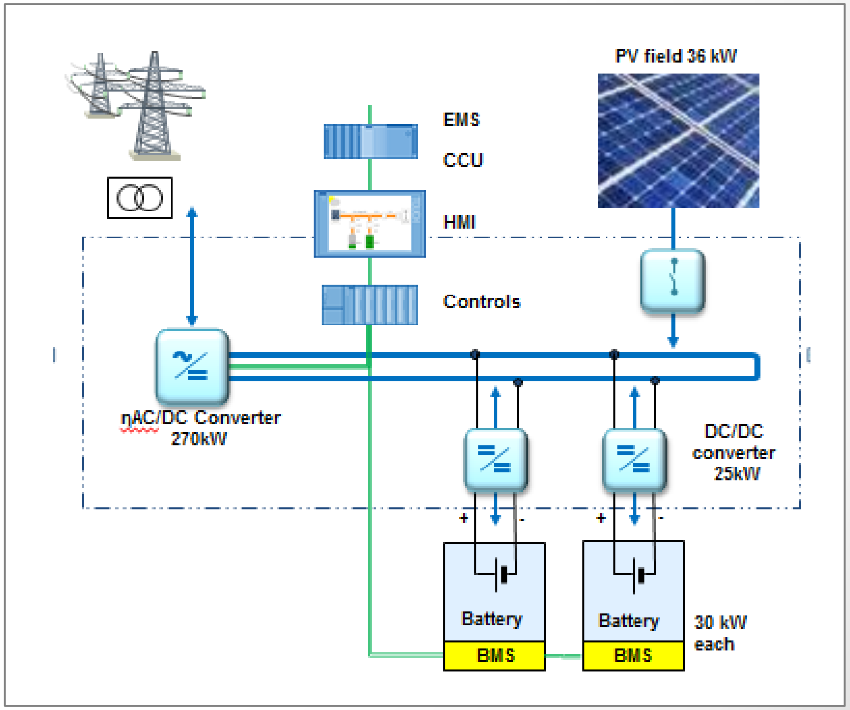

Fig. 10: Schematic system overview

3. Technical Solution

3.6 Scale up geographical Island

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A small European island produces its electrical power exclusively with diesel generator sets. The diesel generator sets feed the island grid in parallel mode, without connection to the mainland grid. Diesel is supplied by vessel and stored in tanks, which is elaborate and expensive.

The power demand has a significant seasonal variance as the population in summer is 5 timers higher as in winter. There is also a typical scheme for peak loads in the course of a day. The use of renewable energy sources is currently limited to <30% in order to meet grid stability criteria.

It is desired to support the grid with more energy (>70%) from renewable sources and substitute some of the diesel generators. This objective guides the layout of the PV plant and the battery system.

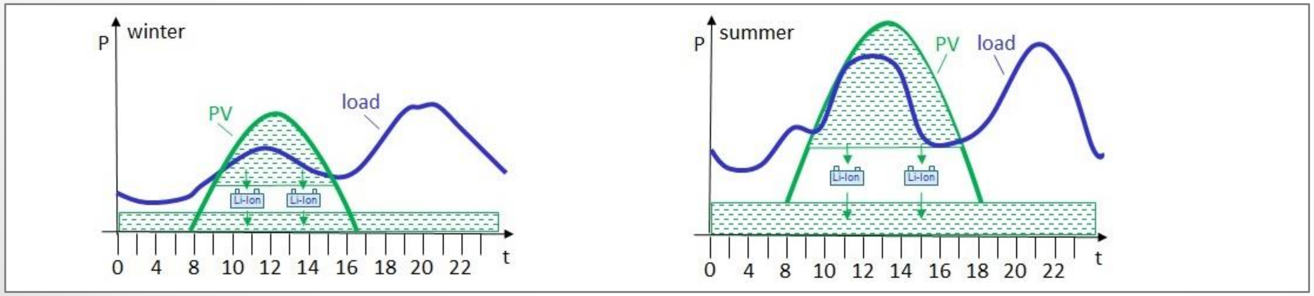

Fig. 11: Load curve and supply scheme for application geographical island

BESS® Advantages:

- Increase the share of renewable energy sources >70%
- Lower the fuel cost in a reasonable way
- Lower the cost of power generation compared to diesel generation sets
- Significant reduction of CO_2 emissions
- Marginal operational expenditure (OPEX) compared to conventional power generation
- Island black-start

4. Summary

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Advantages

- Efficient utilization of renewable energy
- Handling of peak load and peak supply
- Higher grid stability through grid support
- High flexibility regarding the use of energy sources within the grid
- Efficient utilization of the grid inverter in partial load state of the energy sources
- Only one terminal point to the grid
- No adjustment control over the grid
- Higher system efficiency thanks to intelligent control of the energy flow
- Cost advantages through standard components and compact design
- High quality standard as components from the Siemens Industry portfolio are used

Applications

- Diesel generator set substitution
- Geographical/grid island solutions
- Electrification of development zones
- Solar park extensions
- Peak shaving
- Peak shifting
- Support of weak electrical grids
- E-Car charging stations