The Effect of Non-Coordinated Heating Electrification Alternatives on a Low-Voltage Distribution Network with High PV Penetration

J. Alpízar-Castillo, L. Ramírez-Elizondo, P. Bauer
Introduction

• DRES can cause stability issues, grid congestion, and overvoltages on the distribution networks.

• Electric heating alternatives consume considerable amounts of power.

• Including energy storage systems on the grid can help the DSOs to address the issues
Effect of Non-Coordinated Heating Electrification on a LV Distribution Network

18-node CIGRE network model

<table>
<thead>
<tr>
<th>Node</th>
<th>Load (kVA)</th>
<th>Power factor</th>
<th>PV (kW)</th>
<th>BESS (kW)</th>
<th>BESS (kWh)</th>
<th>HP (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>12</td>
<td>0.85</td>
<td>6.4</td>
<td>8</td>
<td>10</td>
<td>5.4</td>
</tr>
<tr>
<td>15</td>
<td>12</td>
<td>0.85</td>
<td>9.6</td>
<td>9.6</td>
<td>15</td>
<td>8.1</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>0.85</td>
<td>14.4</td>
<td>14.4</td>
<td>30</td>
<td>16.2</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>0.85</td>
<td>19.2</td>
<td>19.2</td>
<td>30</td>
<td>16.2</td>
</tr>
<tr>
<td>18</td>
<td>12</td>
<td>0.85</td>
<td>19.2</td>
<td>24</td>
<td>30</td>
<td>16.2</td>
</tr>
</tbody>
</table>
Control architecture

House 1

Converter
Electric loads
Thermal loads
EMS

House 2

House 3

Distribution Network

Effect of Non-Coordinated Heating Electrification on a LV Distribution Network
Results – Case 1: Buildings without DRES or MCES

Multi-carrier coupling and system aggregation

Summer

Voltage [pu]

Node

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

- Voltage in the node at 8:00 am
- Voltage in the node at 10:00 am
- Voltage in the node at 09:00 pm
Results – Case 2: Buildings with PV

Summer

- Voltage in the node at 8:00 am
- Voltage in the node at 11:30 am
- Voltage in the node at 09:00 pm

Winter

- Voltage in the node at 8:00 am
- Voltage in the node at 10:00 am
- Voltage in the node at 09:00 pm
Multi-carrier coupling and system aggregation

Results – Case 3: Buildings with the full MCES

Winter – Only heat pump

Winter – Heat pump, solar collectors, and TESS
### Results

<table>
<thead>
<tr>
<th>Case</th>
<th>Season</th>
<th>Maximum voltage (pu)</th>
<th>Minimum voltage (pu)</th>
<th>EN50160 compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>1</td>
<td>0.943</td>
<td>Satisfied</td>
</tr>
<tr>
<td>2</td>
<td>Summer</td>
<td>1.058</td>
<td>0.943</td>
<td>Satisfied</td>
</tr>
<tr>
<td>2</td>
<td>Winter</td>
<td>1.037</td>
<td>0.943</td>
<td>Satisfied</td>
</tr>
<tr>
<td>3</td>
<td>Summer</td>
<td>1.037</td>
<td>0.980</td>
<td>Satisfied</td>
</tr>
<tr>
<td>3</td>
<td>Winter: HP</td>
<td>1</td>
<td>0.890</td>
<td>Not satisfied</td>
</tr>
<tr>
<td>3</td>
<td>Winter: HP, SC</td>
<td>1</td>
<td>0.912</td>
<td>Near limit</td>
</tr>
<tr>
<td>3</td>
<td>Winter: HP, SC, TESS</td>
<td>1</td>
<td>0.952</td>
<td>Satisfied</td>
</tr>
</tbody>
</table>
Conclusions and future work

• Adding only PV increases the voltage in summer.

• Replacing gas-based boilers for heat pumps as sole heat sources in most buildings can cause the voltage to drop outside the limit allowed by the technical standard EN50160.

• Combining heat pumps with solar collector reduces the usage of the heat pump, but the voltage still remains near the allowed limit.

• Adding thermal storage showed the best voltage behavior in the distribution network.

• Further work is recommended in aggregating the individual MCES systems to enhance the flexibility of the network, consider aging of the batteries and including EV chargers.
The project was carried out with a Top Sector Energy subsidy from the Ministry of Economic Affairs and Climate, carried out by the Netherlands Enterprise Agency (RVO). The specific subsidy for this project concerns the MOOI subsidy round 2020.
Discussion and contact

Multi-carrier coupling and system aggregation