Using DGHost™ To Determine the Hosting Capacities of Low Voltage Networks
GREEN Grid Conference
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Outline

• Background
• DGHostr™ Method
• Using DGHost™
• Congestion Monitoring
Background

- SSDG Guide introduces the concept of hosting capacity, the ability of LV networks to host Distributed Generation (DG)
- As LV networks are all so different, we need to know the hosting capacity of individual networks
- EDB’s have many thousands of networks to administer, require thousands of DG Hosting Capacities

Problem:
- Limited documentation of the network configuration
  - Often paper based
  - Often incomplete
DGHost™ Service: Determine Hosting Capacities via Approximate Methods

- Hosting Capacity – maximum export power per DG
- Estimate hosting capacity (HC) of each LV network using the reference data set
  - 20 million HC results
- Optimization of predictor variables
  - As independent as possible
  - Easily determined by Electricity Distribution Businesses (EDBs)
- \( k \)-Nearest Neighbour Regression
Three basic network parameters are required:
• Transformer size (5kVA to 1.5MVA)
• Number of ICPs (< 250)
• Maximum Feeder Impedance (< 2Ω)

Two optional boolean values can be defined:
• Single phase network (defaults to three phase)
• Reduced neutral conductor sizing not uncommon on overhead lines (defaults to full sized)

Unknown parameter
• The long-term DG penetration estimate $\gamma_{LT}$ is required
**DG Penetration**: The proportion of ICPs in a given LV network that have export-capable DG installed.

**Long-term DG Penetration Estimate**: The long-term penetration forecast from which hosting capacity thresholds are calculated.

Current DG penetration  
= 5DG/22 ICPs = 23%

Long-term DG Penetration Estimate  
= 9DG/22 ICPs = 41%
Selecting a Long-term DG Penetration Value

• Large uncertainty around what the penetration will be on an LV network.
  – New subdivisions with solar ready eg. Highfield in Canterbury, estimate a long-term DG penetration 90 - 100%
  – High density apartments, expect much lower long-term DG penetration
  – Networks with small numbers of ICPs (5 or less) recommend 100%

• DGHost™ allows 4 DG penetration values per simulation

• The Guide also recommends revisiting these values to assess if the estimated long-term DG penetration was underestimated.
DGHoSTM Implementation

- Initially manual process, inputs and outputs via spreadsheets
- Next, web-based tool, create networks to simulate via web-based GUI, or load multiple networks via a spreadsheet, outputs via a spreadsheet

<table>
<thead>
<tr>
<th>Network ID</th>
<th>Transformer rating (VA)</th>
<th>Number of ICPs</th>
<th>Maximum Feeder Impedance (Ω)</th>
<th>Single Phase Network (1 = \text{True})</th>
<th>Reduced Neutral Conductor Sizing (1 = \text{True})</th>
<th>Penetration 1 (%)</th>
<th>Penetration 2 (%)</th>
<th>Penetration 3 (%)</th>
<th>Penetration 4 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any text</td>
<td>5,000-1,500,000</td>
<td>1-250</td>
<td>0-2</td>
<td>0</td>
<td>0</td>
<td>0.4-100</td>
<td>0.4-100</td>
<td>0.4-100</td>
<td>0.4-100</td>
</tr>
<tr>
<td></td>
<td>5,000-1,000,000</td>
<td>1-250</td>
<td>0-2</td>
<td>0</td>
<td>1</td>
<td>0.4-100</td>
<td>0.4-100</td>
<td>0.4-100</td>
<td>0.4-100</td>
</tr>
<tr>
<td></td>
<td>5,000-50,000</td>
<td>1-9</td>
<td>0-2</td>
<td>1</td>
<td>0</td>
<td>0.1-100</td>
<td>0.1-100</td>
<td>0.1-100</td>
<td>0.1-100</td>
</tr>
<tr>
<td>Example 1</td>
<td>200,000</td>
<td>24</td>
<td>0.126</td>
<td>0</td>
<td>0</td>
<td>25%</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>Example 2</td>
<td>50,000</td>
<td>7</td>
<td>0.999</td>
<td>0</td>
<td>0</td>
<td>30%</td>
<td>45%</td>
<td>70%</td>
<td>100%</td>
</tr>
<tr>
<td>Example 3</td>
<td>200,000</td>
<td>38</td>
<td>0.886</td>
<td>0</td>
<td>0</td>
<td>25%</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>Example 4</td>
<td>10,000</td>
<td>2</td>
<td>0.660</td>
<td>1</td>
<td>0</td>
<td>50%</td>
<td>100%</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
**DGHost™ Service Results**

- DG hosting capacity for each LV network provided in an Excel spreadsheet
  - hosting capacities corresponding to each *DG penetration*,
  - Conservative (P25) and Median (P50) hosting capacity per penetration level

- SSDG Guide recommends the use of P25 with approximate methods such as DGHost™

<table>
<thead>
<tr>
<th>Network ID</th>
<th>Penetration Level 1</th>
<th>Penetration Level 2</th>
<th>Penetration Level 3</th>
<th>Penetration Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 1</td>
<td>25</td>
<td>5800</td>
<td>6200</td>
<td>50</td>
</tr>
<tr>
<td>Example 2</td>
<td>28</td>
<td>2000</td>
<td>2300</td>
<td>42</td>
</tr>
<tr>
<td>Example 3</td>
<td>25</td>
<td>4400</td>
<td>4700</td>
<td>50</td>
</tr>
<tr>
<td>Example 4</td>
<td>50</td>
<td>7000</td>
<td>7100</td>
<td>100</td>
</tr>
</tbody>
</table>
DGHoSTM Service Results

• Typically 24 results per network
  – 4 penetrations
  – 2 (conservative or median result of distribution due to DG allocations)
  – 3 levels of volt-var applied (0%, 30%, 60%), one per worksheet
• In reality only need 2 of these values, H1 and H2!
• Additional values helpful for sensitivity analysis
Example #1 LV Network

Long-term DG Penetration: 50% (11DG / 22 ICPs)

Number of ICPs (N) | 22
Transformer Size (kVA) | 100
Max Impedance (Ω) | 0.18

H1: DG export power threshold, above which mitigation measures are necessary | 3.1 kW
H2: DG export power threshold, above which mitigation via inverter volt-var response is insufficient | 9.7 kW
Traffic Light Guide Implementation Example #1

Application for Export Power
\[ P < H_1 \text{ (ie } < 3.1 \text{ kW)} \]

Application for Export Power \[ H_1 < P < H_2 \text{ (ie between 3.1 and 9.7 kW)} \]

Application for Export Power
\[ P > H_2 \text{ (ie } > 9.7 \text{ kW)} \]
Congestion & Hosting Capacity

- Congestion & DG Hosting Capacity are two sides of the same coin.

Hosting Capacity – defined as the upper limit of DG export power before network congestion occurs.

- Monitor the installed DG export aggregate on the LV network
Monitoring Congestion

Compare: Installed DG Export Aggregate

14.7kW

With: Congestion Thresholds

(HC threshold X long-term penetration estimate)

H1 x long-term penetration % x ICPs = 3.1kW x 50% x 22
= 34.1kW

H2 x long-term penetration % x ICPs = 9.7kW x 50% x 22
= 106.7 kW

• Flags which LV networks require further investigation
For more information on DGHost™

- EPECentre website
  - Other Projects -> DGHost

- Talk to EPECentre staff

- Publications on our website
Thank you to the supporters of the GREEN Grid programme.
Improved Hosting Capacity with Volt-VAr

0% Volt-VAr

60% Volt-VAr
Conservative/Median Hosting Capacities

- Different possible allocations of DG in a LV network result in a distribution of hosting capacity results.

- Conservative HC, (P25 or 25th percentile)
  - 75% of possible distributions will have a higher HC threshold

- Median HC, P50 or 50th percentile
  - 50% of possible distributions will have a higher HC threshold

Different HCs dependent on allocated DG locations

Hosting Capacity (HC)

DG Penetration (γ)

25%  50%  75%  100%
Determining Max Feeder Impedance

Example 1

\[ |Z_{\text{max}}| = \max(|Z_{f1}|, |Z_{f2}|, |Z_{f3}|) \]
Hosting Capacity Query

If you would like to process a file, please upload it.

Build Request

1. Network ID
2. Transformer Rating
3. Number of ICPs
5. Single Phase
6. Reduced Neutral Conductor Sizing

A total of 4 networks are valid and may be processed.

Confirmation
Are you sure you wish to process this request?

No | Yes
Hosting Capacity Thresholds to implement the SSDG Guide

- H1 threshold – select penetration, look at conservative P25 result (using approximate method), 0% volt-var response
- H2 threshold – select penetration, look at conservative result P25, 60% volt-var
Example #2
Transformer Limited Network

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ICPs (N)</td>
<td>14</td>
</tr>
<tr>
<td>Transformer Size (kVA)</td>
<td>50</td>
</tr>
<tr>
<td>Maximum Impedance (Ω)</td>
<td>0.0102</td>
</tr>
</tbody>
</table>

Hosting Capacity Determination GREEN Grid
### Example #4
Dense Urban Network

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ICPs (N)</td>
<td>92</td>
</tr>
<tr>
<td>Transformer Size (kVA)</td>
<td>300</td>
</tr>
<tr>
<td>Maximum Impedance (Ω)</td>
<td>0.2413</td>
</tr>
</tbody>
</table>

#### Hosting Capacity Determination

![Graph showing hosting capacity determination for different penetration levels and volt-VAr settings.](chart)

- 60% Volt-VAr
- 30% Volt-VAr
- 0% Volt-VAr P(50)
- 0% Volt-VAr P(25)
Congestion & Hosting Capacity

- **export congestion** means a situation in which a **distribution network** is unable to accept **electricity** exported from a **distributed generation connection** because the injection of an additional unit of **electricity** into the **distribution network** would—
  - (a) directly cause a component in the **network** to operate beyond the component's rated maximum capacity; or
  - (b) give rise to an unacceptably high level of voltage at the **point of connection** between the **distribution network** and the **distributed generation**

**Hosting Capacity** – defined as the **upper limit of DG export before network congestion occurs**.

The maximum export power, per ICP with DG installed, on a LV network which can be tolerated without causing voltage or current limits to be exceeded, for a given DG penetration level.
Selecting a Long-term DG Penetration Value

- Large uncertainty around what the penetration will be on an LV network.
  - New subdivisions with solar ready eg. Highfield in Canterbury, estimate a *long-term DG penetration* 90 - 100%
  - Networks with small numbers of ICPs (5 or less) recommend 100%
- DGHost™ allows 4 long-term DG penetration values per simulation
- The Guide also recommends revisiting these values to assess if the estimated *long-term DG penetration* was underestimated.

\[ \gamma_{LT} = 100\% \]