System Monitoring & Management Resolutions & Tradeoffs

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Today's Outline

- SunSpec Alliance background
- PV monitoring & management system functions
- System design choices & challenges
- Emerging applications

About the SunSpec Alliance

- A federation of 60+ global competitors, collaborators & trading partners
- Establishing Open Information standards for PV
- Expanding affordability of PV around the globe

SunSpec Alliance Members

Google

ADVANCED ENERGY — Better Technology. Better Results.
ARC Advisory Group
ampt — energy realized
ARRAY TECHNOLOGIES
CAMPBELL SCIENTIFIC — WHEN MEASUREMENTS MATTER
CARLO GAVAZZI
CG Power Solutions
Continental Control Systems LLC
Danfoss
DECK Monitoring
Digi
dragonfly SOLAR
ECOGUARD
ELTEK always on
Engenuity systems
[e] enphase ENERGY
ESA — ELECTRICITY STORAGE ASSOCIATION
Fronius
Gridward
Horizon Energy Group
inAccess
Ingeteam
Itron
Locus ENERGY
Loggerware
McCalmont Engineering
Mercatus
MERSEN
MEASURLOGIC
MOXA
OutBack POWER — member of The alpha Group™
PHOENIX CONTACT
PHOTON
powerdash — Energy intelligence. Anywhere.
PSOMAS FMG — ENERGY ENGINEERED
power-one — Changing the Shape of Power
REFU Electronics
SaveEnergy123
Schneider Electric *
SIEMENS
SILVERSPRING NETWORKS
SMA
SOLARBRIDGE TECHNOLOGIES
solaredge — architects of energy
SOLAR FRONTIER
SolarMax — SWISS QUALITY
solarnexus — Accelerating Your Solar Business
SOLECTRIA RENEWABLES
SunEdison
SUNPOWER
10
ten K SOLAR
TMEIC
TÜVRheinland — Precisely Right.
UPVI ALLIANCE
VERIS INDUSTRIES — AT YOUR SERVICE
ZigBee Alliance

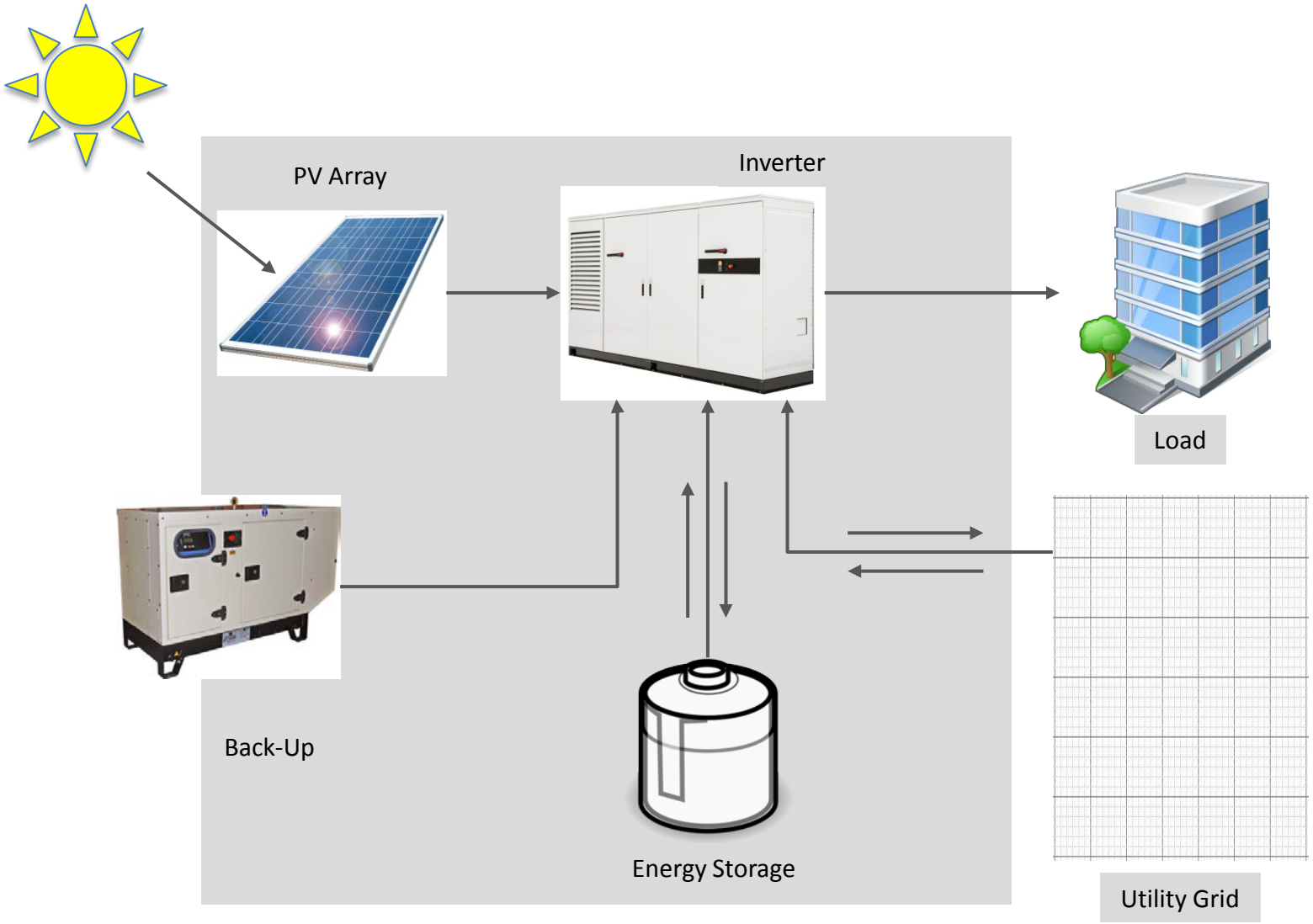
Standardization Partners

- NIST/SGIP National Smart Grid Roadmap
- IEEE 1547/P2030 Interconnection guidelines and interoperability with the electric power system
- ASHRAE Facility to Smart Grid Information Model (FSGIM)
- EPRI Advanced Functrions for Disstributed Energy Resources
- IEC 61850 Communication networks and systems for substation automation, logical nodes, protocol mappings
- ZigBee Smart Energy 2.0 specification
- UPVI Specification for module electronics
- SolarTech Solar 3.0™ Standards for permitting & interconnection

PV Monitoring & Management Functions

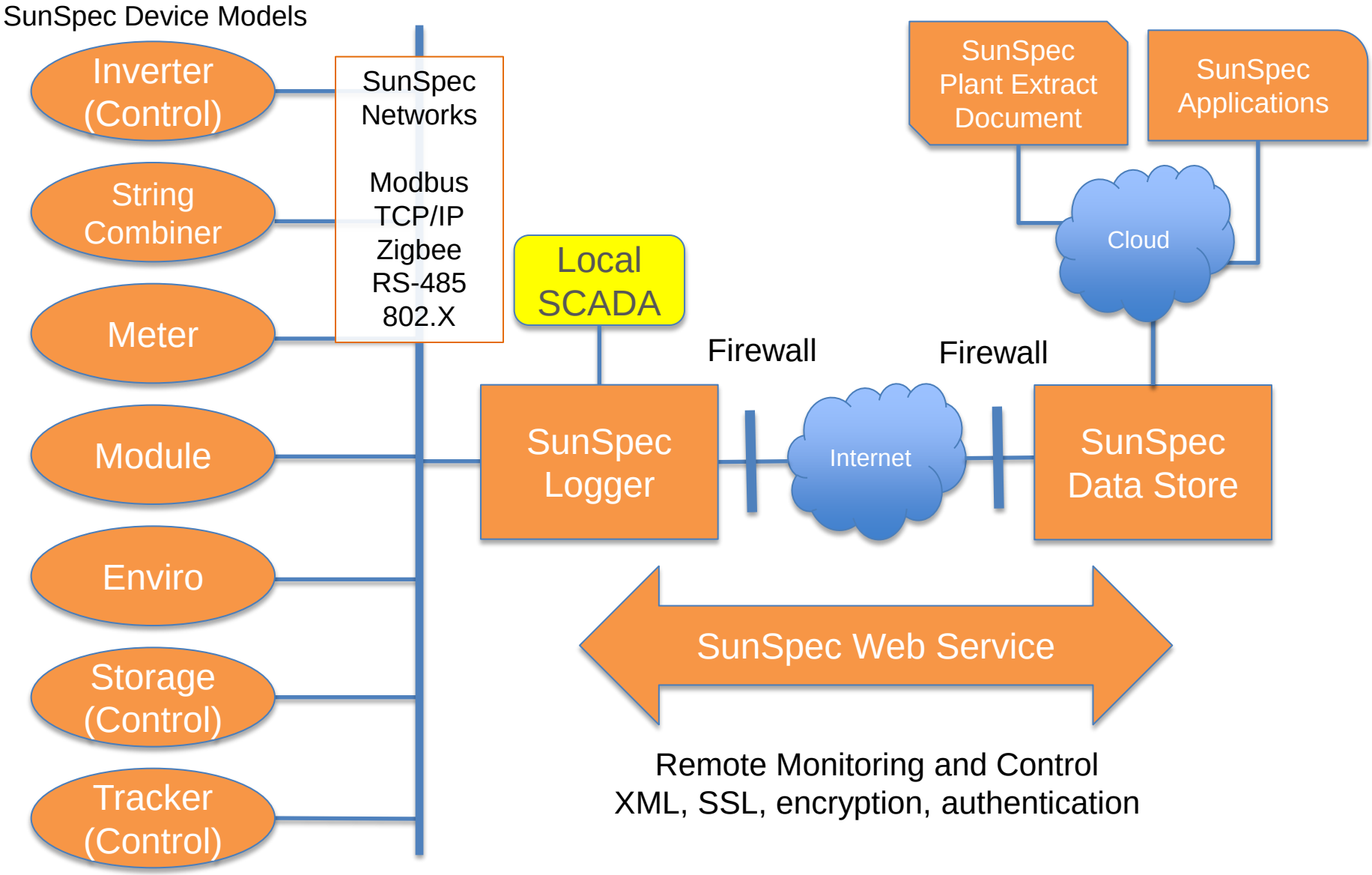
- PV monitoring
  - Optimize plant/fleet operation
  - Detect plant/fleet breakdown
  - Support financial reporting
  - Support grid operations forecasting
- PV management
  - Coordinate plant operations with needs of grid
  - Deliver ancillary electrical services to support grid

Points of Plant Measurement & Control



Source: IEC 61724

Points of Fleet Measurement & Control



Challenges & Tradeoffs

- Getting the data
  - Fleet challenges
  - Network & protocol differences
  - Network quality
- Interpreting the data
  - Approximation/interpretation vs. standardization
  - Multivendor vs. single vendor
  - Sensor quality, location, density
  - Calibration
- Turning data into information
  - Which KPI's?
  - Which metrics?
  - Which software tools?

System Design Choices

- Sensors
  - Coverage
  - Quality
- Networks
  - Field bus
  - Wide area network
- Data management
  - Sampling rates
  - Data retention
  - Security
- Applications
  - Range
  - Scope

Sensors – Current Practice

- Sensor coverage
  - Most elements covered in bigger plants
  - Few elements covered in smaller plants
  - Considerations
    - Monitoring system maintenance
    - Plant repair protocols
- Sensor quality
  - High quality for AC side
  - Minimal quality (typical) for DC side
  - Considerations
    - Instrument maintenance & calibration
    - Upstream requirements (utility, grid operator, bank)

Networks – Current Practice

- Field Bus
  - Hardwired for larger plants
    - Serial (Modbus)
    - Copper or Fiber (Ethernet)
  - Hardwired or wireless for smaller plants
    - Serial (Modbus)
    - ZigBee
    - WiFi
- Wide area network
  - O&M managed (dedicated) networks for larger plants
  - Customer managed (shared) networks for smaller plants
- Considerations
  - Robustness
  - Installation complexity
  - Trend toward cellular wireless

Data Management – Current Practice

- Sampling rates
  - Production & fault monitoring (all plant sizes)
    - 15-minute reporting, 1-minute sampling
  - Grid operations (large plants only)
    - 1-minute reporting, sub-second sampling
- Data retention
  - On-site: weeks or months
  - Off-site: plant lifetime
- Security
  - Physical security (all plant sizes)
  - Authentication (user name/password) for apps

Applications – Current Practice

- Application types
  - O&M
  - Yield management
  - Financial reporting
  - Public display
  - Grid operations
  - Technical analysis
- Limitations/considerations
  - Manned vs. Autonomous operation
  - Most apps tied to single-vendor monitoring system

Open Solar Performance and Reliability (oSPARC) Clearinghouse Case Study

Open Solar Performance and Reliability Clearinghouse – Project Objectives

- A SunSpec Alliance project commissioned by NREL to support bankability
- Establish construct for information exchange
  - Plant Owners
  - Banks
  - Service providers
- Define metrics for risk assessment
  - Critical Measurements & Ratings
  - Key Performance Indicators
  - Quality factors
- Build network/database of participating solar PV plants
  - Plants report once per day
  - Network geographically distributed across U.S.
  - Anonymized to protect consumers & vendors
- Provide access to database by financial industry
  - Assess plant performance and reliability over time
  - Build confidence in the asset class

Construct for Information Exchange

Capital at Favorable Rates

Quality PV Plants and Data

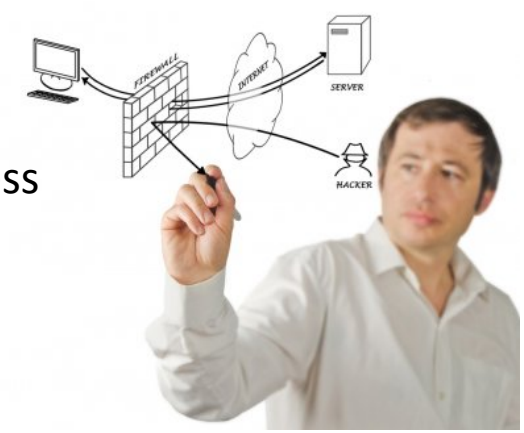
CAPITAL PROVIDER

BORROWER

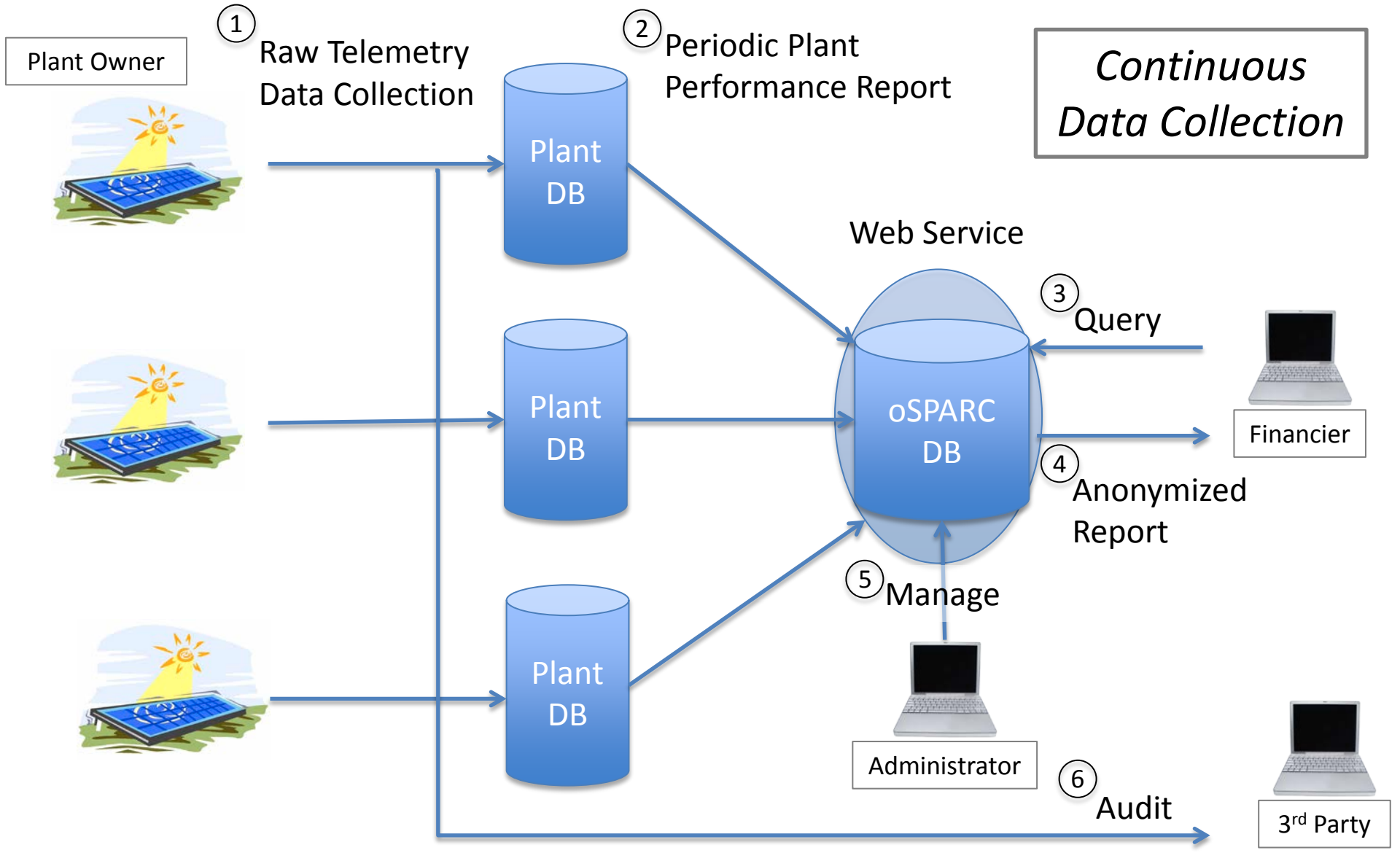
Open
Actuarial
Database

Open Information Access

SUPPLIERS

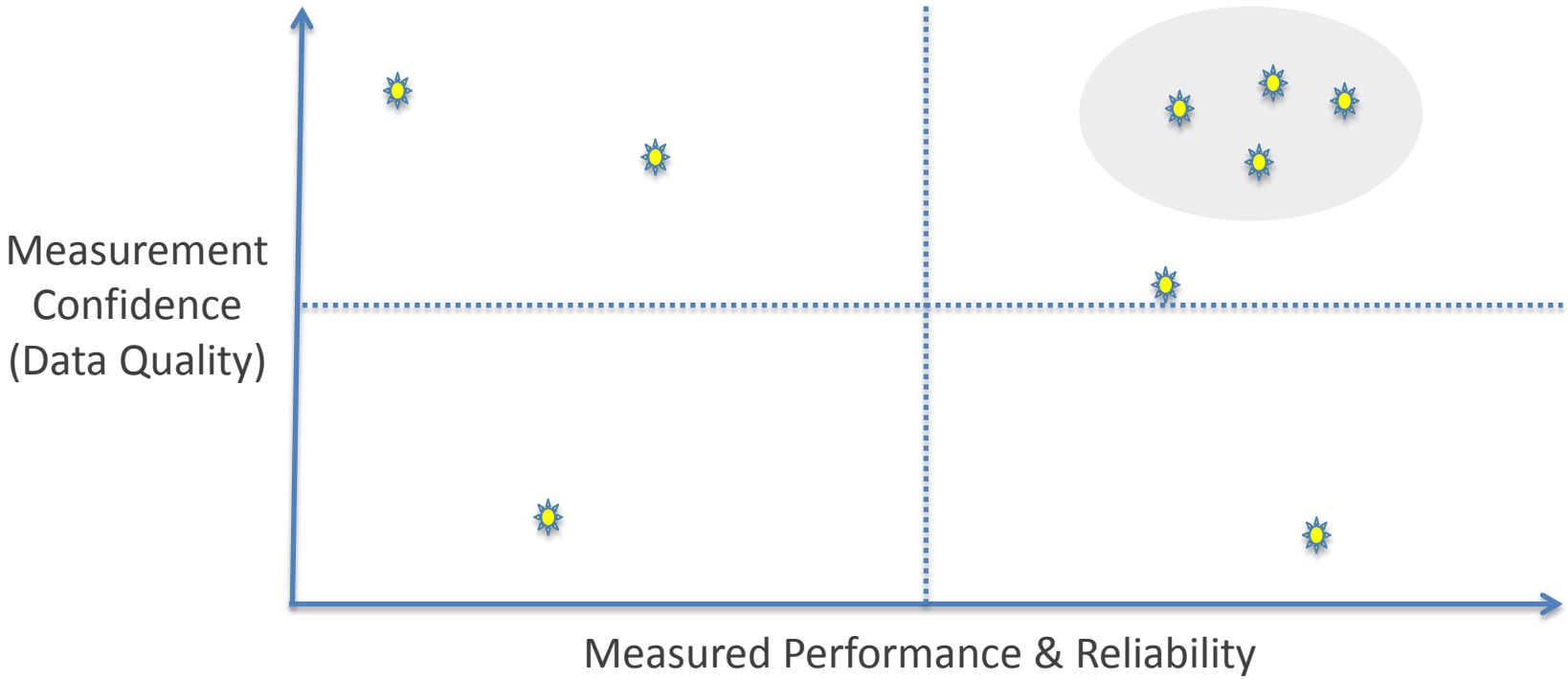


oSPARC Operational Overview



Open Solar Performance And Reliability Clearinghouse Index (oSPARC) Index

Identify best performing plants with highest quality data



Plant Information

Parameter	Description
UUID	The Universally Unique Identifier of the plant. This string value distinguishes this Plant from all others. The UUID is created and assigned when the Plant is first provisioned in the database.
Name	Common name of the Plant.
Location	Physical location of the plant.
Participants	Installer, Owner, O&M provider, Energy Off-Taker, Jurisdiction.
Activation Date	The date the Plant was put into operation and began delivering energy to the Off-Taker.
Array Info	For each array: kWdc stc, Area (m2), module type, orientation, tracker type, fixed tilt, fixed azimuth, height from roof.
Plant Design	Plant class, inverter class, tracker class, DC-optimized, environmental measurement source.

Device Information

Parameter	Description
Module Info	For each Mfr/Model: Wdc STC rating, Area Area (m2), temperature coefficient, total number of modules.
AC Meter Info	For each Mfr/Model: Uncertainty, total number of meters.
Inverter Info	For each Mfr/Model: kWac rating, total number of inverters.
Combiner Info	For each Mfr/Model: Wdc stc rating, total number of combiners.
Weather Info	For each Mfr/Model: Pyranometer class & orientation (ghi/dni/poa).

*STC = Standard Test Conditions

Plant Ratings

Parameter	Description
kWdc stc	Combined total DC Watt rating of all arrays under standard test conditions.
kWp Nominal	AC power rating of the plant.
Kderate	As designed plant de-rate factor.

Plant Electrical Measurements

Parameter	Description
kWhg	Lifetime AC energy generated from plant.
kWac	AC real power output.
Vac	AC Voltage.
Iac	AC Current.
Hz	AC Frequency.
PF	Power Factor.

Array Level Measurements

Parameter	Description
Gpoa	Irradiance in the plane of the array.
Hpoa	Lifetime irradiation over the plane.
Tbom	Back of module temperature.
kWdc	DC power output.
kWhdc	Lifetime DC energy generated from plant.
Vdc	DC Voltage.
Idc	DC Current.

Other Plant Environmental

Parameter	Description
Gghi	Global Horizontal Irradiance reference.
Tamb	Ambient Temperature.
Sw	Wind Speed.
RH	Relative Humidity.
hPa	Barometric Pressure.

Plant Availability and Status

Parameter	Description
Operating	Connected and able to generate power.
Standby	Includes starting up, shutting down, test mode.
Env	Environmental conditions are out of specification. (e.g. Not enough sunlight to generate power.)
Grid	The grid interconnection is out of specification. (e.g. Voltage or frequency violations caused Plant to trip off.)
Shutdown	Operator requested shutdown for maintenance, testing, or other purposes.
Forced	Outage due to Plant failure.
Emergency	Shutdown due to force majeure. Extraordinary event beyond the control of the operator.
X	Number and type of active faults, Timestamp of oldest active.

Net Energy Measurements

Parameter	Description
kWhp	Lifetime AC energy imported to plant (parasitic losses).
kWhl	Lifetime AC energy exported to facility loads.
kWhx	Lifetime AC energy exported to grid.
kWhi	Lifetime AC energy imported from grid.
kWhc	Lifetime AC energy charged to storage.
kWhd	Lifetime AC energy discharged from storage.

Key Performance Indicators

KPI	Description	Formula
Yf	Final Yield	kWhg / kWdc stc
Ye	Expected Yield	Hpoa / Gstc
Ktemp	Temperature Correction	[1 + μ (Tcell - 25)]
Yf tc	Final Yield Compensated	kWhg / (kWdc stc * Ktemp)
Pdc	Expected DC Power	kWdc stc * (Gpoa/Gstc) * Ktemp
Pac	Expected AC Real Power	Pdc * Kderate
PR	Performance Ratio	Yf/Ye
PRtc	PR Compensated	Yf tc/Ye
PRdc	DC Performance Ratio	kWdc / Pdc
PPI	AC Performance Ratio	kWac / Pe
Derate	Actual Derate Ratio	(kWac / kWdc) / Kderate

oSPARC Plant Query Parameters

Query

- Date Range for Report Period
- Location Information
- Size Range
- Equipment Type
- Design Parameters

Response

- Anonymized Report “Plants Like These”
- Key Performance Indicators

Example Anonymized Report Values

For each anonymized plant, display:

KPI	Description	Formula
PR	Performance Ratio	Yf/Ye
PRtc	PR Compensated	Yf tc/Ye
PRdc	DC Performance Ratio	kWdc / Pdc
PPI	AC Performance Ratio	kWac / Pe
Derate	Actual Derate Ratio	(kWac / kWdc) / Kderate
AI	Availability Index	Normalized Availability
HI	Health Index	Ratio of active faults to equipment
Qd	Data Quality Index	Ratio of missing and invalid data samples
oSPARC	oSPARC Index	Blended Overall Score
oSPARCp	oSPARC Percentile	Percentile of SPARC Index

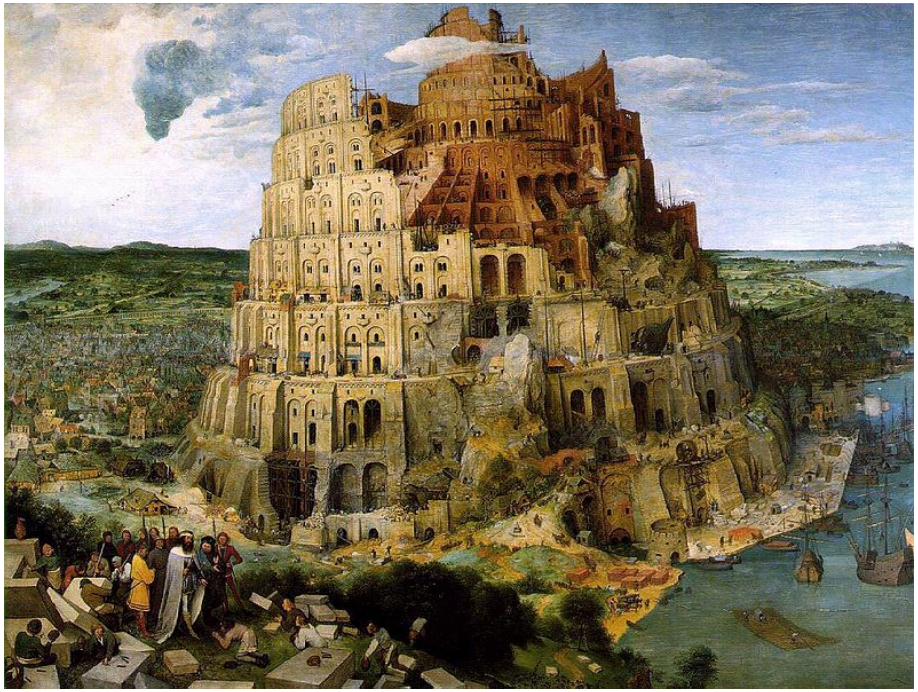
Resolutions & Tradeoffs Summary

Data

Answers

Information

VS.



Thank You

SUNSPEC ALLIANCE

Expanding the Solar PV Market Through Data Standards and Interoperability