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Will Residential Power Systems Disrupt the Grid?

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This is a guest post by Steve Piper. Steve has a M. S. in Public Management and has been a consultant in the utilities business (primarily electricity) for the last 20 years.

A couple of months ago, posters on The Oil Drum raised the question of whether installing large amounts of grid-connected power at the residential level (solar panels, small wind turbines, and the like) would disrupt the grid.

There is a standard (IEEE 1547) covering safe interconnection of small power facilities to the grid. Comparing the amount of increase likely in solar panels and in residential wind turbines with the allowances for disruptions of various types in standard IEEE 1547, it appears that the adding these devices should not be unduly disruptive. The only exception might be in areas with unusually high grid penetrations of these auxiliary devices.

Market Prospects for Residential Power Systems

Policy initiatives in electricity generation have increasingly encouraged installation of residential/small power systems as a way of reducing reliance on central-station fossil fuels. Many of these systems, including solar photovoltaics, small wind turbines, or low head hydro, produce no greenhouse gases when they generate electricity, allowing them to be included in Renewable Portfolio Standards (RPS) promulgated in many states. According to the U.S. Department of Energy's Database of State Incentives for Renewable Energy, 29 states have enacted explicit targets for renewable energy production, and 16 states of the 29 have goals for production of energy from 'distributed generation' or generation below the substation level.

To meet RPS standards, several states (either directly or through their jurisdictional utilities) have rebates, leasing programs, and other incentives to encourage residential renewable energy systems. Additionally, the recently enacted federal stimulus package eliminated the $2000 cap on residential renewable energy systems, leaving in place an Income Tax Credit equal to 30% of the total project cost. These provisions of the stimulus legislation expire at the end of 2016.

The combination of state incentives and the federal tax credit can make residential renewable systems attractive to homeowners. DOE's National Renewable Energy Laboratory (NREL) recently forecast that these incentives would drive cumulative pv capacity installation to 24 GW by 2015, an eight-fold increase from today. While this would put solar pv at about 2% of installed generating capacity by that time, pv would contribute a bit less than 1% of total electricity. Where states encourage residential renewable energy systems we might expect higher rates of penetration, balanced out by lower rates in states that don't have RPS and/or provisions for

distributed generation.

Technical Issues for Interconnecting Residential Power Systems

Electric utilities recognized at the start of the decade that increasing penetration of power systems below the substation level could present problems to the electric grid. The standards-setting body IEEE (for Institute of Electrical and Electronics Engineers) convened committees to determine minimum characteristics for safe interconnection, referred to now as IEEE Standard 1547. There are a number of technical provisions of IEEE 1547, but the most noteworthy standards are as follows:

1. If interconnected distributed generation causes backfeeding or 'islanding' the generator must be able to disconnect until the condition is cleared;

2. Total distributed generation feeding the distribution circuits cannot contribute more than 10% of the circuit's maximum fault current.

3. Total distributed generation feeding the distribution circuits connected to a given substation cannot total more than 15% of the substation's annual peak load;

'Islanding' describes a matching of generation and load within the distribution circuit system that creates a subsystem essentially independent of the grid's central control. One might expect this to happen when local generation is high and grid usage is low, if no built in cut-off of the auxiliary devices takes place. Islanding causes reliability and quality problems in managing grid power.

Bullet item 1 amounts to a technology requirement. Modern grid tie inverters are certified to IEEE 1547, meaning they can respond to backfeed and islanding by shutting off the distributed generation. Grid tie inverters are most often associated with solar pv systems but can be used for small wind generators and other systems that produce DC power.

Other types of distributed generation (micro turbines, wind, or small hydro) can deliver synchronized AC power to the grid, but require upgrades to the circuit to address backfeeding and islanding. These upgrades include addition of reverse power relays and directional power relays that detect the adverse conditions and reduce or shut down distributed generation.

If the number of homes installing distributed generation off of a typical substation remains small (100 or fewer homes) backfeed or islanding conditions resulting in disconnection would be highly unusual. A typical substation might be rated for 10 MW of demand and serve 3-4 thousand residential customers. Disconnections for backfeed would occur during power outages on the circuit.

The current and load limits (bullet items 2 and 3 above) restrict the amount of distributed generation that can be installed on each circuit. Grid tie inverters contribute no fault current, so they are governed by the load limit. DG that does not use an inverter is governed by the current limit.[1]

The load limit of 15% will act to limit penetration to levels lower than 15%, because of the uneven nature of locally generated power. Solar pv systems, for instance, run close to their full output at the height of a sunny day, but contribute relatively little energy (15-20% annual capacity factor). Homes that wanted to tie to the grid and offset substantially all of their utility usage might have a 5 kW system installed. For our 10 MW substation this standard might accommodate 300 homes

(300 X 5kW = 1500 kW, or 15% of substation peak load). The indirect result of Bullet 3 is that instead of being able to add 15% of resources such as wind or PV, one can add perhaps half this, depending on the variability of the resource.

Summary

Some areas of the country are experiencing increasing amounts of distributed generation, especially solar pv. Even with the rapid penetration of distributed generation expected by organizations such as NREL, it does not appear that it will approach limitations on circuit capacity (per IEEE 1547) soon. However, the load and current restrictions may pinch in areas where interest in (and subsidy of) distributed generation is very high. At the same time IEEE 1547 is a work in progress, and will likely be revised as utility experience with distributed generation grows.

Notes:

[1] Many thanks to John Kueck of Oak Ridge National Laboratories for his guidance on these aspects of IEEE 1547.