Carnegie Mellon Electricity Industry Center

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Guidance for Drafting State Legislation to Facilitate the Growth of Independent Electric Power Micro-Grids

Motivation

A variety of small-scale electric generation technologies are now available. Many of these can operate as combined heat and electric power (CHP) systems that achieve much higher overall end-use energy efficiencies than conventional systems. In addition, solid state power electronics and advanced computer control technology make it possible to condition and control the local use of electric power, and interconnections to the distribution system, in ways that had previously not been possible.

Today it is technically possible, and sometimes economically attractive, for small "micro-grid" companies to establish local distribution systems underneath the traditional (or "legacy") electric power distribution system. These micro-grids would serve small groups of customers and could provide special services and needs, such as increased reliability and power quality.[1] Some micro-grids might still purchase a portion of their power from the traditional power system. Most would rely on the traditional system for backup power. Some might occasionally make modest amounts of power available for sale via the distribution system.

As Morgan and Zerriffi (2002) recently reported, laws that grant traditional utilities exclusive service territories prohibit, or seriously inhibit, the growth of micro-grid markets in many states. We believe that new legislation that would permit the development of independent micro-grids should be passed in states where such systems are not now allowed, or where present laws and regulation discourage their development. It is our belief that such enabling legislation could unleash a wave of technological and business innovations similar to what occurred in telecommunications after the 1968 Carterphone Decision allowed customers to attach non-Bell devices such as phones, answering machines, fax machines, and modems to the public telephone system.

A micro-grid system may provide a variety of benefits, both to its customers and to the legacy distribution utility,[2] its customers, and society more generally. These benefits include:

- reducing the need for new generation capacity;
- relieving stressed distribution feeders;
- obviating the need for some transmission and distribution system expansion;
- providing distribution system support and backup power when the legacy distribution system is stressed or experiences failures;
- competing with the legacy utility, and other distributed power options, consequently driving innovation and lowering costs;
- providing special services such as DC power, and clean or highly reliable power; and
- stimulating an equipment and services market for small-scale generation; technologies for power conditioning and control; local power architectures; and demand-side management equipment and services.

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[1] Other examples of such special services include ultra-high reliability, AC power with very low noise and harmonic content, or DC power for electronic systems.

[2] We use the term "distribution utility" to cover investor owned, co-op and municipal systems.

At the same time, micro-grids may impose costs upon a legacy distribution utility and its customers. Possible costs include:

- reducing the customer base over which current distribution system capital investments, and various regional transmission system charges, can be spread;
- contributing to planning ambiguity for transmission and distribution capacity expansion (in much the same way as IPPs and other non-utility competitive players contribute to such ambiguity);
- requiring distribution system upgrades;
- providing standby power (although this will be limited by the magnitude of the micro-grids interconnection to the legacy utility, and the fact that micro-grids with multiple generators are unlikely to loose all of their generating capacity at once);
- adversely impacting the system's load profile;
- complicating distribution system fault protection and emergency repairs; and
- adding strain on the natural gas distribution system.

Not every micro-grid will impose these costs or provide these benefits. Many costs, such as those associated with standby or peak loads, can be readily dealt with through appropriate demand charges and peak load tariffs as they are for other customers. Some of the benefits may require that the distribution utility adopt modern flexible control systems and distribution automation. In the discussion that follows, we suggest policies designed to minimize these costs while realizing the benefits.

Definition of an Electric Power Micro-grid

State law should specify the minimum characteristics that a system must have in order to be classified as an electric power micro-grid. These should include:

- more than one legally distinct entity served with electric power; and
- one or more independent sources of electric power generation and/or storage.

In addition, states may wish to limit the size of micro-grid systems by specifying:

- the maximum installed generating capacity that a micro-grid can have; and/or,
- the maximum number of customers that a micro-grid system can serve.

The first two characteristics are important to distinguish micro-grids from small-distributed generation (DG) installations that serve a single customer. While interconnection to the distribution system continues to present barriers, such small DG installations are now possible in most jurisdictions. Micro-grids should also not be confused with small-scale independent power producers (IPPs). Small IPPs are in the business of making electricity to sell to others over the distribution and transmission systems. In contrast, micro-grids are in the business of serving a small number of local customers with electricity, probably heat, and possibly cooling. They may also purchase power from the distribution utility, or sell a fraction of the power they make over the distribution system, but such transactions are not the primary focus of their business.

Some limit should be set on installed generating capacity, and/or the number of customers served, since otherwise micro-grids could grow into conventional distribution companies. Most states will probably want to preserve the natural monopoly of distribution companies and avoid multiple wires serving the same geographic region.

One way to think about setting a capacity limit is to think in terms of typical loads that a micro-grid may serve. The peak load of a residential home is typically between 10 and 30 kW_e. Peak loads for typical shopping centers range from 2 to 8 MW_e. Typical mid-sized office buildings have peak loads that range from 6 to 20 MW_e.[3,4] We recommend that the maximum capacity level for a micro-grid be set somewhere between 20 and 40 MW_e.

States that wish to develop their micro-grid markets slowly might start with a lower threshold, and then later consider increasing the capacity limit once they have gained some experience.[5] Note, however, that placing a capacity limit that is too low may make micro-grid operations less economically attractive

[3]These estimates are based on calculations done using the 1999 HVAC ASHRAE Applications Handbook.

[4]The Public Utility Regulatory Policy Act of 1972 specified that independent electricity generators selling to the grid cannot exceed an installed capacity of 60 MW.

[5]Such a conditional option for future growth could be included in the initial legislation.

and prevent the development of any micro-grid market. Strachan (2000) shows that engine cogen units installed in the UK and the Netherlands during the 1990's experienced significant economies of scale.

Eight 800-kW Caterpillar engines supply power to a plastics plant in Illinois. Design and photo by LaSalle Associates.

In the early stages of micro-grid development, a customer limit could be set to provide legacy utilities with some measure of stability. Likewise, a limit would ensure that any technical difficulties would affect only a small customer base. However, if a capacity limit is established, it may not be necessary to add a customer limit. States that wish to specify both a capacity and customer limit could think in terms of the maximum size of a residential subdivision that they believe a micro-grid should be allowed to serve. An upper limit of between 100 and 200 customers would be reasonable. If these were all residential customers, their peak load would be well under our recommended capacity limit.

State law should not specify the number or type of generators that a micro-grid system can contain because such a restriction would constrain technical innovation and might prevent the micro-grid market from developing.

Legal Authorization of Micro-Grids

New enabling legislation should allow micro-grid firms to be structured either as:

- co-ops serving their members, or
- for-profit firms.

In many states, such authorization will require a modification of existing state laws that grant exclusive service rights to legacy utilities.

Micro-grid firms should be free to contract fee and service arrangements with their customers without approval by the state Public Utility Commission (PUC/PSC).

Some states might also wish to impose certain consumer protection requirements on micro-grid firms. This possibility is discussed in a later section.

Tariffs Arrangements between Micro-Grids and the Legacy Utility

Virtually all U.S. distribution systems continue to be operated as regulated utilities. In some states, electricity supply has been deregulated and is now provided through a competitive market. In many states, supply remains regulated and operates along with transmission and distribution in a vertically integrated regulated utility. Thus, in considering tariff arrangements between micro-grids and legacy utilities, we must differentiate between states in which supply has, and has not, been restructured.

Guidance for states that have not restructured generation

In these states, state law should require that the PUC/PSC develop a tariff that governs the sales of power[6] and other services between micro-grids and the legacy distribution utility. We recommend that different tariffs be developed for small and large micro-grid systems.

Micro-grids smaller than some *de minimus* size (we suggest between 0.5 and 1 MW) should be served under a standard commercial tariff. Such tariffs typically include both time-of-day and capacity charges. Power sales to the utility from such small micro-grids should be covered under the standard tariff for sales by small independent generators.

A special symmetric tariff governing bilateral transactions between large micro-grid systems and the legacy distribution utility should be developed by the PUC/PSC. The enabling legislation should direct the PUC/PSC to consider both the benefits that could

[6]Here, and in subsequent discussions of rates, the word "power" refers to both real power, and when relevant, to reactive power.

be provided to the state's electric power system by micro-grids and the costs that such systems may impose on legacy distribution systems and their customers. Many of these benefits and costs, such as increased distribution system reliability and the possible need to supply standby power, are listed in the introduction to this document.

As noted in the introduction, one potential benefit that micro-grids could provide to traditional distribution system customers is much higher levels of electric power reliability. However, to achieve such increased reliability, legacy utilities must install more advanced distribution system automation and control than many now use. In developing tariffs, micro-grid firms should not be penalized if the legacy distribution utility chooses not to install such systems, and thus forego these benefits.

One important issue that will arise in the development of a special symmetric tariff governing bilateral transactions between large micro-grid systems and the legacy distribution utility is that of location specificity. Micro-grids located in some places could prove highly beneficial to the operation of the legacy distribution system by relieving congestion and providing needed system support. Location in other places could impose costs on the distribution system.

We believe that the basic tariff should *not* be made location specific because over time the result of a series of location specific tariffs could grow into a path-dependent tangle of different rates. Instead, we recommend a fixed set of basic rates to which both parties must adhere in the absence of any other agreements.[7]

We recommend that there be flexibility to allow micro-grid operators and the legacy utility to reach contractual agreements that supercede the basic rates set by the PUC/PSC. In this way, the legacy utility could provide incentives for private micro-grid firms to locate in places that would provide maximum benefit to the operation of the distribution system. Such special contractual agreements should be filed publicly with the PUC/PSC. In order to minimize red tape, distribution utilities should be authorized to reach such agreements with micro-grid firms without PUC/PSC review so long as the size of the tariff reduction does not exceed some maximum (e.g., a 20% reduction). However, to reduce the risk of abuse, larger proposed reductions should be subject to PUC/PSC review and approval. To avoid long-term "path-dependent" inequities all special tariff agreements should be set for a specified fixed term, not to exceed 20 years, although subsequent renegotiation and extension of special tariffs should be allowed.

In states that have not restructured, legacy utilities should not be allowed to enter the competitive micro-grid market. However, there is no reason they should be precluded from installing and using distributed resources on their own system, including on customers' premises.

Guidance for states that have restructured generation

In states that have restructured, a micro-grid firm should be able to buy additional power it may need from power suppliers in the wholesale market. If there is an operating spot market, a micro-grid firm should be able to buy and sell power in that market. If the nature of its interconnection makes it relevant, it should also be allowed to participate in ancillary services markets.

Micro-grid firms should be able to enter into longer-term contracts to buy or sell power if those markets exist. In such circumstances, no PUC/PSC energy tariff arrangements would be required. There would be a need for PUC/PSC approved tariffs to cover distribution system use, including exchanges between several different micro-grids on the same distribution feeder. Tariffs imposed upon micro-grids smaller than the *de minimus* size should be exactly the same as for any small commercial customer. For larger micro-grids, a special symmetric distribution system tariff may be needed depending upon the state's existing distribution system tariff schedules. If such a special symmetric tariff is created, it should be based on considerations similar to those outlined in the previous section.

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[7]There is currently considerable discussion of implementing locational marginal pricing in transmission systems. Should such schemes become common, and be extended to the distribution level, then, of course, these arguments would change. However, we believe that such a development is too far in the future to be considered in micro-grid legislation today.

States that have restructured generation markets may wish to consider allowing legacy distribution utilities to enter the market for customer-side distributed resources, including micro-grids. In the Netherlands, when distribution entities that had divested their large generation were allowed to install and operate distributed resources, the result was a substantial increase in the market penetration of these systems (Strachan, 2000). If a state decides to allow its legacy distribution companies to enter such markets, they should do so through an appropriately separate unregulated subsidiary.

Guidance that applies to all states

In order to allow the legacy distribution utility to perform adequate system planning, state law should require that micro-grid firms give advance notice to the legacy utility and the PUC/PSC of their intent to make an installation. We recommend a notification time of between 6 and 9 months. If the warning time were shorter, utilities would not have enough time to adjust operational plans. If it were longer, the notification requirement could significantly inhibit the growth of micro-grid markets. Notice should include the capacity, location, number of customers expected on the micro-grid, and an estimate of the power sale and purchase transactions anticipated with, or through, the legacy distribution system. This should include a discussion of the demands on the distribution system associate with scheduled micro-grid maintenance and plausible unscheduled micro-grid outages.[8]

Many states impose small public benefits charges on electric power sales in order to provide funding for a variety of programs such as financial support for low-income customers, research and development, and renewable energy and energy-efficiency initiatives. This fee is usually collected by electricity distribution companies and deposited into a statewide public benefits trust. We recommend that state legislation require that micro-grid firms be required to pay public benefit fees to the state public benefits trust at the same rate per kWh for energy supplied to their customers as applies to other power companies operating in the state. This will require that micro-grid companies submit consumption data to the PUC/PSC, and set up a payment method with the public trust holder. Micro-grid systems and their customers should be eligible to receive benefits from public benefit funds on an equitable basis.

Interconnection and Power Quality Standards

One of the primary obstacles to the development of small independent power producers has been regulatory and bureaucratic impediments that have prevented or slowed interconnection with legacy distribution companies, or made such interconnection so expensive as to be infeasible. Many examples of such problems have been documented by Alderfer et al. (2000). Micro-grids face the same set of impediments.

Clearly there must be standards governing interconnection in order to assure safe and reliable operation. At the same time, innovative technology and flexible engineering solutions can drastically reduce the cost and difficulty of such interconnection. The Institute of Electrical and Electronics Engineers (IEEE), Underwriters Laboratory (UL), and the National Fire Protection Association (NFPA) all have published or are drafting standards that pertain to grid interconnection safety issues.[9]

The recently promulgated IEEE standard for interconnection (IEEE P1547) includes a provision that distributed resources must disconnect from the distribution system within two seconds after a distribution system power outage occurs, so as to avoid the formation of unintentional isolated energized "islands." One of the principal motivations for imposing this requirement is to ensure that linemen performing repair work on distribution feeders are not exposed to energized systems during outages. The ability of the micro-grid to disconnect from the utility is also important to protect against large fault currents.

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[8]Since the micro-grid will typically include several generators, it is unlikely that its entire load would ever have to be served by the distribution system, and the maximum size of the load that could be imposed on the distribution system could be regulated both physically and via tariff.

[9]UL Standard 1741 is designed to ensure that the equipment used in power systems (e.g., inverters, converters) minimize the risk of fire or electric shock or injury. NFPA's National Electric Code sets national standards to minimize the risk of fire from electrical equipment not used in power systems (e.g., conductors in buildings).

Unfortunately, in its present form, this specification is not compatible with some of the key benefits that micro-grids can bring to provide improved security and reliability to distribution systems (Zerriffi et al., 2003). The IEEE plans to update the standard at some time in the future. If legislators or regulators choose to adopt the IEEE standard in its current form as the default standard governing interconnection, they should augment the emergency disconnection portion of the standard for cases in which the legacy utility has installed intelligent distributed control. In such cases, the standard should specify that when a fault occurs in the distribution system, and distributed resources such as micro-grids are not threatened by large fault currents, they should electronically query the distribution system to ask whether they should stay connected, in order to supply limited service to nearby customers or disconnect for safety or other reasons. The default option should be disconnection, especially if there is a risk of large fault currents.

Historically, many legacy utilities have sought to discourage the development of distributed generation technologies by "gold plating" interconnection standards, thus unnecessarily raising the costs of distributed resources. One approach that a legislature might use to mitigate this market barrier is to require that PUC/PSCs establish approved specifications and rates for interconnection under which the utility would be required to cover half the cost of the interconnection. This would provide both parties with an incentive to minimize costs, subject to the necessary constraints of safe and secure operation. Such an approach is reasonable because the micro-grid can provide benefits to the utility, and utilities routinely support the entire cost of transformers and other devices necessary to serve conventional customers.

Tariffs or interconnection standards for micro-grid systems should specify minimum power quality supplied by and to the micro-grid. IEEE P1547 requires that the interconnection system be both designed and tested to meet the power quality requirements. This standard only imposes requirements on the distributed supplier (e.g., micro-grid). In keeping with the arguments advanced above, we believe that any power quality requirements (and any associated penalties) in tariffs or interconnection standards should apply equally to both legacy utilities and micro-grid firms.

Consumer Protection Issues

While state contract and consumer protection laws should be adequate to cover competitive micro-grid firms, some states may wish to impose a set of additional requirements on such firms.

An example of such requirements is provided by Michigan's Customer Choice and Electricity Reliability Act of 2000 (Public Act 141).[10] Section 10a (2) of the Act requires:

"The Public Service Commission of Michigan establish licensing procedures for all alternative electric suppliers. To ensure adequate service to customers in this state, the commission shall require that an alternative electric supplier maintain an office within Michigan, shall assure that an alternative electric supplier has the necessary financial, managerial, and technical capabilities, shall require that an alternative electric supplier maintain records which the commission considers necessary and shall ensure an alternative electric suppliers accessibility to the commission, to consumers and to electric utilities in this state."

In June 2000, the Michigan PSC specified in detail what such "licensing procedures" should entail.[11] Among the requirements, electric suppliers must demonstrate: the products and services it will provide; billing and customers dispute methods; a line of credit; a mechanism for collecting State fees and taxes; a method for meeting minimum electric quality standards; and a method for providing data (consumption, reliability, etc.) to customers and the State.

Some states might wish to impose specific insurance and liability standards on micro-grids. Some may also wish to impose requirements that micro-grid firms provide "escape clauses" in their contracts that would allow customers to return to service provided

[10]The Act is available on line at the Michigan Public Service Commission website: http://www.cis.state.mi.us/mpsc/electric/restruct/pa141.htm, as of July 21, 2003.

[11]Details on this ruling are available on line at the Michigan Public Service Commission website: www.cis.state.mi.us/mpsc/orders/electric/2000/u-11915.pdf, as of July 21, 2003.

A 30-kW microturbine provides heat and power for a municipal building in Durham, England. Photo courtesy of Capstone Microturbines.

by the legacy distribution utility. However, some states may not view such a requirement as necessary, relying upon normal state commercial and contract law to handle such issues.

Environmental Considerations

Electricity generation by micro-grids may[12] impose environmental loading as a result of the burning of fossil fuels (Strachan and Farrell, 2002). In a few cases, micro-grids may also impose externalities such as noise or objectionable aesthetics (wires, smoke, etc.).

In most cases, local zoning ordinances and state air pollution laws should be sufficient to address these issues. Since micro-grids will often displace boilers and other conventional heating equipment (particularly when used in CHP applications), it is reasonable to expect micro-grid generators to meet the same emissions requirements as conventional heating systems. For example, environmental permits are typically only required for natural gas combustion units with a heat output of more than 10 MBTU.[13] Using typical efficiencies of 30-40%, this translates into roughly 1 MW_e of power output. That means that small, clean-burning micro-grids would not require special permitting and would be treated like boilers or furnaces. Larger plants would be subject to standard state and federal air pollution requirements and permitting procedures.

Micro-grids that include CHP capabilities can provide considerable environmental benefits, because they result in greatly increased overall energy use efficiencies (through the use of "waste" heat and reduced transmission and distribution losses). In many cases, they will also burn cleaner fuel than central station plants. If a state decides to consider imposing additional environmental regulations on micro-grid generators, these possible benefits should be carefully considered, since in some cases, micro-grids that replace conventional systems may be able to improve air quality and public health.

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[12]We say "may" because some micro-grids may rely on renewable energy sources.

[13]These specific numbers are those used by the Pennsylvania Department of Environmental Protection. We have confirmed that similar numbers apply in other states including Ohio, Oregon and New York.

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