Designation: E3010 – 15

An American National Standard

Standard Practice for Installation, Commissioning, Operation, and Maintenance Process (ICOMP) of Photovoltaic Arrays[1]

This standard is issued under the fixed designation E3010; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice details the minimum requirements for installation, commissioning, operations, and maintenance processes to ensure safe and reliable power generation for the expected life of the photovoltaic system. Specifically dealing with commercial photovoltaic installations, this practice covers a broad spectrum of designs and applications and is focused on the proper process to ensure quality.

1.2 This practice does not cover the electrical aspects of installation found in existing and national codes and does not replace or supersede details of electrical installation covered by the same. The practice does address the integration of best practices into design and construction.

1.3 This practice shall not dictate specific design criteria or favor any product or technology.

1.4 This practice shall be focused on the proper, documented process required to build and operate a quality PV plant as defined in Section 3.

1.5 Integration of best practices shall be relevant to this standard and promote a mechanism for rapid evolution and reaction to changes or events. Conformity assessment for PV power plants is being developed through the IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications (IECRE System). Sandia Labs has developed several model documents that may be adopted as acceptable consensus standards through other standards development organizations.

1.6 The standard is divided into three key areas:

1.6.1 Design, engineering, and construction of the PV plant. Systems should be designed with operation and maintenance (O&M) in mind. Further standards should be developed for building integrated or building mounted systems, modules with embedded power electronics, lightweight flexible modules, or other specific components.

1.6.2 Commissioning, testing, and approval for power generation (Utility Witness Testing). Standards for owner acceptance will also be addressed.

1.6.3 O&M of the PV plant including performance monitoring, periodic inspection, preventive maintenance, and periodic re-commissioning.

1.7 Safety and hazard considerations unique to this application, such as worker fall protection, electrical exposure, accessibility of modules, and roof clearance (around the perimeter of the array) are addressed by other codes, standards, or authorities having jurisdiction.

1.8 This practice provides guidelines for minimum processes required and must be used in conjunction with applicable codes and standards, government regulations, manufacturer requirements, and best practices.

1.9 This practice is not intended to replace or supersede any other applicable local codes, standards or Licensed Design Professional instructions for a given installation.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E772 Terminology of Solar Energy Conversion

E2047 Test Method for Wet Insulation Integrity Testing of Photovoltaic Arrays

E2848 Test Method for Reporting Photovoltaic Non-Concentrator System Performance

E2908 Guide for Fire Prevention for Photovoltaic Panels, Modules, and Systems

2.2 *IEC Standards:*[3]

IEC 61215: Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval

[1] This test method is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.09 on Photovoltaic Electric Power Conversion.

Current edition approved March 1, 2015. Published June 2015. DOI: 10.1520/E3010-15

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, http://www.iec.ch.

IEC 61724: PV System Performance Monitoring – Guidelines for Measurement Data Exchange and Analysis
IEC 61829: Crystalline Silicon PV Array – On-site Measurements of I-V Characteristics
IEC/TS 61836: Solar PV Energy Systems – Terms, Definitions and Symbols
IEC 62446: Grid Connected PV Systems – Minimum Requirements for System Documentation, Commissioning, and Inspection
IEC/TS 62548: PV Arrays – Design Requirements
IEC 62738: Design Guidelines and Recommendations for PV Power Plants [5 MW and Greater, Ground Mount]
IEC 62446–2 (draft in progress) Maintenance of PV Systems
IECRE-PV: Conformity Assessment

2.3 *ANSI Standards*[4]

ANSI/TUV-R Cleaning Frequency
ANSI/TUV-R 71731 Simulated Sand and Dust Tests of Photovoltaic (PV) Modules: Part 1 – Soiling Testing for Superstrates
ANSI/TUV-R 71732 Qualification Plus Testing for PV Modules—Test and Sampling Requirements

2.4 *UL Standards*[5]

UL 1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
UL 4730 Nameplate Tolerance Standard

2.5 *Other Standards*

IEEE 1547: Standard for Interconnecting Distributed Resources with Electric Power Systems[6]
NECA 412-2012: Standard for Installing and Maintaining PV Power Systems[7]
NFPA 70 National Electrical Code, Article 690[8]
Solar ABCs – PV System Operations and Maintenance Fundamentals[9]

2.6 *NREL Documents*[10]

SAPC PV Operations and Maintenance Best Practices Guide: Considerations for Financial Managers and Industry Practitioners", version 1.0

2.7 *SNL Documents*[11]

SAND 2015 - 0587 Precursor Report of Data Needs and Recommended Practices for PV Plant Availability, Operations and Maintenance Reporting
SAND2014 - 20612 PV Reliability Operations and Maintenance (PVROM) Database Initiative: 2014 Progress Report

2.8 *SunSpec References*[12]

Commissioning Best Practices and Re-Commissioning
oSPARC – Open Solar Performance and Reliability Clearinghouse Database
Solar PV Monitoring Best Practice
SAPC Standard O&M Contract

3. Terminology

3.1 In addition to the terms defined in E772, the following terms are defined for the purpose of this standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *construction, PV system*—the process of preparing and assembling the various components of a PV system, including site preparation, foundations, structural assembly, and installation of mechanical and electrical equipment.

3.2.2 *commissioning, PV system*—the process of starting the operation of a PV system, including verification of construction according to design, confirmation of functional performance, and transfer of responsibility to the system operator.

3.2.3 *design, PV System*—the information required to construct and operate a PV system.

3.2.3.1 *Discussion*—Typically prepared by a qualified engineer or design professional, this information may include drawings, text documents, calculations, or other forms of documentation. Design includes specifications and configuration for components and materials.

3.2.4 *operation and maintenance (O&M), PV system*—procedures to assure functionality of system components and connections for reliability, safety and fire prevention; monitoring of performance indicators, measures to track and maximize anticipated performance, diagnostic measures, troubleshooting, and documentation.

3.2.4.1 *Discussion*—This includes controllable or modifiable maintenance items that impact system yield, uptime, availability, and the ability to operate effectively under existing local environmental and climatological conditions, and site-related activities such as module washing and upkeep of vegetation for both performance and safety reasons.

4. Significance and Use

4.1 With the rapid expansion of the commercial photovoltaic market and the various standards and independent certification entities evolving, a consensus standard practice for the ICOMP process is needed to bring consistency to the market.

4.2 Investors and insurance companies need consistency of product and standards to reduce costs of capital and underwriting. Use of a consensus standard practice is expected to improve consistency and reduce risk for investors.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, http://www.ul.com.

[6] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854, http://www.ieee.org.

[7] Available from National Electrical Contractors Association (NECA), 3 Bethesda Metro Center, Suite 1100, Bethesda, MA 20814, http://www.necanet.org.

[8] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[9] PDF available from Solar America Board for Codes and Standards (Solar ABCs), www.solarabcs.org/about/publications.

[10] Available from National Renewable Energy Laboratory (NREL), 901 D, Street, S.W. Suite 930, Washington, DC 20024, http://www.nrel.gov/docs/fy15osti/63235.pdf

[11] Available from Sandia National Laboratories (SNL), energy.sandia.gov

[12] Available from SunSpec Alliance, 4030 Moorpark Ave, Suite 109, San Jose, CA 95117.

4.3 Photovoltaic systems operate in harsh environments that are not typical for electrical equipment and generally inconsistent with electrical contractor experience. Documented processes are needed to ensure performance and durability of the systems over the long operating life.

4.4 The goal of this practice is to implement processes to improve safety and reliability, reduce lifecycle costs (commonly referred to as Levelized Cost of Energy or LCOE), and encourage the development of feedback loops for continuous improvement of results.

4.5 This practice may be applied during any or all phases of the PV System Lifecycle (refer to Section 5). A record of the activities carried out according to this practice shall be included in the Report (refer to Section 8).

5. PV System Lifecycle

5.1 The lifecycle of a PV system can be divided into the following stages and areas of emphasis. These terms are used in the following section to identify the applicable requirements at each stage of the system lifecycle:

5.1.1 *Design*

5.1.1.1 Reliability

5.1.1.2 Measurability

5.1.1.3 Safety

5.1.2 *Risk Mitigation*

5.1.2.1 Financing

5.1.2.2 Insurance

5.1.3 *Construction*

5.1.3.1 Best practices

5.1.3.2 Risk mitigation

5.1.4 *Commissioning*

5.1.4.1 Design compliance

5.1.4.2 Performance verification

5.1.5 *Operation and Maintenance*

5.1.5.1 Performance monitoring

5.1.5.2 Operations

5.1.5.3 Maintenance

5.1.6 *Transaction Process*

5.1.6.1 Ownership transfer

6. Process Requirements

6.1 *Design*—The design of a PV system shall include, as a minimum, the following characteristics:

6.1.1 Documented process for ensuring quality and implementation of best practices throughout the design process.

6.1.2 For systems larger than 5 MW, data for system verification and commissioning should include validated performance modeling including documentation of assumptions and derating factors used. Such documentation should be reproducible and compatible with current editions of industry standard software.[13] Refer to Appendix X1 for a typical example of the report generated from a common software package.

6.1.3 A strategy for mitigation of lost production should be documented.

6.1.4 The design shall incorporate best practices to facilitate the operation and maintenance of the plant over its expected life time. Accessibility of all equipment shall be ensured, and O&M procedures shall be clearly documented.

6.1.5 There should be a documented review of safety and construction processes.

6.2 *Construction*—There shall be a documented process for construction to ensure quality.

6.2.1 The documented quality process for construction work shall consider environment, roof, soils, and other factors, and it shall include the following:

6.2.1.1 Vegetation control plan designed to ensure proper operation throughout the system lifecycle,

6.2.1.2 Site water flow plan—roof and ground,

6.2.1.3 Plan for inspection, testing, and documentation of materials delivered to the construction site,

6.2.1.4 Material handling plan and spares plan,

6.2.1.5 Plan for replacement of parts,

6.2.1.6 Fire access and training,

6.2.1.7 Siting and access of meteorological station or SCADA equipment (for systems larger than 5 MW), or both,

6.2.1.8 Plan and inspection process for ensuring that conductors are free from strain or abrasion, and allowed to flex due to thermal expansion,

6.2.1.9 Installation of raceways and fixtures for thermal expansion,

6.2.1.10 Plan and accessibility for torque maintenance including appropriate anti-seize provisions and conformance to manufacturers' recommended torque specifications,

6.2.1.11 Documented verification process to ensure correct polarity of all electrical components and connecting cables,

6.2.1.12 Installation of all equipment in accordance with manufacturers' recommendations,

6.2.1.13 Protection of surfaces to ensure long term performance of roofs (especially membrane type), and

6.2.1.14 Access for service of the PV plant and any adjacent equipment.

6.3 *Commissioning*—The commissioning of a PV system shall include, as a minimum, the following activities:

6.3.1 For systems larger than 5 MW, validation and certification of system performance (power output), based on performance modeling developed in the design process,

6.3.2 Documented quality testing for safety and performance consistent with best practices, including:

6.3.2.1 IEC 62446,

6.3.2.2 SunSpec Guide to Commissioning Measurements, and

6.3.2.3 Insulation resistance (megger) or other non-invasive testing (such as differential current monitoring) consistent with design documentation; and

6.3.3 Commissioning documentation shall be organized as a complete package, signed and dated. Details shall be consistent with the documentation standards and requirements identified in section 9 of IEC 62446.

6.4 *Operation and Maintenance*—A PV system shall have an O&M plan that includes the following:

[13] Many standard software packages can be found at http://photovoltaic-software.com/professional.php.

6.4.1 For systems larger than 5 MW, periodic validation of system performance (power output), based on performance modeling developed in the design process and initial results during commissioning,

6.4.2 Service records, including reporting of operational issues and recorded status of issues resolution,

6.4.3 As-built drawings that are readable and accurate,

6.4.4 Site maintenance and safety plan,

6.4.5 Documented process for performance monitoring,

6.4.6 Documented and detailed process for periodic verification of safety and performance,

6.4.7 Mandatory annual preventive maintenance (PM) plan and warranty documentation,

6.4.8 Cleaning plan and vegetation control plan,

6.4.9 Documentation of warranty, service level agreement and claims process, including records of all previous and active claims,

6.4.10 Documented expectations for response time to operational problems, and recorded status of repairs,

6.4.11 Provisions for "invasive" testing if necessary for troubleshooting of operational problems, and

6.4.12 Process for root cause analysis, emphasizing transparency and preventive action.

7. Applicable Standards and Best Practices

7.1 The following standards and other documents have been identified as useful references for each phase in the PV System Lifecycle.

7.1.1 *Design:*

7.1.1.1 Terminology E772

7.1.1.2 Guide E2908

7.1.1.3 IEC/TS 61836: Solar PV Energy Systems – Terms, Definitions, and Symbols

7.1.1.4 IEC/TS 62548: PV Arrays – Design Requirements

7.1.1.5 IEC 62738: Design Guidelines and Recommendations for PV Power Plants [5 MW and Greater, Ground Mount]

7.1.1.6 IEC 61215: Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval

7.1.1.7 IEC 62446: Grid Connected PV Systems – Minimum Requirements for System Documentation, Commissioning, and Inspection

7.1.1.8 IEC 61724: PV System Performance Monitoring – Guidelines for Measurement Data Exchange and Analysis

7.1.1.9 UL1741: Inverters, Converters, Controllers, and Interconnection System Equipment for Use With Distributed Energy Resources

7.1.1.10 NECA 412-2012: Standard for Installing and Maintaining PV Power Systems

7.1.1.11 IECRE-PV Conformity Assessment

7.1.1.12 ANSI/TUV-R 71732 Qualification Plus

7.1.1.13 Precursor Report of Data Needs and Recommended Practices for PV Plant Availability, Operations and Maintenance Reporting – Sandia

7.1.1.14 PV Reliability Operations and Maintenance (PV-ROM) Database Initiative: 2014 Progress Report– Sandia

7.1.2 *Risk Mitigation*

7.1.2.1 IECRE-PV Conformity Assessment

7.1.2.2 UL 4730: Nameplate Tolerance Standard

7.1.2.3 SAPC Standard Operation and Maintenance Contract – SunSpec/NREL

7.1.2.4 TruSolar Risk Scoring Criteria and Methodology

7.1.3 *Construction*

7.1.3.1 IEC 62446: Grid Connected PV Systems – Minimum Requirements for System Documentation, Commissioning, and Inspection

7.1.3.2 NECA 412-2012: Standard for Installing and Maintaining PV Power Systems

7.1.3.3 IECRE-PV Conformity Assessment

7.1.4 *Commissioning*

7.1.4.1 E2047

7.1.4.2 E2848

7.1.4.3 IEC 61724: PV System Performance Monitoring – Guidelines for Measurement Data Exchange and Analysis

7.1.4.4 IEC 61829: Crystalline Silicon PV Array – On-site Measurements of I-V Characteristics

7.1.4.5 IEC/TS 61836: Solar PV Energy Systems – Terms, Definitions, and Symbols

7.1.4.6 IEC 62446: Grid Connected PV Systems – Minimum Requirements for System Documentation, Commissioning, and Inspection

7.1.4.7 IEC 62738: Design Guidelines and Recommendations for PV Power Plants [5 MW and Greater, Ground Mount]

7.1.4.8 IEEE 1547: Standard for Interconnecting Distributed Resources with Electric Power Systems

7.1.4.9 NECA 412-2012: Standard for Installing and Maintaining PV Power Systems

7.1.4.10 IECRE-PV Conformity Assessment

7.1.4.11 Commissioning Best Practices and Recommissioning – SunSpec

7.1.5 *Operation and Maintenance*

7.1.5.1 E2848

7.1.5.2 IEC 61724: PV System Performance Monitoring – Guidelines for Measurement Data Exchange and Analysis

7.1.5.3 IEC 61829: Crystalline Silicon PV Array – On-site Measurements of I-V Characteristics

7.1.5.4 IEC/TS 61836: Solar PV Energy Systems – Terms, Definitions, and Symbols

7.1.5.5 IEC 62446: Grid Connected PV Systems – Minimum Requirements for System Documentation, Commissioning, and Inspection

7.1.5.6 IEC 62446–2 (draft in progress): Maintenance of PV Systems

7.1.5.7 NECA 412-2012: Standard for Installing and Maintaining PV Power Systems

7.1.5.8 IECRE – PV Conformity Assessment

7.1.5.9 PV Reliability Operations and Maintenance (PV-ROM) Database Initiative: 2014 Progress Report – Sandia

7.1.5.10 Precursor Report of Data Needs and Recommended Practices for PV Plant Availability, Operations and Maintenance Reporting– Sandia

7.1.5.11 Solar PV Monitoring Best Practice – SunSpec

7.1.5.12 oSPARC Database – SunSpec

7.1.5.13 ANSI/TUV-R-71731 Soiling Standard

7.1.5.14 ANSI/TUV-R Cleaning Frequency

7.1.5.15 SAPC PV Operations and Maintenance Best Practices Guide – NREL

7.1.5.16 PV System O&M Fundamentals – Solar ABCs

7.1.6 *Transaction Process*

7.1.6.1 IEC 61829: Crystalline Silicon PV Array – On-site Measurements of I-V Characteristics

7.1.6.2 IEC 62446: Grid Connected PV Systems – Minimum Requirements for System Documentation, Commissioning, and Inspection

8. Report

8.1 The user of this practice shall prepare a report of the activities undertaken for a specific PV system, including at minimum the following information:

8.1.1 Phases of system lifecycle addressed,

8.1.2 Standards or best practices utilized in each phase, and

8.1.3 Documentation of system configuration or performance, or both, according to the requirements of the standards or best practices utilized.

9. Keywords

9.1 best practice; certification; conformity; commissioning; design; durability; fundamental; installation; insurance; LCOE; lifecycle; maintenance; O&M; operation; performance; photovolatiac; PV system; reliability; requirements; solar; validation

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE OF PV SYSTEM OUTPUT MODEL FROM A COMMON SOFTWARE PACKAGE

			03/06/13	Page 1/5

Grid-Connected System: Simulation parameters

Project: **Farm at Marseille**

Geographical Site	**Marseille Marignane**		Country	**France**
Situation	Latitude	43.4°N	Longitude	5.2°E
Time defined as	Legal Time	Time zone UT+1	Altitude	14 m
	Albedo	0.20		
Meteo data:	**Marseille Marignane**	Synthetic - Meteonorm 6.1		

Simulation variant: **With shadings (module layout)**

Simulation date 03/06/13 12h48

Simulation parameters

Collector Plane Orientation	Tilt	25°	Azimuth	20°
Horizon	Average Height	8.0°		
Near Shadings	According to strings		Electrical effect	80 %

PV Array Characteristics

PV module	Si-poly Model	**Poly 110 Wp 72 cells**		
	Manufacturer	Generic		
Number of PV modules	In series	9 modules	In parallel	15 strings
Total number of PV modules	Nb. modules	135	Unit Nom. Power	110 Wp
Array global power	Nominal (STC)	**14.85 kWp**	At operating cond.	13.14 kWp (50°C)
Array operating characteristics (50°C)	U mpp	277 V	I mpp	47 A
Total area	Module area	**121 m^2**	Cell area	107 m^2
Inverter	Model	**4.2 kWac inverter**		
	Manufacturer	Generic		
Characteristics	Operating Voltage	125-500 V	Unit Nom. Power	4.20 kW AC
Inverter pack	Number of Inverter	3 units	Total Power	12.60 kW AC

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m^{2}K	Uv (wind)	0.0 W/m^{2}K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m^2, Tamb=20°C, Wind=1 m/s.)			NOCT	56 °C
Wiring Ohmic Loss	Global array res.	99 mOhm	Loss Fraction	1.5 % at STC
Array Soiling Losses			Loss Fraction	1.0 %
Module Quality Loss			Loss Fraction	1.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 – bo (1/cos i – 1)	bo Param.	0.05
User defined profile				

User's needs : Unlimited load (grid)

FIG. X1.1 Example of PV System Output Model

			03/06/13	Page 2/5

Grid-Connected System: Horizon definition

Project: **Farm at Marseille**

Simulation variant: **With shadings (module layout)**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	8.0°		
Near Shadings	According to strings			
PV Field Orientation	tilt	25°	azimuth	20°
PV modules	Model	Poly 110 Wp 72 cells	Pnom	110 Wp
PV Array	Nb. of modules	135	Pnom total	**14.85 kWp**
Inverter	Model	4.2 kWac inverter	Pnom	4200 W ac
Inverter pack	Nb. of units	3.0	Pnom total	**12.60 kW ac**
User's needs	Unlimited load (grid)			

Horizon	Average Height	8.0°	Diffuse Factor	0.94
	Albedo Factor	100 %	Albedo Fraction	0.49

Height [°]	9.2	5.7	1.4	12.4	14.7	4.6	1.4
Azimuth [°]	−119	−57	−14	9	69	95	121

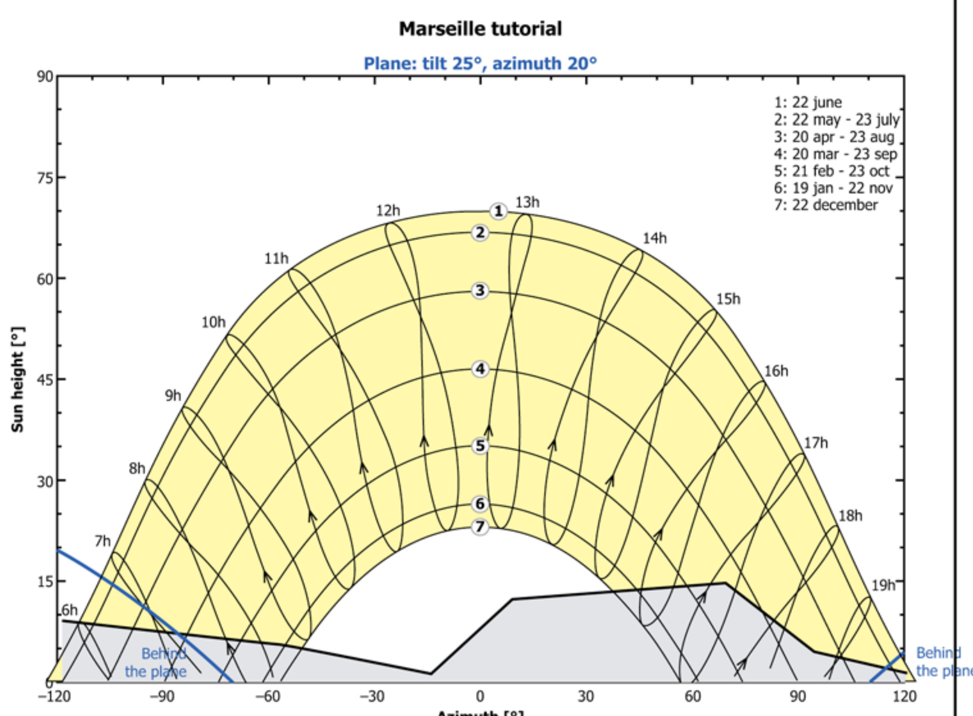


FIG. X1.1 Example of PV System Output Model *(continued)*

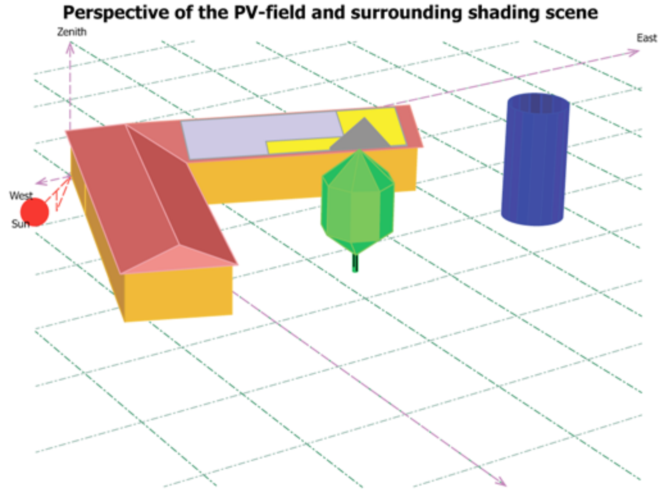
Grid-Connected System: Near shading definition

Project: **Farm at Marseille**

Simulation variant: **With shadings (module layout)**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	8.0°		
Near Shadings	According to strings			
PV Field Orientation	tilt	25°	azimuth	20°
PV modules	Model	Poly 110 Wp 72 cells	Pnom	110 Wp
PV Array	Nb. of modules	135	Pnom total	**14.85 kWp**
Inverter	Model	4.2 kWac inverter	Pnom	4200 W ac
Inverter pack	Nb. of units	3.0	Pnom total	**12.60 kW ac**
User's needs	Unlimited load (grid)			

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

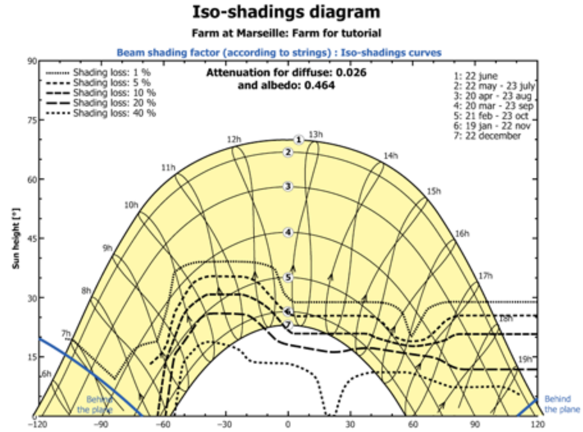


FIG. X1.1 Example of PV System Output Model *(continued)*

03/06/13 | Page 4/5

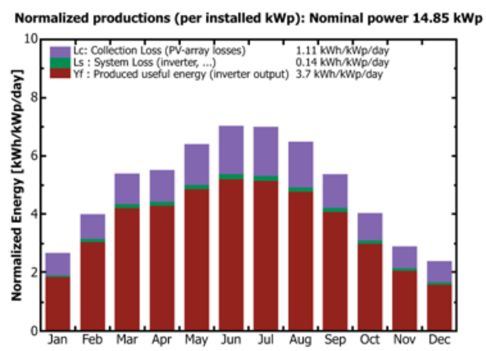
Grid-Connected System: Main results

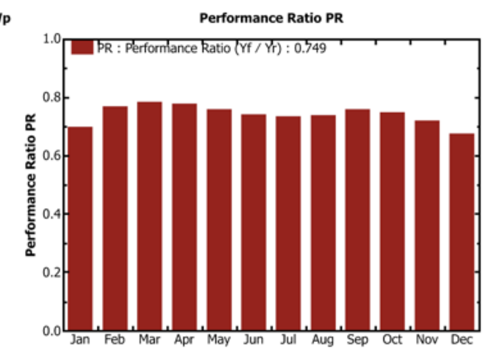
Project: **Farm at Marseille**

Simulation variant: **With shadings (module layout)**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	8.0°		
Near Shadings	According to strings			
PV Field Orientation	tilt	25°	azimuth	20°
PV modules	Model	Poly 110 Wp 72 cells	Pnom	110 Wp
PV Array	Nb. of modules	135	Pnom total	**14.85 kWp**
Inverter	Model	4.2 kWac inverter	Pnom	4200 W ac
Inverter pack	Nb. of units	3.0	Pnom total	**12.60 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**20.05 MWh/year**	Specific prod.	1350 kWh/kWp/year
	Performance Ratio PR	74.9 %		





With shadings (module layout)
Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	53.5	6.29	83.0	70.1	0.897	0.861	8.91	8.55
February	79.2	6.99	112.0	99.7	1.326	1.278	9.76	9.41
March	133.9	11.20	167.4	154.3	2.021	1.950	9.95	9.61
April	153.4	14.37	165.6	153.2	1.986	1.916	9.89	9.54
May	199.4	19.14	198.7	184.4	2.327	2.245	9.65	9.31
June	217.8	23.44	210.9	196.9	2.409	2.324	9.42	9.09
July	220.9	24.90	217.1	202.2	2.463	2.377	9.35	9.03
August	188.2	24.67	200.9	187.8	2.283	2.204	9.37	9.05
September	138.9	19.74	161.5	149.8	1.891	1.825	9.65	9.31
October	93.0	16.05	125.0	112.3	1.444	1.392	9.53	9.18
November	58.3	9.96	87.1	75.3	0.968	0.932	9.16	8.81
December	46.1	6.50	74.2	61.2	0.776	0.744	8.62	8.26
Year	1582.5	15.32	1803.3	1647.2	20.790	20.048	9.50	9.17

Legends:	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

FIG. X1.1 Example of PV System Output Model *(continued)*

			03/06/13	Page 4/5

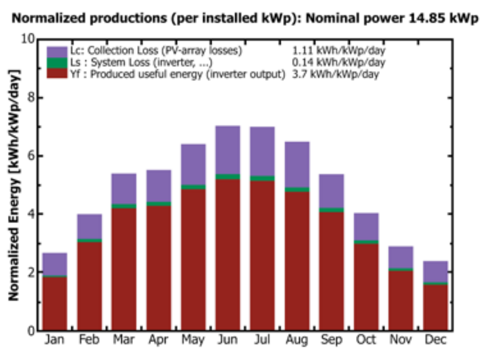
Grid-Connected System: Main results

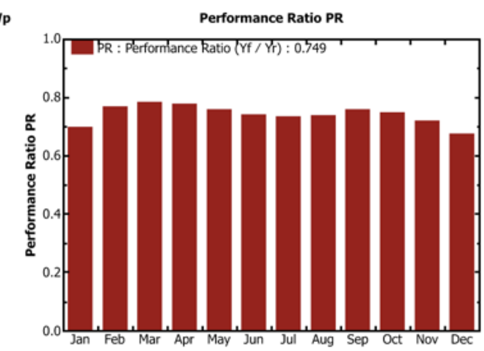
Project: **Farm at Marseille**

Simulation variant: **With shadings (module layout)**

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	8.0°		
Near Shadings	According to strings			
PV Field Orientation	tilt	25°	azimuth	20°
PV modules	Model	Poly 110 Wp 72 cells	Pnom	110 Wp
PV Array	Nb. of modules	135	Pnom total	**14.85 kWp**
Inverter	Model	4.2 kWac inverter	Pnom	4200 W ac
Inverter pack	Nb. of units	3.0	Pnom total	**12.60 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**20.05 MWh/year**	Specific prod.	1350 kWh/kWp/year
	Performance Ratio PR	74.9 %		





With shadings (module layout)
Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	53.5	6.29	83.0	70.1	0.897	0.861	8.91	8.55
February	79.2	6.99	112.0	99.7	1.326	1.278	9.76	9.41
March	133.9	11.20	167.4	154.3	2.021	1.950	9.95	9.61
April	153.4	14.37	165.6	153.2	1.986	1.916	9.89	9.54
May	199.4	19.14	198.7	184.4	2.327	2.245	9.65	9.31
June	217.8	23.44	210.9	196.9	2.409	2.324	9.42	9.09
July	220.9	24.90	217.1	202.2	2.463	2.377	9.35	9.03
August	188.2	24.67	200.9	187.8	2.283	2.204	9.37	9.05
September	138.9	19.74	161.5	149.8	1.891	1.825	9.65	9.31
October	93.0	16.05	125.0	112.3	1.444	1.392	9.53	9.18
November	58.3	9.96	87.1	75.3	0.968	0.932	9.16	8.81
December	46.1	6.50	74.2	61.2	0.776	0.744	8.62	8.26
Year	1582.5	15.32	1803.3	1647.2	20.790	20.048	9.50	9.17

Legends:				
	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

FIG. X1.1 Example of PV System Output Model *(continued)*