Locational Impact of Distributed Generation on Feeders

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Commonwealth Edison Company

United States

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Our Customers:

- 3.9 million customers in northern Illinois

Our Company:

- One of four utilities owned by Exelon
- ~6,000 Employees
- Service Territory: 11,428 square miles

Our Grid:

- Peak Load: 23,753 MW (7/20/2011)
- 526,000 distribution transformers
- 65,000 circuit miles of primary distribution
  - o 53% overhead, 47% underground
- 5,800 circuit miles of transmission

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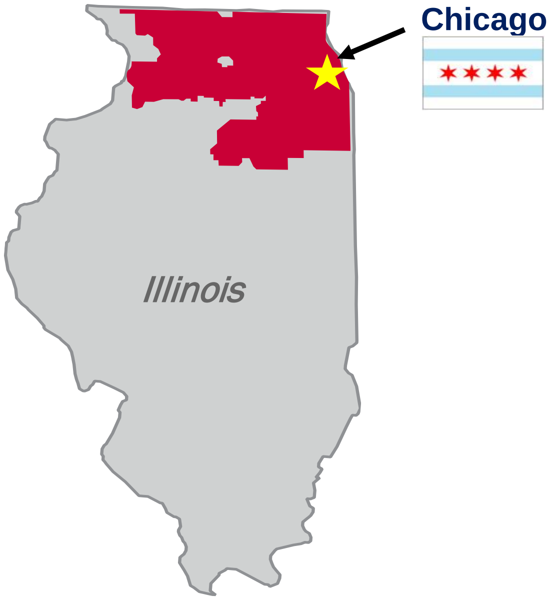

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Introduction

- Distribution feeders are experiencing significant growth in distributed generation (DG) installations
- Growth is due to reducing costs of DG technologies, attractive incentive schemes, legislative mandates, and renewable generation targets
- DG hosting capacity of a feeder or hosting capacity (HC) can give a more realistic estimate of the amount of DG a feeder can accommodate

Network Issues from Distributed Generation

Voltage	Overvoltage
	Voltage regulation
	Phase imbalance
Loading	Equipment overload
Protection	Loss of co-ordination
	Loss of reach
	Anti-islanding
Harmonics	Total harmonic distortion

Hosting Capacity: Terminology and Definitions

- **Hosting Capacity** is defined as the maximum amount of new power production that can be connected without endangering the reliability or power quality for other customers
- **Minimum HC (HC_{min})** the penetration of DG where feeder constraints are first violated and is a worst-case scenario
- **Maximum HC (HC_{max})** the highest penetration of DG that can possibly be accommodated without violation of a feeder constraint
- **Distributed Hosting Capacity (HC_D)** relates to a given level of DG penetration on a feeder to the probability of a constraint violation occurring
- **Centralized Hosting Capacity (HC_C)** is defined as the maximum amount of DG that could be installed at a single location on the feeder without resulting in a constraint violation
- **Locational marginal hosting capacity (MHC_L)** quantifies the change in the distributed hosting capacity of a feeder -- at a defined probability with addition of DG generation to a fixed node

Proposed Simulation Framework

Proposed is a stochastic simulation framework to quantify the effect of distributed generation on distribution feeders

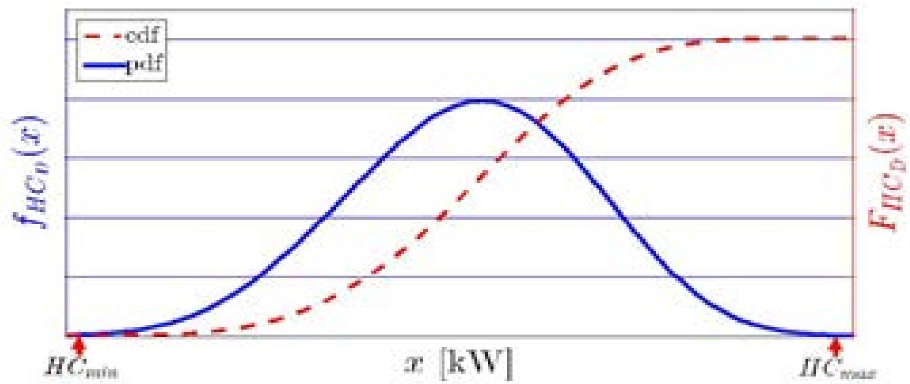

Figure 1: Calculation of Hosting Capacity

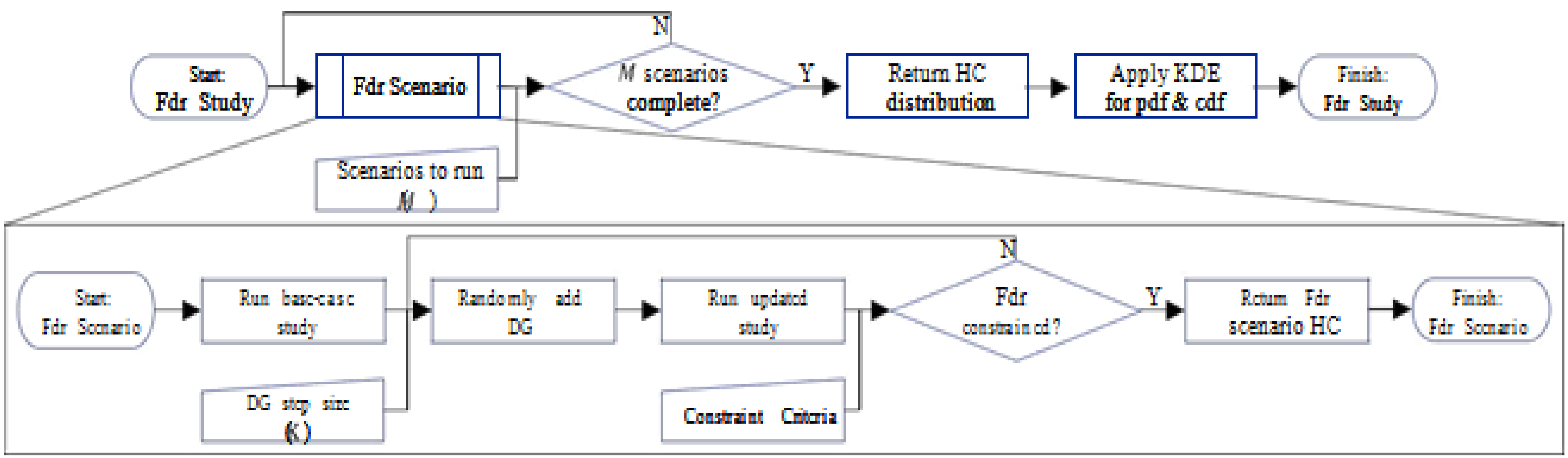

Figure 2 : Modelling Algorithm

Real Feeder Test Case

- Study Feeder is a 12kV feeder (Figure 3)
  - 1026 nodes
  - 1044 lines
  - 208 spot loads
  - Mixture of single and multi-phase configurations
  - Unbalanced loading conditions

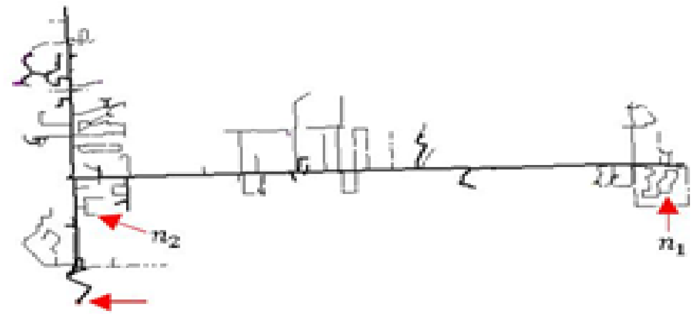

Figure 3: One-line diagram of the real utility feeder

- Distributed and Centralized Hosting Capacity

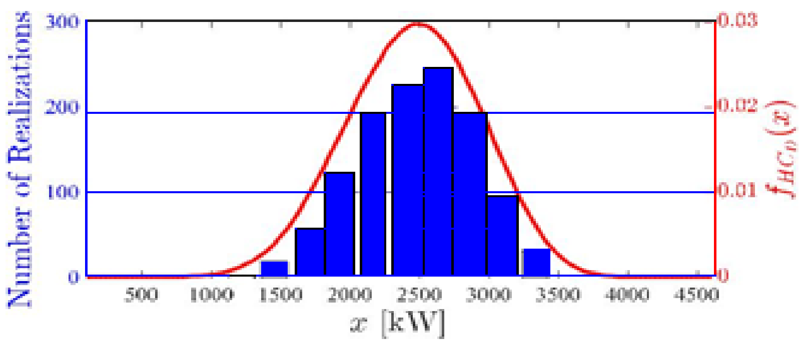

Figure 4: Simulation output and Kernel Density Estimation (KDE)

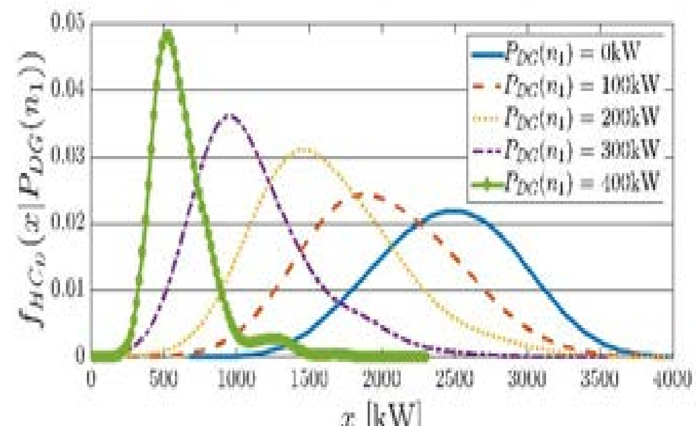

Figure 5: Conditional pdfs of distributed hosting capacity (HC_D) for n_1 based on P_{DG}

Table 1: Percentage of observations where no constraints occurred based on DG penetration level

Observations with no constraints	95%	50%	5%
Penetration level	1664 kW	2479 kW	3145 kW

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Real Feeder Test Case 1/2

Presented are the analytical results of the MHC_L for two representative nodes within the study. Each node differs in electrical distance from the substations.

To determined locational sensitivity, 200 scenarios for each level of DG penetration at the node were applied.

1. Locational Sensitivity for Node n_1 [distance from substation $a(n_1)$= 28.74 pu]

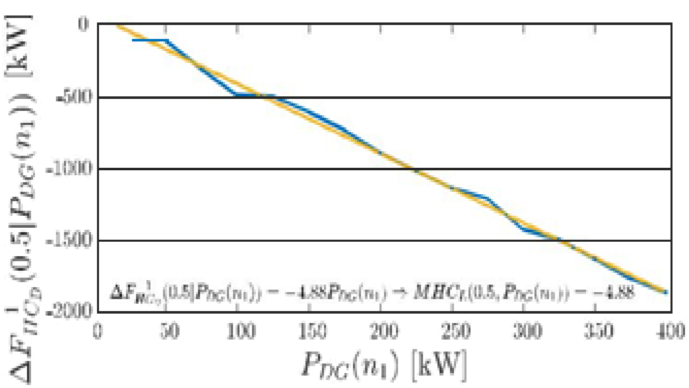

Figure 6: Locational marginal hosting capacity (MHC_L) with probability (p) 0.5 at n_1

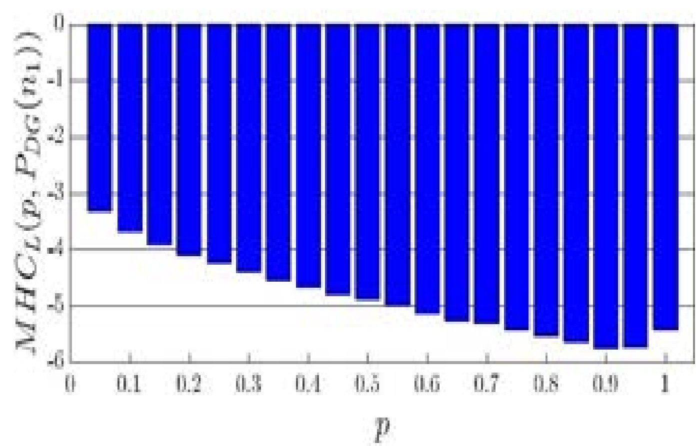

Figure 7: Sensitivity of MHC_L with respect to probability p at n_1

Table 2: Conditional Hosting Capacity based on DG penetration level at n_1

$P_{DG}(n_1)$ [kW]	50	100	150	200	250	300	350	400
$F^{-1}_{HCD}(0.5\|P_{DG}(n_1))$ [kW]	2385	1876	1825	1461	1265	967	750	528

Real Feeder Test Case 2/2

2. Locational Sensitivity for Node n_2 [distance from substation $a(n_2)$= 2.25 pu]

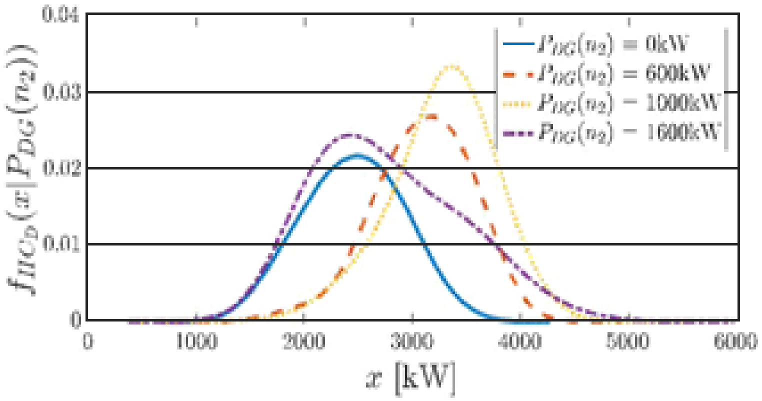

Figure 8: Conditional pdfs of distributed hosting capacity (HC_D) for n_2 based on P_{DG}

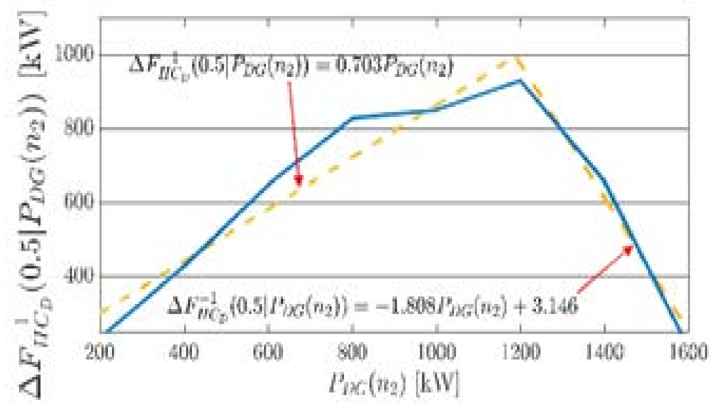

Figure 9: Locational marginal hosting capacity (MHC_L) with probability (p) 0.5 at node n_2

From the locational sensitivity analysis at the nodes, it may be concluded that the electrical distance of a feeder node has a large impact on the sensitivity of the feeder's HC_D

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Application of Analysis

Once quantified, the MHC_L could find use in a number of applications in sustainably integrating DG within distribution systems. In particular, the MHC_L will assist in:

- Distribution system planning and development of processes to identify locations for optimal placement of DG
- Developing targeted incentive programs that encourage installation of DG in locations that minimize the impact on feeder performance
- Monitoring and measuring the impact of DG on the distribution system over time

Concluding Remarks

In this presentation we have :

- Proposed a framework that deploys DG in various locations and sizes to determine the feeders HC
- Performed a sensitivity analysis to demonstrate that the location of DG installation greatly affects the voltage levels at the feeder nodes
- Found that the electrical distance of the node where DG is installed plays a role in defining the feeder's HC

Key Takeaway:

- The results demonstrated the strong locational sensitivity of the study feeder to DG, with installation of DG on one node reducing the feeder HC by 5kW for every 1kW of DG installed
- The sensitivity was found to be strongly linked to the electrical of the node from the source