Grid Architecture Component Class Specification

Component Class Designation: Solar Photovoltaic

Summary Overview

Photovoltaic systems are constructed using solid state opto-electronic devices, typically called a photovoltaic cell. When illuminated by light, they produce a DC electric voltage and current which can be converted into AC power using inverter systems. These cells are combined to form a photovoltaic system, which may be small or large with a commensurate power generation capability. These systems may be found on residential rooftops at the kilowatt scale, commercial buildings and parking lots at the 10-s of kilowatt scale, or utility systems up to hundreds of megawatts. The systems operate only when sunlight is exposed to the solar cells. Although these systems can be paired with energy storage devices such as batteries, they do not include useable energy storage, thus cannot be used to generate electricity when sunlight is unavailable.

The use of solar PV is primarily dependent upon cost benefit of alternative sources of energy. The financial justification of solar is affected primarily by the cost of the infrastructure, the geographic location of the solar panel (insolation), and any financial incentives that may be granted such as government incentive programs, and possibly, the value of environmental benefits. These costs must be weighed against the availability, cost and environmental impact of acquiring the electricity by other means.

The technical interconnection of solar PV is guided by rules governing the inverter as opposed to the solar PV system, although solar does have uniqueness in terms of its effects on system balancing. Costs associated with those effects are typically included in either a utility tariff structure or a power purchase agreement.

Definitions

Insolation – the amount of solar radiation reaching a given area

Solid State – An electronic device made using semiconductor materials.

Solar cell – a semiconductor device, using a P-N junction that converts light into DC electrical power

Inverter – a collection of solid state components arranged in a manner to convert DC energy into an AC waveform of specific frequency, voltage, power and reactive power. Smart inverters include capabilities to aid the management, performance, and efficiency of the grid to which it is connected.

Solar Tracking – a motorized capability of a solar panel to track the sun for the purposes of achieving the maximum incident solar flux density. Tracking requires electricity to accomplish, and therefore should be evaluated as a tradeoff between additional cost and additional benefit. Tracking may be single or dual axis.

Component Class Description

Purpose and Function

Solar PV generation is a renewable source of electric power. As such, it does not require a fuel source other than natural sunlight to generate electricity. These systems provide a useful source of electric power at the level of, or below the level of the maximum generating capacity of the PV cells and the incident sunlight due to system design capacity and/or soiling. Therefore, the function of these systems is greatly improved when paired with energy storage, which will aid the distribution of the generated electricity to loads as it is needed. Additionally, the function and performance of a solar panel system is also greatly affected by the inverter to which it is connected. The topic of inverter functionality is discussed in a separate component class specification.

Solar system efficiency is calculated as the product of several individual subsystem efficiencies, including optical reflection, soiling, the solar cell efficiency, electrical losses/ambient temperature, thermal losses, and inverter losses. For high grade silicon-based systems, the maximum system efficiency (from solar energy in, to electrical AC energy out) is approximately 17 percent. Advanced systems used in space applications (typically DC systems using GaAs, InP, and Ge), may approach 50% efficiency but are cost prohibitive for use when alternative sources of electricity are available. Specific calculations of the above losses can be accomplished using the free software referenced in [1].

The electrical protection of solar systems is typically accomplished by the attached inverter, which identifies and manages both AC faults as well as DC faults.

Key externally visible properties

The primary visible properties of a solar PV system are the characteristic diurnal generation shape of electricity in proportion to the available sunlight, as well as the electrical functionality provided to the utility by its associated inverter. Intermittency in the generation of electricity occurs primarily due to moving cloud coverage and does require additional resources to balance to the load shape.

Interface descriptions

There are typically no communications interfaces to a solar PV system except from the inverter system to which it is connected. Inverter systems are described in a separate component class specification document.

Table of relevant standards

Standard Name	Description	Version/Date
IECRE (Preliminary)	IEC:2015 Conditional PV Project Certificate	Preliminary, 2015
IEC 62446:2017	IEC 62446:2017 Photovoltaic Systems-Requirements for Testing, Documentation and Maintenance. Part 1: Grid Connected Systems, Part 3: PV Modules and Plants- Outdoor IR Thermography, 2017.[1-4]	2017

IEC 61724-1:2017(E)	IEC 61724-1:2017(E) Photovoltaic System Performance - Part 1: Monitoring, 2017.	2017
IEC 61724-1:2017(E)	IEC 61724-1:2017(E) Photovoltaic System Performance - Part 3: Energy Evaluation Method, 2016.	2017
IEC 61724-1:2017(E)	IEC 61724-1:2017(E) Photovoltaic System Performance - Part 2: Capacity, 2016.	2017
UL 1741	UL 1741 Supplement (SA) Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, 2010.	2010
UL 1741 SA	UL 1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, 2016.	2016
IEEE P1547	T. S. Basso and R. DeBlasio, "IEEE 1547 series of standards: interconnection issues," *IEEE Transactions on Power Electronics,* vol. 19, no. 5, pp. 1159-1162, 2004.	2004
California Rule 21	(2017). *Rule 21 Generating Facility Interconnections*. Available: http://www.cpuc.ca.gov/General.aspx?id=3962 - gi21	2017

List of Attached Documents

Document Name/File Name	Description	Version/Date

References

No.	Reference
1	N. Blair *et al.*, "System advisor model, sam 2014.1. 14: General description," National Renewable Energy Laboratory (NREL), Golden, CO.2014.
2	C. H. a. S. Bowden. (2018). *PV Education*. Available: http://www.pveducation.org/

Version History

Action	Date	Description	Author(s)
created	1-Jan-18	Initial draft	R. Guttromson
modified	27-Jul-18	Updated formatting; added section headers.	B. M. Kelley