Clustering of LV Feeders

Appendix J

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3rd October 2014
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Outline

- Why clustering?
- Data overview
- Data cleansing and validation of feeders
- Clustering process
- Final clusters and representative feeders
- Key remarks
Why Clustering?

- ENWL has more than 2 million LV customers, 30,000+ LV substations and 180,000+ feeders.

- Analysing all the feeders (for whatever study) is not feasible.

- Hence, representative feeders can be used to carry out studies and extract rules that can then be extrapolated to the population they represent.
  - Less complexity
  - More detailed analysis from what is done now
Data Overview

- **99 + 61 LV Networks with processed GIS data**
- **topological data**
- **monitoring data**
- **Set of 383 feeders with both combined**
- **Validation and data cleansing**
- **Set of 232 feeders**

- The set of 232 feeders was clustered in order to obtain a set of representative feeders.
Data Cleansing and Validation of Feeders

- Any sort of outliers need to be excluded.
  - An initial data cleansing process was applied to remove feeders with uncommon characteristics.

- Feeder validation using monitoring data.
  - Monitored Energy vs. ENWL’s Elexon-based profiles
  - Max difference from 2 periods compared:

\[ E_{3\Phi\text{ (all day)}} \& E_{3\Phi\text{ (5-8pm)}} \leq 60\% \rightarrow \text{Feeder is valid} \]

245 validated feeders (64%) → 232 final feeders
Clustering Process

M feeders (patterns)

Select H features to represent each feeder

M x H Data set

Normalization of data

Clustering

Validity indices

Set of representative feeders

Do the cluster by feeder

Each feeder will be defined by a vector

Different Algorithms

- K-means++
- K-medoids++
- Hierarchical
Optimal Number of Clusters

- Multiple validity indices are used to assess the quality of different number of clusters
- Algorithms are compared to identify the optimal number
Macro-Partitions (with/without DG)

- In which conditions a new group of representative feeders could be created in base of the presence of DG units.
Characteristics of Clusters – without DG

- Total n° of customers
- Domestic unrestricted customers
- Domestic TWO RATE customers
- Small non domestic OFF PEAK customers
- Small non domestic unrestricted and TWO RATE customers
- LV medium non domestic customers
Characteristics of Clusters – without DG

- Mean 3 phase daily active power
- Power factor
- Neutral current
- Total conductor length
- Main path distance
- Total path impedance
Characteristics of Clusters – with DG

![Characteristics of Clusters – with DG](image_url)

- Total n° of costumers
- Mean 3 phase daily active power
- Neutral current
- Total conductor length
- Penetration level
- Total DG declared capacity

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## Final Set of Representative Feeders

<table>
<thead>
<tr>
<th>K</th>
<th>Total cable length</th>
<th>N° of costumers</th>
<th>Type of costumers</th>
<th>Power consumption</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small</td>
<td>Low</td>
<td>Domestic (mainly domestic unrestricted)</td>
<td>Low</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Small-medium</td>
<td>Medium-high</td>
<td>Domestic (presence of some low consumption non-domestic and LV medium non domestic costumers)</td>
<td>Highest</td>
<td>Highly density area - High neutral current</td>
</tr>
<tr>
<td>3</td>
<td>Small</td>
<td>Low</td>
<td>Domestic (presence of some low consumption non-domestic and LV medium non domestic costumers)</td>
<td>Medium</td>
<td>High neutral current</td>
</tr>
<tr>
<td>4</td>
<td>Large</td>
<td>Medium</td>
<td>Domestic-non and domestic (considerable presence of LV medium non domestic costumers)</td>
<td>Medium-high</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>Small</td>
<td>Low</td>
<td>Domestic and non-domestic (30% small non-domestic costumers)</td>
<td>Medium</td>
<td>High neutral current</td>
</tr>
<tr>
<td>6</td>
<td>Large</td>
<td>Medium</td>
<td>Domestic (mainly domestic unrestricted)</td>
<td>Medium</td>
<td>N/A</td>
</tr>
<tr>
<td>7</td>
<td>Largest</td>
<td>High</td>
<td>Domestic (mainly domestic unrestricted)</td>
<td>High</td>
<td>Low neutral current</td>
</tr>
<tr>
<td>8</td>
<td>Small</td>
<td>Low</td>
<td>Domestic (big presence of domestic two rate costumers)</td>
<td>Low</td>
<td>Main cable path represents 50% of the total cable length</td>
</tr>
<tr>
<td>9</td>
<td>Small</td>
<td>Low</td>
<td>Domestic (mainly domestic unrestricted)</td>
<td>Lowest</td>
<td>High PV panels penetration level (~40%)</td>
</tr>
<tr>
<td>10</td>
<td>Medium</td>
<td>Medium</td>
<td>Domestic-non and domestic (presence of LV medium non domestic costumers)</td>
<td>Low</td>
<td>Medium PV panels penetration level (~30%) - Low neutral current</td>
</tr>
<tr>
<td>11</td>
<td>Large</td>
<td>Medium-high</td>
<td>Domestic (mainly domestic unrestricted)</td>
<td>High-Medium</td>
<td>Low PV panels penetration level (~20%) - insignificant neutral current</td>
</tr>
</tbody>
</table>

![Pie chart showing distribution of clusters](chart.png)
Final Set of Representative Feeders
Final Set of Representative Feeders
Key Remarks

- 11 representative feeders were obtained (3 with PV).

- Three representative feeders (1, 6 and 7) correspond to pure domestic feeders of different lengths without PV penetration (or insignificant). They represent >70% of the whole population.

- The proposed methodology is scalable and generic. It can be applied to a larger set of feeders as well as other DNOs.

- Analysis can be carry out on the representative feeders and the results can then be extrapolated to the corresponding populations.
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