# DTE Energy Technologies With Detroit Edison Co. and Kinectrics Inc.

**Distributed Resources Aggregation Modeling and Field Configuration Testing**

## Background

In the 20th century, the United States built an electric power system that became the envy of the world for its reliable, low-cost power. Today, that system consists primarily of large central-station power plants intertied via a high-voltage transmission system. The transmission system feeds lower-voltage, local distribution networks that provide one-way power flow to end-users.

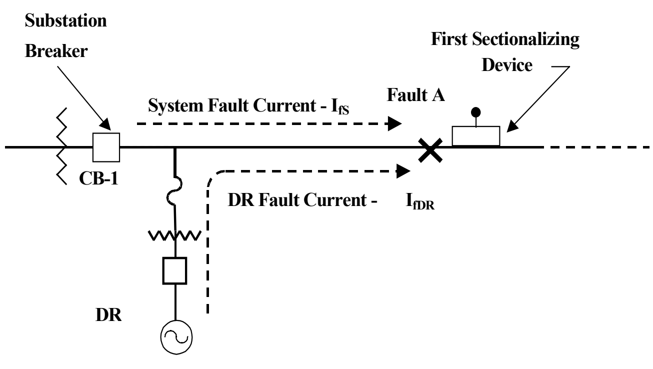
Interest in distributed resources (DR), or local energy generation and storage, has increased substantially because of their potential to improve reliability and lower costs by providing power at or near the load. To realize these benefits on a larger scale, utilities and generating customers need quantitative data and analytical tools to assess interactions between DR and distribution lines.

## Aggregation Effects

The effects of low concentrations of DR on the distribution system are generally known. However, the effects of larger generators and larger concentrations of generators are not well understood. A number of utility grid coordination issues—including the performance of utility fuses, reclosers, and protective relays as well as limits to uphold system quality and reliability standards—are involved.

## Goals

DR can provide many benefits, but local electric distribution systems traditionally have not been designed to operate in parallel with interconnected distributed power systems. As a result, there are concerns about compatibility, reliability, power quality, system protection, voltage dynamics, and safety. The goals of this study are to address selected system integration issues and determine the DR system penetration limits imposed by the local grid because of utility coordination issues.




*Current sensitivity example*

### *System Protection Issues*

- Improper coordination – protective device operates for fault on adjacent circuit
- Improper coordination – reduced fault detection sensitivity
- Nuisance fuse blowing because of DR fault current
- Faults within the DR zone
- Isolating DR for upstream fault
- Fuse blowing because of upstream single-phase fault

### *Voltage and Stability Issues*

- Harmonics
- Voltage regulation malfunctions
- Steady-state stability
- Dynamic stability during fault conditions
- Loss of exciters causes low voltage

## Overview

This research is an example of ongoing efforts to develop the data and analytical tools necessary to assess the reliability and performance of the transmission and distribution system and foster the deployment of new technologies.

The study examined two typical distribution feeder circuits in the Ann Arbor, Michigan, area. One was a radial distribution line, and one was a ring configuration. DTE developed three-phase circuit models of the feeder lines, protective devices, and DR. It used comparisons with simplified analytical results and short test simulations to verify the accuracy of the models. Later, it used ASPEN, MATLAB, PTI PSS/E, and EMTP software to generate detailed simulations that represent how aggregated DR affect system characteristics such as voltage, harmonics, phase and ground overcurrent, fault conditions, islanding detection, loss of excitation, transient stability, and coordination between circuit breakers, fuses, and reclosers.

DTE determined the maximum size of aggregated DR possible at locations on the sample feeders without disrupting the line performance or the behavior of protective devices. In general, the study should help other engineers determine DR penetration limits by providing validated methods, algorithms, and device charts that can be adapted to specific cases.

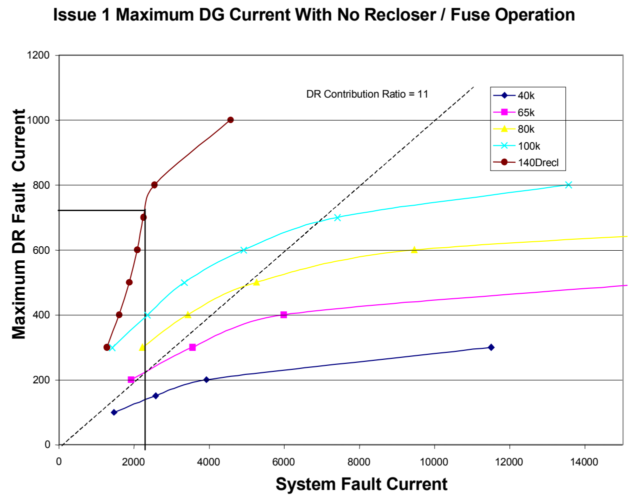
## Findings

This study provided detailed modeling, simulations, and validated analyses to ensure sound conclusions and recommendations concerning DR penetration limits and equipment requirements. It established generic methods and procedures to evaluate DR effects.

The conclusions include:

- The DR aggregation limits were typically on the order of 1–10 MVA.
- The system voltage has a significant effect on the maximum DR size (or aggregated size) that can be connected to a circuit. Doubling or tripling the system voltage would roughly double or triple the maximum aggregated size of DR.
- The type of fault influences the size of DR.
- Nuisance fuse blowing tends to limit DR sizes to less than 2 MVA for compact circuits fed from 15-MVA substation transformers (high system fault current = 7,600 A at substation).
- Harmonic analysis may be required for inverters because of the wide range of acceptable DR sizes (820 kVA–9.2 MVA).
- The location of the DR's circuit is very important in determining the voltage limits for loss of excitation DR limits.
- If critical clearing time is 0.1 seconds or less, stability should be maintained. The larger the machine inertia, the more stable the unit. Multiple machines on a feeder may increase stability by tending to support local voltage during upstream disturbances.

Too much distributed generation in the wrong location can create or aggravate problems with voltage, harmonic content, system stability, or protective device coordination. However, DTE clearly presents how DR, far from being a detriment, can significantly benefit the grid—with proper evaluation of the local power grid and careful DR selection and placement.




*Maximum DR fault current versus system fault current*

## Publications

Davis, M.; Costyk, D.; Narang, A. "Distributed and Electric Power System Aggregation Model and Field Configuration Equivalency Validation Testing." NREL/SR-560-33909. July 2003.

Publications are available on the NREL publications database at http://www.nrel.gov/publications/.

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