A Critical Technology: Interconnecting Distributed Generation to the Grid

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Are current interconnection rules, as utilities often state, simply meeting utilities' needs for protecting the grid and ensuring the safety of linesmen? Or—as independent developers of distributed generation claim—are the rules' anti-competitive measures designed to block the spread of on-site generation? Conflicts of interest appear to be commonplace, and the answer probably depends on one's perspective. But no other issue controls the future of distributed generation like interconnection.

After nearly a century of ever-increasing efficiency derived from ever-larger central generators, it looks as though distributed micro energy sources may become more prevalent. Two good indications are a regulatory landscape that is shifting toward competition and manufacturers' continuing innovations in alternative generation sources. Shifting the "balance of power" to include more distributed generation presents significant transition issues—a central one being how (both technically and from a policy perspective) to interconnect small-scale dispersed generators to the power system, or grid.

All players agree on the importance of guaranteeing the safety of the public and utility personnel, preventing damage to equipment, and maintaining power quality and the grid's reliability in terms of continuity of service. But economic turf issues complicate the matter. As things stand today, utilities, in addition to their historical identity as protectors of the grid, are competitors that may lose market share to distributed generation, should it be interconnected.

The interconnection conundrum will have far-reaching consequences for the future of distributed generation. The economics and case of interconnection will help determine whether distributed generation ends up operating grid-parallel; isolated via an automatic transfer switch; or completely separated from the network of wires, switches, and poles that blankets industrial countries.

The Nuts and Bolts of Interconnection

The grid is a complex web of assorted hardware that includes generators, power lines, substations, transformers, switches and breakers, fuses, and other components including user's loads. Amazingly, this system operates in a synchronous mode—that is, as one single network with all equipment throughout the interconnection rotating in lock-step. If this synchronicity falters, problems arise that threaten the integrity of the entire grid.

Existing interconnection requirements were usually written for (and are more appropriate to) units of at least 100 megawatts. They call for detailed engineering studies, dedicated isolation transformers, ground-fault-current-limiting reactors, and so on—requirements that distributed generators find extremely burdensome. Some utilities go so far as to specify the type of pipe that must be used for conduit and the molecular weight of the control wire insulation.

Today, a distributed generator seeking interconnection with the grid faces a specific installed distribution system with set protection schemes and safety procedures—and with each utility promulgating its own requirements to govern that interconnection. Utilities can expertly connect generators rated in the hundreds of megawatts or greater, but most have little experience with units that produce only a few hundred watts or even a megawatt. In addition, a small distributed generator simply cannot economically support the full array of interconnection devices sprouting from a 1,000-megawatt central station.

The Financial Conundrum

The financial burden for interconnection rests largely with the distributed generator owner, who must pay for any necessary modifications to the grid and must buy equipment, studies, or services (for example, meters, protective relays, and load flow studies) from the utility itself. Frequently, utilities require these payments in advance.

Things aren't necessarily easier for on-site generators when operations finally commence. For example, the New York utility Central Hudson requires generator owners to maintain and present to the utility a log of all generator operations: dates and times it goes on and off line, a record of all relay and breaker operations, and a record of all maintenance protection equipment. This alone could be daunting for the owner of a small automatic photovoltaics or fuel cell system.

Utilities, meanwhile, are concerned not just about individual generators but also about their aggregated impact at a single location or on a single feeder. Specifically, the total uncontrolled fault current coming from a collection of distributed generators is what complicates the existing grid's protection scheme. This is why it is harder to determine if a specific generator can be accommodated at a specific location without adding cost in the form of upgrading the scheme the utility has developed to protect the grid. Yet, when added load is the issue, utilities (and their regulators) deal with this problem all the time. The house most recently added to a distribution feeder isn't charged for a new substation transformer if it pushes the aggregated load over the transformer's limit.

Policies and Laws

Work on two fronts is addressing interconnection. Professional- and standards-writing organizations have tried to modify their standards to account for changes in how electric power markets are evolving. And a growing number of state governments are working to ease interconnection requirements, even before work concludes on updating the voluntary standards (see table).

The Institute of Electrical and Electronics Engineers (IEEE) is the principal professional organization developing interconnection standards. In January 2000 it approved a new standard called 929-2000 that specifically addresses the interconnection of small (less than 10- kilowatt) photovoltaic systems with the utility grid. Although 929-2000 specifically addresses only photovoltaics, the industry and regulators are recognizing that its principles apply to all inverter-based distributed generators. "At the utility interface, energy source is immaterial. P929 [929-2000] can be adopted to any inverter-interconnected distributed resource," says Sandia National Laboratory's John Stevens, a central figure in developing the standard.

Bringing 929-2000 to completion took its working group roughly four years. Working on an accelerated schedule, a newer IEEE group (IEEE Standards Coordinating Committee 21 P 1547) is developing a broader standard for all distributed generation sized less than 10 megawatts. A final draft standard is expected by spring 2001. The committee is pursuing this ambitious schedule in recognition of market forces that resist having to wait longer for what they perceive as more reasonable interconnection requirements.

On the legislative front, state regulators—feeling the pressure from manufacturers, energy service providers, and others—are working to enact statewide mandatory standards for interconnection. In November 1999, for example, after a year-long process, Texas approved a new statewide interconnection standard and process for all distributed generators sized less than 10 megawatts. Other states are also approving new (though more limited) standards or have opened proceedings to develop them.

Given the push by individual states, energy users and manufacturers still might face the prospect of 50 unique state standards. But efforts are also under way at the federal level, including proposals before the U.S. Congress, to establish a national interconnection standard,

The Changing Role of the Grid

The power system of the future and its interconnection characteristics may be dramatically different. Market penetration by distributed generation may be high enough that common costs can be spread over a larger group of users—just as transmission and distribution expenditures are spread among all users today.

In the future, it may be possible to upgrade and expand the distribution system to accommodate normal growth and support distributed generation at little or no added cost. Most importantly, the entire integrated system can probably be reevaluated and redesigned to maximize the benefits (benefits utilities may not recognize) that distributed generation can add to the resource mix, from improving reliability to providing ancillary services.

Might distributed generation be recognized as an asset to system reliability, thus leading to the development of distribution systems designed to work with distributed generation? The new Texas standard includes some requirements of generators that implicitly recognize these benefits. For now, it may be necessary to accept the fact that benefits from distributed generation are reduced because of the way the grid is designed and operated. Designers of future distribution expansion, though, should consider ensuring that the full capabilities of distributed generation are supported.

Selected State Activities in Developing New Interconnection Requirements (October 1999)

Many state governments are not waiting for the professional standards organizations to come up with new guidelines and recommendations. Rather, feeling the pressure applied by manufacturers, energy service providers, and others, state regulators are moving to enact statewide mandatory standards for interconnection.

State	Activities Underway
Arizona	Arizona is starting to address distributed generation interconnection issues. The Arizona Corporate Commission is hosting a series of workshops with utilities, equipment installers, manufacturers, and others.
California	The California Alliance for Distributed Energy Resources Interconnection Committee (INCOM) is developing performance-based requirements for interconnection of distributed generation in California. INCOM is first articulating the safety, protection, and performance requirements each utility currently accepts. It has compiled these from utilities rules, contracts, handbooks, and so on. Although differences exist among utilities requirements, they are still remarkably similar, requiring: detailed studies of each installation, utility review and approval of the distributed generator's design, inspection rights, provision of maintenance and calibration reports to the utility, disconnect switch, and power quality restrictions. It is likely that INCOM's work will prove useful to the California Public Utilities Commission as it is expected to address interconnection standardization as part of its on-going proceeding on distributed generation and competition in distribution services.
Florida	The Florida Public Service Commission started to formally examine the requirements for interconnecting small (less than 10-kW) photovoltaic systems with the grid in the fall of 1999. Florida Power Corporation has asked the commission to use the current draft of IEEE 929 to set requirements for interconnecting a single 10-kW PV installation at the Disney Wilderness Preserve.
Massachusetts	Massachusetts is developing interconnection standards for PV, with IEEE 929 forming the basis. Issues such as requiring a utility-accessible disconnect are contentious.

New Hampshire	New Hampshire is addressing technical and contractual interconnection issues for solar, wind, and hydro systems under 25 kW associated with the state's net metering law. The initial focus is on inverter-based systems under 10 W, and it will likely be based on IEEE 929 and UL 1747. Public Service of New Hampshire recently made its interconnection standard easier by dropping the requirement for an external disconnect and making the contract simpler.
New Mexico	New Mexico has allowed interconnection of small renewable generators for 15 years through Rule 570. Unfortunately the standard interconnection requirements are extremely complex, and few installations have resulted from the rule. The Public Regulation Commission is developing new interconnection standards. One utility has suggested that rules be implemented that are similar to those adopted by California for renewable-based generators up to 10 kW, with a re-evaluation when penetration reaches 0.1 percent of 1998 load.
New York	In 1998, the New York Public Service Commission established technical and non-technical distributed resource interconnection working groups to develop standard interconnection requirements for systems of 300 kV or less on radial feeders. These groups were also charged with developing contracts for "smaller" and "larger" systems. A requirement that is unique to New York is that inverters be type-tested for dynamic performance response to a set of 30 digitized wave forms supplied by the Empire State Electric Energy Research Corporation. Major inverter manufacturers are now testing to this standard. The direction in New York has not pleased everyone. For example, the Distributed Power Coalition of America, in its comments to the January 28, 1999, draft, stated that "the document flies in the face of the Commission's expressed intent to standardize the process of interconnection."
North Carolina	North Carolina is addressing simplified interconnection requirements for small PV systems through workshops with utilities, manufacturers, and users. IEEE 929 and UL 1741 are being discussed as the basis for the requirements.
Ohio	The Ohio state legislature passed a comprehensive restructuring bill for the state's electric power industry in June 1999, and it was signed into law in July. The law establishes a net metering provision for customer-owned generators (specifically solar, wind, biomass, landfill gas, hydro, microturbines, and fuel cells). For interconnection, it requires that net metering installations meet the standards established by the National Electrical Code, the Institute of Electrical and Electronics Engineers, and Underwriters Laboratories. Any additional requirements, such as complying with additional safety or performance standards, performing or paying for additional tests, or purchasing additional liability insurance, is prohibited. However, the Public Utility Commission of Ohio can order additional rules on interconnection.

Oregon	In 1999, the state legislature approved a net metering law that limits utility control over interconnection requirements for approved customer-based technologies (specifically solar, wind, fuel cells, and hydro). Facilities that comply with applicable IEEE, UL, and NEC requirements will not be required to meet any additional interconnection requirements.
Rhode Island	In 1998, the state's utilities created a one-page interconnection contract for small-scale photovoltaic systems that greatly simplifies the process of obtaining intertie approval for pre-approved systems. No other activities are under way regarding interconnection of small-scale distributed generation technologies.
Vermont	In April 1998, the state legislature passed a net metering law that required the Public Service Board to adopt interconnection standards for renewables-based customers up to 15 kW and farms up to 100 kW. The final rule for systems up to 15 kW was adopted in April 1999; the rule for systems up to 100 kW is still being considered, though it is near completion. The rule makes use of IEEE 929, UL 1741, and existing standards. Sample requirements: • Harmonics, voltage flicker, and steady-state voltages are limited by existing standards IEEE 519-1992 and ANSI C84.1-1995. • A utility-accessible, lockable, load-break rated, visible-break disconnect switch is required. Inverters should be UL-listed and installed according to NEC requirements. • Anti-islanding functionality is required per IEEE 929 and must be tested every two years. • Detailed studies are not required unless the distributed generator pushes the aggregate distributed generation capacity on the feeder above 10 percent of the feeder capacity at the substation or 20 percent of the capacity downstream. Specific requirements are provided for synchronous generators, induction generators, and inverters.

Source: E SOURCE

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Nick is co-author of the 1994 book *Power Surge: Guide to the Coming Energy Revolution,* which postulates a future energy economy that operates primarily on modular, distributed energy technologies. Nick earned a BA *cum laude* in Geography with high distinction from Dartmouth College.

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