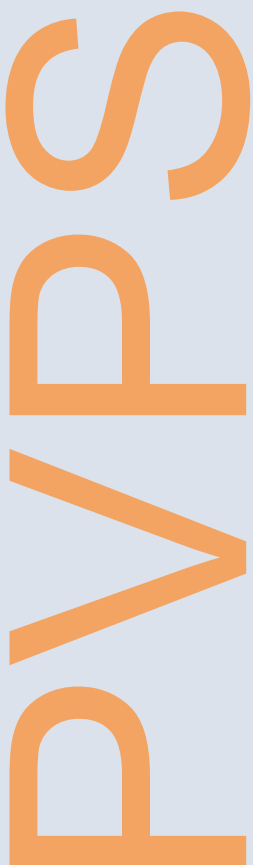


Task 14 Solar PV in the 100% RES Power System



# Communication and Control for High PV Penetration under Smart Grid Environment

## Case Study Analysis 2021



# I. SCENARIO DEFINITION AND QUESTIONNAIRE OF GERMANY (EXAMPLE FROM THU)

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## Role of Editor

Name of editor/ organization (optional):

THU, Germany

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E-mail (optional):

Shuo.chen@thu.de

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## Role of editor:

- Grid operator
  - Grid regulator
  - Metering point operator
  - PV-system operator
  - PV-system owner
  - Energy market retailer
  - Energy service provider
  - Scientific organization
  - Standardization committee
  - Technical / legal commission
  - PV-system manufacturer
  - IT service provider
  - Other, please specify
-



## Scenario description

### Scenario description:

Please specify the scenario here.

#### **Residential PV systems (< 10kWp)**

Single Homes and other small dwellings. PV systems below 7kWp are not obliged to install a Smart Meter.

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# 1 SCENARIO: RESIDENTIAL PV SYSTEMS (< 10 KWP) (EXAMPLE FROM GERMANY)

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## 1.1 Regulatory Documents

Which legal requirements are relevant for the operators of grid-connected PV systems in your country?

EEG 2017 (German Renewable Energies Act (EEG)), new EEG amendment will be published in 2021) [1] [4]; EnWG (German Energy Industry Act) [5]; VDE-AR-N 4105 (LV-grid) [6]; GDEW (Law on the digitization of the energy transition) [7]; NABEG (German Grid Expansion Acceleration Act) [8]

---

Which business models do PV systems have in the scope of your scenario?

- Feed-in tariff (FIT)
  - Self-consumption
  - Net metering
  - Virtual power plant (e.g. participation with an aggregator)
  - Participation in energy market
  - Power purchase agreement (PPA)
  - Peer-to-peer contract
  - Other, please specify:
- 

## 1.2 Grid Connection

To which voltage levels are the PV systems connected in your scenario?

- LV (low voltage)
- MV (medium voltage)
- HV (high voltage)
- More than one is possible

Which connection topologies are allowed?

- Single Phase
- Multiple Single Phase
- 3 Phase
- Split Phase
- Not defined



**Which further specialties are regulated in your project / country concerning grid connection?**

PV systems are in grid-connected operation

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**1.3 Metering Data for Invoicing**

**Which Parameters are recorded?**

|                                                 | Mandatory                           | Optional                            |
|-------------------------------------------------|-------------------------------------|-------------------------------------|
| Active energy                                   | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Reactive energy                                 | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| <input type="checkbox"/> Other, please specify: |                                     |                                     |

---

**Which interval is used for the measurement and data transmission (for invoicing)?**

|                                                | Measurement                         | Data transmission                   |
|------------------------------------------------|-------------------------------------|-------------------------------------|
| Annually                                       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Quarterly                                      | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Monthly                                        | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Weekly                                         | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Daily                                          | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Hourly                                         | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Quarter hourly                                 | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Minutes                                        | <input type="checkbox"/>            | <input type="checkbox"/>            |
| <input type="checkbox"/> Other, please specify |                                     |                                     |

---

**How are these data collected?**

- Collected by DSO-Official
- Meter operator
- Costumer sends Postcard
- Costumer uses an App / Webpage form
- Transmitted (Smart Meter)

**Is it planned to transmit the measurements in the future?**

- Yes, please specify  
 over 7 kWp transmitted by Smart Meter Gateway (hourly 15 min energy values, shorter periods available in next generation of SMGW [9] [10])
  - No
-



**If measurements are transmitted or will be transmitted in the future, please give details on technology and procedures.**

Smart Meter Gateway (SMGW) - core of the smart metering system. It acts as a central communication unit between three different network types: the wide area network (WAN), the home area network (HAN) and the local metrological network (LMN). Both HAN and LMN belong to the consumer's local area network (LAN).

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## 1.4 Metering Data for grid operation

**Which Parameters are recorded?**

|                    | Mandatory                           | Optional                            |
|--------------------|-------------------------------------|-------------------------------------|
| Active energy      | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Reactive energy    | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| Active power       | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| Reactive power     | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| Phase active power | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Phase voltage      | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Phase currents     | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Grid frequency     | <input type="checkbox"/>            | <input type="checkbox"/>            |
| THD or harmonics   | <input type="checkbox"/>            | <input type="checkbox"/>            |

**Which interval is used for the measurement and data transmission (for grid operation)?**

|                                                | Measurement                         | Data transmission                   |
|------------------------------------------------|-------------------------------------|-------------------------------------|
| Annually                                       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Quarterly                                      | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Monthly                                        | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Weekly                                         | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Daily                                          | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Hourly                                         | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| Quarter hourly                                 | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Minutes                                        | <input type="checkbox"/>            | <input type="checkbox"/>            |
| <input type="checkbox"/> Other, please specify |                                     |                                     |

**How are these data collected?**

- Collected by (DSO) Official
- Meter operator
- Customer uses an App / Webpage form
- Transmitted (Smart Meter)



### Is it planned to transmit the measurements in the future?

- Yes, please specify  
 over 7 kWp transmitted by Smart Meter Gateway (hourly 15 min energy values, shorter periods available in next generation of SMGW [9] [10])
- 
- No

### If measurements are transmitted or will be transmitted in the future, please give details on technology and procedures.

Smart Meter Gateway

---

## 1.5 PV System Registration

### Which registrations are required for the grid interconnection of a PV system?

- Registration at grid operator (asset management)
- Registration at grid operator (grid operation)
- Registration at renewable energy system register [11]
- Registration at energy market register
- Valid certificate for PV system operation
- Other, please specify
- 

## 1.6 Ancillary Services

### Which preconditions are required for the grid-connected operation of a PV inverter? [6] [12]

- FRT (Fault Ride Through) capability
- Automatic power limitation/disconnection in over frequency cases
- Voltage rise check by DSO before installation
- Communication access (e.g. for curtailment)
- Other, please specify
- 

### Which ancillary services are provided for grid operators by grid-connected PV inverters? [12] [13]

- Frequency regulation & reserve power
- Harmonic compensation
- Fast ramping resources
- Grid dynamic voltage support
- Grid restart after blackout



- Grid-disconnected microgrid operation (Unintentional islanding)
  - Reactive power capability & voltage regulation
  - Other, please specify
- 

#### Is there a compensation for delivering ancillary services?

- No
  - Yes, please specify  
curtailed feed-in active power [14]
- 

## 1.7 Monitoring & Remote Control

#### Is there any regulatory document for PV monitoring?

- No
  - Yes, please specify
- 

#### Which control methods are applied to PV systems?

- Active power curtailment (set a feed-in limit)
  - Special commands for ancillary services (e.g. reactive power provision)
  - Modification of inverter parameters (e.g. set power factor of the inverter)
  - Forecast-based scheduling
  - Local regulation regarding customer home energy system
  - Other, please specify
- 

#### Which protocols and technologies are considered in the control commands? [15] [16] [17]

- Control based on relays
  - IEC 60870-5-103/104 (classic standard for tele control) [18]
  - IEC 61850 (modern standard for tele control) [19]
  - IEC 61970, IEC 61968 (CIM: Common Information Model) [20] [21]
  - Open ADR [22]
  - IEEE 2030.5 [23]
  - SunSpec Modbus-TCP [24]
  - Proprietary protocols, please specify  
Vendor specific Modbus, EEBUS (one German specific fieldbus protocol) [25]
-





**Which communication infrastructure is used to send the commands?**

- Ripple control (long wave radio)
  - DSL
  - Power line communication
  - Fiber optics
  - GSM /UMTS/LTE
  - 5G
  - Fax or Papers exchange or telephone
  - Other, please specify
-



## 1.8 Opportunities for PV integration into smart grids

Which of the following scenarios are currently regarded in your country? In addition, which will be considered in the future? [26] [27]

| No. | Scenarios for the integration of PV in the smart grid                                                                                                       | Present                             | Planned                             | Future                              | Not Discussed            |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|--------------------------|
| 1   | Transmit measurements<br>Transmission of meter data for invoicing and grid measurements for grid operation                                                  | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> |
| 2   | Control of active power<br>Direct control of PV system feed-in active power, e.g. via active power curtailment                                              | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| 3   | Control of reactive power<br>Using the grid-support functionalities of PV inverters for reactive power regulation (e.g. voltage support)                    | <input type="checkbox"/>            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 4   | Use of existing ICT infrastructure<br>Realizing tele-communication without installing extra ICT devices (e.g. ICT device in customer network)               | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| 5   | Change parameters for the inverter control<br>Amendment of inverter operation modes by configuring inverter control parameters (e.g. P(f), V-control modes) | <input type="checkbox"/>            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 6   | Inverter Plug and Play<br>Automatic registration in the MDS (metering data system) and SCADA of grid operator                                               | <input type="checkbox"/>            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 7   | Autonomous DER functions<br>Autonomous control of DER on behalf of (coordinated and cascaded) DSO/TSO commands or market signal                             | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| 8   | Provide black start capabilities<br>Contributing to grid restart after local or regional grid black out                                                     | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> |
| 9   | Storage specific function<br>Supporting operational or economic use cases with different types of energy storage for customers and grid operators           | <input type="checkbox"/>            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 10  | Time-based scheduling<br>Day-ahead time-based scheduling of PV control configuration regarding available weather/load forecast                              | <input type="checkbox"/>            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> |



| No. | Scenarios for the integration of PV in the smart grid                                                                                                                                                          | Present                  | Planned                             | Future                              | Not Discussed                       |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| 11  | <p>Monitor PV-Status and provide emergency alarm</p> <p>Monitoring of PV system operation states and alert the stakeholder/operator in case of emergency and operational fault</p>                             | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 12  | <p>Participation in local energy markets</p> <p>Enabling energy trade of PV feed-in surplus in local energy market</p>                                                                                         | <input type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 13  | <p>Neighborhood energy exchange (within one feeder)</p> <p>Enabling energy trade of PV feed-in surplus with consumers in neighborhood</p>                                                                      | <input type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 14  | <p>Participation in flexibility-platform</p> <p>Participating in flexibility trade by providing PV system capacity as reserve power (e.g. via prosumer aggregation)</p>                                        | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            |
| 15  | <p>Participation in crossing region energy markets</p> <p>Enabling energy trade of PV feed-in surplus in crossing region energy market (e.g. via p2p energy trade, block-chain application)</p>                | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            |
| 16  | <p>Documentation of executed PV curtailments</p> <p>Providing evidence for compensation of flexibility trade by documentation executed power curtailments and other kinds of power regulation restrictions</p> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            |
| 17  | <p>PV - EV compensation</p> <p>Enabling compensation of EV peaks by charging with PV surplus, hybrid storage system could also be associated</p>                                                               | <input type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 18  |                                                                                                                                                                                                                | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            |
| 19  | <hr/>                                                                                                                                                                                                          | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            |
| 20  | <hr/>                                                                                                                                                                                                          | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            |
|     | <hr/>                                                                                                                                                                                                          |                          |                                     |                                     |                                     |



## 1.9 Security

Which of the 4 Goals of an IT system security policy / discussion is rated the most? Please give numbers to rate the 4 different goals from 0 = not considered / not important to 10 = most important [28]

| No. | Goals                                           | 0                        | 1                        | 2                        | 3                        | 4                        | 5                                   | 6                        | 7                        | 8                        | 9                                   | 10                                  |
|-----|-------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|-------------------------------------|--------------------------|--------------------------|--------------------------|-------------------------------------|-------------------------------------|
| 1   | Confidentiality (also considers privacy issues) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 2   | Integrity                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 3   | Availability                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            |
| 4   | Accountability                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            |

Which measures for IT security should be considered? [9] [28] [29] [30] [31]

| No. | IT security measure                                                                      | Present                             | Future                              |
|-----|------------------------------------------------------------------------------------------|-------------------------------------|-------------------------------------|
| 1   | Threat analysis & risk management for PV systems to identify threats and vulnerabilities | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 2   | Regular cyber security assessment for existing infrastructure                            | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 3   | User authentication                                                                      | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 4   | Device identification and authentication                                                 | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 5   | Role-based device access control                                                         | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 6   | Attack/intrusion detection system                                                        | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 7   | ICT cryptographic techniques                                                             | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 8   | Internet cryptography                                                                    | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 9   | Wireless cryptography                                                                    | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 10  | Certificate-based PKI cryptography and key management                                    | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 11  | Design secure network configurations                                                     | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 12  | Implementation of security testing and validation procedures                             | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 13  | Redundant communication network                                                          | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 14  | Redundant equipment                                                                      | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 15  | Centralized monitoring and control via SCADA system                                      | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 16  | Centralized power system analysis and control for DER via EMS and DMS                    | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 17  | Security awareness & training for system operator staffs                                 | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 18  | Utilization of block-chain technologies                                                  | <input type="checkbox"/>            | <input checked="" type="checkbox"/> |
| 19  | Secured storage and transport of ICT devices                                             | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| 20  |                                                                                          | <input type="checkbox"/>            | <input type="checkbox"/>            |



Please rate the following scenarios for IT security in respect to utilization vs danger (risk vs opportunity) with following rating:

- -2: This is a great danger
- -1: we consider the use but have doubts
- ND: Not discussed
- +1: it is interesting and offers potential
- +2: This is the way to go

| No. | Scenarios for the integration of PV in the smart grid | -2                       | -1                                  | ND                                  | +1                       | +2                                  |
|-----|-------------------------------------------------------|--------------------------|-------------------------------------|-------------------------------------|--------------------------|-------------------------------------|
| 1   | Transmit measurements                                 | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 2   | Control of active power                               | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 3   | Control of reactive power                             | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 4   | Use of existing ICT infrastructure                    | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/>            |
| 5   | Change parameters for inverter control                | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 6   | Inverter Plug and Play                                | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 7   | Autonomous DER functions                              | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 8   | Provide black start capabilities                      | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 9   | Storage specific function                             | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 10  | Time-based scheduling                                 | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 11  | Monitor PV Status and provide emergency alarm         | <input type="checkbox"/> | <input type="checkbox"/>            | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |
| 12  | Participation in local energy markets                 | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 13  | Neighborhood energy exchange (within one feeder)      | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 14  | Participation in flexibility-platform                 | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 15  | Participation in crossing region energy markets       | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 16  | Documentation of executed PV curtailments             | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 17  | PV - EV compensation                                  | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| 18  |                                                       | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/>            |
| 19  |                                                       | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/>            |
| 20  |                                                       | <input type="checkbox"/> | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/>            |



## LIST OF ABBREVIATIONS

|       |                                                                                                                                               |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| ADR   | Automated Demand Response                                                                                                                     |
| CIM   | Common Information Model                                                                                                                      |
| CLS   | Controllable Local System                                                                                                                     |
| DER   | Distributed Energy Resources                                                                                                                  |
| DSL   | Digital Subscriber Line                                                                                                                       |
| DSO   | Distribution System Operator                                                                                                                  |
| EEG   | Erneuerbare-Energien-Gesetz (English: German Renewable Energies Act)                                                                          |
| EMS   | Energy Management System                                                                                                                      |
| EnWG  | Energiewirtschaftsgesetz (English: German Energy Industry Act)                                                                                |
| EV    | Electric Vehicle                                                                                                                              |
| FIT   | Feed in Tariff                                                                                                                                |
| FRT   | Fault Ride Through                                                                                                                            |
| GDEW  | Gesetz zur Digitalisierung der Energiewende (English: Law on the Digitization of the Energy Transition)                                       |
| GSM   | Global System for Mobile Communications                                                                                                       |
| HAN   | Home Area Network                                                                                                                             |
| HV    | High Voltage                                                                                                                                  |
| ICT   | Information and Communication Technologies                                                                                                    |
| IEA   | International Energy Agency                                                                                                                   |
| IEC   | International Electrotechnical Commission                                                                                                     |
| LMN   | Local Metrological Network                                                                                                                    |
| LTE   | Long Term Evolution                                                                                                                           |
| LV    | Low Voltage                                                                                                                                   |
| MDS   | Metering Data System                                                                                                                          |
| MV    | Medium Voltage                                                                                                                                |
| NABEG | Netzausbaubeschleunigungsgesetz Übertragungsnetz (English: Grid Expansion Acceleration Act)                                                   |
| PKI   | Public Key Infrastructure                                                                                                                     |
| PPA   | Power Purchase Agreement                                                                                                                      |
| P2P   | Peer to Peer                                                                                                                                  |
| PV    | Photovoltaic                                                                                                                                  |
| SCADA | Supervisory Control and Data Acquisition                                                                                                      |
| SMGW  | Smart Meter Gateway                                                                                                                           |
| TSO   | Transmission System Operator                                                                                                                  |
| THD   | Total Harmonic Distortion                                                                                                                     |
| UMTS  | Universal Mobile Telecommunications System                                                                                                    |
| VDE   | Verband der Elektrotechnik, Elektronik und Informationstechnik (English: Association for Electrical, Electronic and Information Technologies) |





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