3rd International
Hybrid Power Systems Workshop

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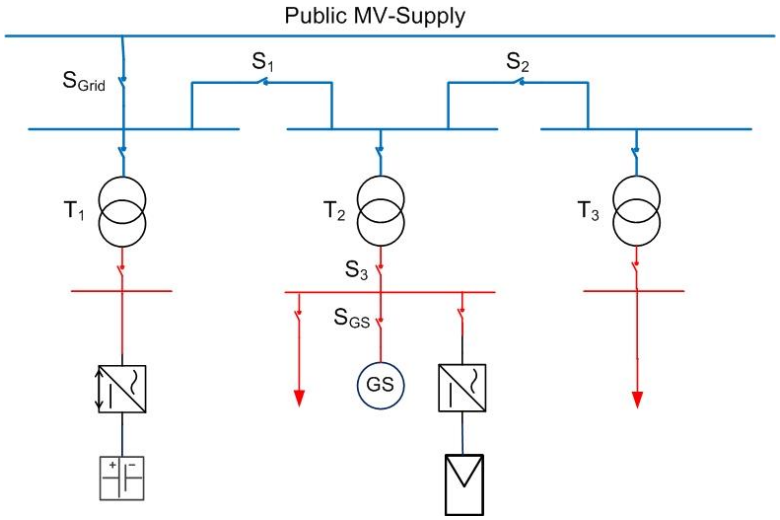
Tenerife, Spain

Test Scenarios and Test Results for the Qualification of PV-Diesel Power Systems



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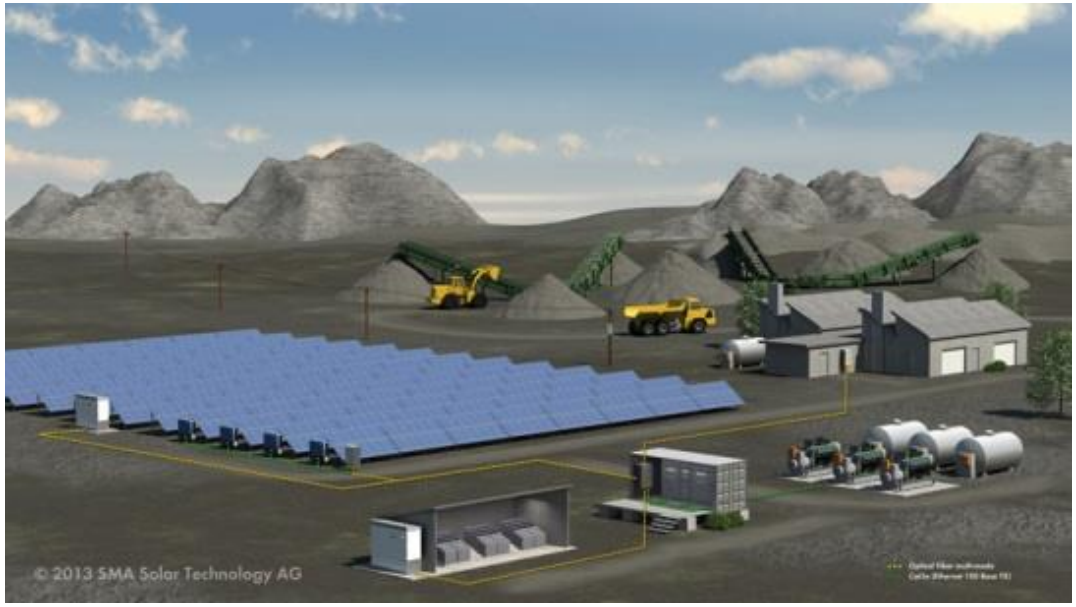
OUTLINE

- Motivation
- Test Procedures
  - Objectives and Test Infrastructure
  - Grid-parallel operation
  - Island operation
  - Dynamic Island operation
- Component Tests
  - Diesel Gen-set
  - Battery Inverter
- System Tests
- Outlook

Motivation

- Supply of remote sites today mainly with Diesel gen-sets, working as grid former and running 24/7 (non-stop)

- Introduction of PV systems, Wind turbines etc. could reduce fuel consumption and operation costs



Source: https://www.solarstromforschung.de/pv-diesel/

- Application of storage systems to maximize PV contribution and to ensure smooth gen-set operation
- Technical design based on individual components requires high engineering effort and experience
- Application of standardized design methods requires basic technical characteristics and parameters of system components, measured with well-defined test procedures

Test procedures – Objectives and Test Infrastructure

- Fraunhofer IEE- SysTec:
  Medium voltage (20kV) test grid and outdoor test bed for hybrid systems and micro grids

Test procedures – Objectives and Test Infrastructure

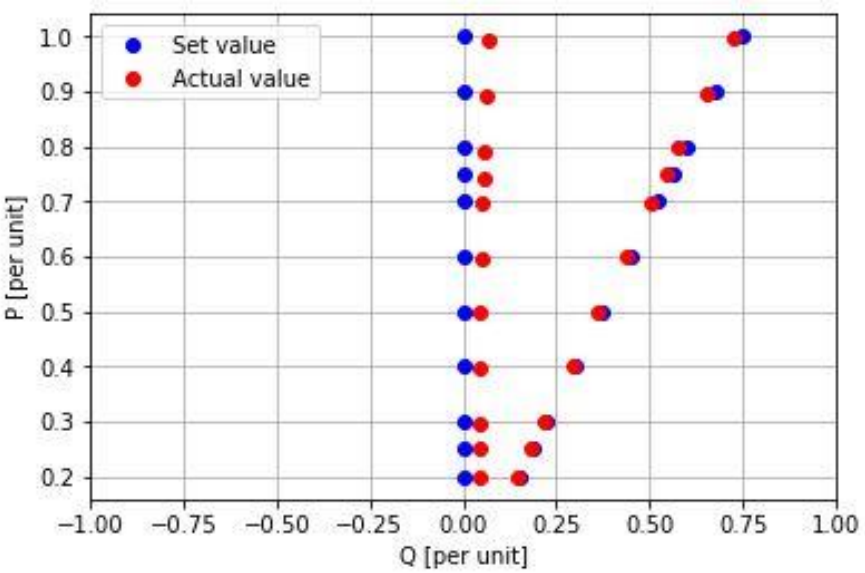
- Identification of component characteristics:
  - Diesel Gen-set
    (MAB SEA 200DE)
  - Battery Inverter
    (SMA Sunny Central Storage 2200)
  - Hybrid Controller
- Tests of full system to analyze component interactions

Source: https://www.sma.de/produkte/batterie-wechselrichter/sunny-central-storage-2200-us-2475-us-2500-ev-us-2750-ev-us.html

- Main focus of tests:
  - Grid-parallel operation with external setpoints
  - Voltage- and frequency response to dynamic load changes in island operation
  - Dynamic transitions between grid-parallel and island operation

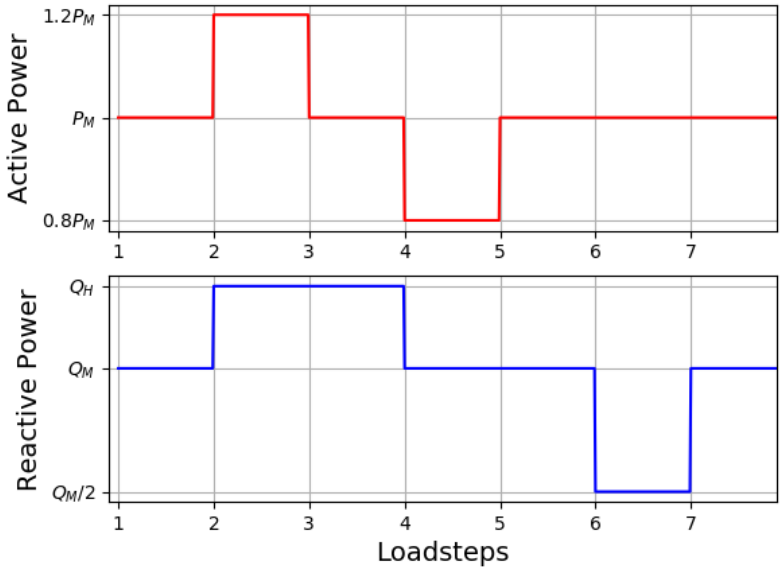
Test procedures – Grid-parallel operation

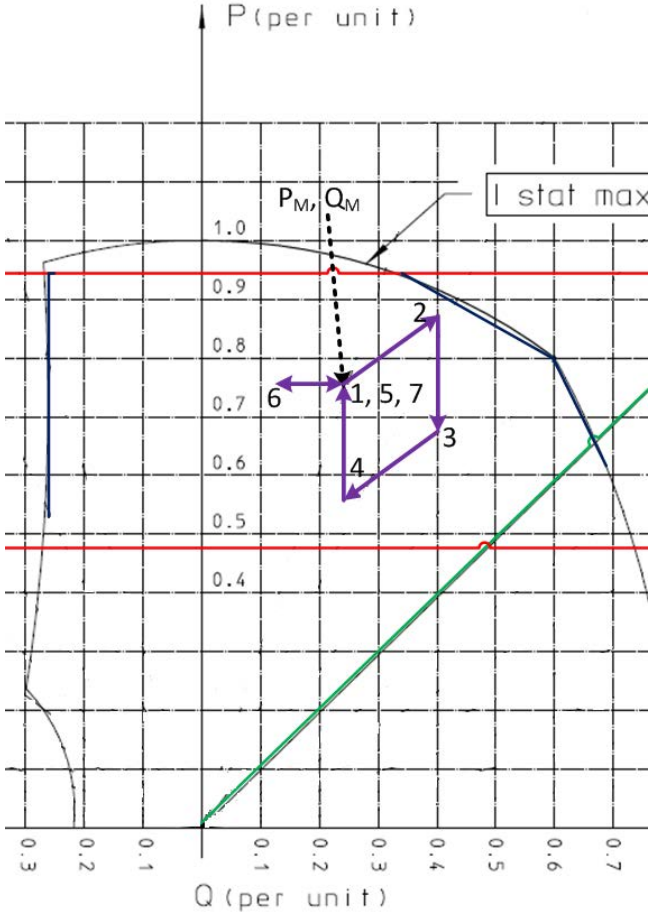
- Identification of…
  - …Operational ranges with regard to Active and Reactive power output (PQ-Diagram)
  - …accuracy and response time when operated with external power setpoints
- Well defined test procedures for DGs (WTG, PV, CHP units) avail. in different national / international standards:
  - IEC 61400-21 (WTG)
  - FGW TG3 (WTG, PV, CHPs)



Test procedures – Island operation of Diesel Gen-set

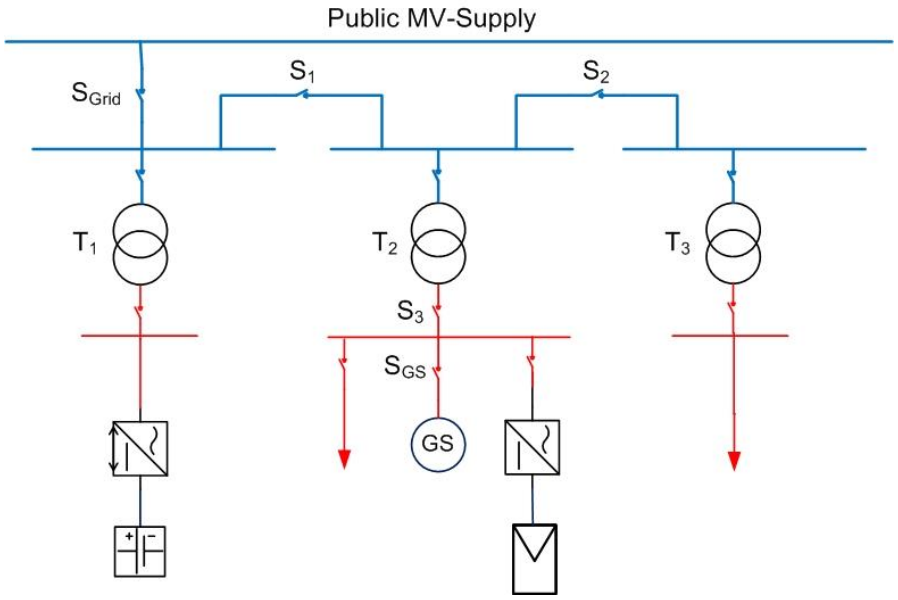
- Objective: Analysis of dynamic frequency and voltage stability
- Tests of components (e.g. Diesel gen-set) during dynamic load changes





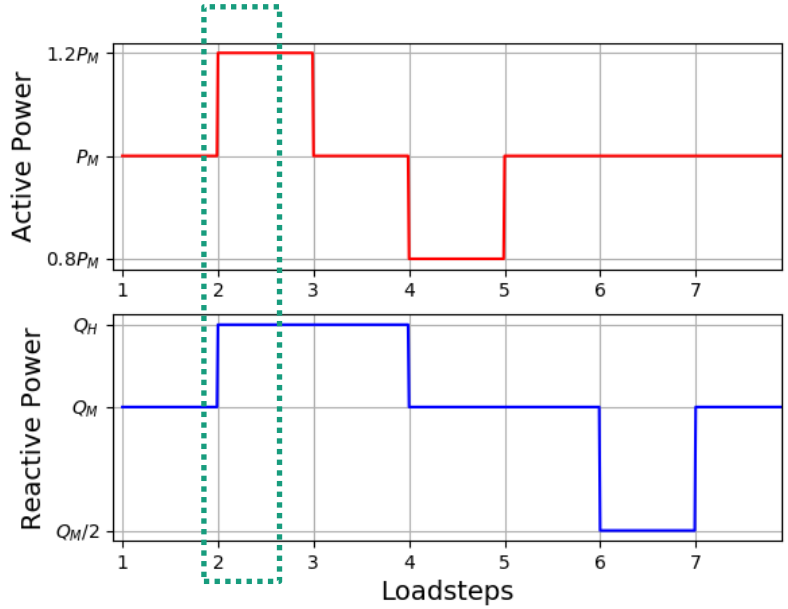
- P_M: Mean Active Power of the entire operation range
- Q_M: Reactive power to reach a power factor of 0.95 with P_M

Test procedures – Dynamic Island operation

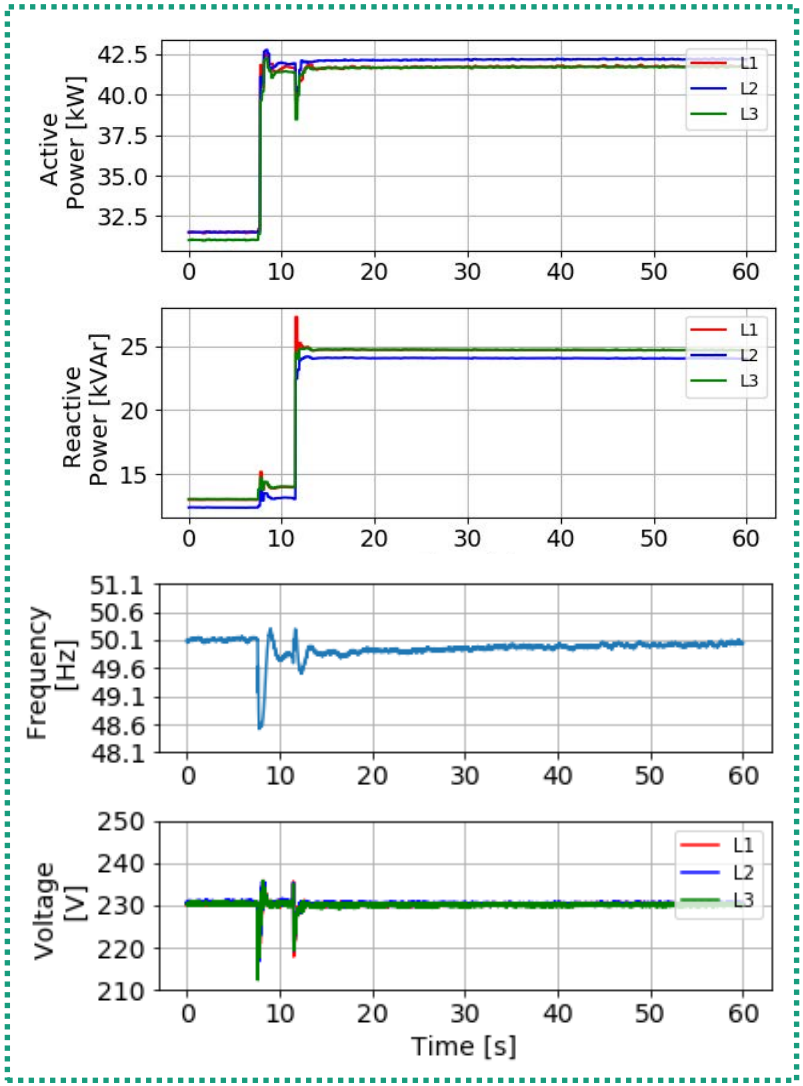


- Investigation of dynamic transitions between a) Island and b) Grid-parallel operation; Test of black start capability
  - Scenario 1: Load transfer and transition to island operation
  - Scenario 2: Black start and subsequent supply of island loads
  - Scenario 3: Transition to grid parallel-operation after grid recovery

Component Tests – Island operation Diesel Gen-set

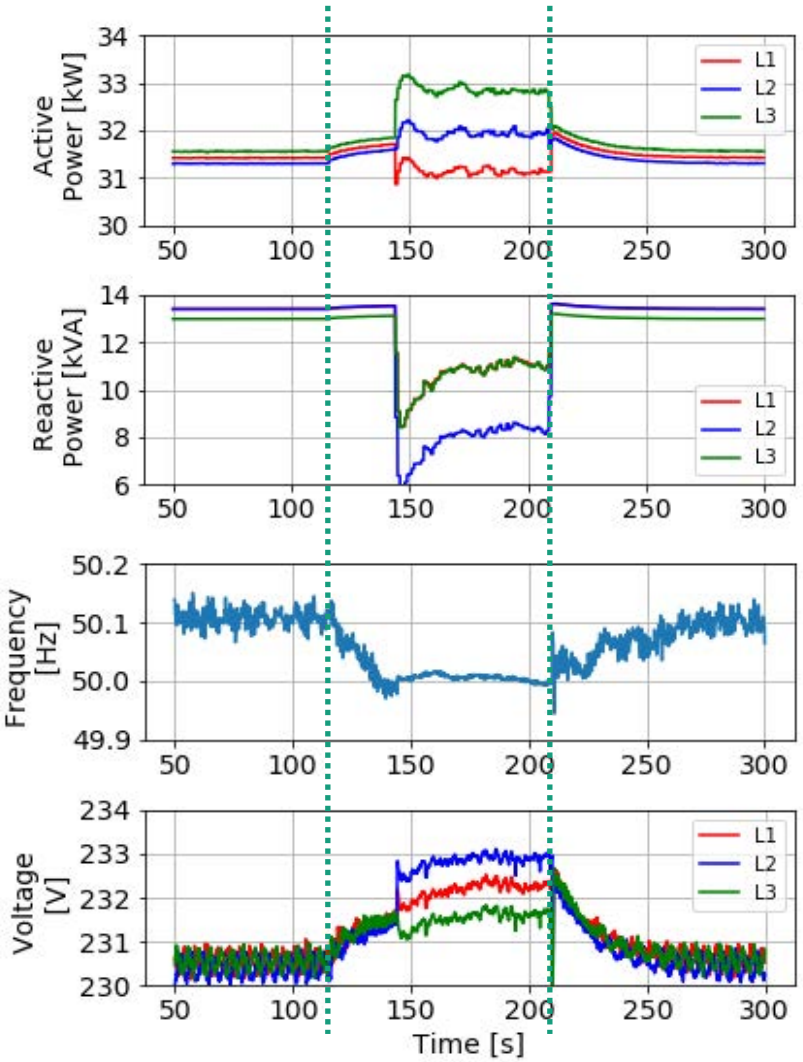


- First reaction of governor to Active Power step almost instantaneous, frequency reaches setpoint (50,1Hz) after approx. 40-50s
- Fast reaction of AVR to Reactive Power step, voltage setp. (230V) is reached within 1-2s



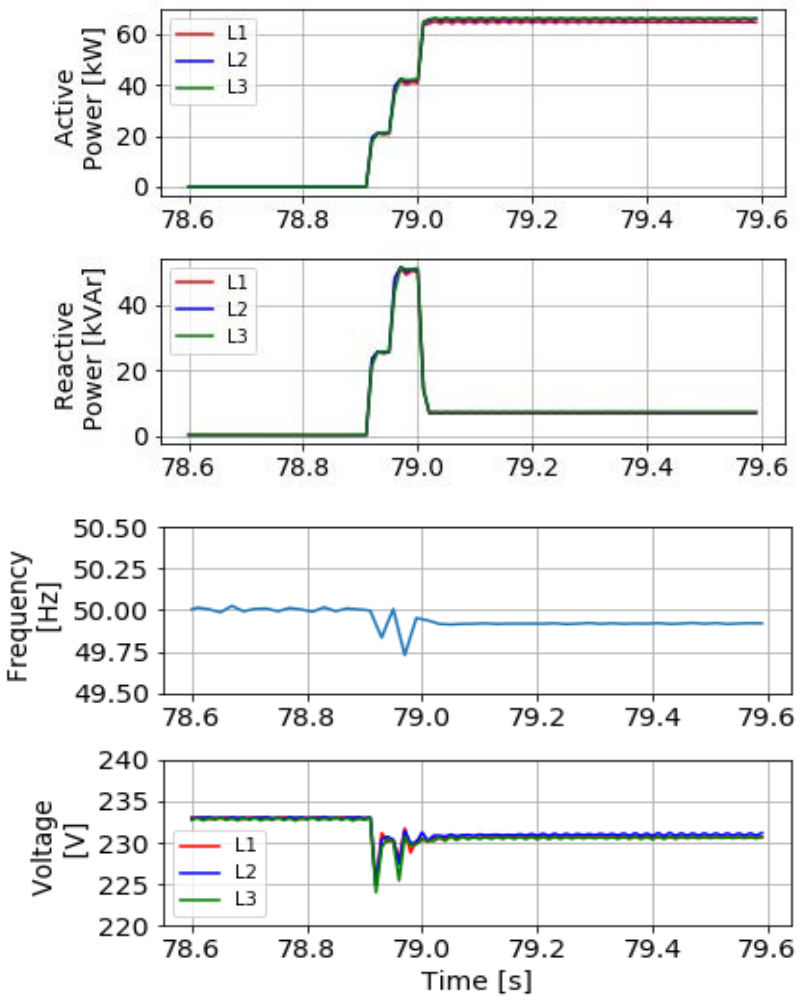
Component Tests – Dynamic Transition Diesel Gen-set

- Transition between grid-parallel and island operation
  - Start in island operation
  - Initiation of synchroni-sation to public grid at approx. 120s, completed after 20s
  - Return to island operation at approx. 210s
- Frequency settles in island mode within 40–50s to set-point value of Diesel Gen-set (50.1Hz)

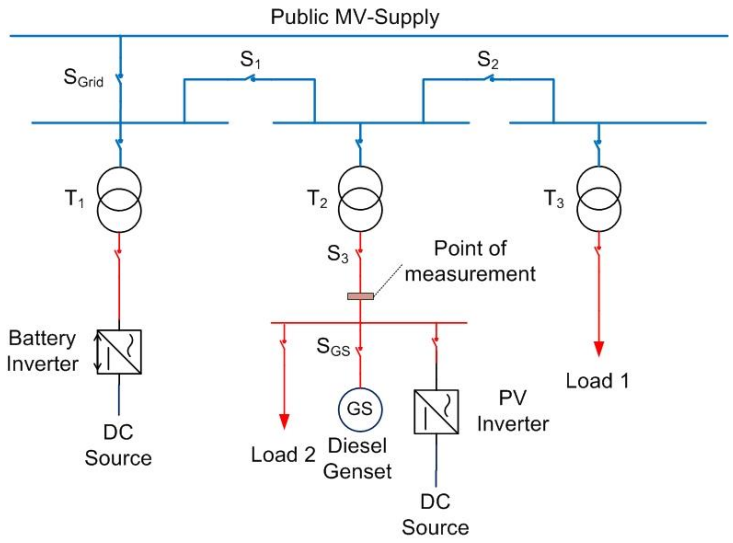


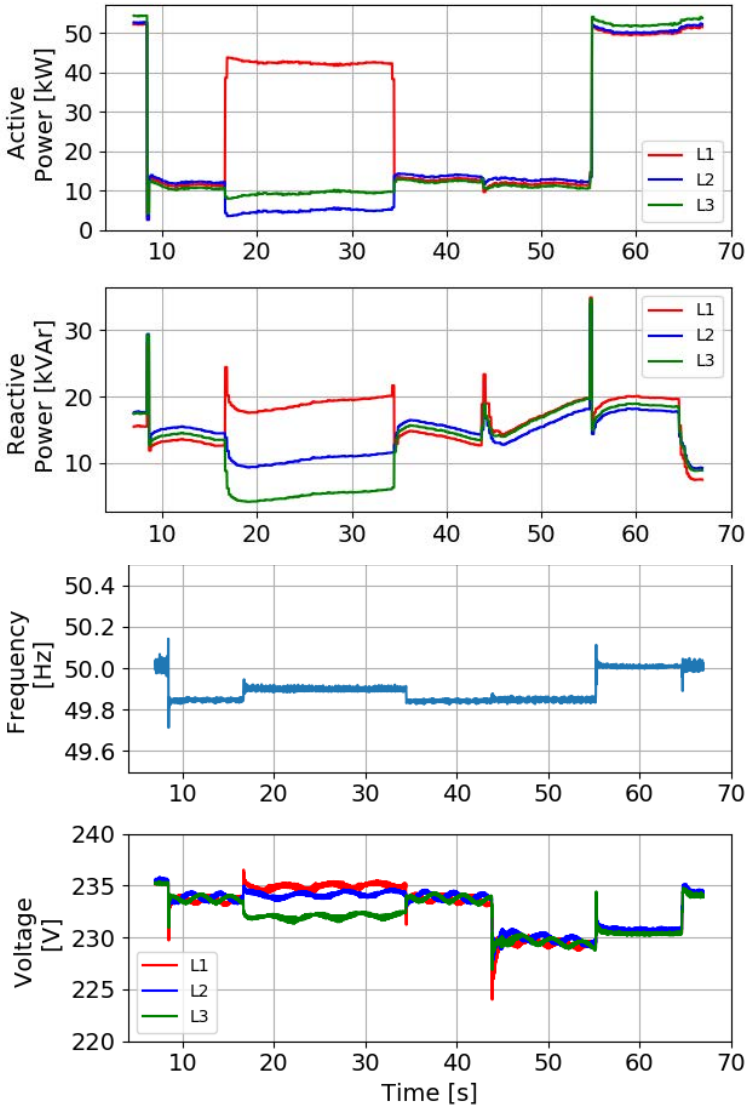
Component Tests – Island operation Battery Inverter

- Adaption of test procedure to fit to the rated power of Battery Inverter (2.2 MVA)
- Island operation of Battery Inverter: f-droop setting of 1Hz/P_R
- System response to a synchronous load step
- Different to tests with Diesel Gen-set: Frequency and voltage do not return to rated values due to f(P), U(Q) droops
- Frequency- and voltage-response completed after a few periods



System Tests - Island operation of Diesel & Battery Inv.





- Joint island operation of Battery Inverter, Diesel Gen-set, Loads and PV inverter
- Battery inverter resp. for frequency control; f-droop setting of 1 Hz/P_R
- Diesel operation with constant Power: P = 160 kW; cos(φ) = 0.95

Summary & Outlook

- High engineering effort for design of hybrid power systems
  - Customized solutions with diff. types of generators (Diesel, PV, Wind)
  - For grid stability assessment: Steady state and dynamic behavior of key components has to be analyzed
- Test procedures for key components:
  - Diesel Gen-set, Battery inverter, hybrid system controller
  - Different operating modes: Grid-parallel, Island operation and transitions
- Hybrid controller necessary in the present setup to re-adjust system frequency and voltage to rated values
- Future test scenarios:
  - Tests with hybrid controller
  - Tests with different parametrization of gen-set AVR and governor
  - Tests including fluctuating generators (PV, Wind)

Thank you for your attention!
Questions?

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