Not All Megawatts are Created Equal

Draft

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Contrary to most regulatory policy, all megawatts are not equal; one megawatt-hour generated near users with a distributed generation plant (DG) can displace 1.2 to 1.5 centrally generated (CG) megawatt-hours and displace even more central generation and wires capacity. Treating all megawatts as equal – paying a DG MWh the same price as a CG MWh – discourages DG deployment, which causes society to suffer higher costs, and higher emissions. To induce an optimal electric supply, policy makers and regulators need to recognize the relative value of DG megawatts.

All megawatts were roughly equal in yesterday's world of integrated electric monopolies. Each utility generated electricity in remote stations and then delivered to end users through its T&D system, selling to end users at rates covering return on total capital investment, fuel, operations, maintenance and line losses.

Much has changed. Today, to paraphrase George Orwell, 'all megawatts are equal, but some megawatts are more equal than others'. Society began a long path to competitive generation and transmission in 1978 when law changes allowed independent power producers (IPPs) to build distributed generation plants at or near users. In 1990, IPP-built central plants gained rights to compete with utility-owned generation. IPPs subsequently built or purchased generation, leaving less than half of total U.S. generating capacity in rate base. Furthermore, the IPPs build both DG and central generation (CG) using multiple technologies and multiple energy inputs, including renewable energy. Independent firms now build and own transmission wires. Some regulated utilities were forced to divest all generation to non-regulated entities. A majority of states mandate distribution utilities to purchase a growing portion of total power from renewable or clean generation. However, the emerging generation and transmission markets face distorted price signals that do not reflect the differences between DG and CG megawatts. DG will not claim its optimal share of generation until financial and environmental regulatory agencies stop treating all megawatts as equal.

Why DG Megawatts Have More Value than CG Megawatts

DG megawatts usually flow directly to users, regardless of who purchased the power, thus bypassing long wires and associated line losses. By reducing the power flowing through the wires, DG also reduces line losses on all remaining centrally generated power. Furthermore, most DG burns less fossil fuel than central generation. Fueled combined heat and power plants (CHP) located near thermal users do two jobs with one fire, recycling normally wasted exhaust energy to displace boiler fuel; CHP efficiency rises to 85% versus average CG delivered efficiency of only 33%. Some DG plants recycle waste process energy into electricity with zero incremental fuel or pollution. Other DG plants convert renewable energy – sun, wind, biomass, hydro, etc. – into power with no fossil fuel. In other words, each DG megawatt-hour reduces fossil fuel use versus generating the same MWh in an electricity-only central fossil fueled plant, and then displaces more than one CG megawatt-hour.

Society needs DG to meet today's goals of reducing fossil fuel use and energy imports, reducing greenhouse gas emissions, protecting and adding local jobs and decreasing grid vulnerability to extreme weather and terrorists. Federal Energy Regulatory Commission Chair Jon Wellinghoff recently noted a danger of overinvesting in transmission, '*if we don't break down the non-economic barriers to putting in the distributed generation.*'[i] Recognizing the extra value of DG megawatts will speed achievement of today's societal goals.

Two of the authors (Ilic and Nazari) identified rich rewards from deploying strategically placed DG. **Studies by Carnegie Mellon/MIT professor Marija Ilich and her doctoral candidates have shown how to cut line losses in half by generating about 10% of total power with DG, and shown how each megawatt-hour of DG could displace 1.2 to 1.5 MWhs of CG generation.** Installing 80 gigawatts of appropriate DG could reduce U.S. end-user electric costs by $21 to $29 billion per year, free transmission lines to carry over 100 gigawatts more renewable energy and avoid 95 million metric tons of CO_2 emissions per year. Here are the details:

- The U.S. T&D system losts 236 million megawatt-hours per year (2001-2010), equivalent to the annual consumption of California (239 million MWh in 2010).[ii] At 2010 retail power costs of 9.8 cents per kWh, the US line losses cost $23.2 billion. Deploying 80 gigawatts of DG could eliminate half of the losses, saving about $12 billion per year.
- Deploying 80 GW of DG would:
  - Cut peak system requirements by 100 to 120 gigawatts, and avoid the need for another 10 gigawatts reserve capacity (17%) that would have covered the avoided line losses.
  - Reduce U.S. CO_2 emissions by 242 million tons or 4.1% of US emissions. (Generating 236 million MWh of line losses with today's CG fleet emits 137 million metric tons of CO_2, (0.58 metric tons of CO_2 per MWh in 2010).[iii] 80 gigawatts of DG would eliminate half, or 68 million tons associated with line losses, and then displace 526 million CG MWhs with cleaner, more efficient DG, avoiding another 170 to 200 million tons, or a total reduction of 238 to 268 million metric tons of annual CO2. (DG, emits ~ .25 tons or less/MWh)
  - Avoid $95 to $260 billion of capital investment. 80 gigawatts of DG provides capacity for 10% load growth for $160 to $240 billion of capital investment, versus investing $335 to $420 billion in 96 to 120 gigawatts of new CG and T&D capacity (assuming T&D costs

$1.5 million per MW and peaking generation costs $1.0 million per MW). Spread over 10 years, DG would save $9.5 to $26 billion per year in capital investment.

Technical Explanation of the Added Value of DG Generation

The power distribution system is like a big toaster that uses low resistance wires; Between 2% and 25% of the power heats the lines, depending on system load, with average U.S. losses of 6.2% last year.[iv] DG megawatts, by flowing directly to users, avoid direct line losses, and then, by reducing the flow of remaining power through T&D wires, reduce line losses on all power. The second part of the savings occurs because line losses are roughly proportional to the square of the flow of power. A wire carrying 100% of its design capacity loses 1^2 times a constant factor. When the wires carry 50% of design capacity, line losses are 0.5^2 times the factor or 25% of the peak line losses. In other words, a 50% reduction in power flow results in a 75% reduction in line losses.

To determine the average line loss reduction over time, Ilic, Nazari and others have modeled two Portuguese islands operating at distribution voltages, a complex continental system with transmission and distribution, and analyzed several U.S. area grids. To optimize savings, DG capacity was limited to the power in the distribution node and was placed at the end of distribution lines, and interconnected at distribution voltage. (Note that DG connected at transmission voltage will provide less reduction of line losses than DG connected at distribution voltage)

In the most detailed studies, each DG MWh displaced 1.2 to 1.45 MWhs of CG. Roughly 80% of the savings resulted from supplying active power to avoid and displace line losses, while the remaining 20% of savings resulted from using the DG to supply balancing reactive power.

Transmission lines and loads create varying amounts of reactive power – electric and magnetic fields. The inevitable conversion of active power into reactive power would increase system losses but for a magic relationship; reactive magnetic and electric fields cancel each other one for one, providing the two fields are in balance. The fields seldom balance and change as loads change. For example, florescent lights create capacitance while partly loaded motors create inductance, the opposite type of reactive power. Except for DG, grid managers have only gross methods of balancing reactive power, such as large capacitance or inductance banks that are either on or off. As a result, reactive power is usually unbalanced and contributes to line losses.

Addition of relatively simple controls would enable grid managers to source balancing reactive power from DG plants. CG plants can and do produce balancing reactive power, but with limited value, since VARS (variable amperes reactive) cannot be shipped down the wires in the direction of power flow. By contrast, DG VARS flow into the business end of the wires, balancing reactive power and reducing losses. Further, reactive power generated by DG does not degrade as system voltage decreases, making DG VARS higher quality reactive power than from capacitors or inductance banks. **However, virtually no grid manager currently sources (or pays for) balancing reactive power from DG**.

Policy Issues and Opportunities

Treating all megawatts as equal sends sub-optimal price signals to the power industry, needlessly increasing both cost and pollution. **As an example, typical power purchase agreements pay each DG MWh only the avoided fuel cost of generating the same 1 MWh of central power, and this understates fuel costs by 20% to 50%.** Furthermore, purchasing utilities assume that each MW of new DG capacity will displace only one MW of the least cost CG capacity, and will not displace any T&D capacity, versus the reality of each DG MW displacing 1.2 to 1.4 MW of the highest cost CG and displacing capital investment for both CG and associated T&D. This understates the financial advantages of DG and thus retards DG deployment. Utilities argue that since a single DG plant might be out of service at the system peak hour, DG should receive no generation of T&D capacity deferral payment. For a system of multiple DG plants, the argument is actuarial nonsense. One hundred DG plants, with a capacity of 10 MW each, and 96% average availability, will provide at least 900 MW of peak capacity, greatly reducing societies T&D needs.

Current environmental rules penalize DG in two ways. First, the rules require each new generating plant, whether DG or CG, to control emissions to 'Best Available Control Technology' or BACT levels. Since each MWh from DG avoids 1.2 to 1.5 MWh of central generation, DG is forced to emit less pollution per delivered MWh than new central plants. Second, existing central generation plants enjoy grandfathered rights to historic emission levels. Given that current BACT standards for NOx emissions are 99% lower than allowed from a 1980 plant, a proposed new DG must control NOx emissions to 1% of the emissions allowed from existing 30 year-old CG.

A final hurdle to DG deployment is the near universal utility opposition to all local power, which is rational under current regulations. Approved rates provide an allowed rate of return on invested capital, and to prevent 'windfall' profits, regulators typically pass all cost savings through to end users. Under this century-old regulatory paradigm, DG cuts utility profits in three ways. First, utilities receive no financial reward for reducing line losses or fuel costs. Second, the DG plants, by reducing the need for new T&D and new generation, may reduce future utility rate-base investment and thus decrease future profits. Third, DG power that is sold directly to the host cuts utility revenues and lowers profits until the next rate case. Not surprisingly, utility managers go out of their way to discourage all DG.[v] One utility strategy to discourage DG is to require interconnection at transmission voltages, which raises costs. Unfortunately, DG must connect to the distribution system to achieve maximum line loss reductions.

This historic approach to utility rate making produces a bizarre result. Electric consumers receive 100% of savings from DG deployment, which ends up being 100% of nothing. Without any credit for the savings, DG appears uneconomic relative to CG. Utilities, with no opportunity to share the value and decreased needs for rate-based capital, oppose DG and erect every possible hurdle to deployment. The law of unintended consequences comes to mind.

Five decades of U.S. electric efficiency stagnation proves the point. The power industry delivered 33% of the energy in the fuel it burned to end users in 1960, when Eisenhower left the White House. In 2010, the power industry still delivered only 33% of the fuel's energy to end users, in spite of incredible technical progress and partial opening of generation markets. Deploying DG would significantly improve U.S. delivered electricity efficiency, but suffers from the unintended consequences of an outdated regulatory paradigm. Until these perversities are fixed, utility actions will continue to retard penetration of DG, in spite of massive rewards to society.

Conclusions

DG is an important key to a sustainable energy system. Besides avoiding line losses, DG lowers fossil fuel use by sometimes combining heat and power generation and by sometimes eliminating fossil fuel altogether by using solar, biomass or waste energy. DG lowers the cost of power, making local manufacturing more competitive. DG reduces fossil fuel consumption and greenhouse gas emissions. Finally, a system with many relatively small DG plants is less vulnerable to extreme weather and terrorism than the current system of a few large remote stations.

We ask policy makers to consider our findings and to recognize the differential value of megawatts and megawatt-hours from strategically placed distributed generation, and then to share those benefits among DG developers, electric utilities and end users, so as to induce economically optimal DG deployment. DG can provide a triple bottom line by benefiting end users, DG investors and utilities, all while reducing societal emissions associated with providing electricity.[vi]

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[i] 'Reshaping Federal Transmission Policy', energy biz, Volume 9, issue 2 March/April 2012 page 20
[ii] See U.S. Energy Information Agency, Electric Power Annual 2010, revised January 2012

[iii] From same report of endnote ii.
[iv] Cite Hydro Quebec and Boston Edison
[v] Many utilities seem to have embraced roof-top solar, which would contradict the statement. This may be explained by three factors: 1) Solar energy has very broad public support and utility managers do not like to be seen as opposing public interest, and 2) In spite of the massive press coverage, the total generation from solar remains miniscule, and thus not much of a threat, and 3) Some utilities, like Duke, see ways to invest directly in roof top solar and put the generation in rate base, thus increasing profits. So far, no one has enacted regulatory changes to give utilities comparable reasons to support other DG, which does have the potential to displace as much as 40% of central generation.
[vi] Interested readers may send an email to areick@recycled-energy.com to request the Department of Energy's EIA files that have added the calculations to determine fuel and carbon dioxide savings from extrapolating Ilic and Nazari insights to the overall U.S. power system.