Active & Reactive Power Control in RE Environment (Rooftops Plants)

V 3.1 - 0818

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Grid Connected Solar Energy- Project Development

Globally Grid-tied Solar Projects has followed 2 broad routes:

Utility Driven Solar Project Development

- Large MW-scale centralized solar projects developed to meet **renewable purchase obligations (RPO)** of the utilities

- **either developed by utilities themselves** or **by third parties** for their procurement.

Customer Driven Solar Project Development

- Small-scale **decentralized** projects developed by electricity consumers on their own premises.

- Interest fueled by the declining cost of solar energy, fiscal incentives like **feed in tariffs (FiT's), net metering** and **tax rebates**, coupled with the increase in the cost of grid based conventional energy.

- Several hybrids of the above routes have emerged in specific markets, depending on the **regulations**, **market opportunities** and **role of intermediaries.**

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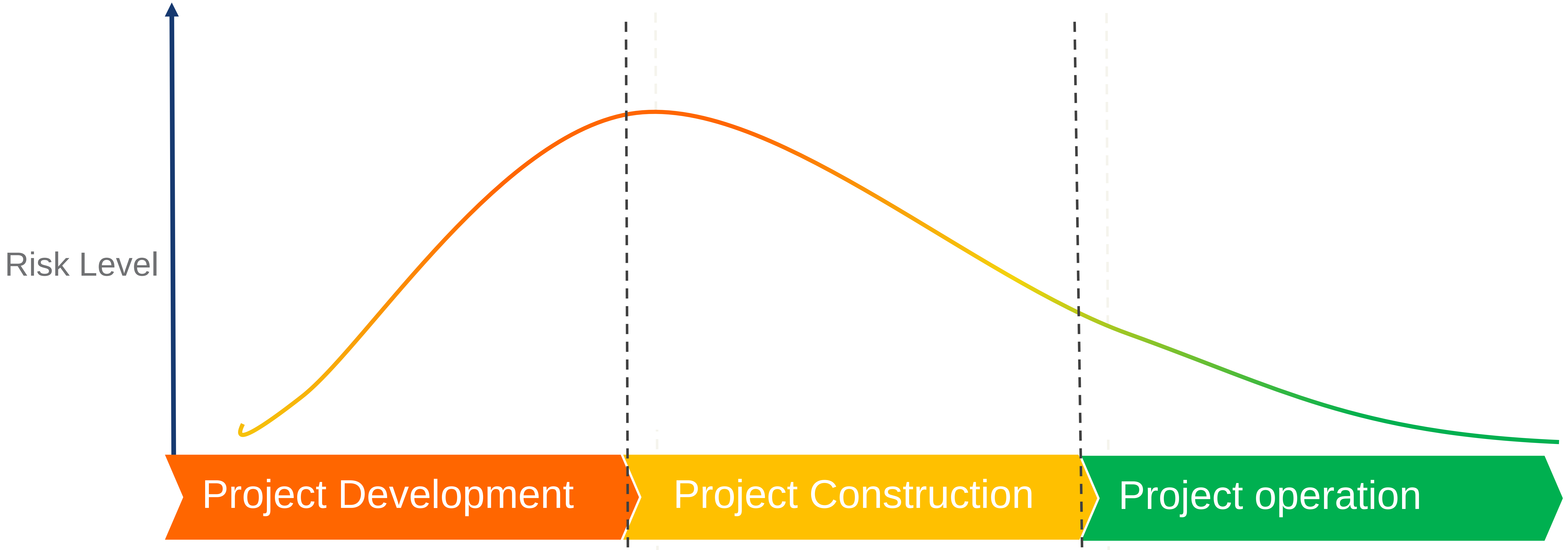
Grid-Tied Solar Power Plant Concerns

Concerns in Utility Driven and Customer Driven Solar Project Development

Risk Profile of Renewable Energy Projects



	Project Development	Project Construction	Project operation
Technical	Energy resource assessment, site location, design, technology	Actual site conditions, Suitability of the Equipment to local conditions (Logistics)	Reliability of Equipment, suitability to local conditions (corrosion, cyclones…), Local O&M competencies
Commercial	Grid connection, offtake agreement	EPC track record, Project management	Interest rates, labour costs
Regulatory	Permitting, land acquisition	Regulatory change, interconnection	Regulatory change

Two Significant Classes of Concern :

1. Technical Concerns in Customer Driven Solar Project Development

Concerns with Rooftop PV Power quality:

- DISCOMs are apprehensive about the quality of the power being injected into their distribution grids. This is mainly to do with flicker, harmonics and DC injection.
- Breach of voltage regulations with tail-end generation feed

Safety:

- Grid-integration challenge with likelihood of Reversal of power flows across the LT network.
- Utilities are rightly concerned about the safety of their personnel, especially while working around the possibility of the formation of an unintentional island from the operation of the distributed solar PV systems

Low voltage distribution grid:

- They are also concerned about the impact on the LV distribution grid (voltage levels, power factor, higher wear and tear of equipment, etc.) from high penetration of a large number of distributed solar generators.
- Erratic behavior of LV protection systems

Two Significant Classes of Concern :

2. Commercial Concerns in Customer Driven Solar Project Development

Commercial: Utility likely to have certain valid long-term concerns :

- Loss of consumers / reduction in revenue in **net-metering / captive operation**
- Regulators don’t often factor in / compensate for the cost of grid support provided to distributed generators
- **Transaction Costs:** Another logistical worry for utilities is the significantly higher transaction effort in terms of metering, inspection and certifications.

Effects of High Penetration Level of PV Generation

Observations from Field Data

IMPACTS OF CONNECTING PV SYSTEM TO THE GRID

if the PV penetration is really high Photovoltaic systems can subject the grid to several negative impacts. They are

i) **Reverse power** flow,

ii) **Overvoltage** along Distribution feeders,

iii) Voltage control difficulty,

iv) **Phase unbalance**,

v) Power Quality problems,

vi) Increased **Reactive power** and

vii) **Islanding** detection difficulty.

3 Major Impacts of High PV Penetration to Grid in rooftop plants

A. ***Power quality problems/Harmonics***

The inverter forms the core of the grid connected PV system and is responsible for the quality of power injected into the grid. Inverters also introduce harmonics into the system in the presence of non-linear loads, during DC to AC conversion. Harmonic currents introduce voltage drop and result in distortion of supply voltage. Harmonics can also cause resonance in the supply system, resulting in malfunction, reduction in lifetime or permanent damage of electrical equipment.

B. ***Islanding Detection***

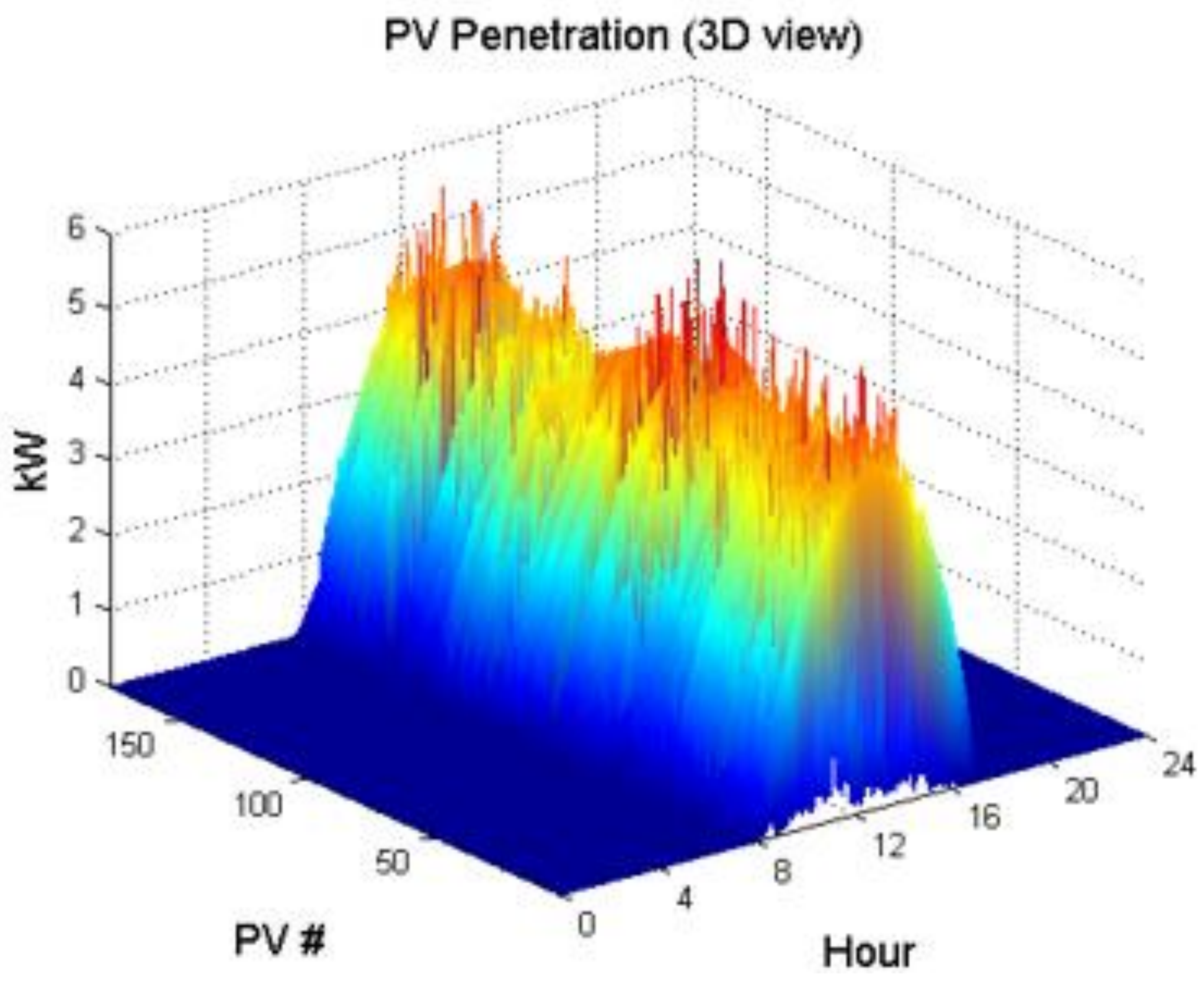
The condition when the solar system continues to supply to the load even though grid power from the utility is not present is called islanding. Islanding can be dangerous to utility workers, who may not realize that a circuit is still energized while working on repairs or maintenance. Hence, the solar inverter must detect islanding and disconnect the PV system when the grid is down. This function of the PV system is known as **'anti-islanding';** which is strictly supposed to be incorporate by Inverter manufacturers.

C. ***Increased Reactive Power***

Photovoltaic inverters **usually operate at unity power factor.** The owners of small residential PV systems in an incentive based program are levied based on their **kilowatt-hour yield** and not on their **kilovolt-ampere hour yield**. Hence they prefer to operate PV inverters at unity power factor, maximizing the active power generation, and accordingly their returns. As a result the reactive power demand met by the PV system is minimal. Hence, the grid is responsible for supplying majority of reactive power, and it makes the distribution transformer operate **at a low power factor**.

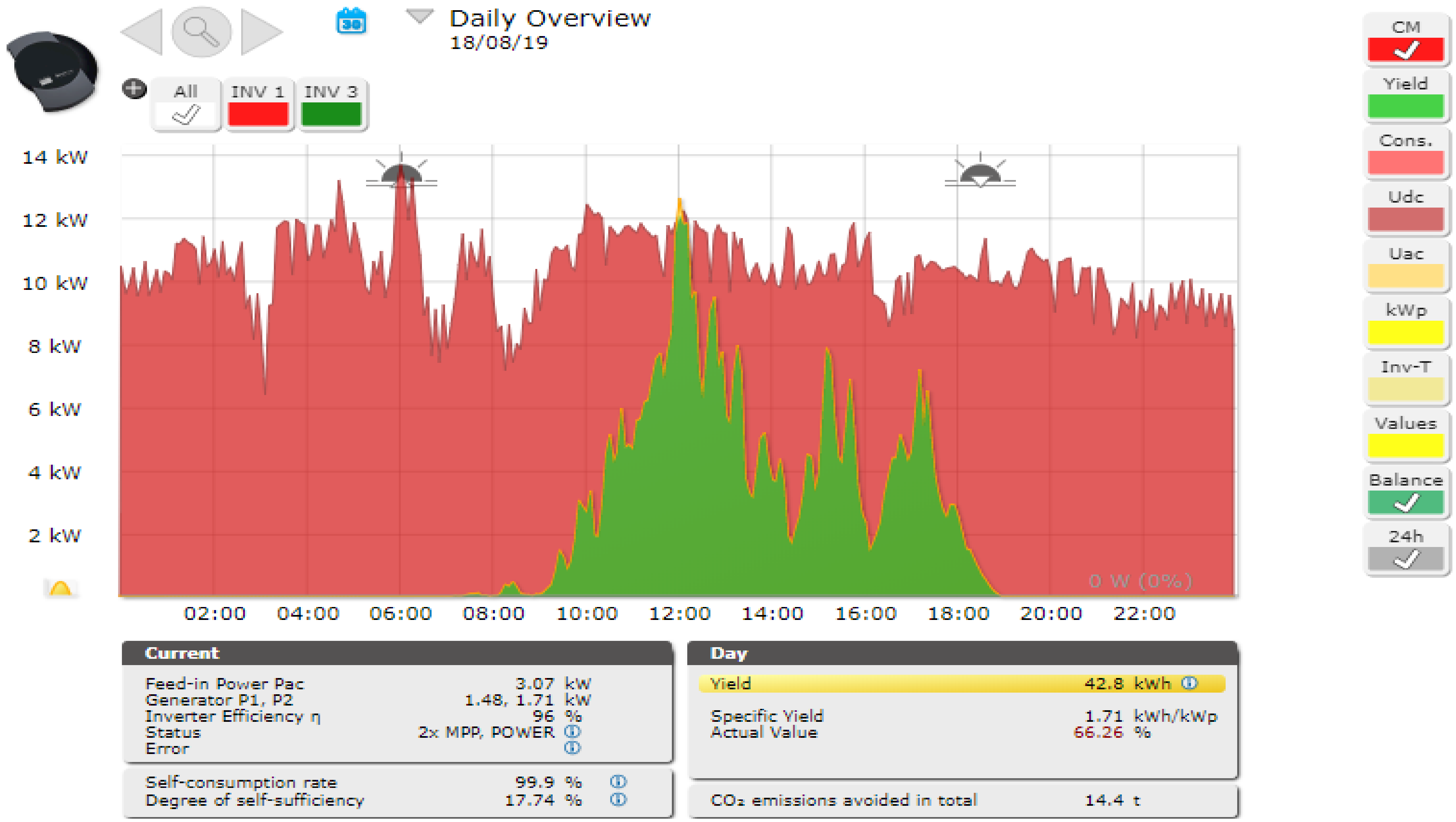
Case Study of PVs on Power Factor, Voltage rise and Voltage Unbalance

- PV generation profiles of 178 homes in USA.
- Analysis is based on recorded (i.e., real) residential power consumption and PV generation data by Solar-Log USA.
- 735 homes, including 178 grid-tied PV systems



DATA

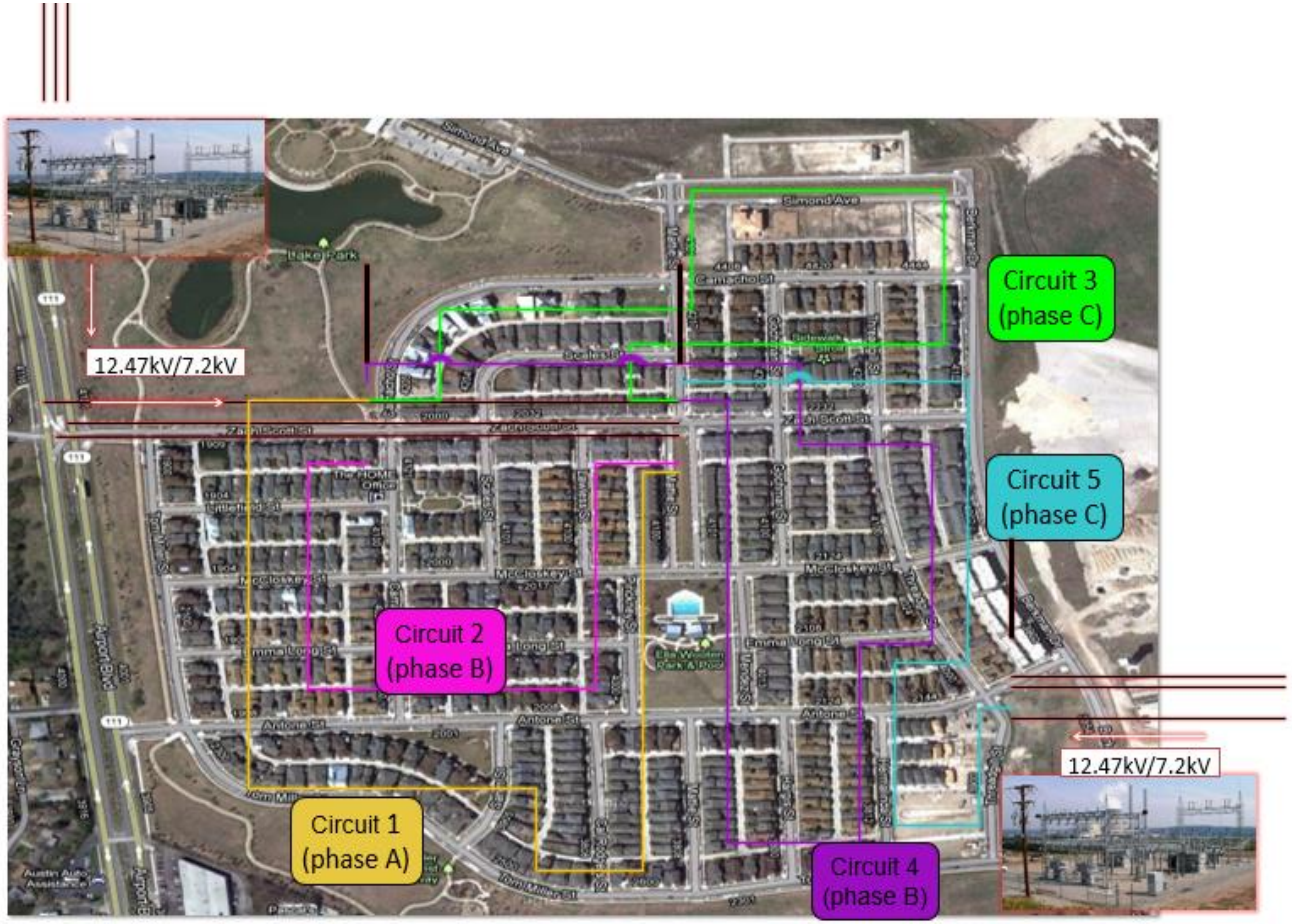
- Monitoring equipment capture power consumption and PV power generation at 5-minute intervals
- Equipment is located between utility meter and home’s service panel



Household real power usage and generation for a single home

Distribution System Model

- Two 12.47 kV three-phase feeders emanating from two different substations
- 94 single-phase pad-mount distribution transformers
- Ratings of 25, 50, 75, 100, or 167 kVA
- 7.2 kV (line-to-ground) primary and a 240 V split-phase secondary



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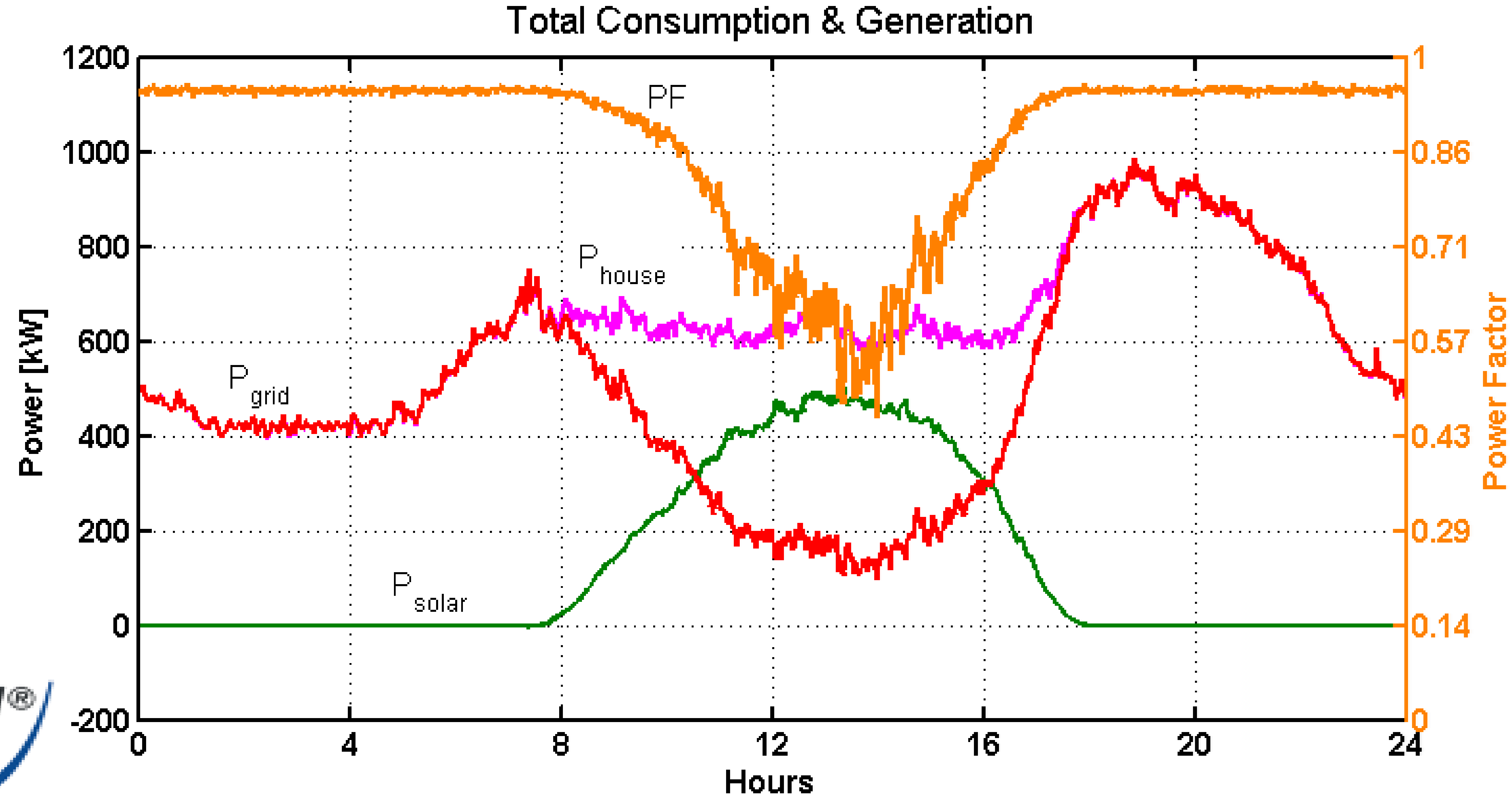
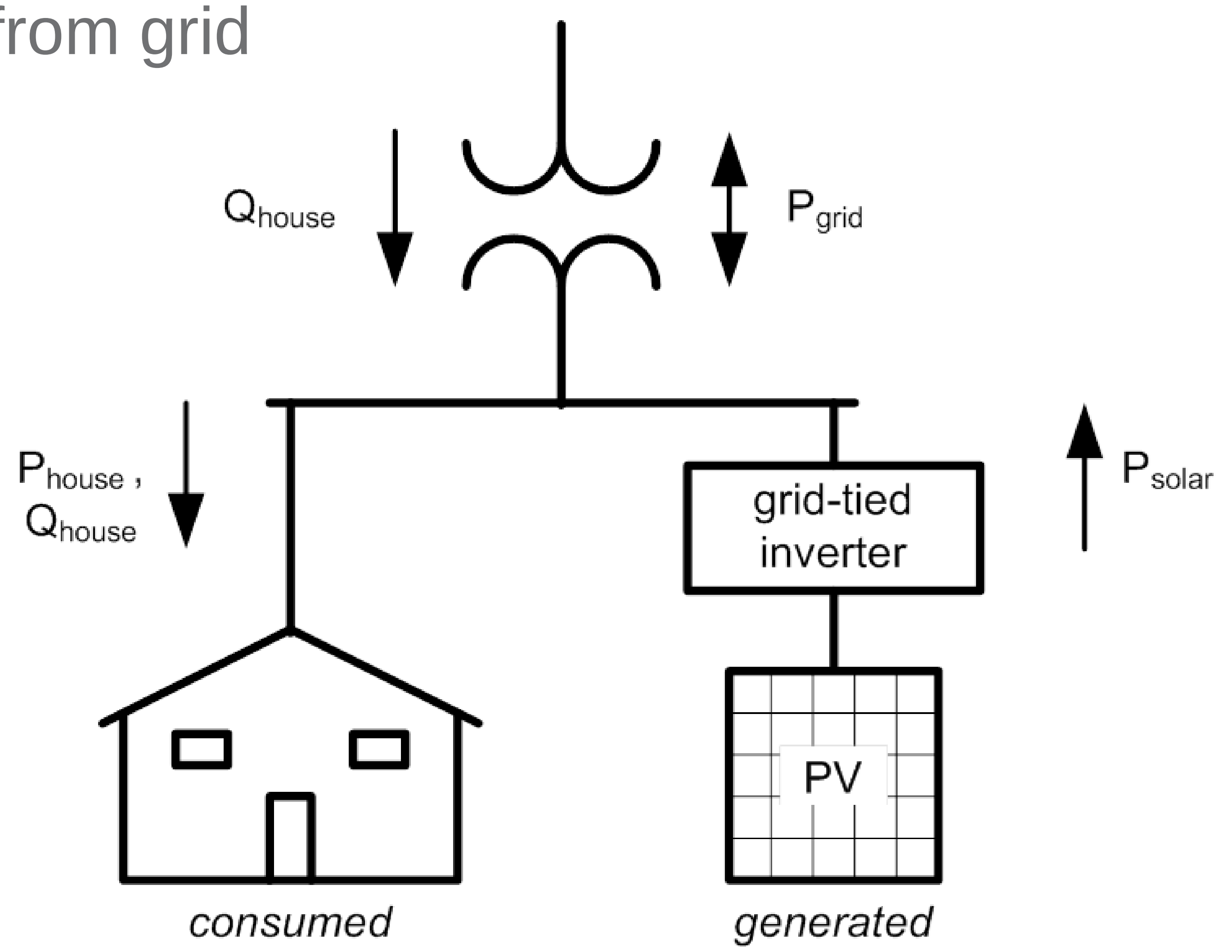
Power Factor

- Residential grid-tied PV inverters normally operate at unity power factor, producing only real power
- A large portion of demanded real power is provided from PVs; all of reactive power provided from grid
- Utility experiences low power factors with high penetration of PVs
- Power factor attains a value as low as 0.465
- Power factor remains below 0.9 between 9:00 and 16:00





Aggregate power flow behind residential distribution transformer in presence of PV generation

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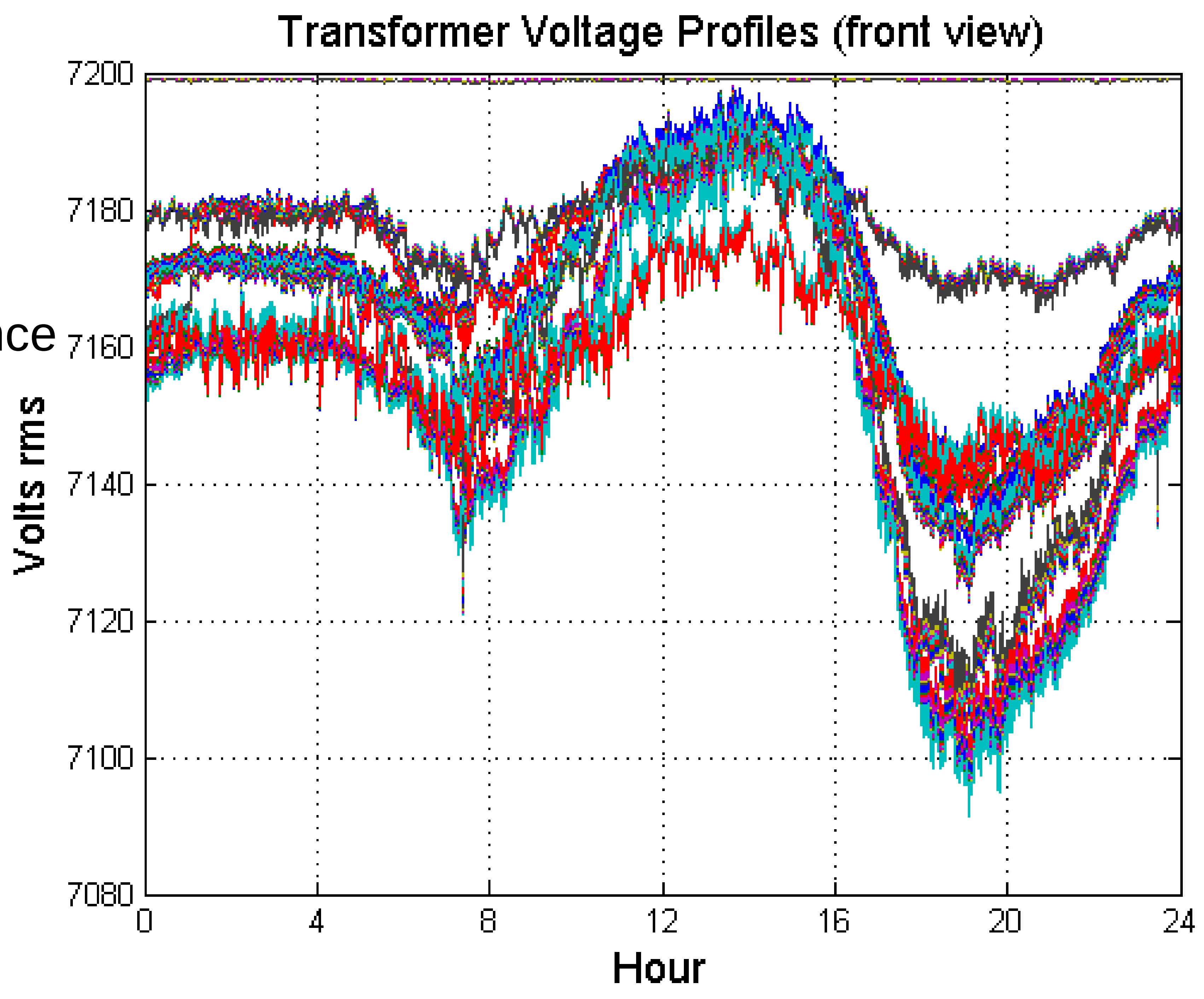
Voltage Rise

- Voltage rise is expected when power is injected into distribution system from load side
  - Voltage drops along power lines are reduced
  - PVs may adversely affect voltage levels of other customers

- High voltage levels are undesirable
  - May reduce equipment lifetime
  - May increase power consumption without providing noticeable improvement in performance

- Voltage levels are required to be within ±5% of nominal voltage

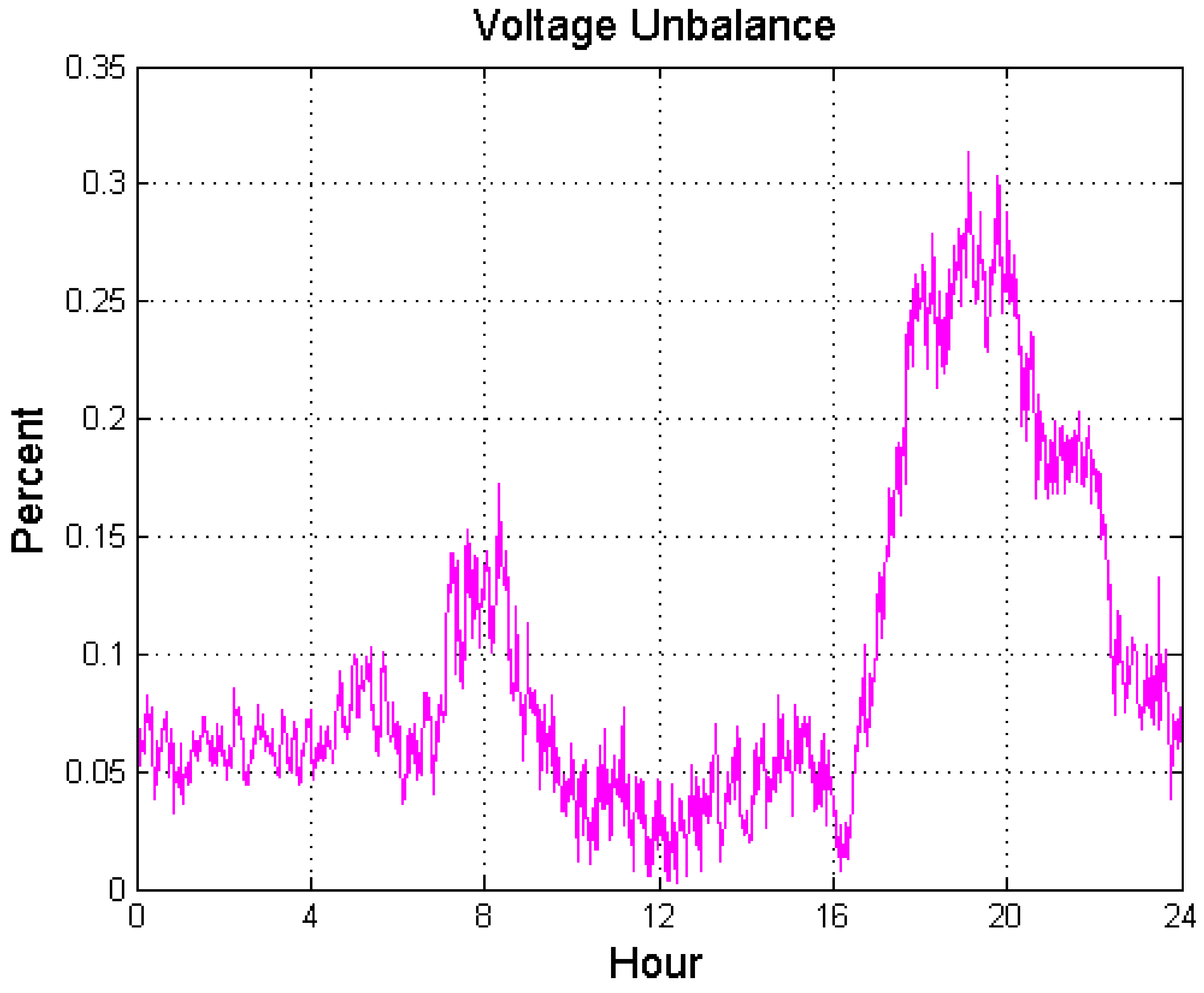


Voltage profiles for all 94 transformers (primary sides).

Voltage levels in Mueller are within ±5% of nominal (7.2 kV line-to-ground) even when PV systems are at their peak power generation time.

Voltage Unbalance

- Voltage unbalance is a consequence of line voltages not being equal
- Caused by uneven distribution of single-phase loads on a three-phase system
- PV sources also contribute to unbalance as they generate power on only one phase (and, contrary to load’s phase-assignment, PV are integrated to the grid without control to which phase they are connected)
- Unbalance of 2.5% to 3% or greater is unacceptably high



Case Study Conclusion

- Although PVs help reduce overall real power supplied by utility, the power factor decreases to significantly low levels
- Effects of conventional grid-tied PV sources could be severe if are extended to a widespread deployment in an entire city or country
- Several distribution transformers in the city were noted to experience a reversal in the flow of real power during times when PV generation was abundant
- Even though voltage rise and voltage unbalance were expected in city, these variables were maintained within appropriate limits

  These issues may be more noticeable with “weak” power grid feeders and laterals
- Stability problems may be observed if an area with significant PV penetration of grid-tied inverters is isolated to form a microgrid (supported by other power generation source, such a diesel generators)
  - These issues could be avoided if inverters that allow for reactive power control are used instead

Challenges in State-level policies:.

Key Challenges

–Grid Connectivity Issues

–Different Connectivity norms–Some States like UP/Tamil Nadu have come out of net metring policy and most of the stats they are having net metering capping only upto 1 MW (e.g. Haryana)

– Uniform technical standards across all states are required

– Penetration standards are required via technology adoption on a long term basis

—Metering Standards and Net metering regulations

–Feed-in-Tariff for surplus power into the grid

–Commitment by DISCOMS to absorb surplus power

–“Rooftop Solar PV has huge potential and the government policies and regulations should be enabling to promote large scale deployment”

Solar-Log & iPLON Feed-IN Management Solutions

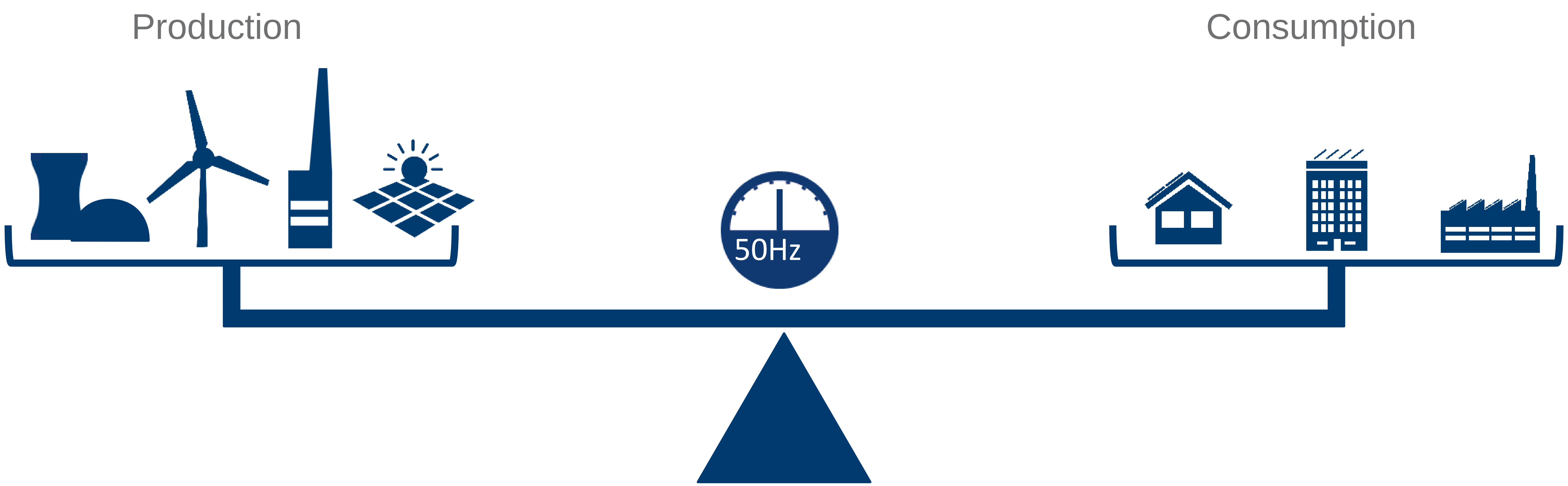
Possible Applications for Rooftop Plants

Grid Stability

Network operators are responsible for keeping the net balanced (voltage and frequencey)

Electricity network can not store energy

Production and consumption both have and are always to be balanced



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Control Techniques for Active & Reactive Power Control

Possible Applications

Active Power

Stand-alone functions

- fixed reduction in %
  with or without calculation of self-consumption
- fixed reduction in watt
  with or without calculation of self-consumption
- reduction to percentage of consumption

Reactive Power

Stand-alone functions

- Fixed value cos (Phi)
- Fixed reactive power in Var
- Characteristic curve P/Pn
- Characteristic curve Q(U) (only with Utility Meter)

Solution: Feed-In-Management

Problem:

1. The more decentralized and volatile production units are being setup in the grid, the more complex it becomes for the network operator

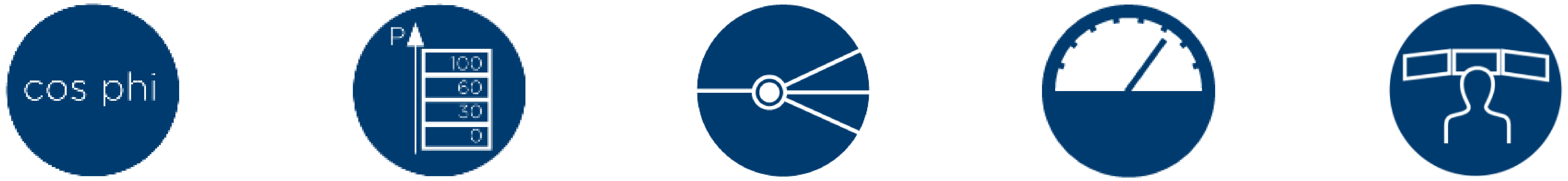
2. The capacity of the grid becomes more and more limited due to increase of new installations in individual segments

Solution:

- Peak loads capping: fixed reduction of feed-in power to x% or x Watt (70% regulation, zero export, …)
- Power reduction or switching off individual production plants (since EEG 2012)
- Provision of Reactive Power for adaptation of voltage

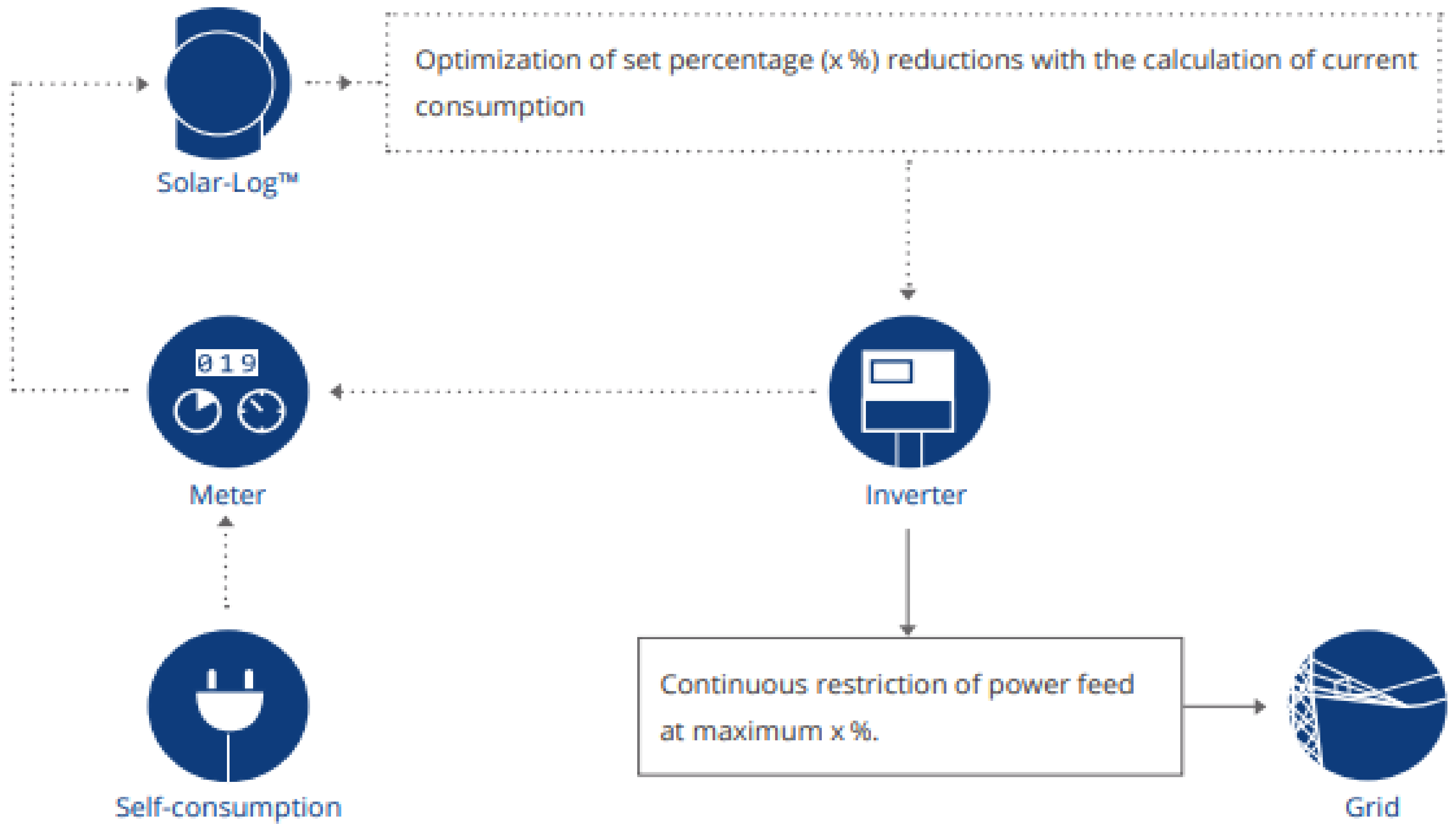
Solar-Log™ PM+ Packages for indivdual grid areas

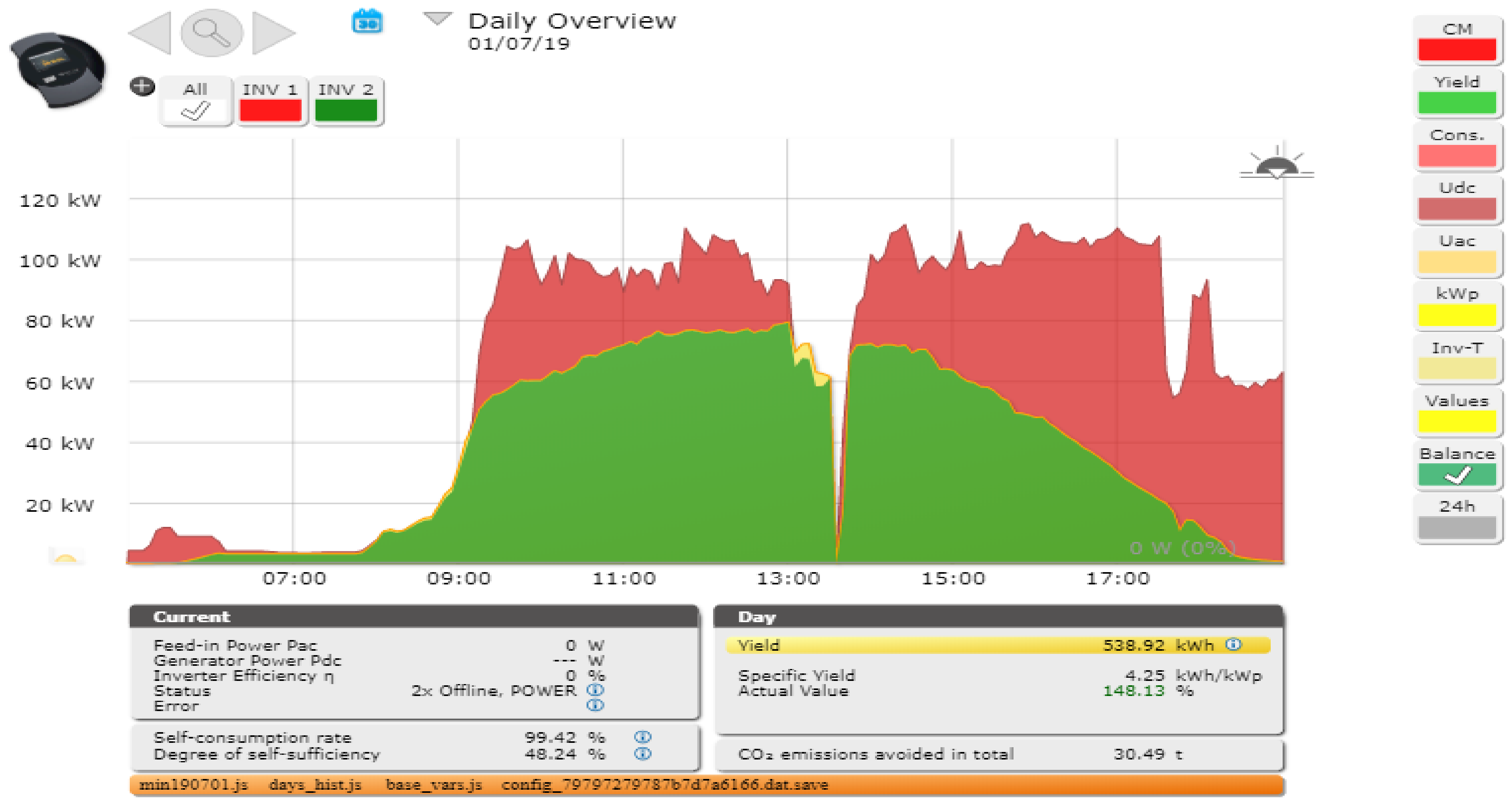
Solar-Log™ Modbus TCP PM Interface as flexible solution



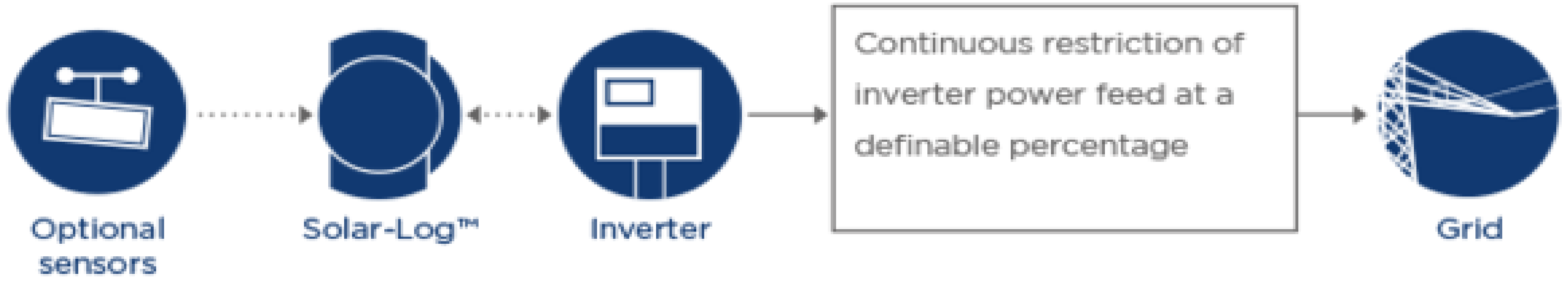
Active Power Controlled Evacuation

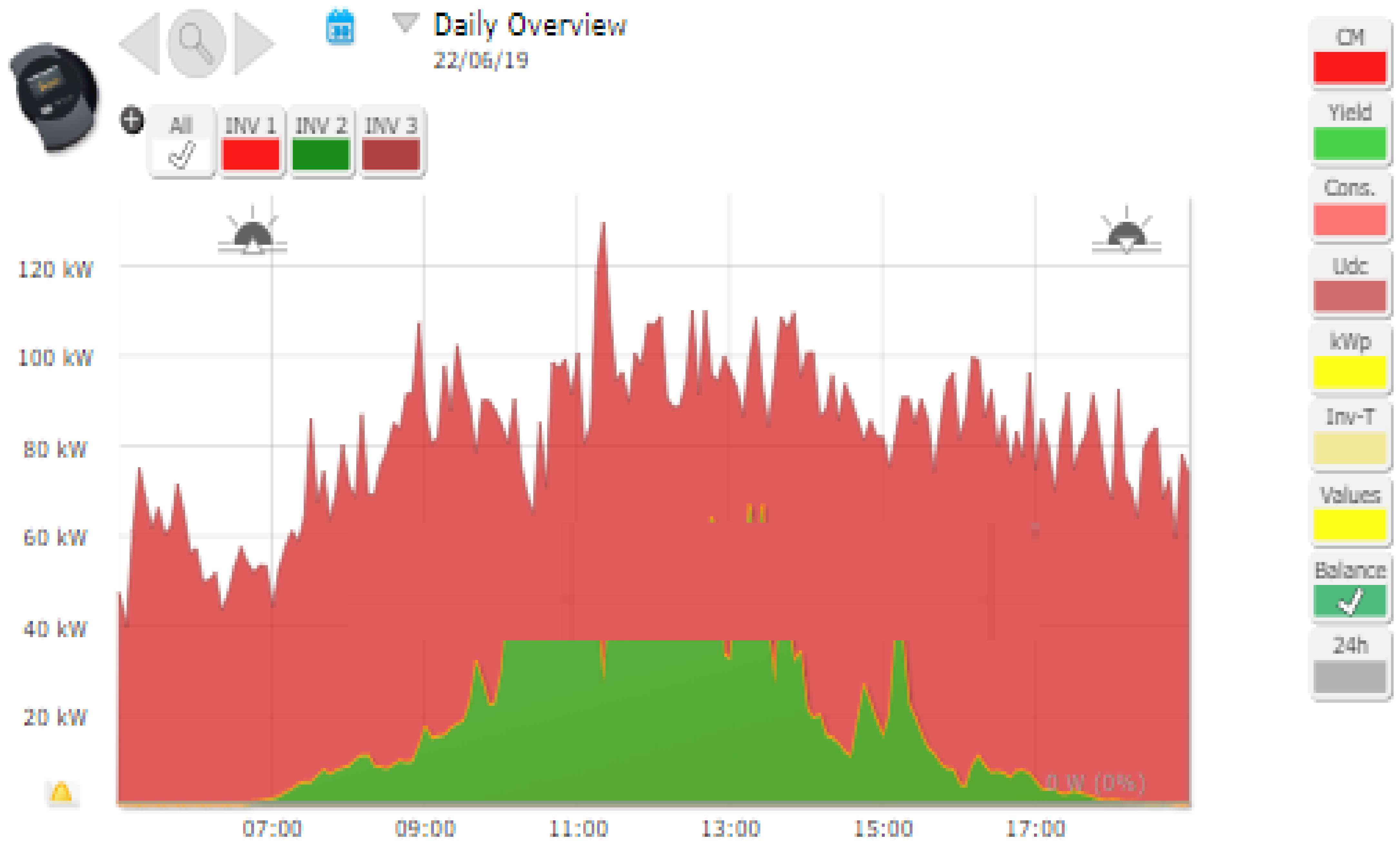
Adjustable reduction with the calculation of Self-consumption





Fixed Reduction





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Live Demo for Active Power Control Evacuation

25 kWp Active Power Control (0% Feed-IN Management)

Current

Last Transfer
Time: 22/08/19 02:35:52
Feed-in Power
PAC: 153 W
PDC: 199 W

Plant Status

Status
1 x Fault
2 x Mpp
Error
1x Under Load

Plant Info

Serialnumber:	Plant Power:	Orientation:	Pitch:	Location:
1351209915	DC 25 kWp / AC 10 kVA	*Not Specified*	*Not Specified*	IN - 201301 Noida

Inverter

Qty.	Manufacturer	Type
1	Delta	RPI M10A
1	Delta	RPI M15A

Remote Configuration

Plant Name	AVAADA-Noida (25 kWp)
Type / Serial Number	Solar-Log 1900 PM+ / 1351209915
Firmware	4.2.4 Build 113 / 04.06.2019
Connection Method	DSL, HTTP (10 Minutes), Solar-Log WEB Enerest™ (integrated)

› Network › Internet › Devices › Plant › Notifications › Smart Energy › Feed-In Management › System

Configuration / Feed-In Management / Active power

PLANT PARAMETERS | ACTIVE POWER | REACTIVE POWER | LINKING

Power reduction

Type	Adjustable reduction with the calculator
Percentage for the adjustable reduction	0
LCD-Display	Control value power (% AC)

Interface assignments to control

Delta Standard (RS485-A) — Activated

Dynamic control for different module orientations — Deactivated

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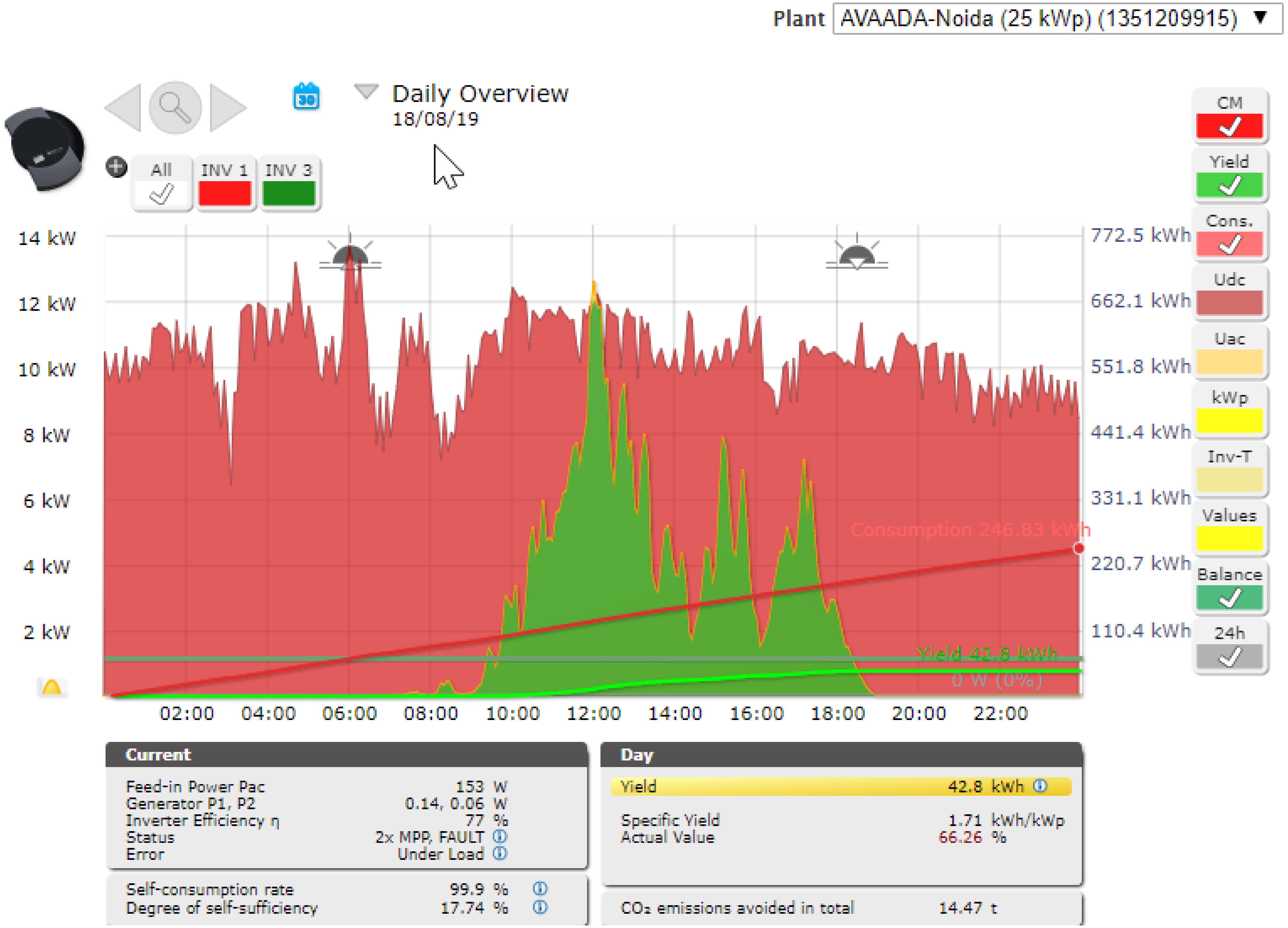
Live Demo for Active Power Control Evacuation

25 kWp Active Power Control (0% Feed-IN Management)



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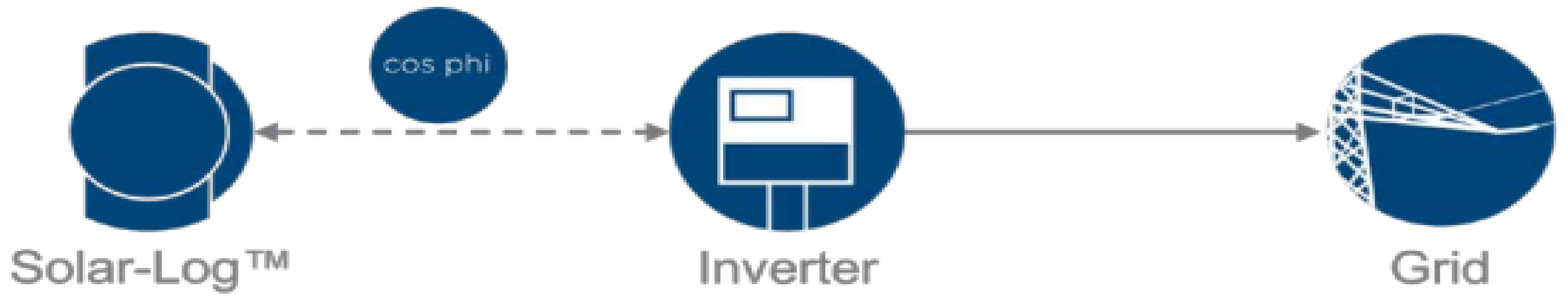
Reactive Power Controlled Evacuation

Case 1: Fixed cos(phi) & Fixed reactive power

If a photovoltaic plant has to feed in a fixed value cos phi shift factor or fixed reactive power in Var, the Solar-Log™ can adjust the connected inverters accordingly.



Reactive power control (fixed value cos Phi or fixed reactive power in Var)

fixed shift factor cos(Phi)

from (time)	Cos(Phi)	inductive/underexcited
00:00	0,97	☑

Configuration of a fixed shift factor (valid for 24 hours)

fixed reactive power in Var

from (time)	Reactive power (Var)	inductive/underexcited
00:00	300	☑
10:00	600	☑
14:00	300	☑

Figure 10: Configuration of the fixed reactive power in Var

Reactive Power Controlled Evacuation

Case 2. Characteristic curve P/Pn

Configuration / Feed-In Management / Reactive power

PLANT PARAMETERS | ACTIVE POWER | REACTIVE POWER | LINKING | PROFILE

Reactive power control

Type: Variable cos (Phi) shift factor over character

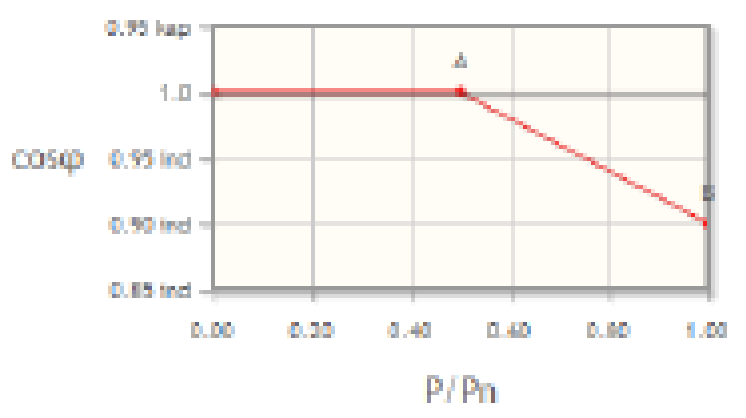
Characteristic curve type: 2 point characteristic curve

Interface assignments to control

SMA Data1 (RS485-A) — Deactivated

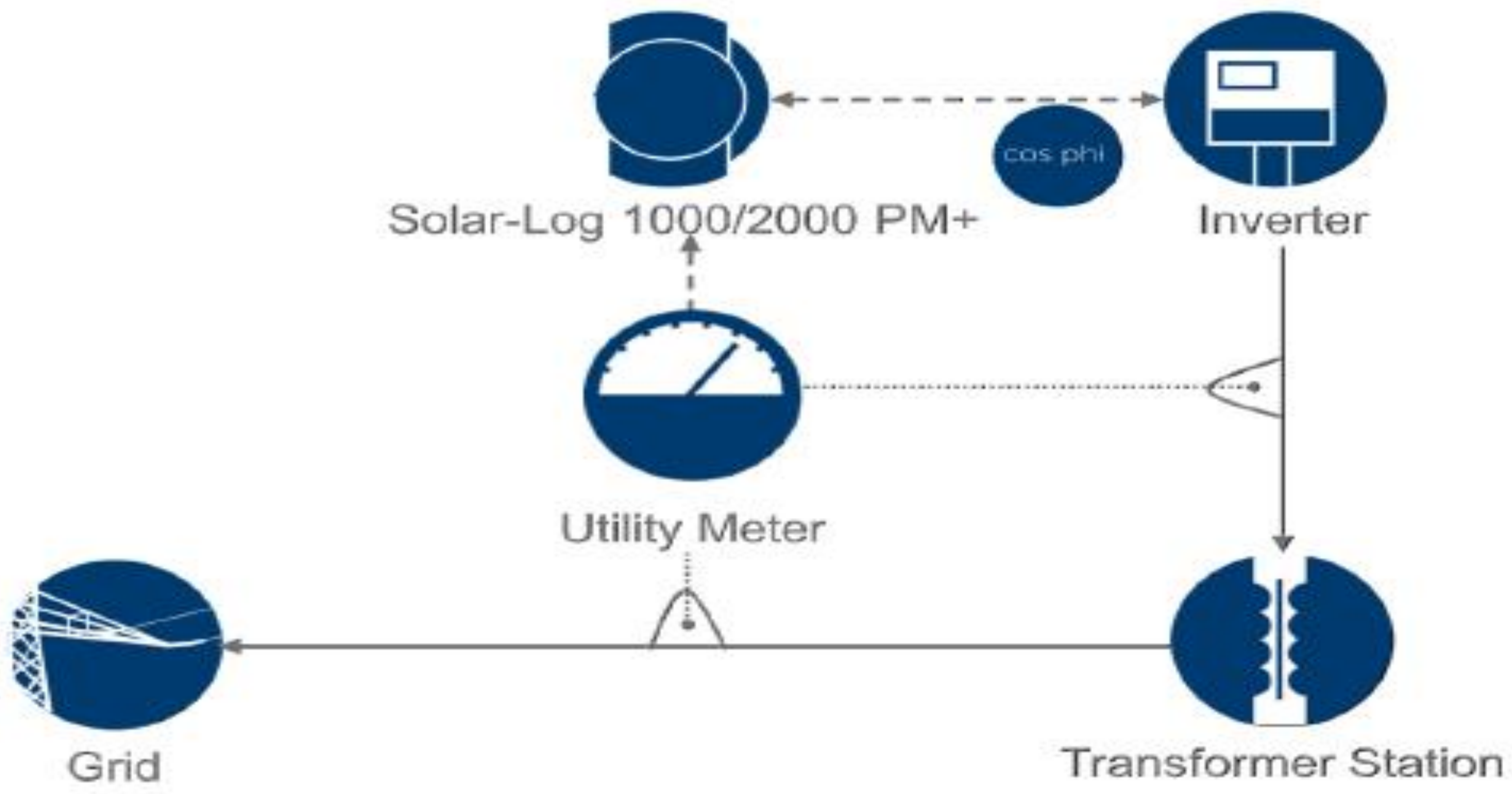
SMA Data1 (RS485/422-B) — Deactivated

Variable cos (Phi) shift factor over characteristic curve P/Pn

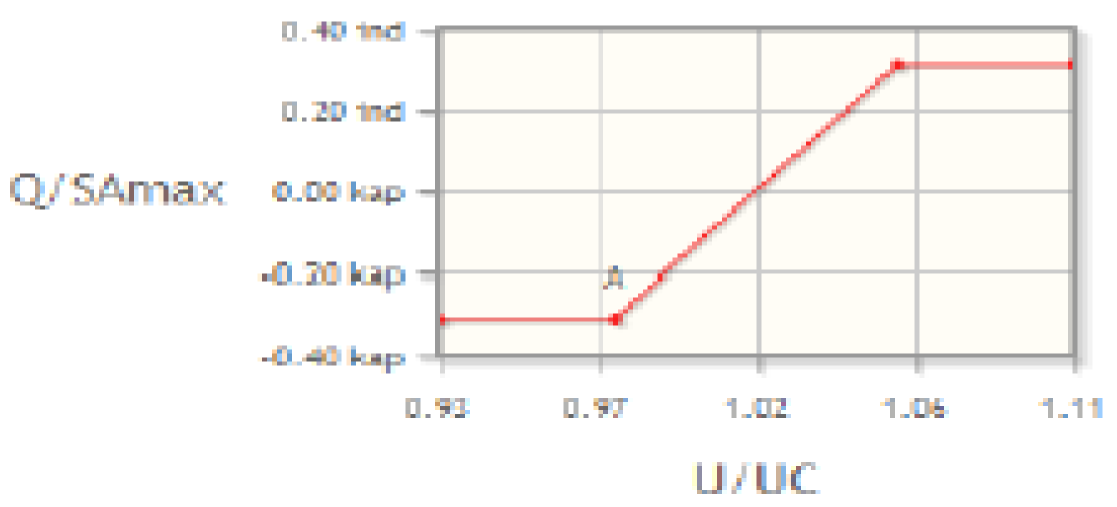


Point	P/Pn	Cos(Phi)	Inductive/under-excited
A	0.50	1.00	☑
B	1.00	0.90	☑

Case 3. Characteristic curve Q(U)



Variable reactive power via characteristic curve Q(U)



Point	U/Uc	Q/SAmax	Inductive/under-excited
A	0.9800	0.31	☐
B	1.0600	0.31	☑

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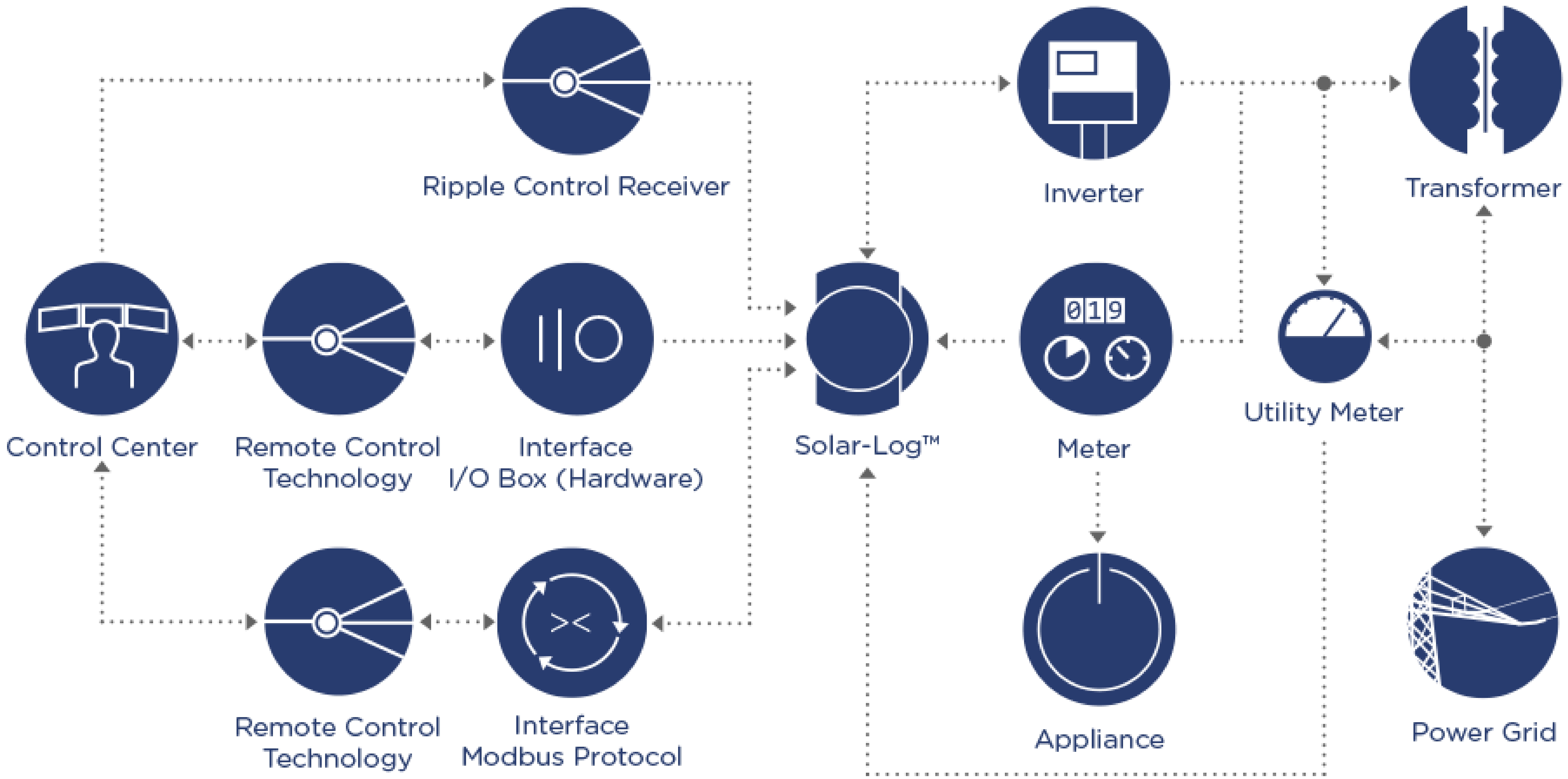
Plant Control Options

Current Trend in Germany/ Europe



Application Example

Germany, PV plant size 7 MWp, remote controlled

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Customised Daily Report

Controlled Evacuation- Self Consumtion

Consumption of self-produced power

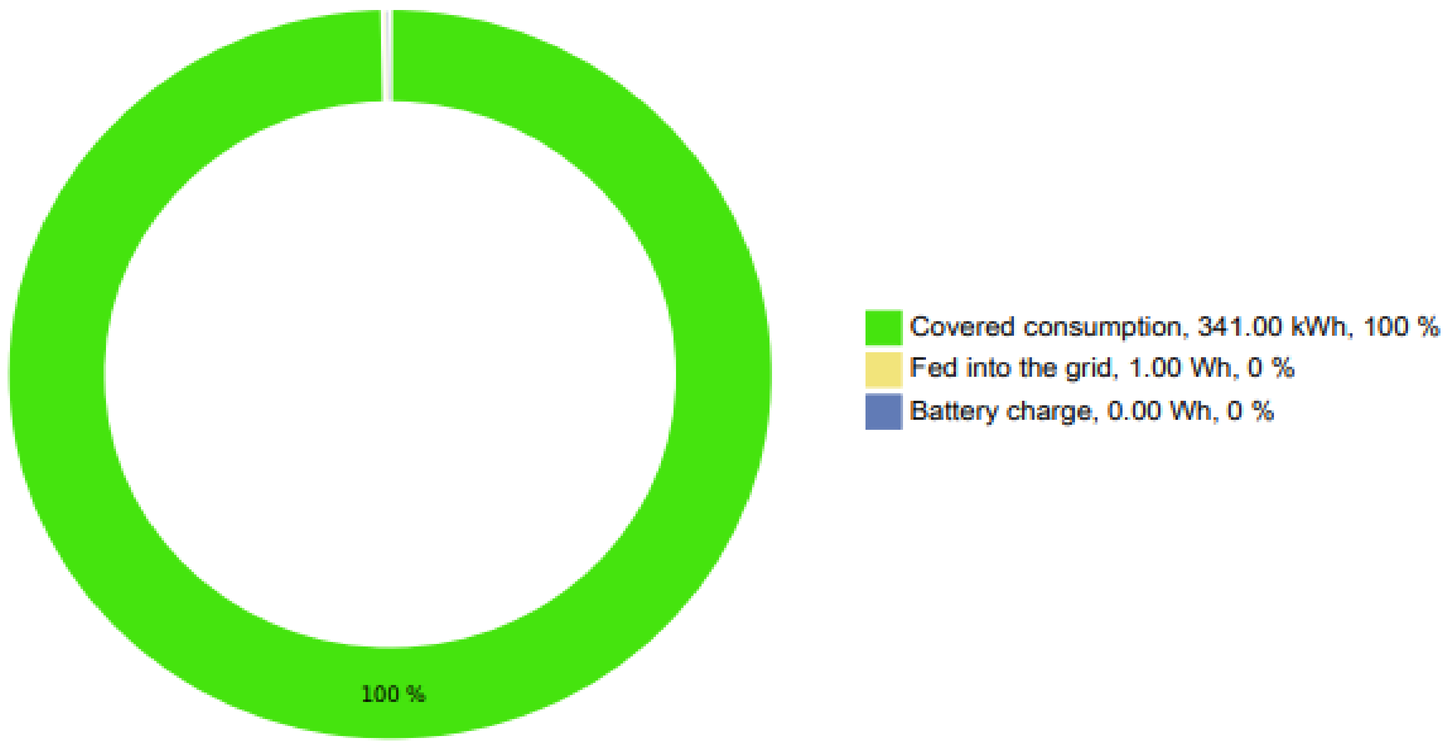
Self consumption

Time Frame: 26/06/2019 - 27/06/2019

Date	Total Yield	Total Consumption	Covered consumption	Uncovered consumption	Self-consumption rate
26/06/2019	183.31 kWh	258.22 kWh	183.31 kWh	74.89 kWh	100.00%
27/06/2019	157.70 kWh	174.85 kWh	157.70 kWh	17.12 kWh	100.00%
	341.00 kWh	433.07 kWh	341.00 kWh	92.01 kWh	

The self-consumption rate is calculated with unrounded values.
In the selected period, there was a total self-consumption rate of 100.00%.
Production: Feed-in + Battery Charge Level + Covered consumption from the production
Total consumption: Covered consumption from the production + Covered consumption from the battery + Uncovered consumption

Yield



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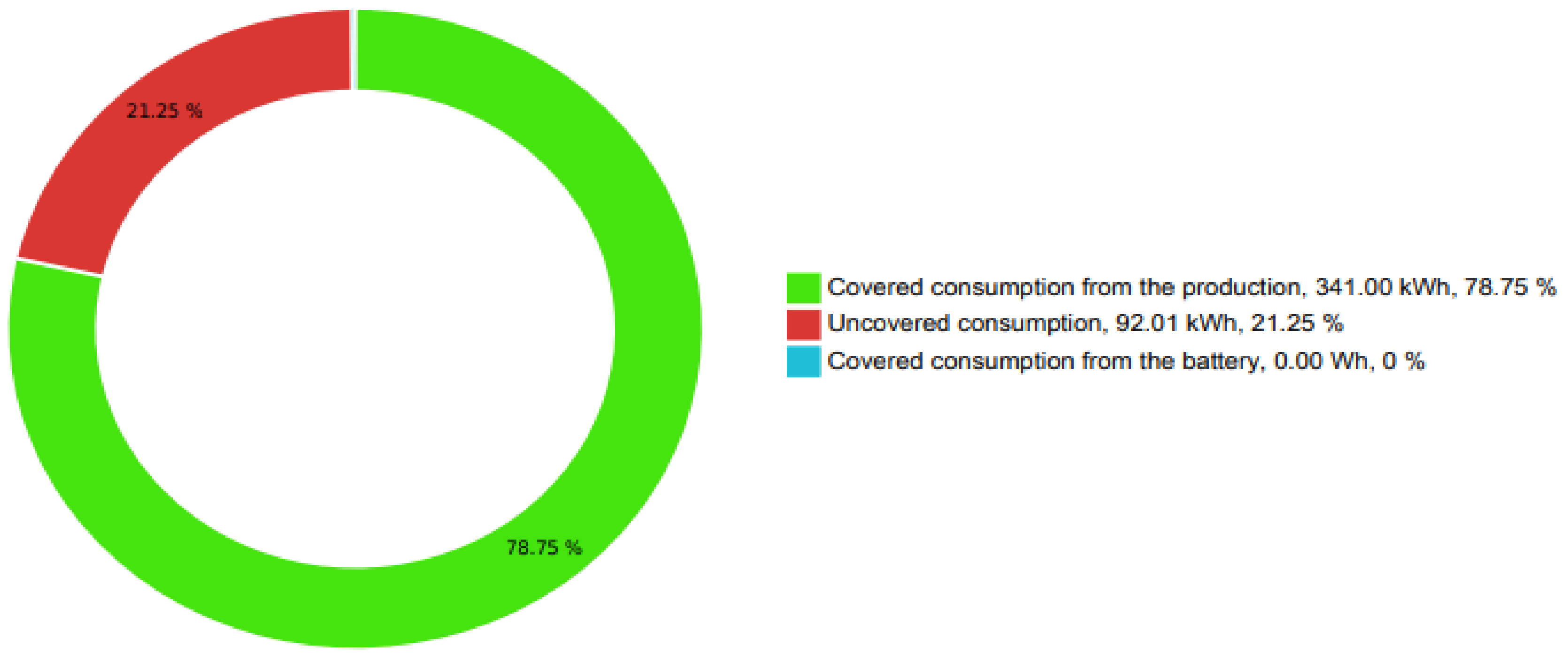
Consumption balance



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Thank You !!

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