Distributed Generation Impact

White Paper Executive Summary

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The concept of distributed generation (DG) is presently receiving widespread attention in the power industry. Some forecasts indicate that DG will provide a substantial portion of future incremental generation capacity. Wide proliferation of these devices will necessitate changes in how power distribution systems are designed, operated, protected, and maintained.

At the present time, overall penetration of DG in the North American power system is very small, and any system issues presented by DG are localized to those few feeders where DG penetration has become significant. DG capacity costs and operating costs are generally not competitive with grid power for most applications at this time. Additional factors, however, sway the balance in favor of DG for certain niche applications. Some of these applications include:

- Combined heat and power (CHP), or combined cooling, heat and power (CCHP) applications where DG waste heat is recovered.
- High reliability installations where generation is installed primarily for backup purposes, but also used to offset peak demand or participate in the energy market.
- Recovery of "free" fuel, such as landfill gas, or renewable energy sources such as solar power, wind power, or small hydro installations.

The application of DG is also being encouraged by various forms of subsidy such as demonstration project grants, tax credits, and regulatory policies such as net metering.

There are forecasts of DG becoming much more widespread in the future. Whether this happens depends greatly on changes in the economic viability of DG, including technical developments reducing DG costs, increased central generation costs, or constraints on delivering remotely-generated power.

The term "distributed generation" has a wide range of definitions, some based on size, others on location with respect to loads, and yet others based on where the generation interconnects with the electric power grid. In this report, DG is defined as generation connected to a distribution feeder which also serves other loads.

Distribution systems are conventionally designed with the assumption that the flow of power is always from the substation to the end user. Similarly, the only source of short-circuit capacity is assumed to be provided via the primary substation. Installing generation on a distribution system invalidates these assumptions, and introduces a range of system issues. These issues include:

Voltage regulation - Power output from DG distorts feeder voltage profiles, and can interact with voltage control devices such as voltage regulators and switched capacitor banks. This can result in overvoltage and undervoltage conditions for other customers.

Fault current contribution – Additional fault current contributed by DG can result in exceeding equipment withstand capabilities. More importantly, feeder protection can be desensitized, making fault detection more difficult. Uncoordinated operation of fuses and reclosers, caused by DG short-circuit contribution, can result in unnecessary customer outages.

Inadvertent islanding – Operation of feeder breakers, reclosers, fuses or sectionalizers can isolate a DG along with other customers. It is possible for the DG to continue in operation, providing energization which is out of the control of the utility. Such islands are not synchronized to the utility system, and reclosing can widespread damage to utility and customer equipment. Thus, such islands are to be avoided, or quickly detected and eliminated. Conventional means for detecting islands entails relatively sensitive voltage and frequency trip points, which are likely to be falsely triggered by other events.

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Grounding and distribution system overvoltages – The DG interconnection can provide an ungrounded source to a normally-grounded primary feeder, making severe overvoltages possible which could lead to widespread destruction of utility and customer equipment. An excessively-strong ground source, however, can interfere with feeder ground fault protection. In ungrounded or uni-grounded primary systems, the DG must not provide an undesired ground source. Thus, attention to grounding considerations is essential DG interconnections.

Power quality – Inverter-interfaced DG equipment can be a substantial injector of harmonic currents, increasing system distortion levels and possibly leading to equipment heating, capacitor unit failure, and resonant overvoltages. Certain types of DG, with variable output can result in rapid voltage fluctuations causing unacceptable lamp flicker.

Network interconnections – DG interconnection to secondary spot or grid networks are particularly problematic. A number of scenarios can lead to reverse flow through all of the protectors on a network, isolating the network from the utility system. This can lead to outage of the network (which is otherwise the most reliable of all distribution configurations), and to destructive duty on the network protectors.

The severities of these DG impacts are greatly dependent on the DG penetration (DG capacity compared to local load) and the type of DG power "conversion" device used. The conversion device is most often a synchronous generator, which inherently provides a significant source of short-circuit current contribution. Also used are induction generators and electronic inverters. While synchronous generators are the norm for reciprocating engine applications, many of the newly-introduced forms of distributed generation, including microturbines, fuel cells, and photovoltaic arrays require inverters to produce 60 Hz power. Short-circuit current contribution from inverters is very small, and the system impacts are decidedly different from those produced by rotating generators.

A common misconception is that DG will increase distribution system security and reliability. While the DG may provide backup power for the facility where it is installed, the net impact of the DG on distribution system reliability, using current interconnection practices, is more likely to be negative than positive. The presence of DG can potentially lead to undesirable power quality, prolong outages, or even cause outages.

DG may not offset the need for transmission and distribution system capacity when it cannot be guaranteed to be available when needed. In fact, the necessity to avoid inadvertent system islands typically requires that the DG trip settings be set rather sensitively. A system disturbance is likely to result in widespread DG tripping, thus removing this resource at a time when the system is most vulnerable. For this reason, it may be necessary to discount the DG capacity when planning system upgrades. It is possible, at higher DG penetration levels, for the DG tripping to greatly aggravate the system disturbance. An extreme example provided in this report shows a hypothetical example of DG tripping leading to power system instability and blackout of the western U.S. power system.

Many of the DG integration issues can be resolved by appropriate application of controls and communications, such that the DG operates as an integral part of the power system instead of autonomously. With better controls and coordination between the DG and the utility system, the DGs can potentially improve system reliability and power quality, and reduce transmission and distribution infrastructure requirements.

Some innovative concepts have been developed for "microgrids" where multiple DGs and loads are interconnected with or without interconnection to a utility grid. Such schemes rely on advanced control techniques to allow coordinated operation and system protection.

Whether or not DG application takes off and becomes widespread, or just remains a special niche application, cannot be predicted with certainty. Therefore, it is prudent for distribution utilities to consider today the potential impacts of greater DG penetration so that practices and policies can be adopted in advance of any large-scale penetration in the future.