Grid-tie inverter

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A **grid-tie inverter** converts direct current (DC) electricity into an alternating current (AC) suitable for injecting into an electrical power grid, normally 120V RMS at 60Hz or 240V RMS at 50Hz. Grid-tie inverters are used between local electrical power generators: solar panel, wind turbine, hydro-electric, and the grid. [1]

Inverter for grid-tied solar panel

In order to inject electrical power efficiently and safely into the grid, grid-tie inverters must accurately match the voltage and phase of the grid sine wave AC waveform.

Some electricity companies will pay for electrical power that is injected into the grid.

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Payment for injected power

Three-phase grid-tie inverter for large solar panel systems

Electricity companies, in some countries, pay for electrical power that is injected into the electricity utility grid. Payment is arranged in several ways.

With net metering the electricity company pays for the net power injected into the grid, as recorded by a meter in the customer's premises. For example, a customer may consume 400 kilowatt-hours over a month and may return 500 kilowatt-hours to the grid in the same month. In this case the electricity company would pay for the 100 kilowatt hours balance of power fed back into the grid. In the US, net metering policies vary by jurisdiction.

Feed-in tariff, based on a contract with a distribution company or other power authority, is where the customer is paid for electrical power injected into the grid.

In the United States, grid-interactive power systems are specified in the National Electric Code, which also mandates requirements for grid-interactive inverters.

Operation

Grid-tie inverters convert DC electrical power into AC power suitable for injecting into the electric utility company grid. The grid tie inverter (GTI) must match the phase of the grid and maintain the output voltage slightly higher than the grid voltage at any instant. A high-quality modern grid-tie inverter has a fixed unity power factor, which means its output voltage and current are perfectly lined up, and its phase angle is within 1 degree of the AC power grid. The inverter has an on-board computer which senses the current

AC grid waveform, and outputs a voltage to correspond with the grid. However, supplying reactive power to the grid might be necessary to keep the voltage in the local grid inside allowed limitations. Otherwise, in a grid segment with considerable power from renewable sources, voltage levels might rise too much at times of high production, i.e. around noon with solar panels.

Grid-tie inverters are also designed to quickly disconnect from the grid if the utility grid goes down. This is an NEC requirement[2] that ensures that in the event of a blackout, the grid tie inverter will shut down to prevent the energy it transfers from harming any line workers who are sent to fix the power grid.

Properly configured, a grid tie inverter enables a home owner to use an alternative power generation system like solar or wind power without extensive rewiring and without batteries. If the alternative power being produced is insufficient, the deficit will be sourced from the electricity grid.

Types

Inside an SWEA 250W transformer-coupled grid-tie inverter

Grid-tie inverters include conventional low-frequency types with transformer coupling, newer high-frequency types, also with transformer coupling, and transformerless types. Instead of converting direct current directly into AC suitable for the grid, high-frequency transformers types use a computer process to convert the power to a high-frequency and then back to DC and then to the final AC output voltage suitable for the grid.[3]

Transformerless inverters, which are popular in Europe, are lighter, smaller, and more efficient than inverters with transformers. But transformerless inverters have been slow to enter the US market because of concerns that transformerless inverters, which do not have galvanic isolation between the DC side and grid, could inject dangerous DC voltages and currents into the grid under fault conditions.[4]

However, since 2005, the NFPA's NEC allows transformerless, or non-galvanically isolated, inverters by removing the requirement that all solar electric systems be negative grounded and specifying new safety requirements. Amendments to VDE 0126-1-1 and IEC 6210 define the design and procedures needed for such systems: primarily, ground current measurement and DC to grid isolation tests.

Datasheets

Manufacturers datasheets for their inverters usually include the following data:

- *Rated output power*: This value is provided in watts or kilowatts. For some inverters, they may provide an output rating for different output voltages. For instance, if the inverter can be configured for either 240 VAC or 208 VAC output, the rated power output may be different for each of those configurations.
- *Output voltage(s)*: This value indicates to which utility voltages the inverter can connect. For smaller inverters that are designed for residential use, the output voltage is usually 240 VAC. Inverters that target commercial applications are rated for 208, 240, 277, 400, 480 or 600 VAC and may also produce three phase power.
- *Peak efficiency*: The peak efficiency represents the highest efficiency that the inverter can achieve. Most grid-tie inverters on the market as of July 2009 have peak efficiencies of over 94%, some as high as 96%. The energy lost during inversion is for the most part converted into heat. Consequently, in order for an inverter to output its rated power it will require a power input that exceeds its output. For example, a 5000 W inverter operating at full power at 95% efficiency will require an input of 5,263 W (rated power divided by efficiency). Inverters that are capable of

producing power at different AC voltages may have different efficiencies associated with each voltage.

- *CEC weighted efficiency*: This efficiency is published by the California Energy Commission on its GoSolar website. In contrast to peak efficiency, this value is an average efficiency and is a better representation of the inverter's operating profile. Inverters that are capable of producing power at different AC voltages may have different efficiencies associated with each voltage.[5]
- *Maximum input current*: This is the maximum amount of direct current that the inverter can use. If a system, solar cells for example, produces a current in excess of the maximum input current, that current is not used by the inverter.
- *Maximum output current*: The maximum output current is the maximum continuous alternating current that the inverter will supply. This value is typically used to determine the minimum current rating of the over-current protection devices (e.g., breakers and fuses) and disconnects required for the output circuit. Inverters that are capable of producing power at different AC voltages will have different maximum outputs for each voltage.
- *Peak power tracking voltage*: This represents the DC voltage range in which the inverter's maximum point power tracker will operate. The system designer must configure the strings optimally so that during the majority of the year, the voltage of the strings will be within this range. This can be a difficult task since voltage will fluctuate with changes in temperature.
- *Start voltage*: This value is not listed on all inverter datasheets. The value indicates the minimum DC voltage that is required in order for the inverter to turn on and begin operation. This is especially important for solar applications, because the system designer must be sure that there is a sufficient number of solar modules wired in series in each string to produce this voltage. If this value is not provided by the manufacturer, system designers typically use the lower band of the peak power tracking voltage range as the inverter's minimum voltage.
- *IPxx rating*: The Ingress Protection rating or IP Code classifies and rates the level of protection provided against the ingress of solid foreign objects (first digit) or water (second digit), a higher digit means greater

protection. In the US the *NEMA enclosure type* is used similarly to the international rating. Most inverters are rated for outdoors installation with IP45 (no dust protection) or IP65 (dust tight), or in the US, NEMA 3R (no windblown dust protection) or NEMA 4X (windblown dust, direct water splash and additional corrosion protection).

See also

- Grid-tied electrical system
- Inverter (electrical)
- Islanding
- Solar inverter
- Stand-alone inverter

References and further reading

1. http://www.osti.gov/bridge/servlets/purl/463622-TtEMSp/webviewable/463622.pdf OSTI
2. NEC Handbook 2005, Section 705, "Interconnected Electric Power Production Sources," Article 705.40 "Loss of Primary Source"
3. Solar Energy International (2006). *Photovoltaics: Design and Installation Manual*, Gabriola Island, BC: New Society Publishers, p. 80.
4. "Summary Report on the DOE High-tech Inverter Workshop" (PDF). *Sponsored by the US Department of Energy, prepared by McNeil Technologies*. eere.energy.gov. Retrieved 2011-06-10.
5. gosolarcalifornia.org, "List of Eligible Inverters" (http://www.gosolarcalifornia.org/equipment/inverter.php), accessed July 30, 2009,

External links

- California List of Eligible Inverters (http://www.gosolarcalifornia.org/equipment/inverters.php) - This is the official California Energy Commission (CEC) list of inverters that are eligible for California's rebate program. Other states use this list as well.

- Grid Tie Inverter Comparison Tool (http://www.solardesigntool.com/compare-inverters.html) - website that allows people to compare the data sheets of various grid-tie inverters. One can also use the website to filter and search inverters by technical data.
- Grid-Tie Wind Inverters Versus Solar Inverters (http://www.dtims.com/whitepapers/gale_versus_solar.pdf) - describes in detail the differences between existing grid tied inverters.

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