Grid Architecture Component Class Specification

Component Class Designation: Inverter

Summary Overview

Inverter systems are power electronic devices which convert DC electric energy into an AC waveform of specific frequency, voltage, power, and reactive power. These devices are typically applied at the output of DC electric power sources, including photovoltaic (PV) systems, some wind turbines (e.g. Type 4), energy storage devices such as batteries and supercapacitors, and solid-state power system devices such as power flow controllers.

Definitions

Solid state – an electronic device made using semiconductor materials.

Inverter – a collection of solid state components arranged in a manner to convert DC energy into an AC waveform of specified 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.

Synchronous generator – an electric power system generator that utilizes a rotating shaft that is electromagnetically coupled to a rotating magnetic field created by a three-phase grid.

Power flow controller – a solid state device that is used to transfer real and reactive power between two power systems without the need for them to be synchronously aligned.

Component Class Description

Purpose and Function

Basic inverter functionality provides the ability to inject real power into an AC power system. Some of these inverters are single phase, and some are three phase. Basic inverters are typically designed as either voltage source inverters or current source inverters. Voltage source inverters control real power and voltage (P-V) but let current and reactive power swing. Alternatively, current source inverters control real power and reactive power (P-Q) and allow voltage to swing. Basic inverters as they are normally created with two quadrant inversion, which includes plus and minus real power but omits plus and minus reactive power. Basic inverters are set to disconnect from the grid upon immediate detection of a system contingency.

Smart inverters require four quadrant controls, with the ability to control P-Q, P-V, I-Q, or I-V as the situation demands. They are designated as 'smart' because they are made with a variety of control functions such as the ability to autonomously regulate voltage by supplying reactive power output (termed voltage regulation), and to regulate frequency using real power output (termed frequency regulation). The latter is possible only when sufficient power is available to the inverter and it is connected to a system which has a positive $\frac{\partial P}{\partial f}$ response where P is power injected by the source into the system and f is the system frequency. This applies to systems with synchronous generation, but not all static power systems.

Other functions of smart inverters include their ‘grid forming’ ability, which establish and maintains a 60Hz system frequency to which other inverter resources can synchronize using a phase-lock-loop. This functionality is necessary for a grid or microgrid formation that does not include synchronous generation.

Smart inverters also have voltage and frequency ride through capability, which are fully defined in reference UL 1741 and UL7141 SA. These capabilities define how a grid connected inverter must behave in the presence of a system disturbance such as a fault (voltage drop) or frequency increase (most commonly due to an instantaneous load drop). Generally, these requirements allow the inverter to help secure the grid during a contingency but require the inverter to separate from the grid when traditional protection devices have cleared a fault. This is done for safety reasons to ensure a line de-energized by system protection devices does not remain energized from the inverter.

Many smart inverters are starting to employ functionality to detect and protect the DC side of the system in the case of DC faults or short circuits. These features are meant to protect the power source devices from damage, such as a PV panel, or a DC energy storage device.

Inverters are designed with an inherent output limitation based on total current. This means that their design will limit their apparent power, S, where S=P+jQ. When constrained by this limit, inverters are required to utilize their resources to prioritize Q supply over P supply, which aids the grid security at the cost of lost power production.

<u>Key externally visible properties</u>

Smart inverters have a communication link to an owner/operator or an OEM. This link can be used to upload new types of operating rules, such as a new definition of voltage regulation behavior, or of lesser benefit, they can be used to make manual changes to the operating condition of the smart inverter.

Most inverters also utilize this communications link to export information in near real-time about the operation of the inverter and its performance.

<u>Interface descriptions</u>

<u>Table of relevant standards</u>

Standard Name	Description	Version/Date
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
IEC TR 61850-90-7:2013(E)	IEC TR 61850-90-7:2013(E) Communication networks and systems for power utility automation – Part 90-7: Object models for power converters in distributed energy resources (DER) systems	2013

List of Attached Documents

Document Name/File Name	Description	Version/Date
Inverter Component Class Description	R. Guttromson	2/2/18

References

No.	Reference

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