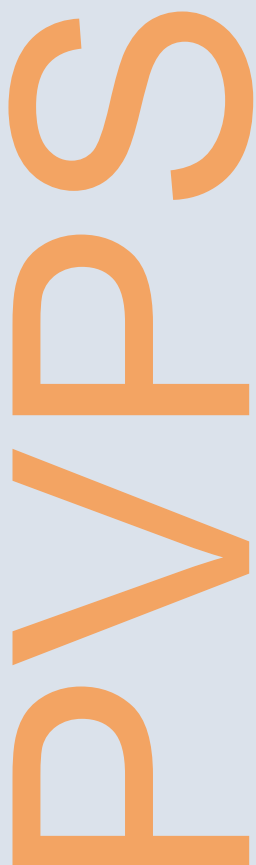


Task 14 Solar PV in the 100% RES Power System



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)

Role of Editor

Name of editor/ organization (optional):

THU, Germany

E-mail (optional):

Shuo.chen@thu.de

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.



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

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

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).

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 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 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 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 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 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 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 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 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 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 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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