SMA Sunbelt Energy GmbH

Case studies

Eduardo Rocha
Regional Sales Manager
SMA Sunbelt Energy GmbH
Email: eduardo.rocha@sma.de

Agenda

1. **Introduction to SMA Group and SMA Sunbelt Energy GmbH**
2. St Eustatius – Ramp-rate control, Grid Forming and UPS – Case Study
3. Brando Island – Grid Forming and Black Start – Case Study
4. Pelham – Frequency Response – Case Study

SMA Group and SMA Sunbelt in a nutshell

Highlights

SMA is a leading global specialist for PV system technology

- Founded in 1981
- >65 GW installed base
- Complete portfolio to serve all PV segments
- 20 subsidiaries with strong service capabilities and access to all channels
- Award-winning 20 GW production to achieve scale

Sunbelt is the off-grid, hybrid and storage specialist @ SMA

- 100% subsidiary of SMA Solar Technology AG
- Focus on off-grid, hybrid and battery based solar projects in the sunbelt region
- Business model covers component and solution sales as well as system integration
- Executed >100 MW of hybrid & storage projects

Key Figures SMA Group

Sales 2017:	891 Mio. Euro
EBITDA 2017:	97,3 Mio. Euro
Inverter output sold 2017:	8,5 GW
Employees:	> 3.000
O&M portfolio:	2,6 GW
Patents and utility models:	>1.000

Product Innovations

> SMA has know-how & products to benefit from strong growth in the field of battery storage.

SMA Sunbelt business model

Components

- Supply of SMA's off-grid portfolio and 3rd party products (batteries, modules, mounting structure, etc.)
- Additional services (engineering, training, commissioning support, etc.)

Solutions

- Engineering and supply of Battery Storage solutions integrating 3rd party products
- Battery Containerization; Development of SCADA and Energy Management Systems

Project Support

- System integration for large scale hybrid and storage projects
- Modular support through the entire project value chain as required (development, engineering, procurement, construction management and service)

> SMA Sunbelt is a one-stop-shop for off-grid, hybrid and storage projects.

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Large Scale PV Diesel storage Hybrid system
Diesel Off-Mode, Grid Forming SCS, St. Eustatius

Today, solar energy covers 46% of St. Eustatius' total electricity need. Grid Forming SCS 2200 inverters allow to operate the island grid for 10.5 hours in Diesel Off-Mode operation with 100% Solar Power Fraction. In total a 5.9MWh Li-Ion storage facility has been integrated for energy shifting and grid services. Thanks to the SMA Fuel Solution about 4,560 tons CO2 per year can be saved. The project has been designed and implemented by the SMA Sunbelt Energy GmbH.

Project "St. Eustatius Phase 1+2"

- Location: St. Eustatius, Caribbean
- Commissioning: November 2017
- Requirements: Grid Forming Inverter, overall power and energy management system

Plant information

- Installed PV power: 4.15 MWp
- Installed Storage capacity: 5.9 MWh
- Diesel capacity: 4 MVA
- Annual energy yield: 6,400 MWh
- Annual diesel savings: > 1,700,000 liters
- Island Load: ~2MW

System Technology

- Battery: 2 x SCS 2200 Grid Forming in 2 x MVPS 2200 and 1xSCS 1000 in MVPS 1000
- PV: 2xSC CP XT1000 in 1xMVPS 2000 and 74 SMA Sunny Tripower 25000TL-30
- Control: FSC 2.0 with Automatic Genset Shutdown

SMA system solutions for hybrid applications

STUCO Solar + Storage Main driving factors

Up to 2015, STUCO 100% depending on fossil fuel (5.3 MVA diesel gensets capacity). More than its 78% income was going directly in fuel related operational costs.

Dutch Government financed the installation to reduce exposure of STUCO to the high cost of fuel with significant operational losses.

The installation offsets sufficient fuel to significantly eliminate operational losses.

STUCO Solar + Storage Implementation

The system has been implemented in 2 phases, each of them with particular open tender processes.

The tenders called for innovation to meet the Caribbean environment and Micro grid complexity.

- Solar panels, Warranty performance >90% and >80%, after 10 and 20 years respectively. Comply with IEC standards (e.g.: IEC 61215, 61730 and 61701).
- Mounting structures, originally design to withstand CAT 4 at 15^0 angle, but later adjusted to 5^0 to maximize space (Withstand cap. ↑ for CAT 5).
- PV Inverters, comply to "Technical Regulation for Generating Plants in Medium Voltage grids , German Federal Assoc. of Energy and Water Industries (BDEW)
- Battery Storage - Inverters, Provide grid stability, energy shifting and Grid Forming during Power management control to enable diesel off/on mode. Operation as generator class G2 according to ISO 8528-5.

Challenges compared to a large utility grid

- **Generators often fail**
  Lot of moving parts. Generators often fail and when failing usually cause massive load shedding or blackout

- **Few fossil generation units cover high shares of load**
  Dropout of one unit usually means 50% to 100% loss of production (depending on time of day)

- **Solar production on a compact area with high wind speeds**
  Clouds often reduce PV production by 80% within seconds

- **Large load shedding on grid disturbances**
  up to 50% in case of frequency deviation

- **Grown infrastructure not built for 100% renewable power**
  Solar and storage have to integrate seamlessly into existing electricity grid

- **Resiliency**

- **Customer and operating personnel in doubt about performance and interoperability**

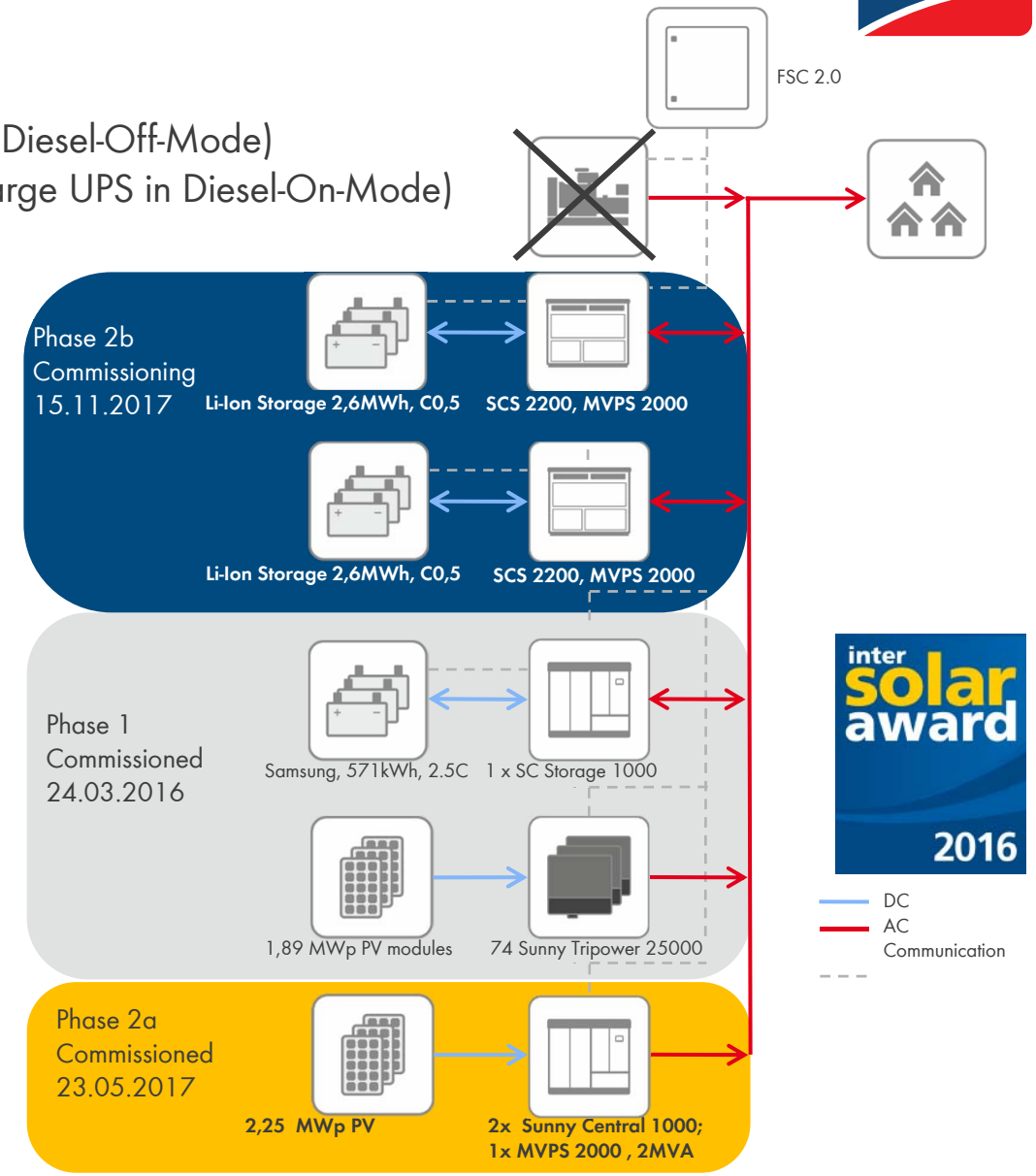
Technical overview

GRID FORMING BATTERY INVERTERS
Day operation without Diesel Generators (Diesel-Off-Mode)
Full redundancy for generator operation (large UPS in Diesel-On-Mode)

- **Voltage source**
- Frequency regulation
- Spinning Reserve Provision
- Synchronisation Diesel On-Mode

  Diesel Off-Mode

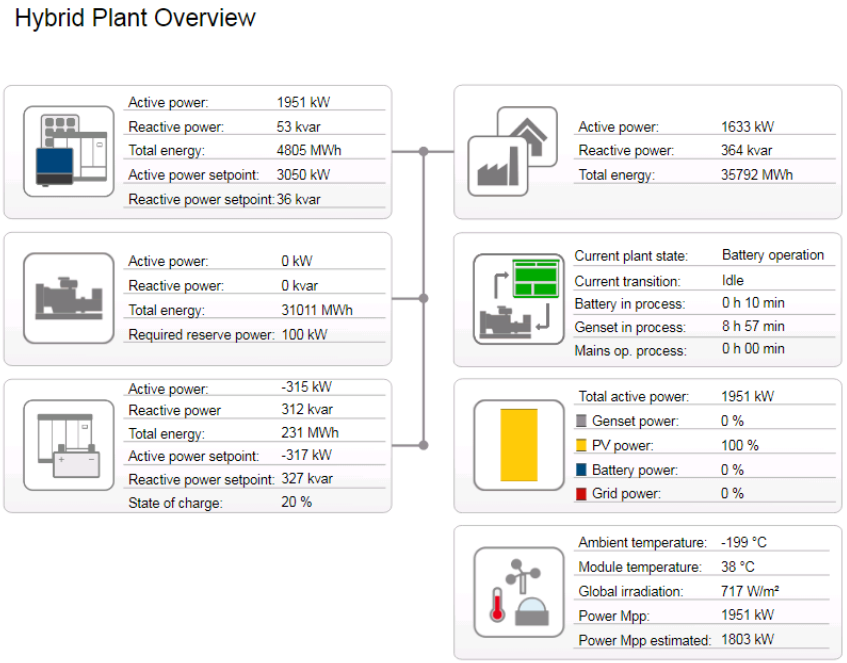
St. Eustatius II	
Estimated fuel savings	1 728 000 liters/a
Solar Energy Produced (net)	6.4 GWh /a
CO2 savings	4,561 to CO^2/a
Used PV energy	6 494 547 kWh
Solar energy fraction	46%

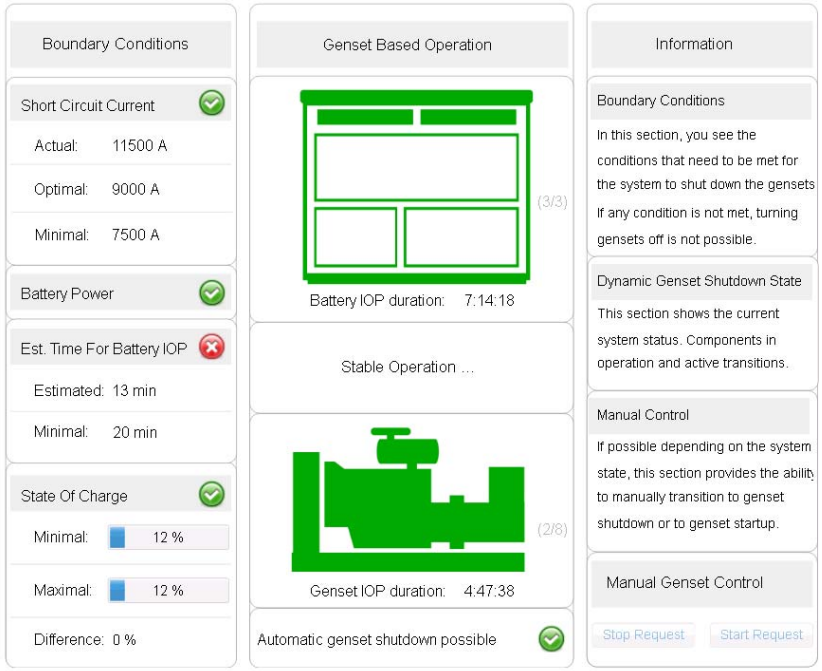


inter solar award 2016

Fuel Save Controller „Diesel Off Mode“
Complex Functions made easy

- > Easy to operate
- > Comprehensive information in overview and detail page
- > Transparend display of system conditions that allow or prevent from switching off gensets





Smart Hybrid Plant Control

- **Reverse Power Protection**
  Prevents energy flow into the genset

- **Minimum Genset Load**
  Ensures that the gensets' minimum load is not undercut.

- **Reactive Power Control**
  Controls reactive power of battery and inverters to reach a configurable power factor at the gensets

- **Ramp Management**
  Allows to configure the slope of the ramps that may occur during operation

- **Feedin Protection**
  Prevents from feeding too much energy into the grid. Also Zero Export can be realized with this function

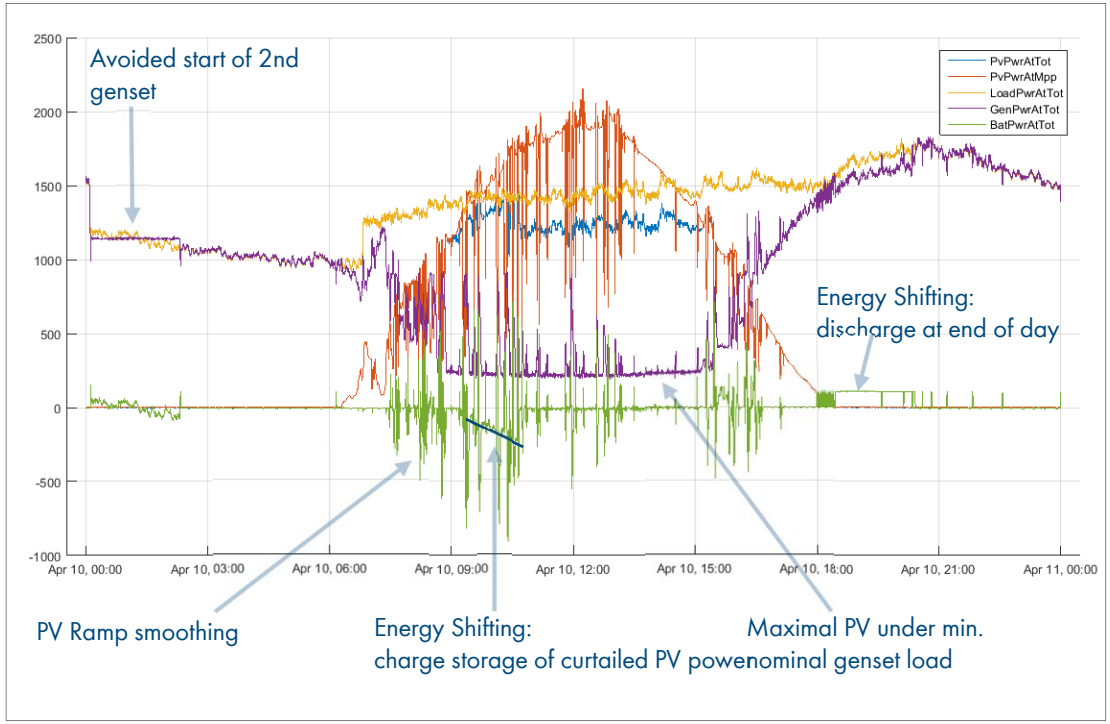
- **Inverter Management**
  Automatically disconnects solar inverters if share of solar inverter power to genset power gets too high

Smart BATTERY Storage OPERATION
Phase 1

> **Ramp Rate Control**
Fuel Save Controller uses storage to smoothen fluctuating solar generation

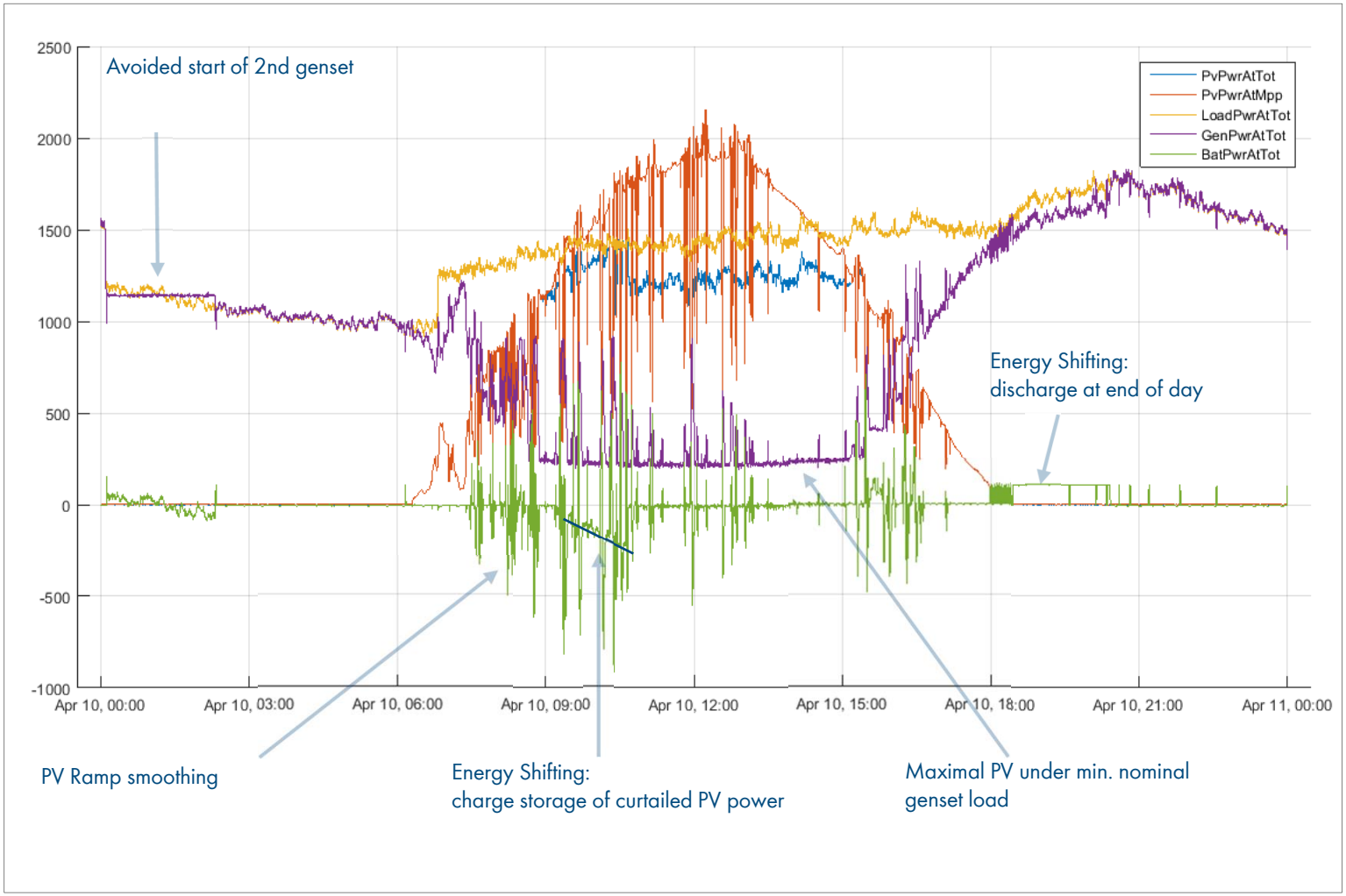
> **Genset Start Avoidance**
Fuel Save Controller detects when treshold for starting next genset approaches and uses storage to avoid genset start

> **Energy Shifting**
Fuel Save Controller uses otherwhise curtailed energy to charge the battery during daytime and discharges at night



> **State-Of-Charge Control**
ensures that the battery's state of charge is always sufficient to fulfill grid stabilizing tasks

> **Battery for frequency and voltage stabilization**
Battery inverter monitors grid and reacts instantaneously according to preset characteristics

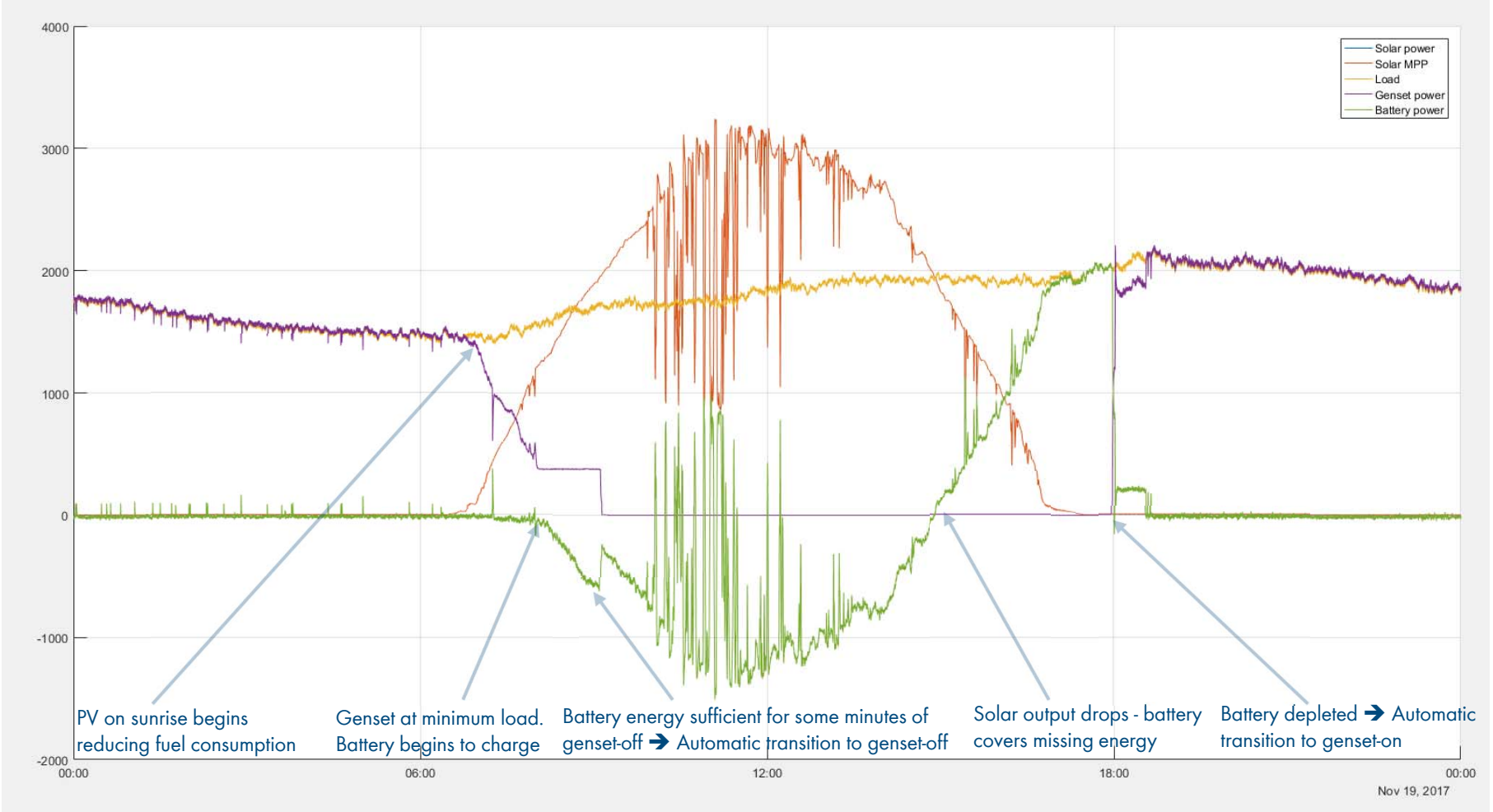

Avoided start of 2nd genset
PvPwrAtTot
PvPwrAtMpp
LoadPwrAtTot
GenPwrAtTot
BatPwrAtTot
2500
2000
1500
1000
500
0
-500
-1000
Apr 10, 00:00
Apr 10, 03:00
Apr 10, 06:00
Apr 10, 09:00
Apr 10, 12:00
Apr 10, 15:00
Apr 10, 18:00
Apr 10, 21:00
Apr 11, 00:00
Energy Shifting:
discharge at end of day
PV Ramp smoothing
Energy Shifting:
charge storage of curtailed PV power
Maximal PV under min. nominal
genset load

„Diesel Off Mode“ - Daytime without diesel
Dynamic Genset Shutdown

- **Turns off diesel gensets for large parts of each day**
  (Grid Forming Battery Inverter required)

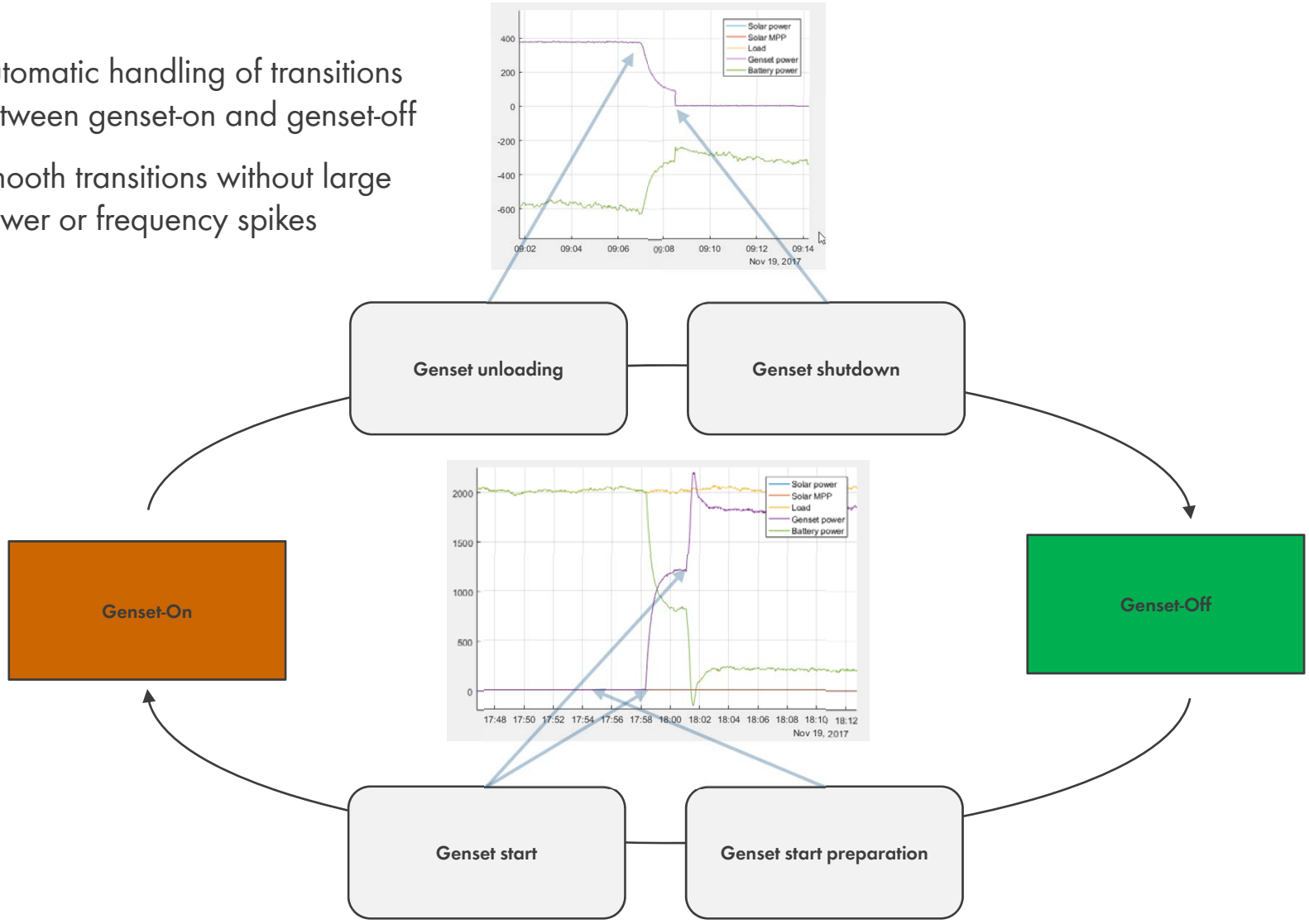
  - Saves more fuel
  - Saves significantly on genset operating hours
  - Stabilizes grid (frequency & voltage) on fluctuations
  - UPS function

„Diesel Off Mode“ - Daytime without diesel
Phase 2



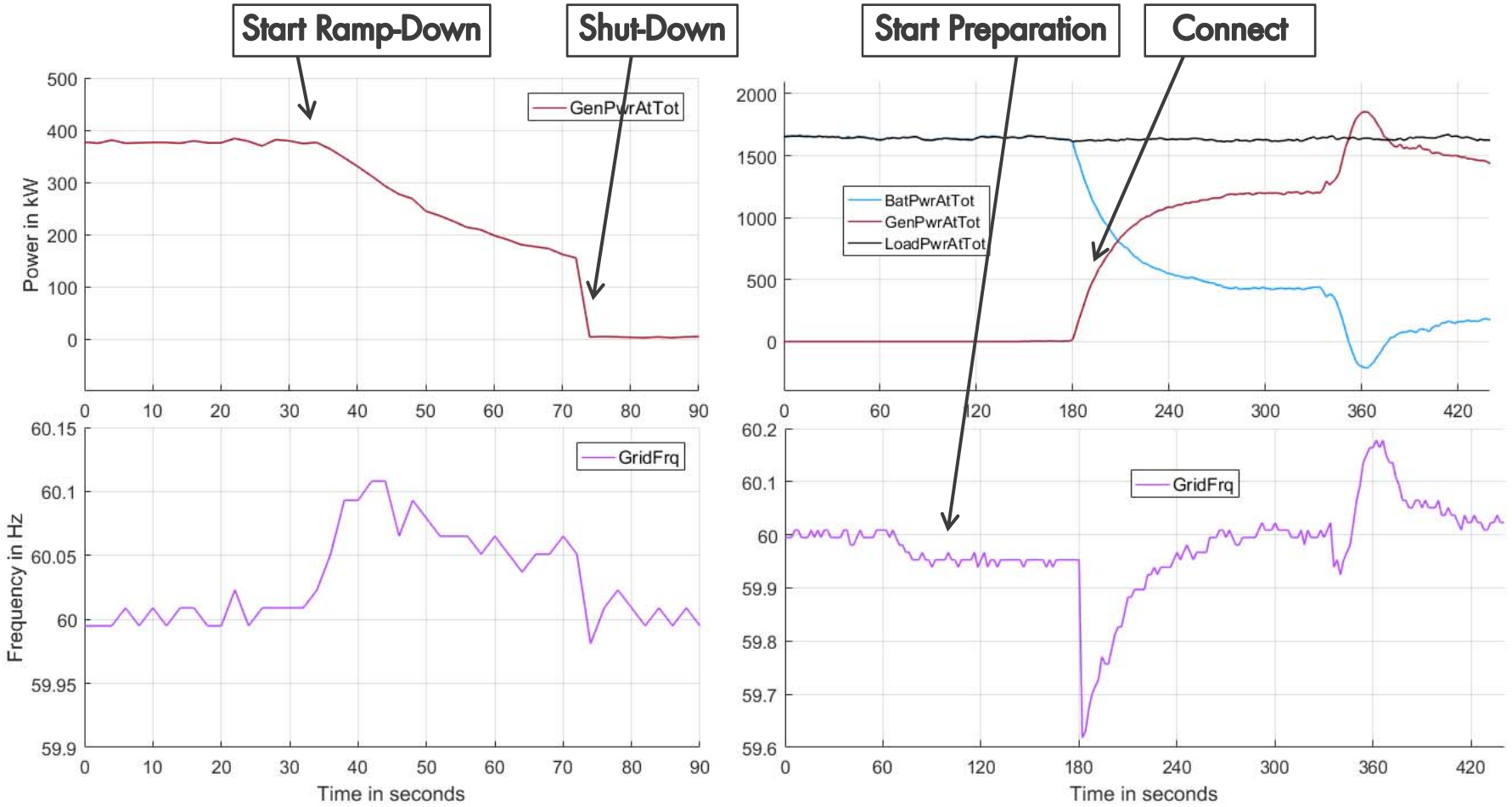
„Diesel Off Mode“ - Transition

- Automatic handling of transitions between genset-on and genset-off
- Smooth transitions without large power or frequency spikes



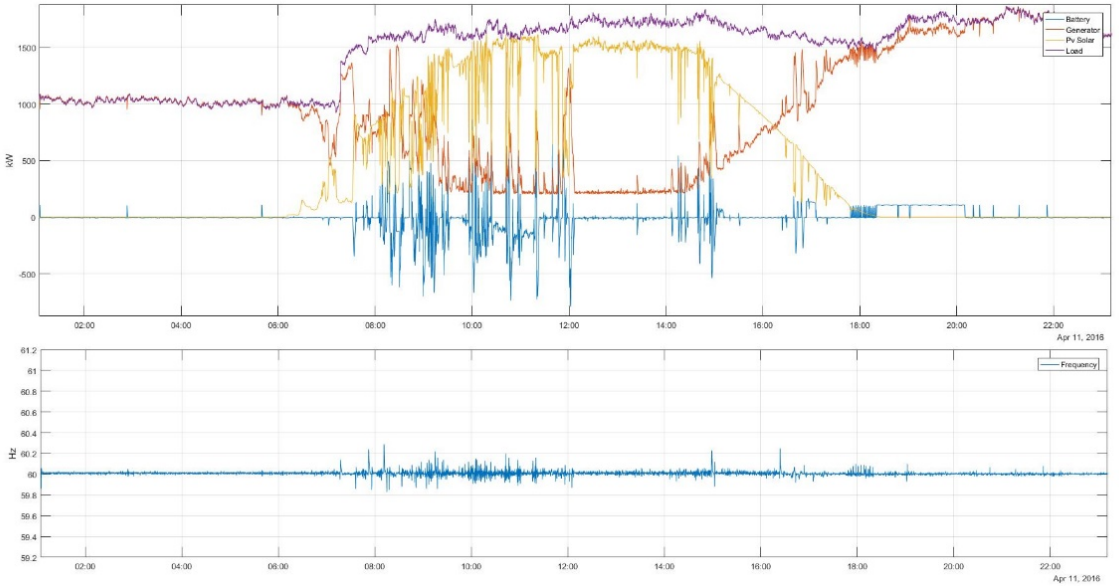
Transitions Diesel-On, Diesel-Off

Ramp-Down der Gensets and reconnection

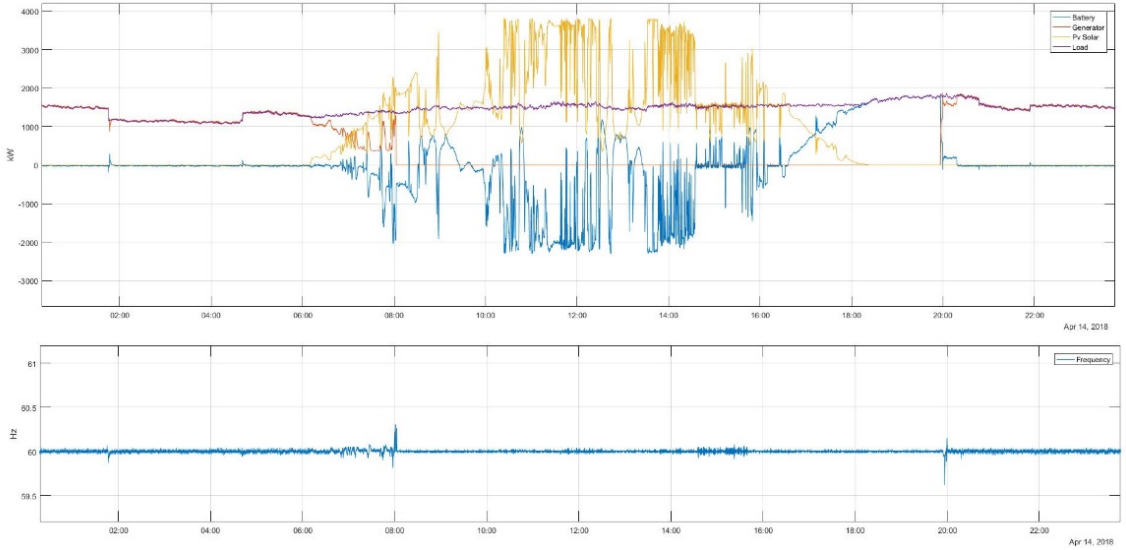


Results - Frequency response on cloudy days

Phase 1 → current controlled battery system
Active power and frequency on 11.04.2016



Phase 2 → voltage controlled (grid forming) battery system
Active power and frequency on 14.04.2018

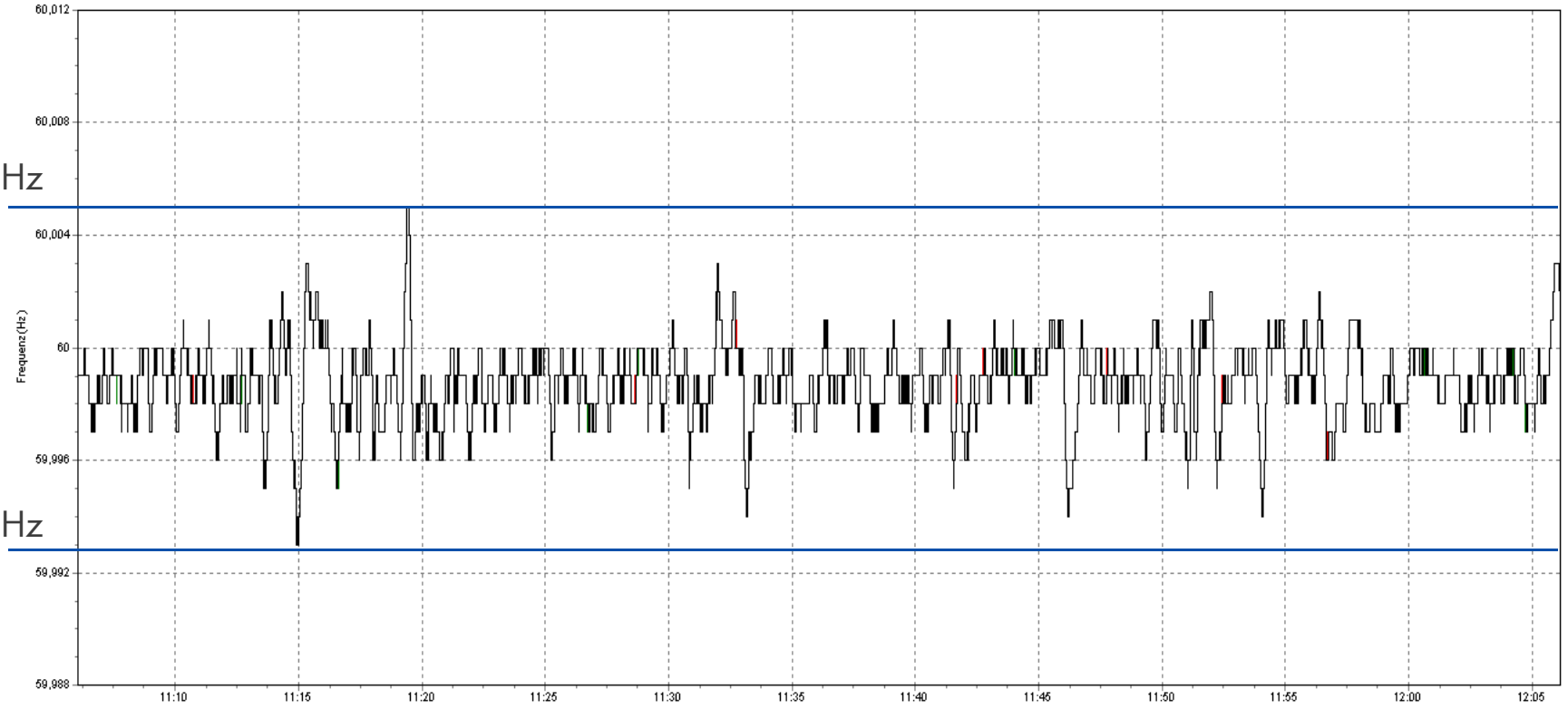


Results - Frequency Stability in Diesel Off Mode

Frequency bandwith of 0,013Hz

60.005 Hz

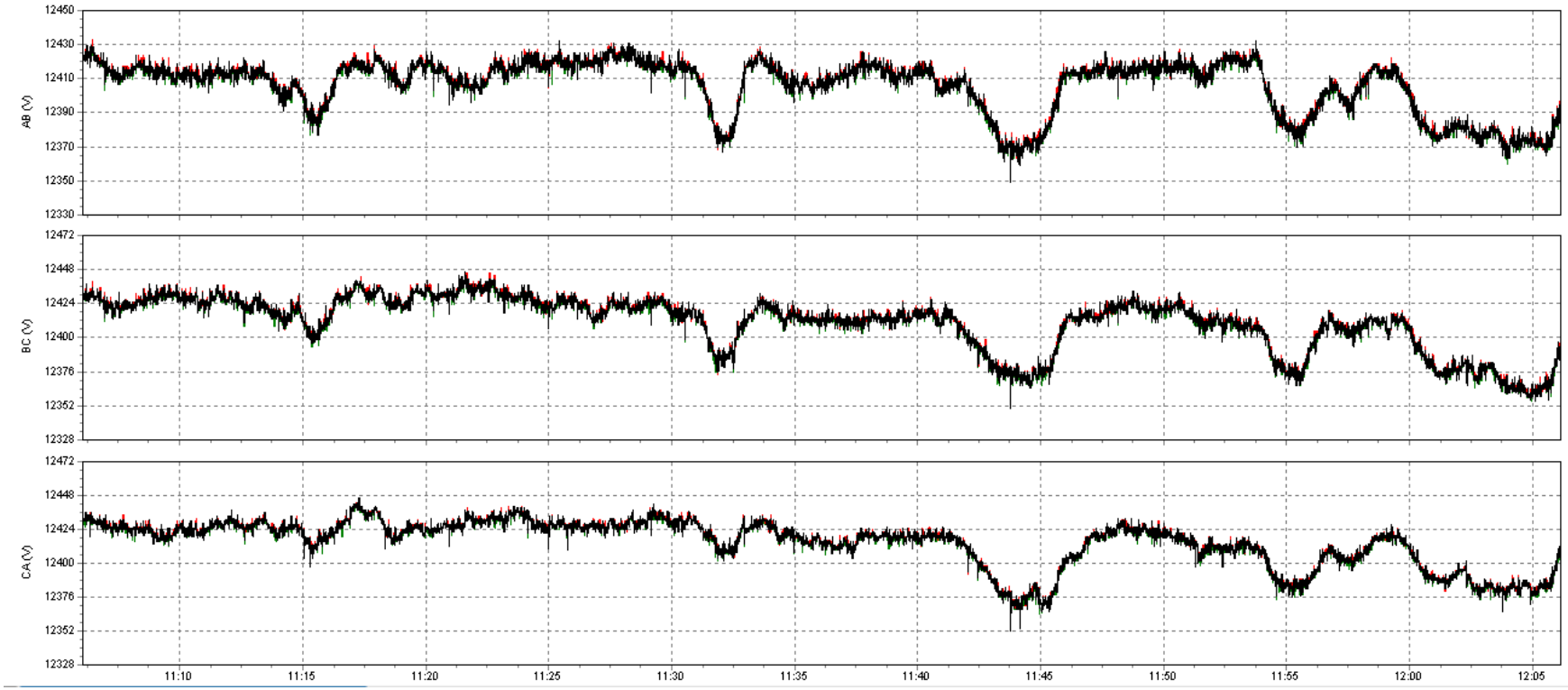
59.992 Hz



› **Recording on 31.10.2017 from 11.00 am to 12.05pm during step load tests**

Results - Voltage Stability in Diesel Off-Mode With 1MW Step load tests (50% load Shedding)

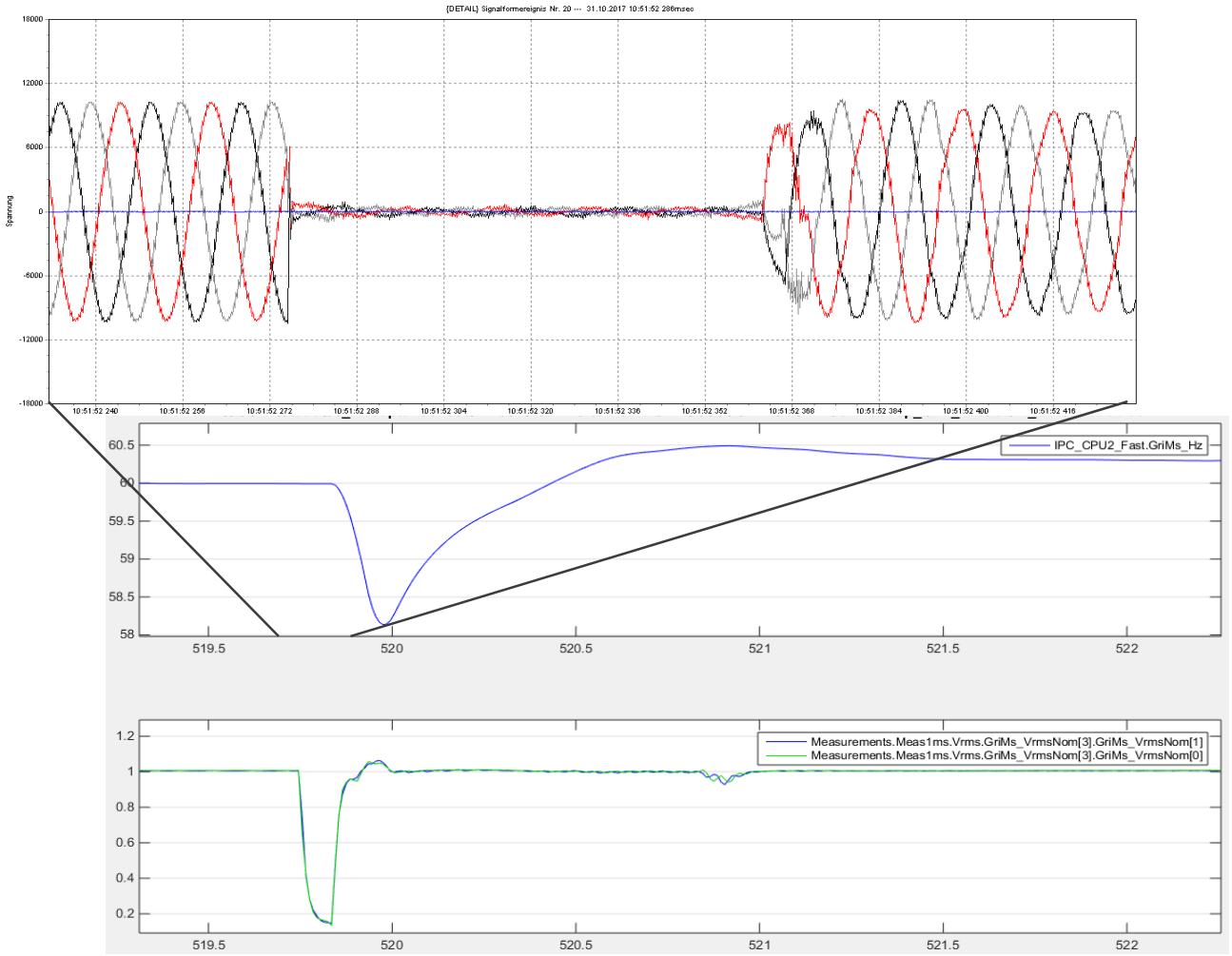
The voltage stays between 12.43kV and 12.37 kV → Voltage Fluctuation of 0.4%



› **Recording on 31.10.2017 from 11.00 am to 12.05pm during step load tests**

1. The regular load is around 2MW in St. Eustatius.

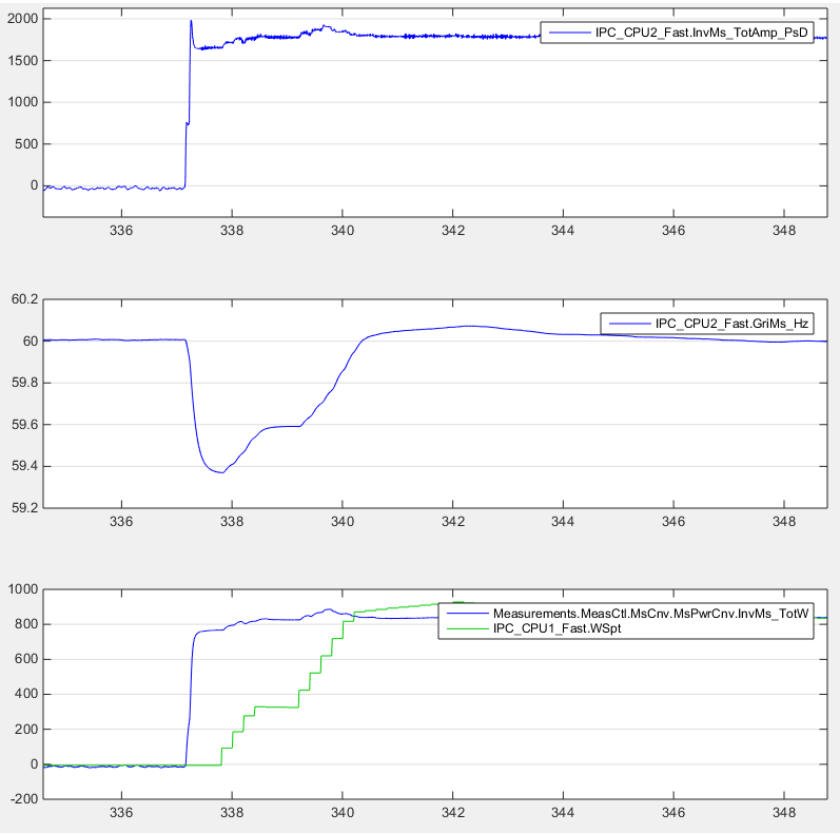
Results - 3 phase Short Circuit (30A) clearance in 120ms



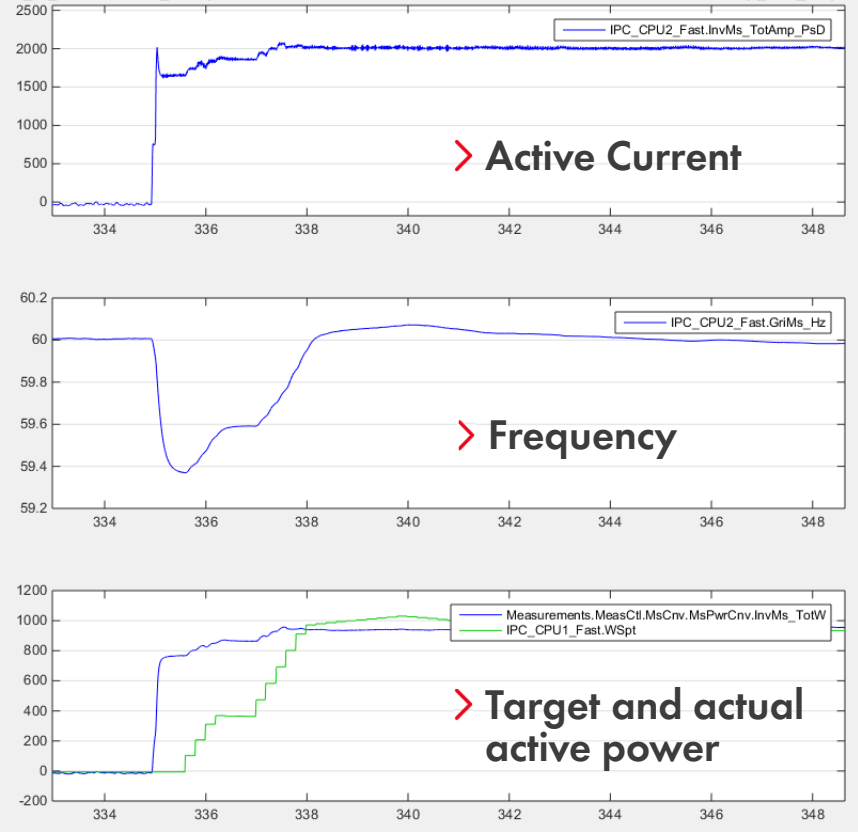
- **Drop to 58.2 Hz for about 100ms (according to Droop-Settings at nominal power) recovered to 60Hz within 500ms.**

Results - grid-forming system works as UPS

SCS-Gridforming 1

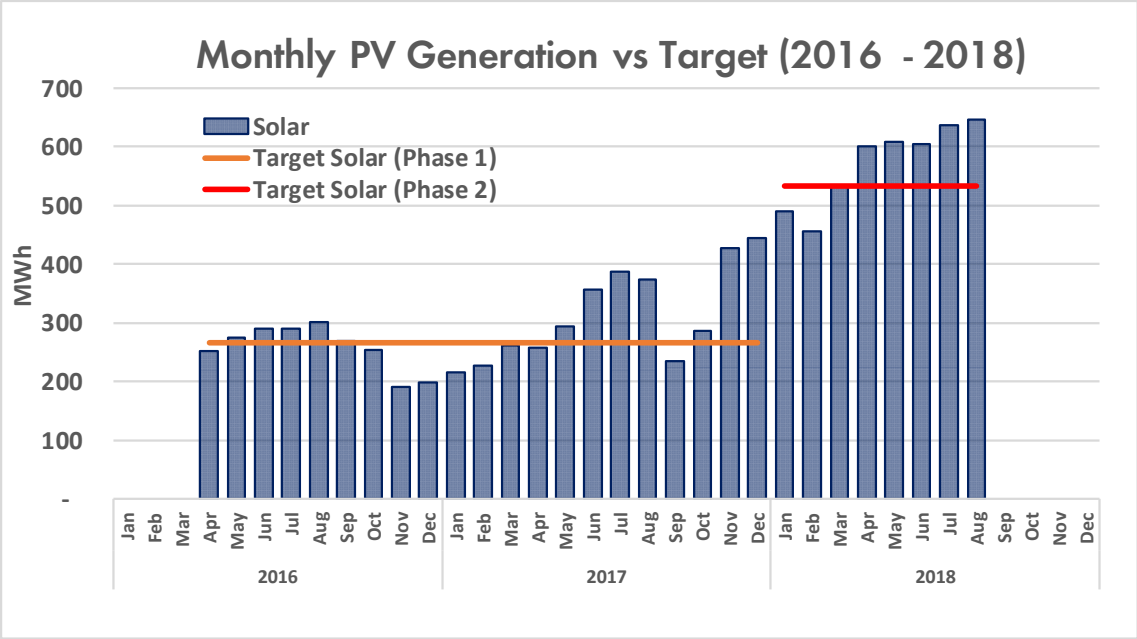


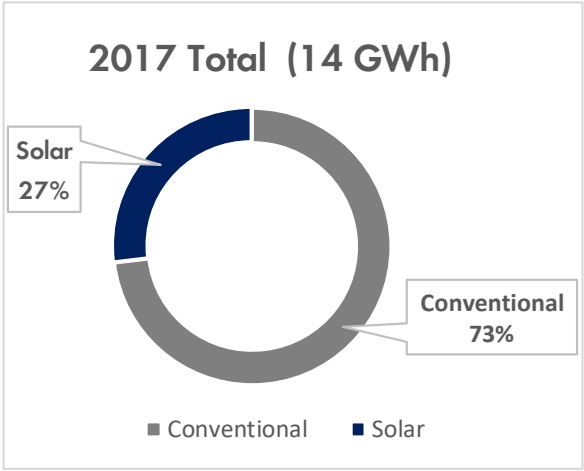
SCS-Gridforming 2

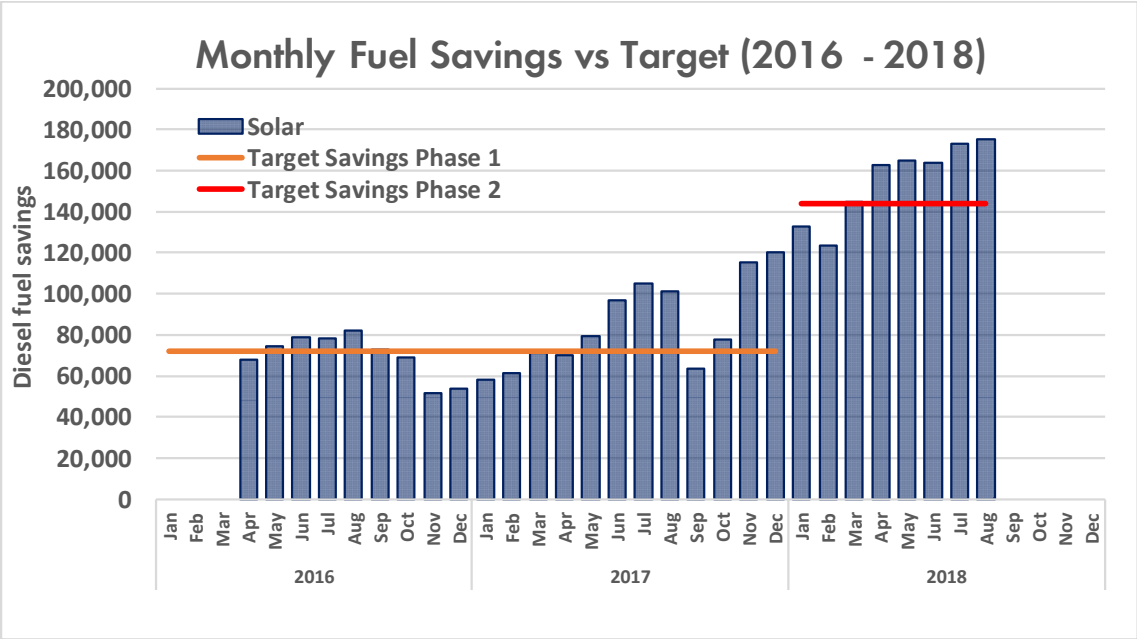


- Load jump shows simultaneous shutdown of all diesel generators
- Immediate reaction through battery inverter
- Even load distribution on devices without any communication
- Frequency built up in 2.5s by FSC

Results - KPIs March 2016 to August 2018







PV Share Target

> Phase 1 → 23%

> Phase 2 → 46%

Outcomes of adding Solar + Storage

- **Easy to operate**
  Once configured operates autonomously

- **1.7 Million Liter Diesel savings per year** (46% of previous annual consumption) confirmed by client and exceeding projections

- **Improved grid stability** while using voltage controlled (grid-forming) inverters

- **Improved resilience against component failure**
  every single component may fail without grid going to blackout (even system controller itself)

- **Reduction of dependency on fuel costs**

- **Reduced diesel genset maintenance and step loads**

St. Eustatius in the Web

YouTube Long version https://youtu.be/xBM7Rdz5ajA
YouTube Short version: https://youtu.be/vP8ljKZnoO8

PM https://www.sma.de/en/newsroom/current-news/news-details/news/2876-system-solution-from-sma-provides-caribbean-island-with-100-solar-power-supply.html

Blog https://en.sma-sunny.com/en/st-eustatius-100-solar-power-in-the-caribbean/

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Large Scale PV BESS Off-grid System
The Brando, French Polynesia

Hollywood legend Marlon Brando had a life dream; a sustainable, exclusive resort "The Brando" on the paradisiac atoll of Tetiaroa in French Polynesia.

For the hotel the new SMA solution enables not only a solar energy ratio of 60%, but improves significantly the grid in terms of resilience and quality; harmonics, stability of frequency and voltage and a full UPS function. It blackstarts the grid within seconds.

Project "The Brando, Tetiaroa"

- Location: Tetiaroa, French Polynesia
- Commissioning: December 2018
- Requirements: Design study, retrofit, resilience, grid quality improvement, automation, integration to existing infrastructure, respecting logistic limitations

Plant information

- Installed PV power: 1.3 MWp
- Installed Storage capacity: 2.6 MWh
- Generator capacity: 1.2 MVA

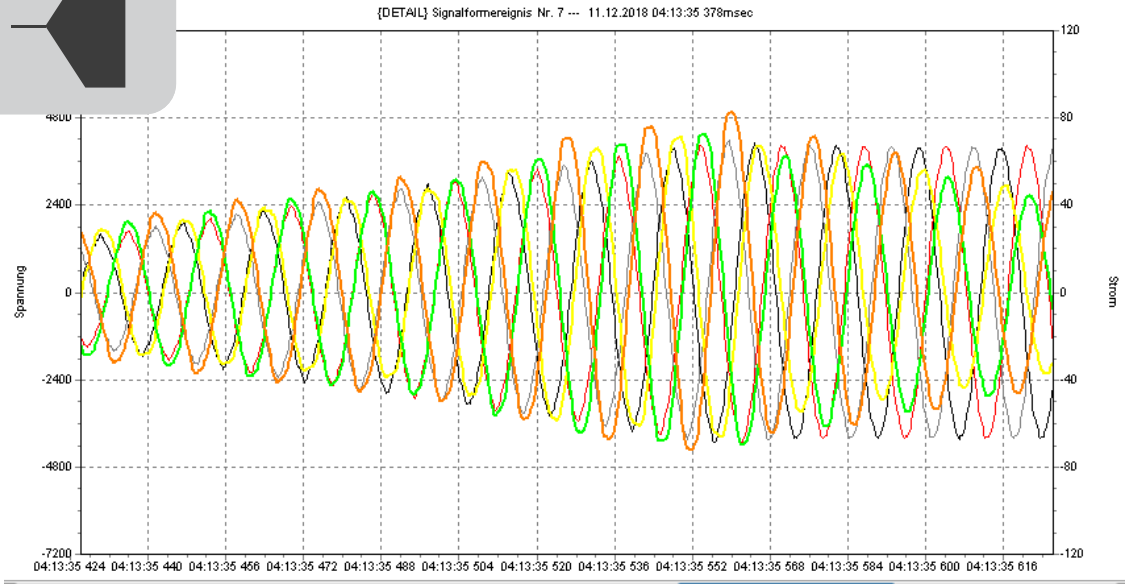
Integrated System Technology

- SMA SCS 2200 Blackstart Grid Forming, MV Block
- SMA Sunbelt containerized battery storage with 2,6MWh Li-Ion (NCM) cells
- Energy and Power Management System
- PV inverters, MV components, SMA Sunbelt's Monitoring, accessories

SMA System Solutions for hybrid applications

Large Scale PV BESS Off-grid System
Blackstart of complete electrical infrastructure

Smooth voltage ramp up within 200ms



Advantages and Innovation

- Integration of all components and existing genset infrastructure into control scheme
- Blackstart function to build grid within seconds
- Voltage and frequency source in hot-standby for uninterrupted power supply also at night (UPS function)
- Automatic co-generation with thermal generators
- Short circuit clearance in 120ms
- European grid quality
- Remote Service Support on system level in operation period

Partner

- Customer: Pacific Beach Comber
- Finance: Private
- Installation: Engie, French Polynesia

SMA Sunbelt Energy

- Full system integration including electrical design, network design, operation case definition, overall project management, procurement, delivery and commissioning
- Containerized Li-Ion storage facility
- Long-term remote technical support on system level

SMA System Technology

- Sunny Central Storage 2200 Grid Forming
- MV Block and MVS
- Hybrid Controller
- 32 SMA Sunny Tripower PV inverters

SMA System Solutions for hybrid applications

Comparison conventional vs SMA blackstart

Conventional (genset) Blackstart

> Sudden connection, no pre-charge

> High current peak at MV affecting the quality and durability of equipment

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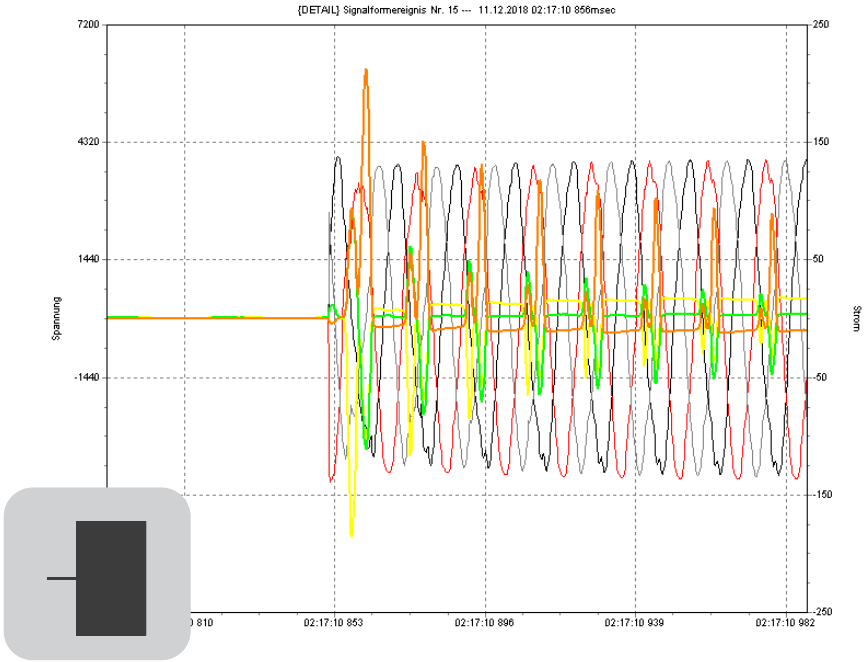
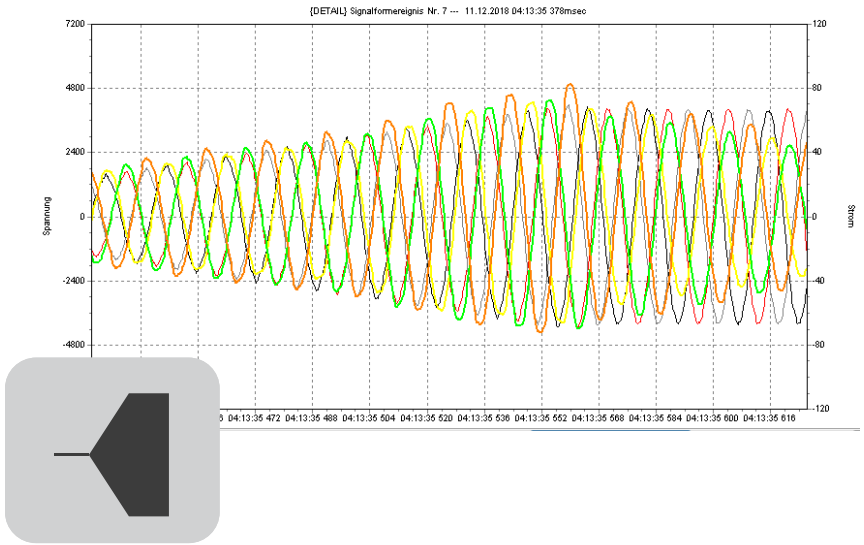


SMA BESS Blackstart

> 200 ms ramp up voltage

> Smooth transition

> Load served properly



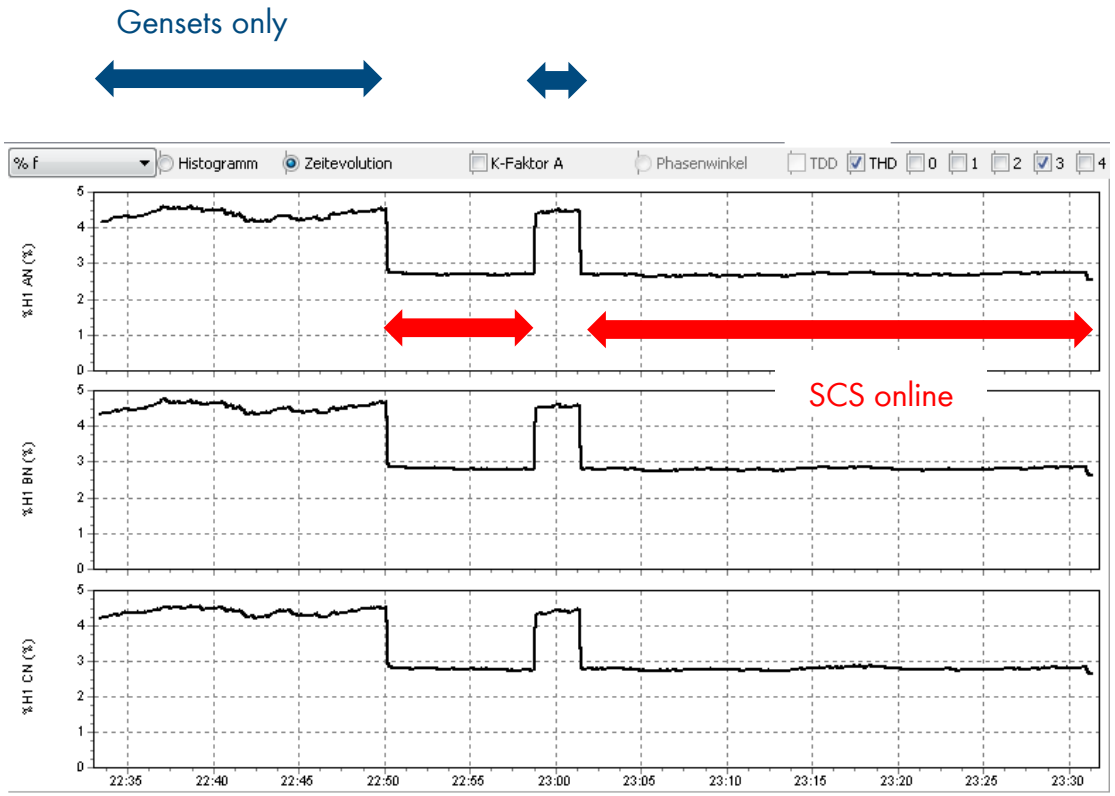
Voltage harmonics drastically improved

Quality improvement

> Existing of high harmonics in current setup

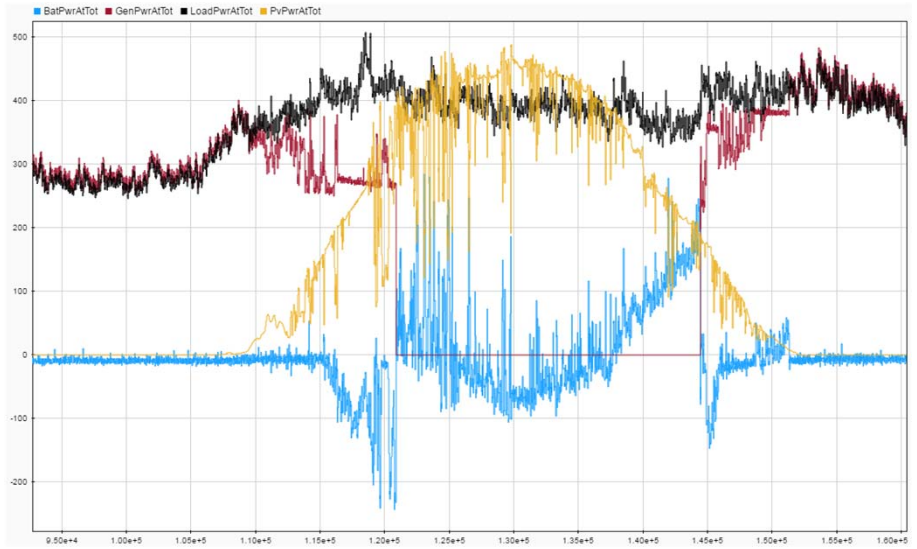
> Typically 4-6% Uthd in genset based operation

> Improvement by about 2% as soon as the SCS2200 is connected in Grid-Forming-Mode



Results – performance indicators

- Saves a lot of fuel (~62% of 3000l at ~1,3€/l)
- >12h Diesel-off per day with the full solar plant
- Less energy consumption by avoiding genset auxiliaries such as Fans, Pumps.... (~15% of energy consumption, ~50kW)
- Better voltage quality throughout the whole day
- Full power system backup (UPS) in case of a genset failure
- More stable operation for the gensets, less wear
- Better work conditions for genset maintenance (previously ~40°C and full engine noise)



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Grid Frequency Regulation
Pelham, United Kingdom

The main application of the project is the capacity market and frequency response services but also features other applications like Triads management and reactive power provision.

This project is the largest battery project in the European Union in a single location till date.

The complete project timeline from contract signature till commissioning was reached within 5,5 months

Project

- Location: Pelham, UK
- Commissioning: November 2017

Plant information

- Installed battery power: 64 MVA
- Installed battery storage: 50 MWh of Li-Ion NMC batteries for frequency regulation
- Batteries installed in customized containers
- Connected at 132 kV

SMA System Technology

- 26 SMA Sunny Central Storage 2475 with noise reduction packages
- 26 Medium Voltage Block 2475
- 7 Customized SMA E-houses
- SMA Hybrid Controller
- EMS

SMA system solutions for hybrid applications

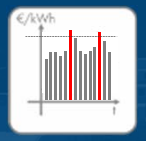
Business Case Large Scale Storage: Multi-Application Sample Plant in the UK

ROI < 3 years

1. Grid services -
Firm Frequency Response (FFR) to stabilize the grid

2. Arbitrage trading -
Revenue stream depending on low electricity prices

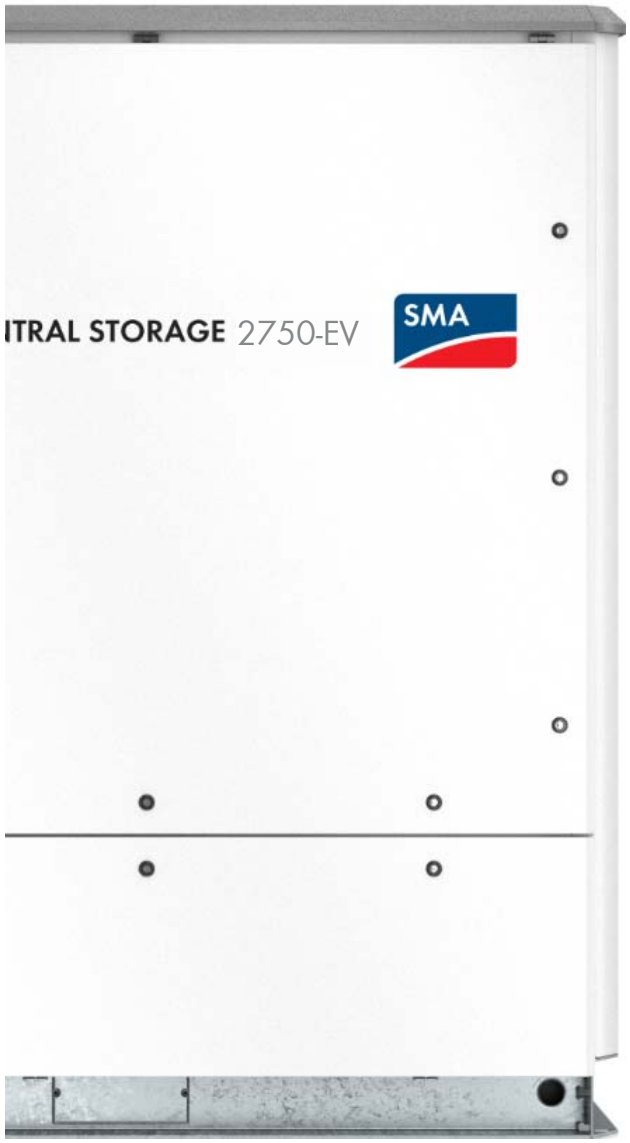
3. Deferral -
Providing capacity to avoid grid extension



4. Balancing -
Providing capacity to shave extreme peaks ("Triads")

› **The business case large scale storage will be accelerated by the decentralization of the energy sector**

Main technical features of the project

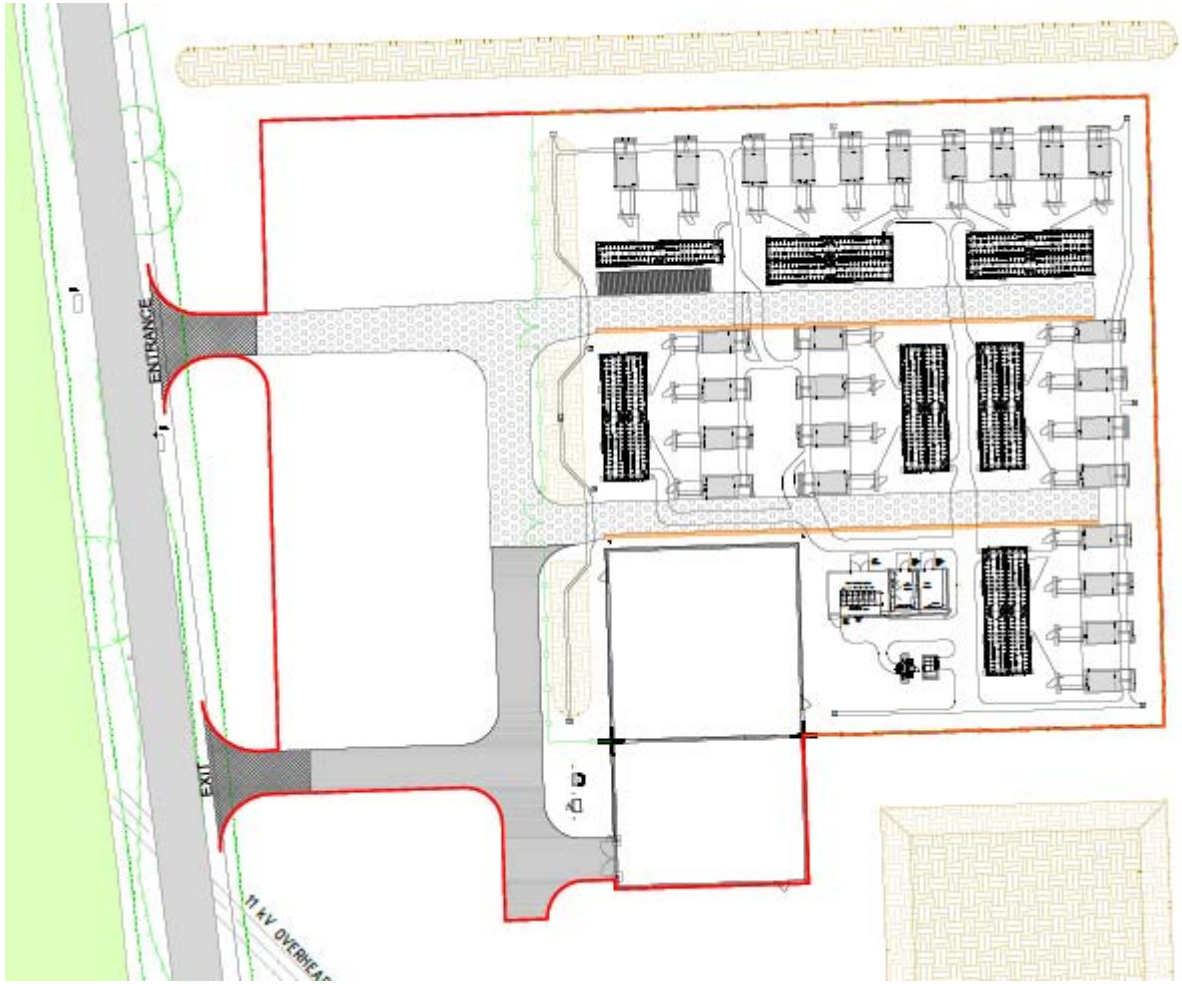


- 26 inverters allow for over 60 MVA at 132 kVA
- 2 step up transformation (33 kV and 132 kV) with MVB
- Local high speed closed-loop control via FSC
- 50 MWh of NMC batteries in only 7 containers
- Noise emission packages to protect environment
- High frequent logging and SCADA interface
- Very rapid deployment

Ancillary services provided by the project

- Frequency regulation, e.g. EFR or FFR, fully configurable
- Multi-day schedule driven ancillary services
- Energy arbitrage
- Capacity market
- Triad avoidance
- Possibility to configure new services, e.g. reactive power provision, blackstart, etc...
- Supports parallel ancillary service types

General design



Battery Storage Facility

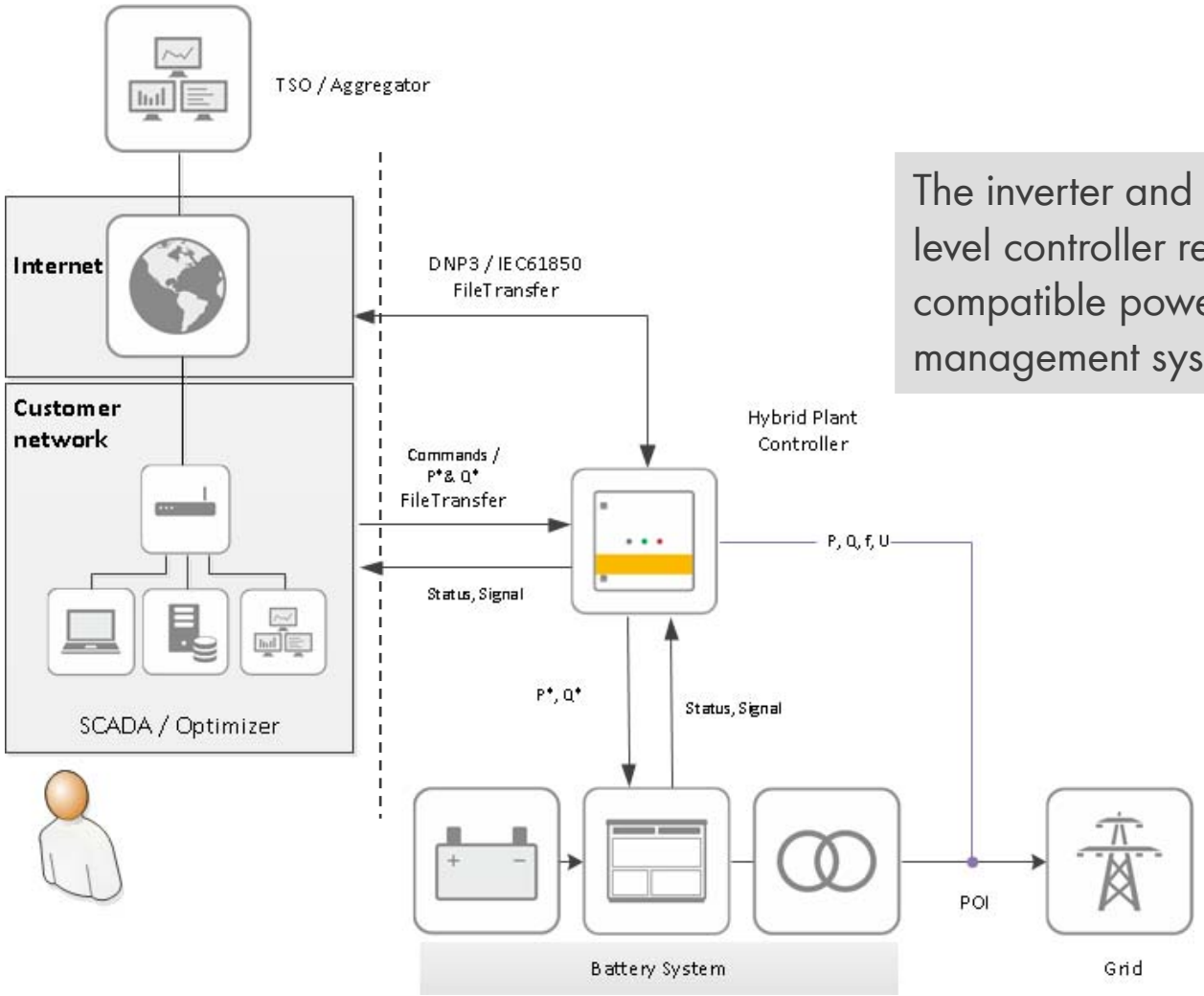
- 6,578 lithium-ion battery modules
- 7 x Battery containers
- 26 x Sunny Central Storage battery inverters
- 26 x 33 kV MV Blocks
- 1 x Auxiliary 850kVA Transformer
- PMS
- CCTV, security fencing
- Storage Container

Customer Substation

- 33kV Switchgear
- 33/132kV Transformer

Control system overview

The plant optimizer and the interface to grid operator represents an energy management system



The inverter and local plant level controller represents a compatible power management system.

Control system overview

Power Management System (PMS)

The Fuel Save Controller is the local power controller that ensures the requested function is carried out according to the grid requirements.

- Operates in 100msec or less to carry out local power control functions
- Implements the following functions:
  - P & Q Control to external set-points
  - EFR / FFR
  - U,F, P, Q Accurate Measurements
  - SoC Control – within the available DoF
  - SoC Symmetry
  - Battery Power & Temperature Monitoring

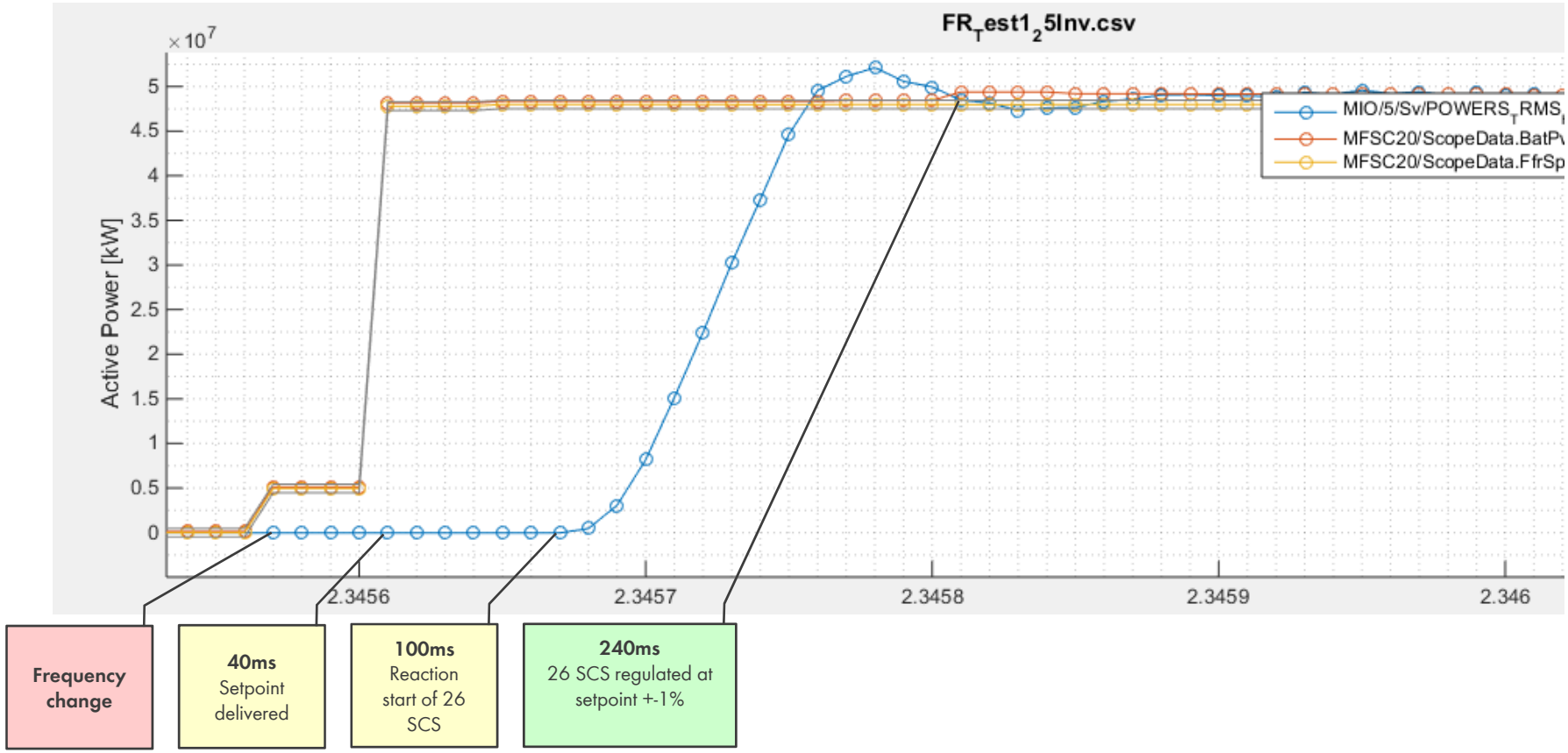
Monitoring and Control (SCADA)

The SCADA is a visualization, basic control and data server that provides human interface to the plant operator to operate the plant and store the data.

It monitors all data and saves them remotely and in the cloud.

Allows the customer to decide on plant's utilization and different operational schemes, e.g. switch from automated to manual control

Grid Frequency Regulation
Pelham, United Kingdom



› **250 ms from measurement till 50 MW are fed into the grid (currently optimized below 150 ms for other markets such as Ireland)**

SMA system solutions for hybrid applications

Source: Pre-Qualification Tests 50MW Battery Park, Pelham, UK

Eduardo Rocha
Regional Sales Manager
SMA Sunbelt Energy GmbH
Email: eduardo.rocha@sma.de