General Electric
Corporate Research and Development

Integrating Distributed Generation with Electric Power

Goals

To make large-scale system integration feasible for distributed generators (DGs), a cost-effective, mass-produced universal interconnection (UI) system must be developed. General Electric (GE) is examining the technical issues associated with interconnecting DG with the electric grid to develop a UI system to facilitate DG interconnection.

The GE approach is to:

- Develop a virtual simulation test bed (VTB) for DGs and their interface to a utility, incorporating models of the DG, its loads, and the affected EPS components
- Conduct case studies to evaluate the DG effect on EPS power quality, protection, reliability, and stability
- Determine the effect to the utility network of increased DG penetration relative to existing network hardware, such as reclosers, and the ability to respond to faults
- Develop, build, and test an interface for safe and reliable DG interconnection.

Current Results

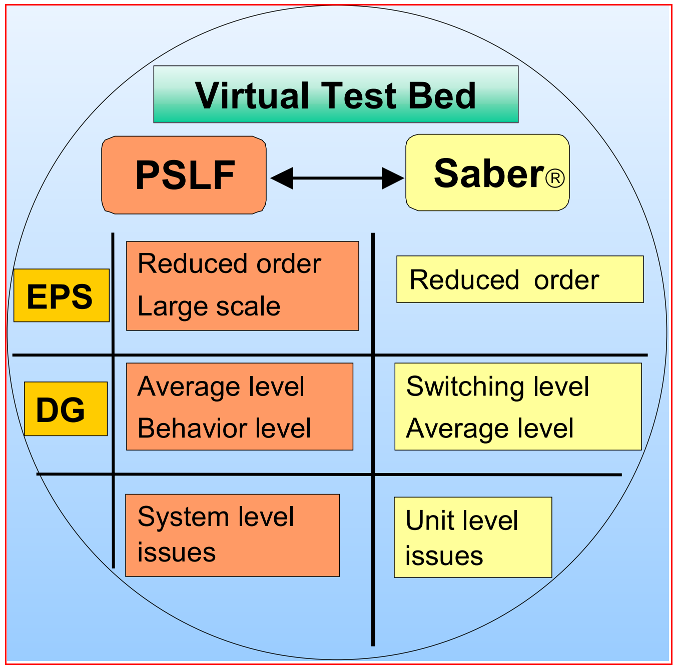
Virtual Test Bed

GE is studying DG-Electric Power System (EPS) interconnection issues using a GE-designed virtual test bed, the VTB, which is a computer simulation package that includes EPS, DG, and load models. This VTB is a mechanism to clearly understand, study, and resolve interconnection issues before a UI is built and will be a tool for the power industry for planning and systems analysis.

The VTB is a synthesis of two modeling programs, Saber® and Power System Load Flow (PSLF). Saber® is a system-modeling tool applying differential analysis and is suited for mixed technologies and detailed component modeling. PSLF is optimized for very large systems. Combining PSLF and Saber® allows a detailed analysis of large interconnection systems.

Case Studies

DG devices interconnected with an EPS have the potential to affect the power quality, safety, and reliability of the EPS. GE modeled generic case studies to understand the potential effects of grid-connected distributed generation devices. These effects were grouped into power quality and protection and reliability categories.

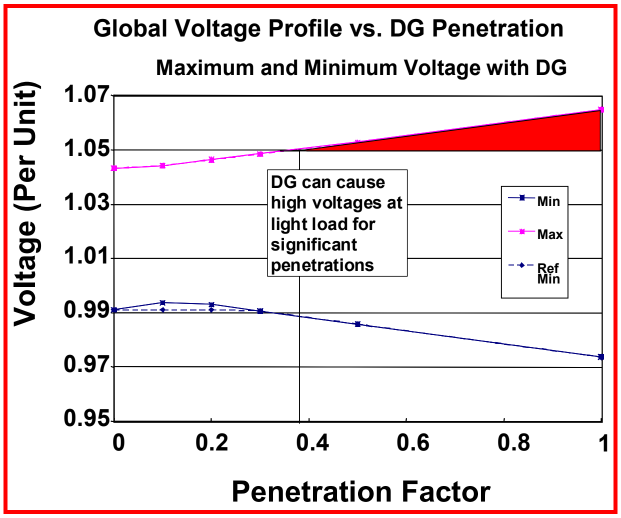


Schematic representation of roles of the two modeling programs, PSLF and Saber®, in the GE virtual simulation test bed

For power quality (voltage regulation, flicker, voltage imbalance, harmonic distortion, and DC current injection), the studies evaluated the effects on the EPS as a function of DG penetration. Highlights include:

- Inverter-type DGs can have a significant beneficial effect on flicker if they are operated as controlled voltage sources.
- Rotating-type DGs have an advantage in their inherent ability to mitigate flicker.
- With significant DG penetration, it will be difficult to avoid detraction from EPS voltage regulation performance.
- Integrated control of system voltage and reactive power management mitigates these effects.

Protection and reliability case studies focused on transient response and fault behaviors, recloser coordination, anti-islanding, and power system dynamics and stability.



The GE model predicts DG penetration will affect EPS voltage regulation

- Without active anti-islanding, an island is highly probable if DG and loads are closely matched.
- Active anti-islanding can detect island conditions with different loads.
- The lack of frequency regulation by DGs aggravates the common-mode frequency depression.
- Sensitive tripping points, intended to detect islands, can cause widespread DG tripping at inopportune times.

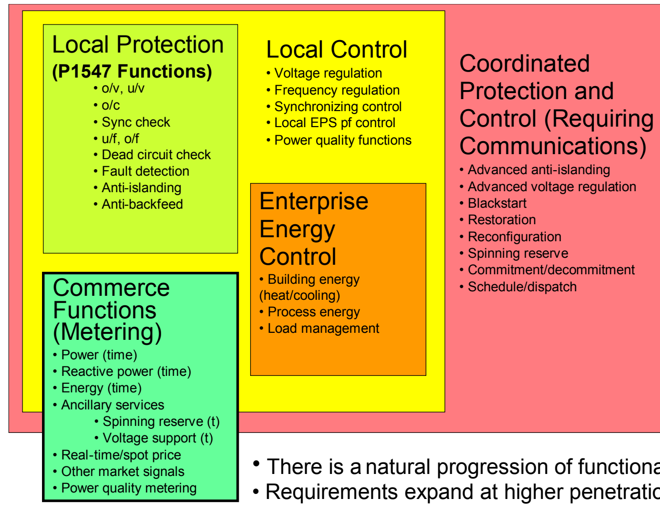
Universal Interconnection System Design

Based on this information, GE modeled the best UI design and recommended it be:

- **Technology neutral** – Must be able to connect all kinds of distributed resources to the utility grid.
- **Modular** – Must meet a minimum level of functionality and should be able to be customized for installation-specific needs. Modularity permits a combination of building blocks.
- **Scaleable** – Systems should be scaleable to size and level of functionality required and/or desired.

GE defined five levels of functionality for a UI.

1) **Local protection** – The minimum protective functions per the IEEE P1547 standards.
2) **Local control** – A range of DG controls such as voltage and frequency regulation.
3) **Coordinated protection and control** – Need to function properly and reliably, with networked communications for coordinated protection and control, emphasizing area EPS reliability.
4) **Enterprise energy and control** – Energy management (e.g., gas and water management) to minimize costs while maximizing efficiency.
5) **Commerce** – Monitor spot pricing, demand, resource costs, etc. to operate the DG.



- There is a natural progression of functionality
- Requirements expand at higher penetrations
- Economic benefits increase with higher functionality

Pictorial representation of a modular universal interconnection system design

Distribution and Interconnection R&D (Formerly Distributed Power Program)

DOE's Distribution and Interconnection R&D supports the development of technologies and policies that enable distributed generation (e.g., photovoltaic systems, wind turbines, fuel cells, and microturbines), storage, and direct load control technologies to be integrated into the electric system. Through a collaboration of national laboratories and industry partners, DOE's Distribution and Interconnection R&D pursues activities in: (1) strategic research, (2) technical standards, (3) distribution system technology, (4) interconnection technology, and (5) mitigation of regulatory and institutional barriers.

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Additional Distributed Power Information
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Produced for the U.S. Department of Energy, 1000 Independence Avenue, SW Washington, DC 20585 by the National Renewable Energy Laboratory, a DOE National Laboratory.

DOE/GO-102003-1687 January 2003

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste.