Large Battery Energy Storage Systems (BESS)

Technical Validation

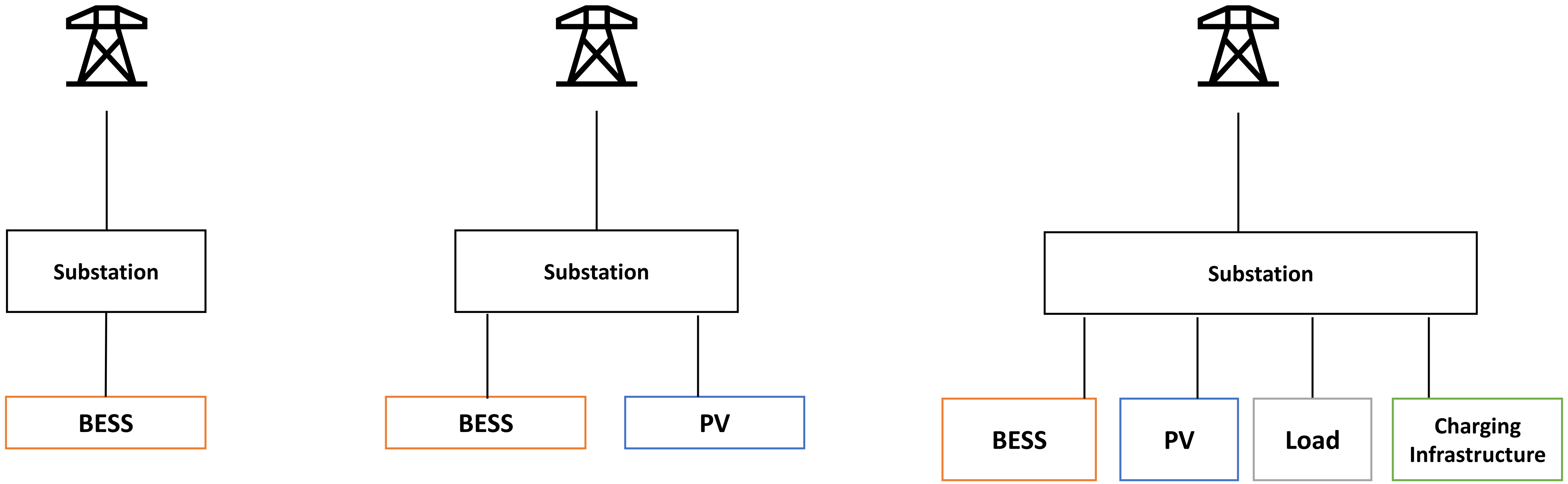
Dipl.-Ing. Christian Binder
Technical Program Management

SENERGY 365
Smarter energy. Every day.

Outline

- BESS Scenarios & Architecture
- BESS Quality Lifecycle
- Technical Validation

Typical BESS scenarios



Utility

- Energy Market
- Control Reserve Services (FCR, aFRR, mFRR)
- Enerita Services

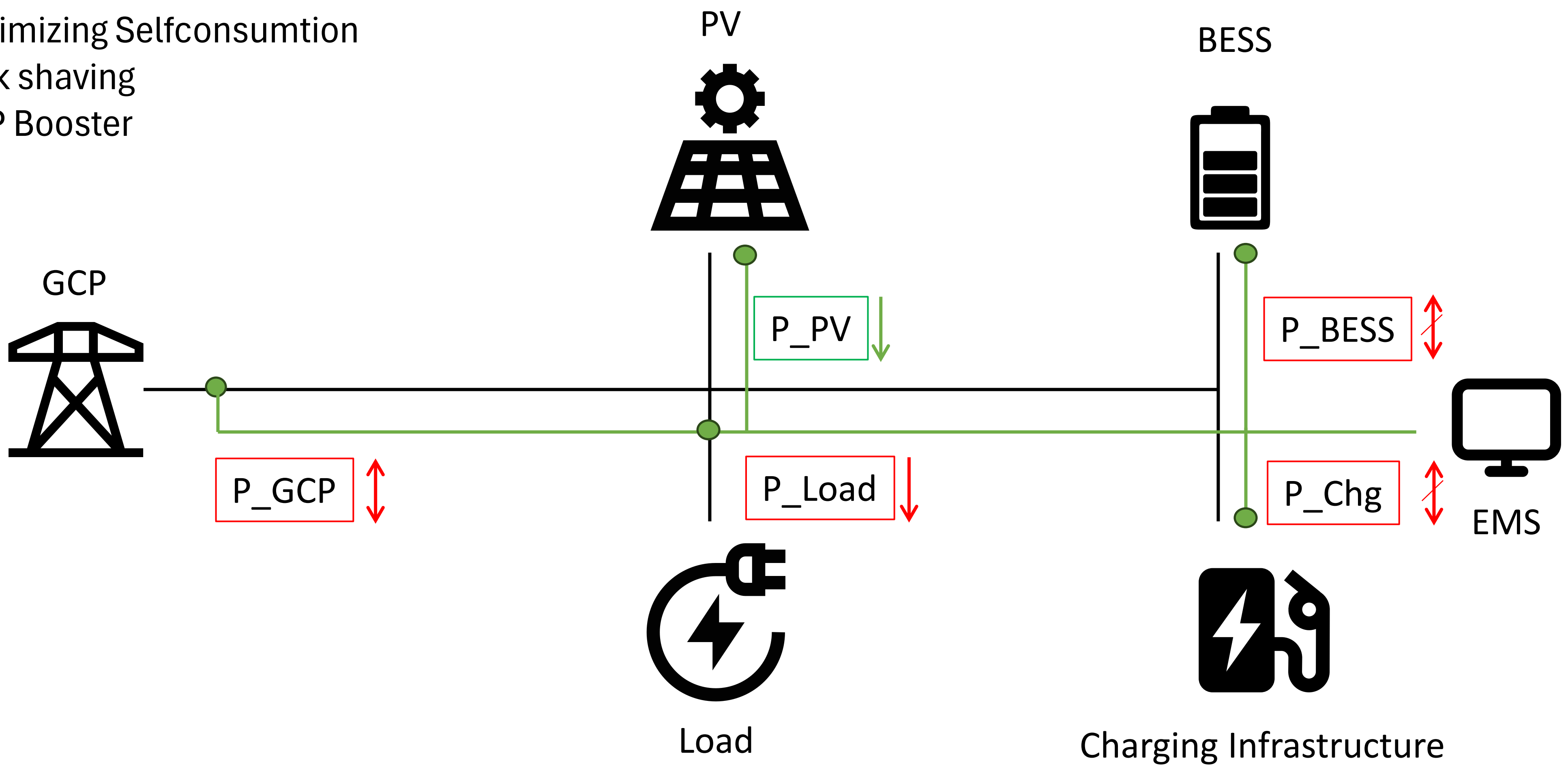
Commercial

- Maximizing Selfconsumtion
- Peak shaving
- GCP Booster

Commercial

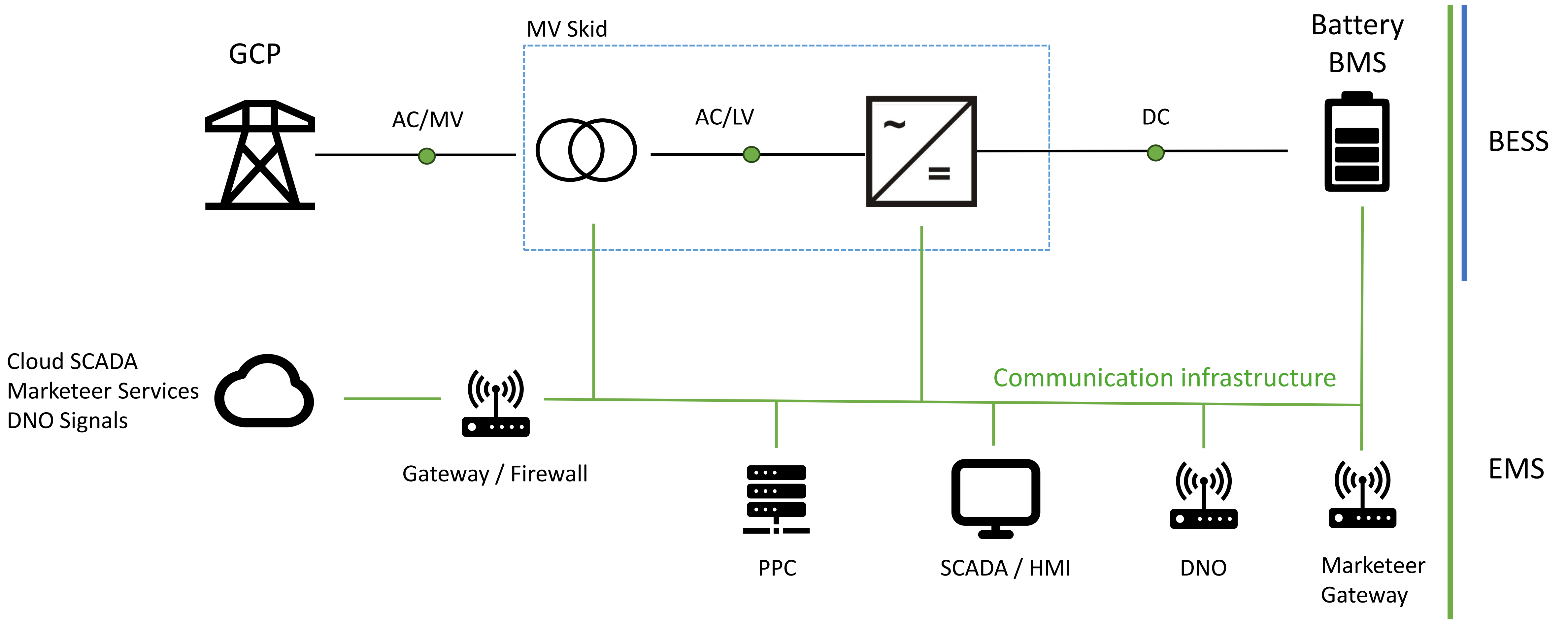
SENERGY 365
Smarter energy. Every day.

- Maximizing Selfconsumtion
- Peak shaving
- GCP Booster



BESS architecture

SENERGY 365
Smarter energy. Every day.



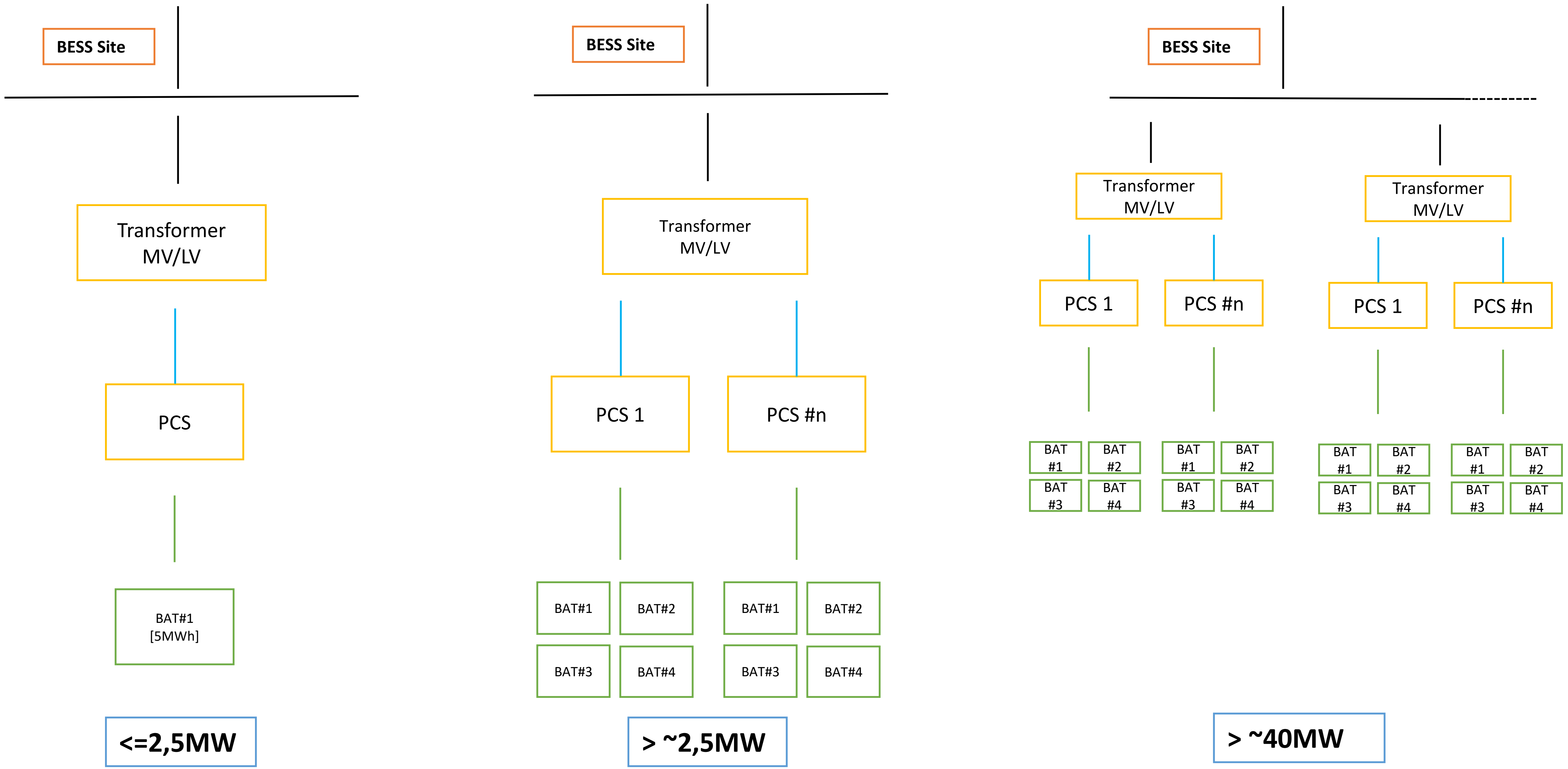
Typical 5MWh BESS container

- Master BMS
  - [n]Rack BMS
    - [n]Module BMS

https://kteck.com.au/

Scaling BESS introduces more system complexity

SENERGY 365
Smarter energy. Every day.

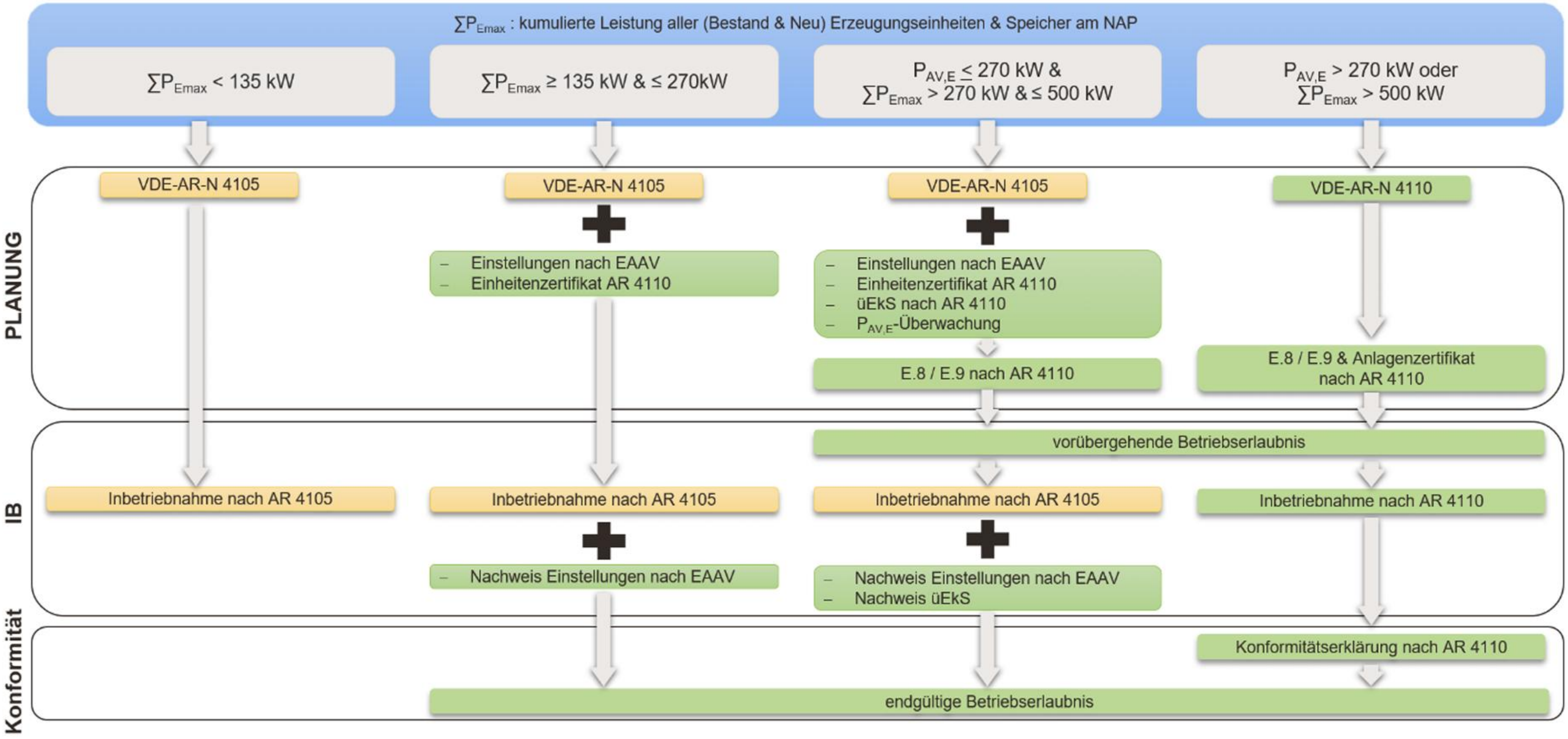


BESS Utility scenarios extent technical system requirements

S E N E R G Y 365
Smarter energy. Every day.

- Energy Market > [DE] **VDE-AR-N 4110**
- Control Reserve Services > [DE] **Präqualifikationsverfahren**
    - Frequency Containment Reserve (FCR)
    - Automatic Frequency Restoration Reserve (aFRR)
    - Manual Frequency Restoration Reserve (mFRR)
- Enerita Services

Energy Market – Grid connection requirement [DE]



https://www.vde.com/de/fnn/aktuelles/vereinfachter-anschluss-und-nachweis-von-erzeugungsanlagen-in-mittel--und-hochspannung-in-kraft

FCR, aFRR, mFRR – Basic IT requirements

1) Local Control & Autonomy

☐ Core reserve control functions run **locally on site**
☐ FCR droop control is **independent of WAN / cloud**
☐ Defined behavior for WAN / SCADA outage exists and is tested
☐ Reserve provision continues without operator intervention

2) Availability & Redundancy

☐ No single point of failure in IT chain
☐ Redundant hardware for reserve-critical components
☐ Automatic restart / watchdogs implemented
☐ Availability targets aligned with reserve commitments

3) Communication & Connectivity

☐ At least **two independent communication paths**
☐ Different technologies / providers (e.g. fiber + LTE)
☐ Automatic failover configured and tested
☐ Communication failure does **not** cause uncontrolled power drop
☐ Telephone fallback available (mandatory for mFRR)

4) Power Supply Resilience

☐ UPS for : Routers, gateways, EMS / control servers
☐ IT survives short outages and switching events
☐ Controlled shutdown / restart behavior documented

5) Cybersecurity

☐ All external communication is encrypted (VPN / TLS)
☐ Secure authentication in place
☐ Role-based access control implemented
☐ No shared or undocumented admin accounts
☐ Network segmentation between:
control network | corporate IT | remote access

6) Change Management

☐ Formal change management process exists
☐ Changes to IT / control logic are:

- documented
- impact-assessed
- approved

☐ Changes affecting reserve capability are traceable
☐ Rollback procedures defined

7) Monitoring & Alarming

☐ Continuous monitoring of:

- communication status
- IT system health
- data exchange

☐ Automatic alarms on relevant failures
☐ Escalation procedures defined
☐ Monitoring outages are distinguished from reserve outages

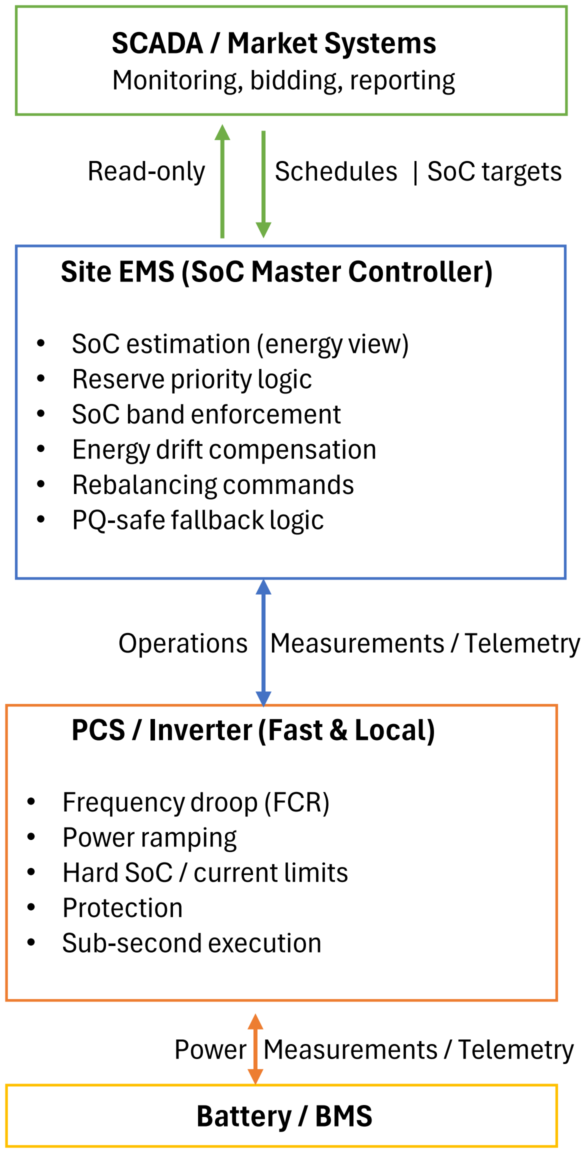
8) Logging & Auditability

☐ Logs include:

- timestamps (time-synchronized)
- received control signals
- executed power
- IT & comms faults

☐ Logs are tamper-resistant
☐ Logs can be retrieved for audits and disputes
☐ Retention period defined and sufficient

FCR, aFRR, mFRR - SOC Control Architecture



Monitoring
- SoC, power, reserve status
- Bidding and scheduling
- Operator visualization / Reporting and analytics

SoC Estimation & Band Management
- Apply **operational SoC bands**, e.g.: FCR core band: 40–60%, extended band for aFRR/mFRR
- Continuously evaluate **energy margin** vs. contracted reserve

Reserve-Aware Control Logic - Priority hierarchy
- FCR - Instantaneous k·Δf characteristic
- aFRR | mFRR
- Rebalancing / optimization

SoC Drift Compensation
- Monitor long-term net energy flow
- Keep SoC centered without violating FCR accuracy or introducing discontinuities

Rebalancing Control
- initiate charge/discharge for SoC recovery
- validate that rebalancing does **not consume reserve headroom**

Fault & Degradation Handling
- SoC approaching limit
- loss of market signal, partial communication loss
- Typical PQ-safe response: keep FCR active, suspend aFRR/mFRR, freeze rebalancing

SoC-Related Responsibilities
- Enforce **hard SoC limits** (0–100% physical limits)
- Enforce **current, voltage, thermal limits**
- Execute **frequency droop (FCR)** locally
- Execute power commands

BMS
- High-accuracy SoC estimation (Coulomb counting + voltage model)

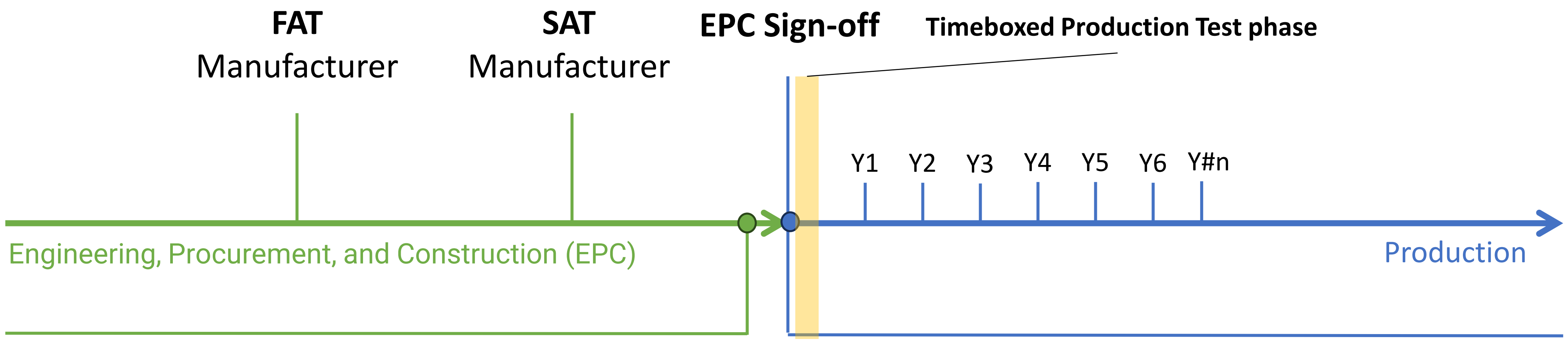
SENERGY 365
Smarter energy. Every day.

Outline

- BESS Scenarios & Architecture
- **BESS Quality Lifecycle**
- Technical Validation

SENERGY 365
Smarter energy. Every day.

BESS technical quality lifecycle



Technical validation

- Grid connection requirements (DE) VDE-AR-N 4110
- Product Documentation / SLD / Certificates
- Commissioning protocols VDE-100-600 / IEC 60364
- Pre-conditions for technical validation
- **Operational BESS-Performance Testcases**
- Grid Blackout validation
- BESS COM Failsafe validation

Long Term Service Agreement (LTSA)

- BESS Performance Warranties
- BESS Capacity degradation (SOH)/ year
- BESS RTE degradation / year
- BESS Availability warranties
- ***BESS SOC accuracy and drift*

Outline

- BESS scenarios & architecture
- BESS Quality Lifecycle
- **Technical Validation**

Technical Validation Framework

Battery Energy Storage Systems (BESS)

Goal is to include technical validations as part of the EPC **to enable quality early and with priority**.

The Framework is based on aspects defined in IEC 62933-2-1

Technical Validation

Process

Review System Documentation & Commissioning protocols

Pre-Onsite briefing defining Test profile

Onsite - Execute Test profile

Debriefing / Sign-off Re-Testing

Technical Validation Framework

Overview

Grid compatibility

- Grid connection requirements (DE) VDE-AR-N 4105/10/20
- [optional] Gird forming Services requirements

Product Documentation

- Product Documentation / SLD / Certificates

Commissioning Protocols

- FAT and SAT
- Electrical Commissioning protocols VDE-100-600 / IEC 60364
- GCP protection gear and Grid code validation protocols

Technical Validation requirements

- Pre-conditions for technical validation

Testprofile / Testcases

- **Operational BESS-Performance Testcases**
- Grid Blackout validation
- BESS COM Failsafe validation

Examination operational BESS-Performance

Capacity
[1] Examination of Usable capacity

Effectiveness
[2] Examination of the system effectiveness of an operating cycle [RTE]

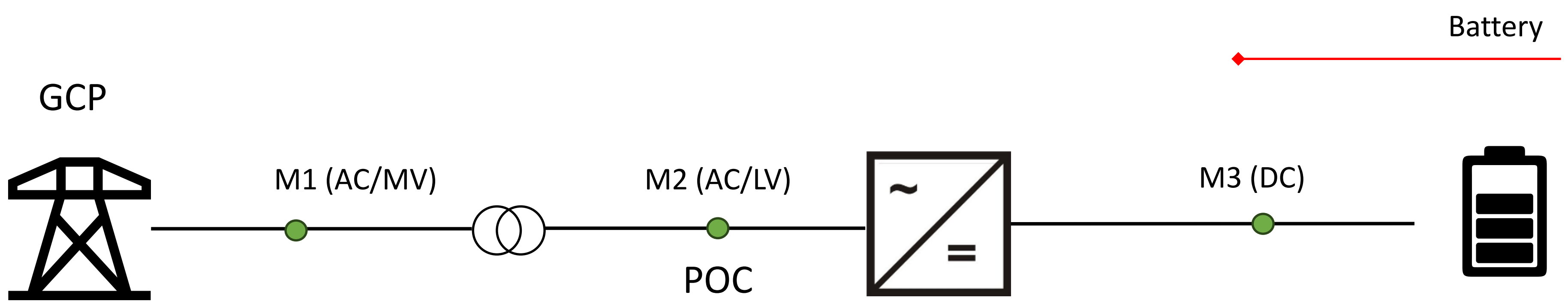
Power
[3] Examination of the input and output rated power
- Examination of inverter operating temperature and derating

[4] Examination of AUX Energy consumption
- Examination of Standby / REST Energy consumption

BMS
[5] Examination of SOC Imbalance
[6] Examination of Cell Voltage Imbalance
[7] Examination of Cell Temperature anomalies

[1] Usable Battery capacity baseline

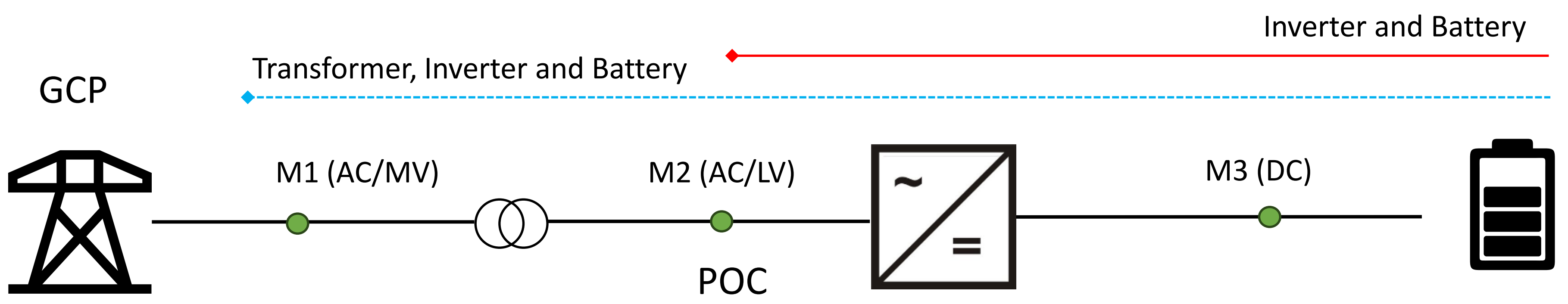
Scope	Examination Usable battery capacity. Used for tracking Battery degradation warranties.
Measurement Steps	Discharge from max SOC 100%
AUX Energy	Excluding AUX Energy. AUX energy will be separately measured due to the ambient temperature dependencies.
Measurement	E_o at [M3] [kWh]
Measurement device	BMS DC data, or DC Meter
Product datasheet reference	Useable Capacity [kWh]



[2] System effectiveness of an operating cycle (RTE)

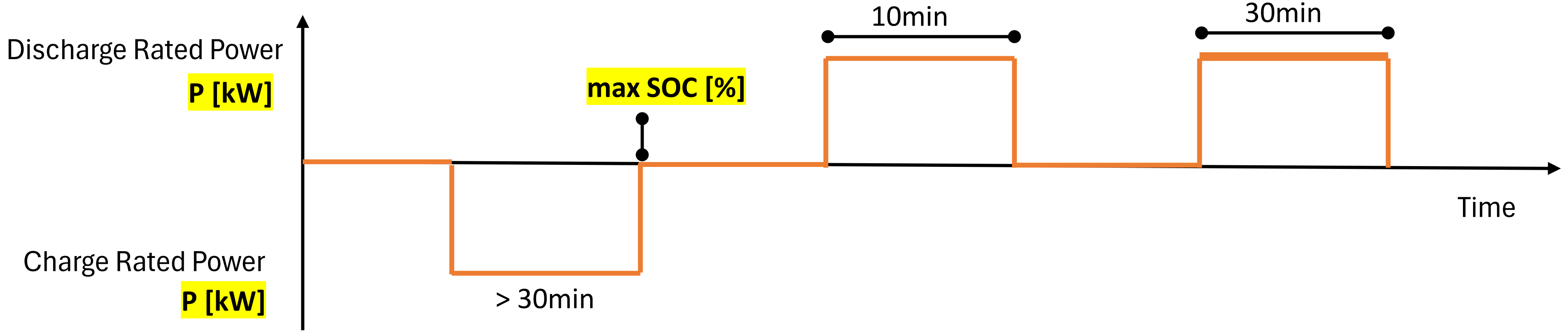
SENERGY 365
Smarter energy. Every day.

Scope	Usable BESS capacity @ POC includes Inverter, battery and cable losses **Option GCP -** extending scope to include Transformer
Measurement Steps	1) Charge to max SOC 100% 2) Discharge to min SOC 0%
AUX Energy	Excluding AUX Energy. AUX energy will be separately measured due to the ambient temperature dependencies.
Measurement	$\eta_{rt} = \frac{E_O}{E_I}$ [%], E_I, E_O at [M2] [kWh] or [M1] [kWh]
Measurement device	Internal Inverter AC data or AC Meter
Product datasheet reference	RTE @ POC [%]



[3] Examination of the input and output rated power

Scope	Validate input and output rated power
Measurement Steps	Charge and Discharge according to the Test profile
Analysis	– Rated P[kW] will be reached. In case of parallel inverters P[kW] is symmetric – No derating of P[kW] is observed because of high temperature – No oscillations of P[kW] during transients are observed
Measurement	P at [M2] [kW] , Inverter Temperature [°C]
Measurement device	Internal Inverter AC data or AC Meter
Product datasheet reference	Inverter rated P [kW], max Inverter Temperature [°C] before derating power

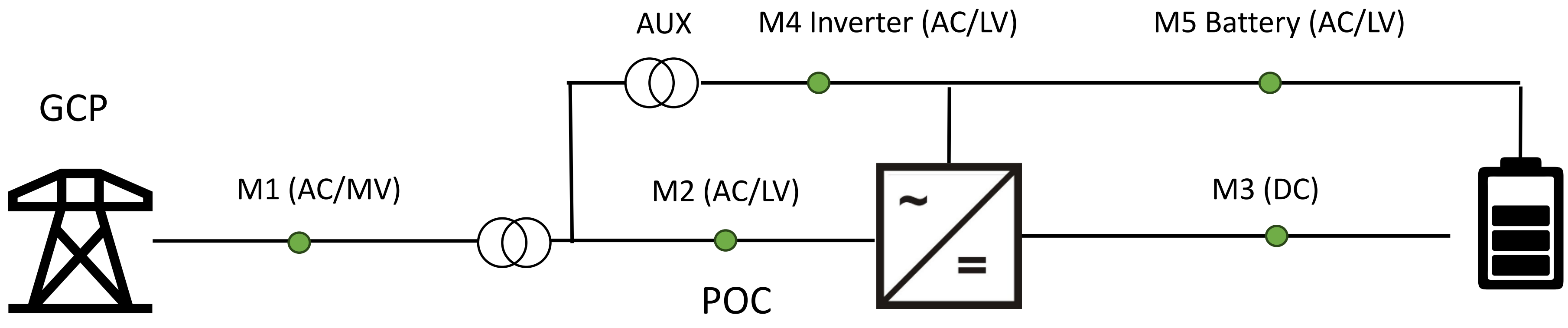


[4] Examination of AUX Energy consumption

SENERGY 365
Smarter energy. Every day.

Caution: Any active measurement of AUX power is only valid for the given ambient temperature as $AUX\_P_{(temp)}$

Scope	AUX energy is not exceeding defined maximum consumption
Measurement Steps	Perform RTE test
Analysis	AUX energy is highly depended on ambient temperature, so this measurement intents the minimum validation that the max consumption is not exceeded. If detailed consumption as function $P_{(temp)}$ is provided by the manufacturer those values should be validated.
Measurement	P_{AUX} at [M 4,M5] [kWh]
Measurement device	Internal AC data or AC Meter
Product datasheet reference	$P_{AUX\_Inverter}$[kW] , $P_{AUX\_Battery}$[kW] ideally provided as function $P_{(temp)}$

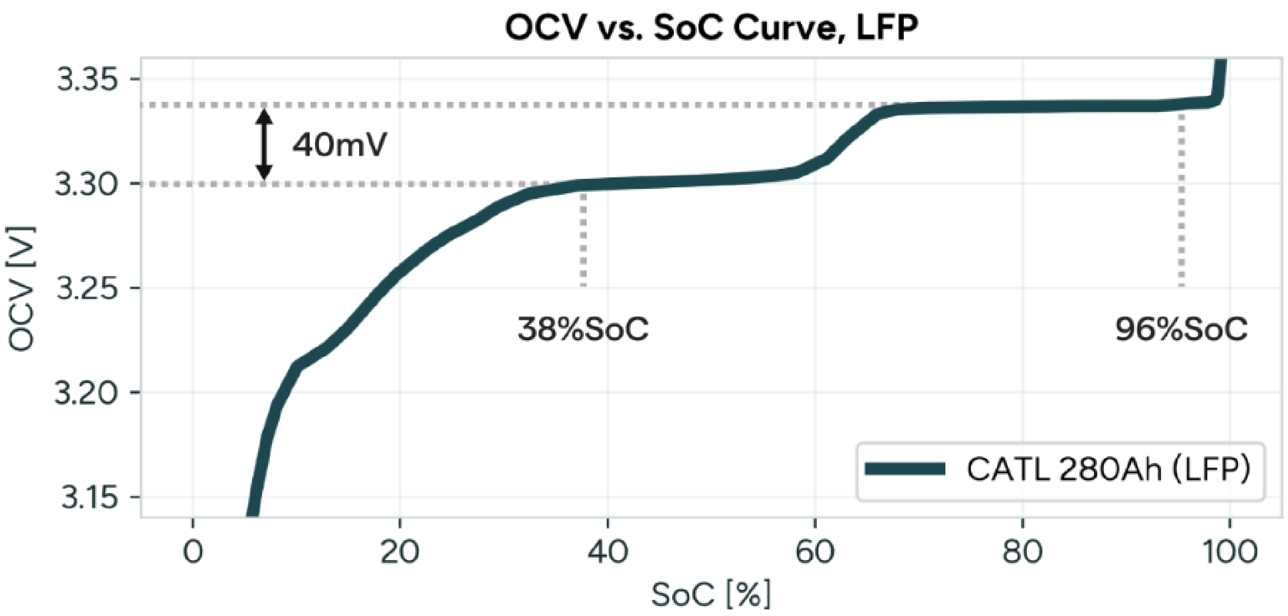


[5] Examination of SOC Imbalance

Scope	SOC is balanced after calibration
Measurement Steps	Analyze data from RTE test
Analysis	- No significant Imbalances on Rack/Modul level [%]
Measurement	SOC [%]
Measurement device	BMS
Product datasheet reference	Max SOC RACK difference after calibration <5%

SOC accuracy drift in production :

SOC, SOE values are computed by the BMS. By charging and discharging LFP batteries there are effects leading to SOC accuracy drift over time depending on SOC estimation methods used by the BMS, which require regular calibration. BMS SOC estimation methods are **OCV Lookup**, **Coulomb Counting** and **EKF**. These effects are not in scope of a one-time Technical Validation as this is would require system monitoring over time.

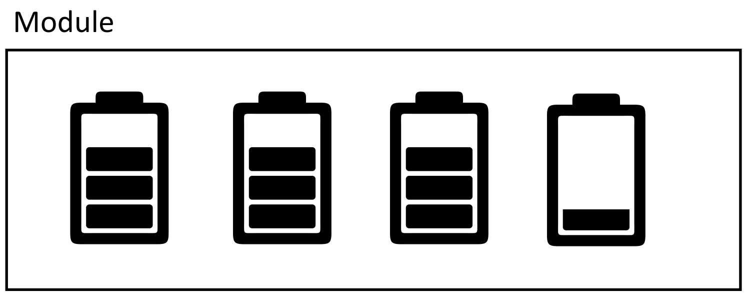


https://www.zitara.com/resources/demystifying-battery-balancing

[6] Examination of Cell Voltage Imbalance

SENERGY 365
Smarter energy. Every day.

Scope	Cell Voltage is balanced after calibration
Measurement Steps	Analyze data from RTE test
Analysis	- No significant Imbalances on Modul level [mV]
Measurement	Cell_Voltage [mV]
Measurement device	BMS
Product datasheet reference	Module Cell Voltage difference < 15[mV]



[7] Examination of Cell temperature anomalies

SENERGY 365
Smarter energy. Every day.

Scope	Cell temperature anomalies
Measurement Steps	Analyze data from RTE test
Analysis	– Cell temperature does not exceed max_ Cell_Temperature – No significant temperature Imbalances on Modul level
Measurement	Cell_Temperature [°C]
Measurement device	BMS
Product datasheet reference	Cell temperature below max _Cell_Temperature[°C] Cell temperature difference <6 [°C] on Module level

Takeaway - BESS technical quality lifecycle

- Understand system requirements based on target Utility scenarios and required certifications
- **Integrating quality early - by defining BESS technical validations as part of the EPC**
- Build the baseline for any LTSA validations like capacity degradation
- **Do not underestimate the digital complexity of the EMS and Integrations. Especially if the system requires a KRITIS certification**

Q&A

SENERGY 365

Smarter energy. Every day.

EMS & BESS

Christian Binder
Dipl.-Ing. (FH)

Founder

www.SENERGY365.de

Christian.Binder@SENERGY365.de

+49 88036393887