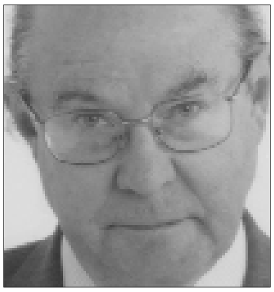

## WALT PATTERSON • PERSPECTIVE

The very existence of old, one-way, radial electricity networks is an obstacle to the development of more efficient, distributed generation. Existing networks need to be reconfigured quite radically in order to unlock the many benefits of decentralized energy – an alternative place to start is in countries without a 'legacy' electricity network. In both cases, it is up to governments and regulators to encourage the growth of distributed generation, argues Walt Patterson.

# Decentralizing networks

What is so special about decentralized energy? Nature isn't centralized. Natural energy is everywhere, in sunlight, wind, water, plants and animals. It runs the planet. We take all that decentralized energy pretty much for granted. What we notice is the centralized energy we ourselves distribute. We extract coal, oil and natural gas from concentrated central sources – coal seams, oilfields and gasfields. We then move it from place to place – distribute it – in mobile transport such as ships, trains and trucks, and in infrastructure networks such as pipelines. We use energy from fuel where and when we wish, converting it into more useful forms such as heat, light, sound, and kinetic energy of movement. We likewise gather, convert and distribute some natural energy flows, notably those of water, wind and sunlight. To distribute both fuel and natural energy flows we also convert them into one particularly versatile form of energy: electricity.

Like natural gas, electricity requires an infrastructure network. Unlike natural gas, however, electricity is not a physical substance, not a fuel nor a commodity. Electricity is different. It is a process, happening simultaneously throughout the whole system infrastructure – generators, network and loads. Indeed without the infrastructure electricity does not even exist. We don't actually want electricity itself. But we can convert it in turn into all the forms of useful energy, easily, cleanly and conveniently. Furthermore, we can generate electricity anywhere, over a vast range of scales, from watch batteries to turbo-alternators, in almost any quantity from imperceptible to overwhelming; and we do.

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### CENTRALIZED GENERATION, DISTRIBUTED LOADS

We pay, however, particular attention to one form of electricity, in which large central stations generate synchronized alternating current and send it out to users over a network that includes long, high-voltage transmission lines. Since the 1880s, electricity systems based on this common technical model have spread all over the world, bringing electric light, motive power and other benefits on which modern society now depends. Large-scale centralized generation of electricity has become so important, and so dominates our thinking, that we have long tended to discount the many alternative forms of electricity generation that are smaller in scale and less centralized.

In recent years, however, these forms of generation have become harder to overlook. Based, for instance, on wind turbines, micro hydro, diesel engines, gas engines, Stirling engines, microturbines, fuel cells and solar photovoltaics, they tend to come in unit sizes much smaller than central station generators, usually less than 5 MW. Since individual units or clusters of units may be widely dispersed across an electricity system, rather than being centralized, these technologies have come to be called ‘distributed generation’, a key form of decentralized energy.

Although traditional electricity generation is centralized, the loads that use the electricity, such as lamps, motors, heaters, chillers and electronics, have always been widely distributed and dispersed. Except for the very largest loads, such as pot lines in aluminium smelters, loads are much smaller than central station generators, usually by many orders of magnitude. This mismatch in scale between generation and loads requires the network to divide up the large output of a generator into flows appropriate to the loads – that is, to distribute the electricity. Alternatively, of course, generation itself could be distributed, closer to loads in both location and scale.

**Although traditional generation is centralized, the loads using the electricity have always been widely dispersed**

The reason why it is not is historical, and overdue for reassessment. In the early decades of electricity, generating technologies were based on water power and steam power. The economies of unit scale of steam engines and turbines, water turbines and alternators meant that a bigger generator produced cheaper electricity. That was the premise on which Edison and his competitors set up the first central station systems. The savings on investment in larger generators more than made up for the extra investment in the necessary network. In the subsequent century this premise continued to prevail, up to generators of gigantic size and networks to match, entailing likewise gigantic investments. The investments were possible because the monopoly franchise made captive customers carry the risks which, by the 1980s, sometimes proved equally gigantic. Nevertheless the arrangement made electric light and other electric services available and affordable over much of the world.

It was so successful that, by the end of the 1980s, free-market enthusiasts decided that electricity, too, was a commodity that should be bought and sold in a marketplace. In a rapidly expanding list of countries they abolished the monopoly franchise, broke up traditional integrated systems, separated generation from networks and made generators compete to sell their output to users. One of the many unexpected consequences of this ‘electricity liberalization’ was to make distributed generation look distinctly more promising. Introducing competition made investment in traditional large-scale generation much riskier; and abolishing the monopoly franchise transferred the risk of investment from captive electricity users to skittish shareholders and bankers.

At the same time, technical innovation widened the range of generating options. Cheap and abundant natural gas made gas turbine generation the new favourite, breaking at last with the long presumption that a better power station was always a bigger one farther away. Gas turbine generation could be at once cheaper, cleaner, more efficient and closer to users. Other, yet smaller generating technologies, some likewise fuelled by natural gas and others based on renewable energy, also began to attract attention. Compared with traditional generation, they were easier to site, quicker to build and commission, and much cleaner. But they still faced problems.

## ONE-WAY, RADIAL NETWORKS

Some arose from existing networks. Traditional electricity regards the network as a ‘natural monopoly’. Natural or not, it has long been a political monopoly almost everywhere. Its essential configuration is radial, from the centre outward. One-way flows carry electricity from large-scale remote central generation along high-voltage transmission and lower-voltage distribution lines to dispersed users. This radial, one-way configuration is less appropriate, however, for distributed generation, which is smaller and closer to users, often most usefully connected at lower voltages. Distributed generation has more in common in scale and in attributes with loads than it has with centralized generation – connecting a 500 kW microturbine has much the same effect on the system as disconnecting a 500 kW motor. But generation connected at low voltage may cause current to flow in the opposite direction through the neighbouring circuits, confusing protective devices and potentially endangering maintenance staff.

**Connecting a 500 kW microturbine has much the same effect on the system as disconnecting a 500 kW motor**

On the other hand, such local generation may provide voltage support and reduce the need to reinforce the network itself. Such trade-offs are now under intensive consideration by electrical engineers and system planners. The ideal arrangement would be technical protocols such as those for loads. A local generator complying with the protocol could then be connected just as loads already are, effectively by plugging it in and turning it on. But such convenient arrangements are still mostly under negotiation in Europe, North America and elsewhere. One point of dispute is the usual one: who is to pay for the requisite reconfiguration of networks?

Before liberalization, network investment and running cost tended to be aggregated with those of generation, and paid for by the aggregate revenue from users, as mediated by government or regulator. After liberalization, governments and regulators expected the network to function also as a market place, linking sellers and buyers of electricity. In other respects, however, it was expected to operate as before, and with the same configuration. In the new market framework, the regulator would impose charges for using the network to carry electricity between buyers and sellers. In effect, despite liberalization, the network would continue to be a regulated monopoly.

In practice, despite the rhetoric of free market enthusiasts, close to half the price of a unit of electricity was thus determined not by a market but by fiat. It still is.

Some policy people nevertheless cite the purported cost of a unit of electricity from different generating technologies, often stated in fractions of a penny per unit, to claim, for instance, that large-scale, remote, fossil-fired generation is 'cheaper' than smaller-scale renewable or cogeneration closer to loads. With no qualification as to the accounting or financial framework, tax treatment, subsidies, risks, system and network effects or other essentials, such cost comparisons are meaningless. They should have no influence whatever on policy. Policy determines costs – not the other way round.

## ELECTRICITY IS NOT A COMMODITY

This further underlines a crucial point about electricity. You can generate electricity without fuel, but not without infrastructure. Electricity depends absolutely on an infrastructure of physical assets. However, by treating electricity as a commodity, the 'electricity market' makes the price of an ephemeral unit of electricity the determinant of all the financial relationships involved, including – crucially – investment. The revenue paid to a generator depends on the number of units sold and the price per unit. That in turn depends on whether the generator can connect to the system – be 'dispatched' by the network operator.

For distributed generation of many kinds this is a serious constraint. A wind turbine generates when the wind is blowing, not when a dispatcher invites it to. A cogenerator responds to requirement for heat, not for electricity. Distributed generators are penalized for not being dispatched. But no fundamental law of electricity says that distributed loads should always be independent, while distributed generators, often of much the same size, have to respond accordingly. The problem of network stability arises not because a wind turbine or cogenerator fails to deliver a few megawatts; what triggers instability and causes blackouts is much more likely to be the abrupt loss of a traditional 500 MW unit, or of the network circuit carrying its output. Replacing centralized with diverse and dispersed distributed generation on a system enhances rather than undermines its stability. Far from being penalized, distributed generators ought to be paid extra for the stability insurance they provide.

For these and other reasons, including environmental issues, planners and policymakers in both OECD and non-OECD countries are at last paying much closer attention to the potential for decentralized energy technologies such as distributed generation. In particular, they have begun to re-examine the interactions between distributed generation and electricity networks. Their efforts to date are undoubtedly helping to foster the expansion of distributed generation; but they have yet to overcome a key problem. Existing networks, their configuration and mode of operation, came into being as a necessary complement to central station generation. If we were starting now to establish an electricity system based, not on central generation but on distributed generation, it would require a very different network – different in configuration, function and operation.

**Rather than being penalized, distributed generators ought to be paid extra for the stability insurance they provide**

## 'LEGACY' NETWORKS AND AVOIDING CONSTRAINTS

Consider two situations – one with and one without an existing traditional network. Remember that traditional electricity, for all its historical success, has failed to reach two billion people – one third of humanity. It may even be losing ground, as population outstrips expansion of traditional systems. Much of the world is indeed still waiting to establish electricity systems. The contrast between the two situations is straightforward. An existing network represents what has come to be called 'legacy' technology, already in place and operating. Any change will be constrained by the need to keep the system operating through the change, to keep the lights on. It also implies legacy institutions and a legacy mindset, committed to a certain way of thinking, acting and interacting – assuming, for instance, the primacy of centralized electricity.

Where no network now exists, these constraints are absent. These parts of the world, however, usually have either limited competence or a tendency to aspire to the traditional central-station model, even when a decentralized alternative might be more effective. Moreover, because electricity infrastructure represents major investment and employment, it also brings with it significant political power, a potent centralizing factor.

In both situations, therefore, realizing the potential of decentralized energy will require positive policy measures to overcome these obstacles. Consider, first, an OECD country with a highly developed existing network. Why might it benefit from more decentralized energy, and what measures would foster this? In recent years one issue above all has come to dominate electricity thinking in OECD countries – that of reliability. Spectacular blackouts in wealthy neighbourhoods grab attention. People demand that something be done, and that governments do it. But people and governments alike have yet to realize that a traditional, synchronized AC electricity system is, in effect, a single giant machine, extending perhaps for thousands of kilometres. It is operating in real time; and like any other machine it can also shut down in real time.

The possibility is inherent in the configuration and operation of a centralized system; and no amount of hand-wringing can change this. The obvious remedy is therefore to loosen the centralization, to reduce the interaction between widespread parts of the system; and distributed generation is the key.

## GOVERNMENTS AND REGULATORS

Those with sensitive loads are already making the initial moves, to gain control of their own electricity and to keep their own lights on. But governments and regulators can accelerate the process. Governments can recognize that electricity is an infrastructure issue. Their most appropriate tax leverage is tax treatment of system assets – not only generation and networks but also, and most importantly, loads. Favourable tax treatment for integrated, optimized local systems, possibly including cogeneration, would give a powerful boost to the requisite reconfiguration. Government procurement for its own buildings and other facilities can set an example. That would also prime the pump for energy service companies able to deliver the complete package – installing, operating and maintaining local systems on the basis of contracts for services.

**Localities still eager for electricity services can establish decentralized systems even more rapidly and effectively**

Regulators can recognize that the radial, one-way configuration of networks must evolve, into a meshed, two-way network, with the requisite technical protocols. Private wires, as adjuncts of local generation, can show the way. Regulators can acknowledge, belatedly, that infrastructure is paramount – that treating electricity purely as a commodity cannot deliver investment, reliability or stable business relationships.

Regulators also need to rethink the nature of transactions. They can incorporate and endorse appropriate payments for generation assets – for availability, for access and for use – just as they already do for networks. That would greatly enhance the attraction of small-scale generation, both renewables and cogeneration. Increasing the proportion of electricity so provided will also, of course, produce a corresponding reduction in carbon emissions, not by coercion or trade-off but as a welcome corollary of other benefits.

Successful implementation of measures such as those in OECD countries would greatly improve the likelihood that they would also be adopted elsewhere. Given the comparative freedom from legacy constraints, localities around the world still eager for electricity services will find that decentralized systems can be established even more rapidly and effectively, using small-scale technologies and local resources, under local control and locally financed, perhaps by micro-credit. Many examples already exist. Appropriate commitment by international agencies and technology suppliers can dramatically expand these activities. Those with outdated systems and those with no systems at all now have the opportunity for genuinely fruitful and mutually beneficial collaboration.

Who knows? Over time, decentralized energy might even become the norm, in human society as it is in nature.

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