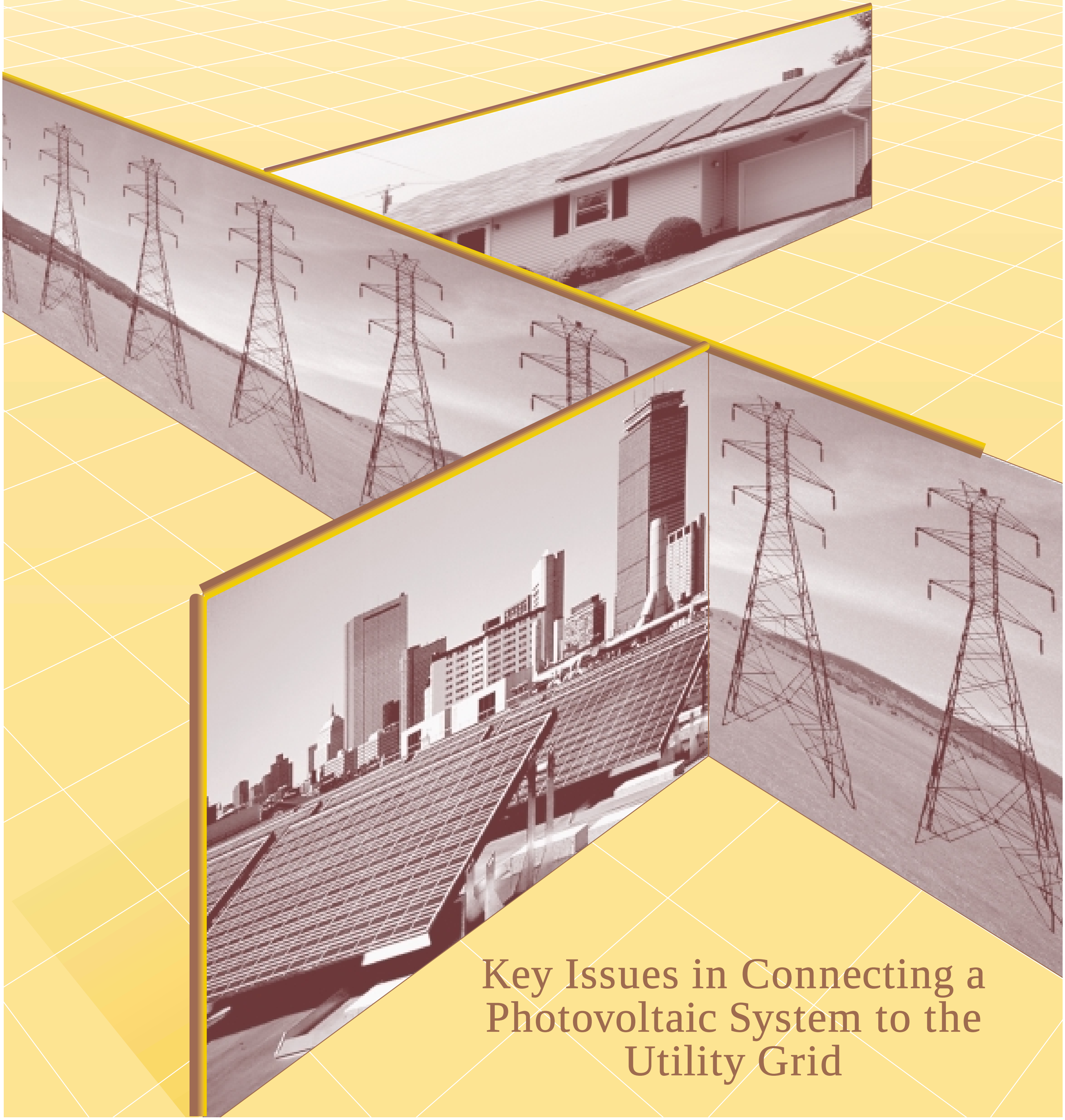
Making the Connection



Key Issues in Connecting a Photovoltaic System to the Utility Grid

We've Come a Long Way

Connecting residential or small commercial photovoltaic (PV) systems to an existing utility grid has come a long way in recent years. Experts within the PV industry have solved many earlier problems, bringing us to the point today where we know how to install, operate, and maintain PV systems safely and conveniently. But governments, communities, and utilities who are not yet familiar with PV systems have legitimate concerns that we must address through education and support.

This brochure will help you understand the issues that surround PV interconnections, whether you are a builder, code expert, utility engineer, regulator, legislator, or private citizen. If not properly addressed, any one of these crucial issues could hinder or halt the installation of a PV system.

As we discuss the relevant issues under the two main categories of code issues and utility issues, remember the bottom line: many former technical obstacles to using PV systems no longer exist, and critical problems raised in the past are being successfully resolved.

Code Issues

Building Codes

Local building authorities rely on nationally developed building codes that delineate required safe-building practices. Building inspectors are concerned with the proper construction of safe buildings. Of primary interest is ensuring that a PV system or structure has been installed correctly. For example, the system must be fastened according to approved design drawings so that it won't cause the roof to leak or be blown off the roof, leading to serious structural damage.

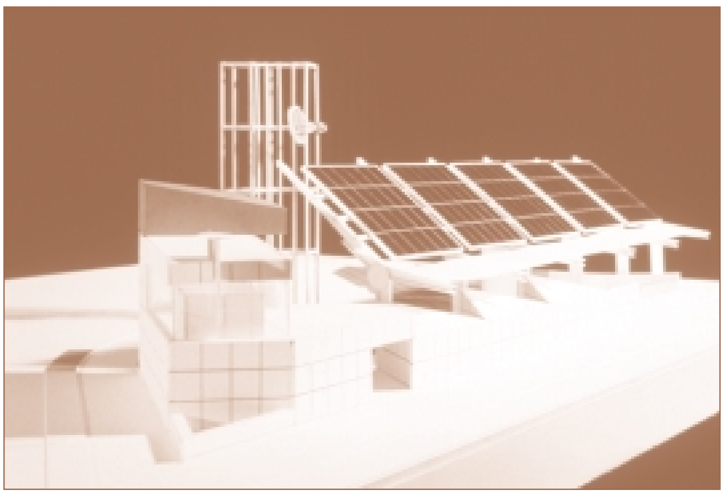
Solutions—The development of innovative building-integrated PV systems that meet building codes has been steady during the last several years. We now see commercial products designed for building systems—such as PV roofing materials and PV curtain wall products—that are included in construction plans. In addition, the mounting of systems on flat roofs has been greatly simplified.

Solar Depot, Inc./PIX04479

Before embarking on a PV installation project, the appropriate code officials should be consulted to ensure compliance with all local codes.

Local Covenants

Some communities may adopt restrictions, primarily for aesthetic reasons, that make it difficult or impossible to install PV modules. If visual aspects are not properly addressed, community representatives are not likely to look favorably on the widespread use of PV within their community. If a community has a particularly restrictive covenant with respect to solar systems, it may be necessary to meet with the covenants board to explain the planned installation and address specific concerns.



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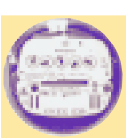
Solutions— Increasingly, U.S. communities are being designed with allowances for solar energy written into the established covenants. The city of Davis, in northern California, is a model community that has pioneered these types of covenants. As more examples of model covenants become widely publicized, the public will be more open to institutionalizing these measures in their communities. Well-prepared materials, such as a sketch of a proposed installation or a photograph of a similar installation, can help allay the concerns of a covenants board.



Electrical Codes

The National Electrical Code (NEC), published by the National Fire Protection Association, is designed to prevent electrical shock and fire hazards associated with electrical systems. Some utility-interconnected PV systems operate at direct-current (dc) voltages exceeding 200 volts before being inverted to standard alternating-current (ac) voltage. Direct-current systems are not as common, and their safe operation requires "dc rated" hardware.

Solutions— In 1984, PV systems achieved the status of a special equipment article in Article 690 of the NEC. Article 690 carefully spells out requirements for making PV systems compliant with the NEC. A guide for recommended practices based on the NEC provides practical information on designing and installing safe, reliable, code-compliant PV systems (see *PV Power Systems, NEC: Suggested Practices*, SAND96-2797). Only within the last few years have fully code-compliant systems been available. However, many systems that comply with the code have operated safely for more than 10 years. PV system installers must understand the Article 690 requirements, and local code authorities unfamiliar with PV systems must be educated.

Representatives from the solar energy industry have actively guided the revisions of NEC Article 690 for many years. The most recent 1999 version will be released in late summer 1998.

Solar Design Associates/PIX04472

The NEC requires that all equipment be listed by a recognized listing agency—for example, Underwriters Laboratories. Several PV inverters are now listed, making it possible to install a fully code-compliant PV system acceptable to most code authorities.

As another example of improved products, the ac PV module is a recent innovation that converts dc power to standard ac before it leaves the module, which eliminates the need for high-voltage dc wiring and allows for PV systems as small as 100 watts.

Utility Issues

Power Quality

Power quality "noise" is any electrical energy that interferes with other electrical appliances operated by the customer and neighbors on the same transformer. The Federal Communications Commission (FCC) is concerned with power-quality noise that affects communications. Utility companies are also concerned because they seek to provide high-quality service to their customers. In particular, utilities care about such issues as harmonic distortion, power factor, and flicker. For a home, power is delivered at 120/240 volts ac at 60 cycles per second. Any electric service not at that rating can interfere with the proper operation of some appliances. A PV inverter that converts dc power from PV modules into usable ac power for a house can also inject noise. If a utility customer's power-quality problem is traced to a PV inverter, the utility can shut down the PV equipment until the issue is resolved.

Solutions—Any electronic appliance, such as a PV inverter, that is FCC Class B compliant means that it has passed the required tests to meet the FCC regulations for high-frequency electronic noise. The Institute of Electrical and Electronic Engineers (IEEE) also has power-quality standards, such as *IEEE 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*. The Underwriters Laboratories standard for listing a PV inverter includes testing for power quality so that listed PV inverters will conform to applicable requirements.

Warren Gretz, NREL/PIX04167

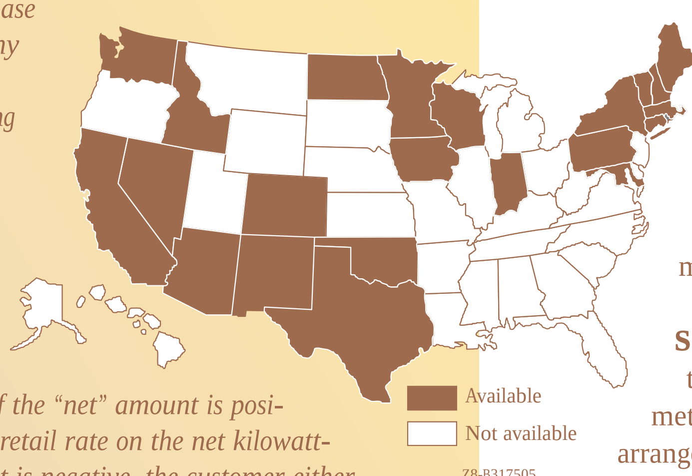
Metering Agreements

Metering agreements directly affect the bottom-line economics of the PV system. For example, special metering and additional metering charges can easily wipe out any economic benefit a small PV system could provide a homeowner. Most utilities require special metering to measure power flowing in both directions—into the house and into the grid. Many utilities impose additional charges on utility-interconnected PV systems, including "standby" charges or higher "minimum monthly" charges. And for the excess electricity generated, utilities normally pay the customer a wholesale rate, rather than the much higher retail rate.

Solutions—Some utilities have established metering and accounting arrangements that make grid-connected PV systems more economical. For example, some states have adopted net-metering policies (see box) that allow utility customers to use their PV generation to offset retail purchases over an entire billing period, or over an entire year. Net metering improves the economics of PV generation by allowing customers to capture the retail value of electricity for most or all of their PV generation. In addition, some utilities offer time-of-day pricing, which results in higher prices during "peak" daytime hours and lower prices during "off-peak" nighttime hours. Time-of-day pricing can provide substantial bill savings to customers with PV systems—by allowing them to reduce their electricity use during peak hours, or in some cases, to sell back any excess electricity they generate at higher

The ABCs of Net Metering

Under federal law, utilities must allow independent power producers to interconnect with the utility grid and must purchase any excess electricity they generate. Many states have gone beyond the minimum requirements of the federal law by allowing "net metering" for customers with PV systems. Where available, the customer is billed only for the "net" electricity purchased from the utility over the entire billing period—that is, the difference between the electricity coming from the utility grid and the electricity generated by the PV system. If the "net" amount is positive, the customer pays the utility at the retail rate on the net kilowatt-hours of energy used. If the "net" amount is negative, the customer either is credited on the next bill for the excess electricity, or is paid for the excess electricity at the wholesale rate.



Dual metering is an alternative, where customers or their utility purchase and install two non-reversing meters that measure electrical flow in each direction. This adds significant expense to installing a PV system. Homeowners pay for all the electricity from the utility at the retail rate—not just the net amount. And the utility only pays them the much lower wholesale rate on the electricity fed back to the utility.

Faced with the alternative between net metering and the traditional dual-metering approach, many states, utility commissions, and utilities have opted for net metering because it is less expensive for all involved. Some opponents believe it imposes financial burdens on utilities or their non-participating customers. Studies have shown that the quantity of PV relative to the size of the utility's revenues is minimal—even without considering reduced costs of meter hardware, interconnection, meter reading, and billing. These studies do not include the issue of peak-shaving capability or the environmental, distribution, and fuel-diversity benefits provided by distributed, small-scale, renewable-energy systems. Nevertheless, to address utility concerns about potential financial burdens, laws limit the number of installations within any single utility service territory. Currently, net metering is available in 23 states to certain customers and technologies—including residential PV system owners.

Oak Ridge National Lab./PIX03205

peak rates. The better the match between the electrical output of the PV system and the time of highest prices, the more effective the system will be in reducing utility bills.

Safety and Reliability

Utilities must ensure the safe and reliable operation of the entire utility grid for employees and the public. Traditionally, utility system safety issues have been the most significant obstacles to installing PV systems. Most utilities have no experience with generating systems smaller than 50 kilowatts, except for small gasoline generators. Because such generators have been a safety concern for linemen nationwide, utilities are understandably wary of small power systems, regardless of type. However, PV inverters are significantly different from small gasoline generators because they have very sophisticated automatic safety controls that rival those used for large generating units.

Solutions—National standards on protection, safety, and operation reliability are now available for utilities and PV system manufacturers. The standards that utilities adopt for safety, reliability, and interconnection usually come from the IEEE. In 1988, IEEE and the American National Standards Institute released *Standard 929-1988, IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic Systems*, which addresses the basic issues of equipment protection, safety, and allowable limits for power quality. For equipment protection and safety, for example, it covers the ranges over which inverters are allowed to operate. With valuable participation by utilities, IEEE 929-1988 is being extensively revised to address utility issues surrounding the safe and reliable interconnection and operation of PV systems. Until the final draft of IEEE 929 is released, the existing IEEE 929-1988 serves as a sound standard for utility interconnection.

How Interconnection Became an Issue

The Public Utilities Regulatory Policy Act of 1978 (PURPA) requires utilities to buy power from owners of PV systems and other independent producers of electricity. An approved, utility-grade inverter converts the dc power from PV modules into ac power. This power must exactly match the voltage and frequency of the electricity flowing in the utility line and meet safety and power-quality requirements. Safety switches in the inverter automatically disconnect the PV system from the line if there is a problem with the utility power, so that utility repair personnel will not be shocked by electricity flowing from the PV array into what they expected to be a "dead" utility line.

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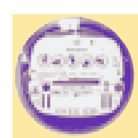

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