Understanding and modelling of load in the power system

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Background

This project has been part of an ongoing research activity between the Nordic Transmission System Operators (TSOs) and STRI. The aim of the research activity has been to validate and update the load models used for planning purposes, as there is a lack of evidence on the suitability of the present model parameters. Currently, the Nordic TSOs represent the load with aggregate ZIP load models. In previous subprojects, the TSOs and STRI have agreed on a methodology to model aggregate loads in the power system.

Methodology

1. Selection of a load model structure: constrained ZIP.
2. Derivation of the model parameters by two approaches:
   - Component-based approach - Aggregation to find the model parameters using predefined ZIP values.

$$(Z_p, I_p, P_p)_{agg} = \sum_{n=1}^{N} c_n \cdot (Z_p, I_p, P_p)_n$$

$$(Z_q, I_q, P_q)_{agg} = \sum_{n=1}^{N} \tan(\arccos PF_1) \cdot c_n \cdot (Z_p, I_p, P_p)_n$$

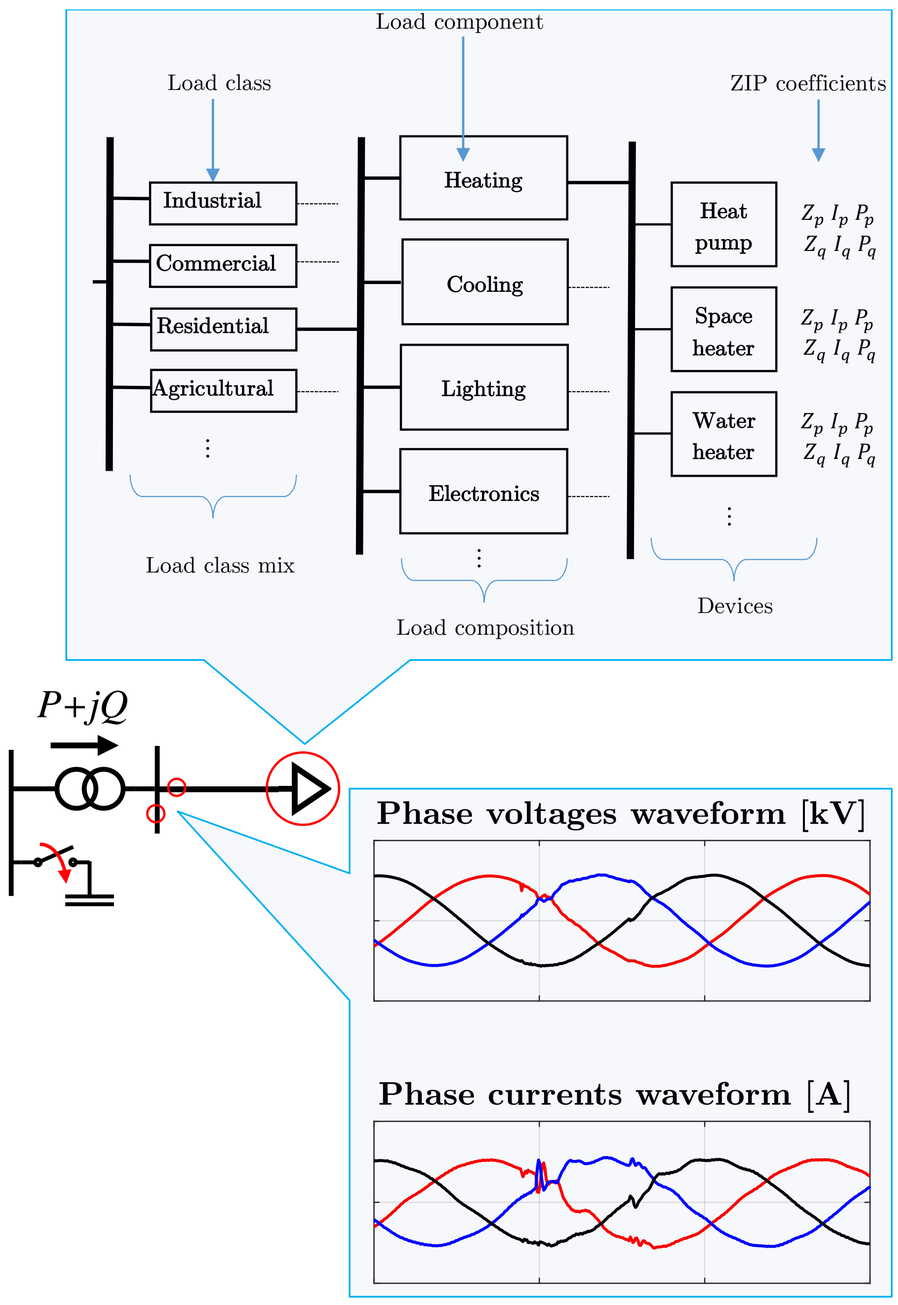
   - Measurement-based - Curve-fitting to the measured aggregate active and reactive response of the load to a voltage step.

$$\text{minimise} \quad \frac{1}{N}\sum_{i=1}^{N}\left\{P_i - P_0\left[Z_p\left(\frac{U_i}{U_0}\right)^2 + I_p\left(\frac{U_i}{U_0}\right) + P_p\right]\right\}$$

$$(Z_p, I_p, P_p)$$

$$\text{subject to:} \quad Z_p + I_p + P_p = 1$$

$$0 \le Z_p, I_p, P_p \le 1 \leftarrow \text{(constrained ZIP)}$$



Case study results

The methodology was applied on a load point in Sweden. The load class mix and load composition were obtained from statistics; and the predefined devices' ZIP parameters, from previous studies. Furthermore, the event initiated by switching a capacitor bank on, resulted in $\Delta U = 1.53\ \%$, $\Delta P = 1.86\ \%$ and $\Delta Q = 252\ \%$.

ZIP parameters obtained from applying the methodology:

ZIP parameters	Zp	Ip	Pp	Zq	Iq	Pq
Component-based	0.27	0.03	0.70	1.54	-1.64	1.10
Measurement-based	0.38	0.41	0.21	1.00	0.00	0.00
TSO's choice	0.40	0.00	0.60	0.90	0.00	0.10

Discussion

- Comparison of the results is limited, as the component-based yields an average, whereas the measurement-based is based on a 'snapshot' of the system.
- Most of the predefined ZIP parameters from previous studies are outside the [0,1]-interval (accurate type), which have influenced the results of the component-based approach, particularly for the reactive power part.
- The measured reactive power response is very large considering the step in the voltage.

Conclusions

- The load class mix and load composition depend heavily on statistics.
- Hard to find representative ZIP parameters in literature.
- The component-based approach can result in non-physical significant ZIP parameters (outside the [0,1]-interval).
- The (constrained) ZIP is unable to represent the step in the measured reactive power.
- There are multiple solutions that yield a good curve-fitting.

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Further reading

PEREZ TELLEZ, Adriel. "Modelling aggregate loads in power systems". KTH, 2017.

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