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AN APPROACH FOR THE SIMULATION AND CONTROL OF MICROGRIDS UNDER CONSIDERATION OF VARIOUS ENERGY FORMS AND MASS FLOWS

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Motivation and Purpose

Microgrids (MG), as an aggregation of distributed generators (DG), energy storage systems (ESS) and energy consumers, can help tackle economic, ecologic and technical issues in distribution grids.

However, to control the MG components in an economically and ecologically reasonable way, all occurring energy forms, e.g. electric and thermal energy, and mass flows, e.g. natural gas, have to be taken into account. The presented approach deals with short-term operation planning in hourly periods. It addresses the problem to determine optimal operating points for each controllable MG component in each time step.

Introduction - Methodology

Characteristics of the presented approach

- Step-wise simulation of a MG consisting of several components (DG, ESS, consumers)
- Step-width = 1 h
- Short-term operation planning: determining operating points for each controllable MG component in each time step via linear optimisation
- Non-linear component behaviour is regarded
- Different energy vectors and dimensions are considered, e.g. electric and thermal energy, natural gas (NG) mass, operation costs
- Suitable for determining Key Performance Indicators (KPI) of the modelled MG

Component in- and outputs & optimisation targets

The considered energy vectors and dimensions constitute the set of possible component in- and outputs and are called model parameters $P = \{p_1, \dots, p_n\}$. They are divided into target *(T)* and balance parameters *(B)* pursuant to the following expressions:

$$T \cup B = P$$
$$T \cap B = \emptyset$$

Target parameters are used to form the target θ of the optimisation that is to be minimized or maximized. Balance parameters are used to formulate balance equations to be fulfilled during the optimisation.

Methodology - Component Transfer Functions & Linearisation

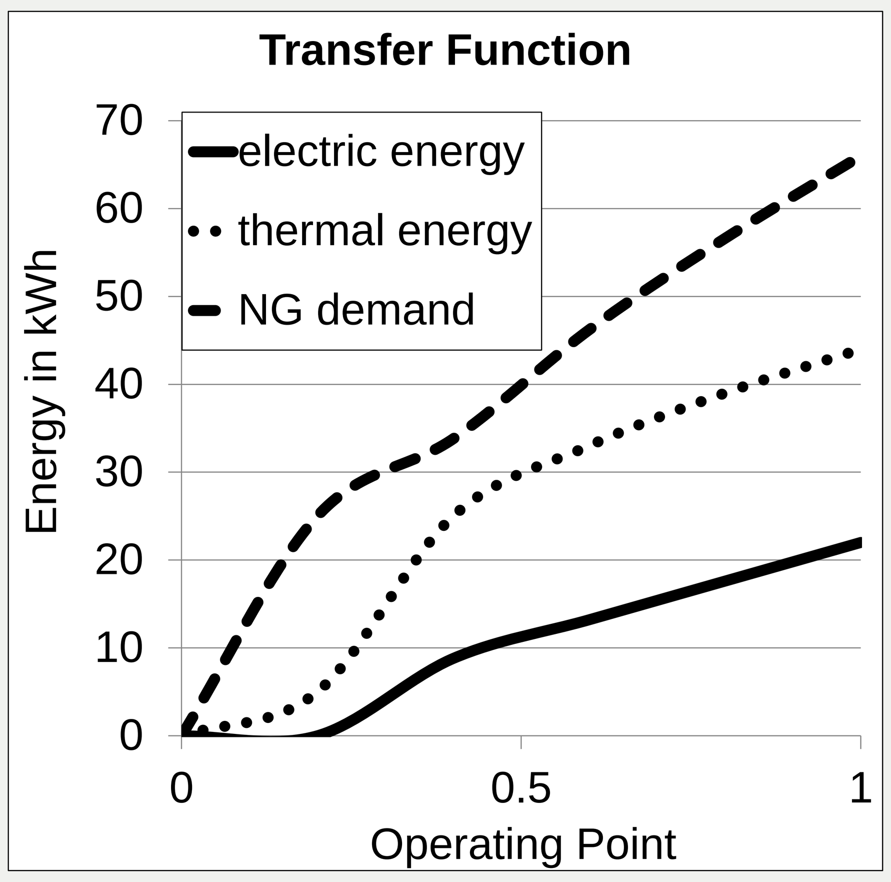

Figure 1: Exemplary transfer function

The components are characterised by their transfer function, which is allowed to be non-linear. Figure 1 gives an example of a model's transfer function. For a given operating point x_i the model produces a vector of results $\boldsymbol{a}_i$. Its elements correspond to the defined parameters $p \in P$. In order to attain a sufficient approximation of the component's behaviour, the result vector $\boldsymbol{a}_i$ of component *i* is computed for *m* chosen sampling points $x_{i,1..m}$. The matrix $\boldsymbol{R}_i$ combines the output vectors resulting from the evaluation of the sampling points: $\boldsymbol{R}_i = (f_i(x_{i,1}) \ \dots \ f_i(x_{i,m})) = (\boldsymbol{a}_{i,1} \ \dots \ \boldsymbol{a}_{i,m})$

It constitutes a section-wise linearisation of component *i*'s non-linear behaviour. This matrix comprises $j \in \{1, \dots, m-1\}$ linear sections, defined by a vector of absolute terms $\boldsymbol{s}_{i,j}^{abs}$, a vector of linear terms $\boldsymbol{s}_{i,j}^{lin}$ and boundaries regarding the component's operating point x_i:

$$\boldsymbol{s}_{i,j}^{abs} = \boldsymbol{a}_{i,j} \qquad \boldsymbol{s}_{i,j}^{lin} = \frac{\boldsymbol{a}_{i,j+1} - \boldsymbol{a}_{i,j}}{x_{i,j+1} - x_{i,j}} \qquad j \in \{1, \dots, m-1\},\ x_i \le x_{i,j+1} \wedge x_i \ge x_{i,j}$$

The result matrices of all *c* components as well as all section terms are determined. One section of each component has to be combined with one section of every other component, in order to constitute a linear equation system (LES) describing parts of the MG behaviour. Since the entire behaviour is to be gathered, every possible combination of sections has to be considered, so there are $(m-1)^c$ LES. They can be solved using linear optimisation techniques. The best solution in regard of θ is determined.

The presented section-wise linearisation can require a high computational effort dependent on the size of $(m-1)^c$. To address this problem, a new method for optimisation of LES is applied. It is called Multiplex and accelerates computation by executing the simplex algorithm on many identically shaped LES at the same time.

Results & Discussion

The result quality of the presented approach is high since it copes with non-linear model behaviour. Furthermore, the section-wise linearisation allows for utilisation of linear solvers and therefore is more efficient than stochastic approaches. Additionally the use of the newly developed Multiplex algorithms shows a significant acceleration of computation compared to solving many LES consecutively with standard solving methods (cf. Figure 2).

On the other hand the computational effort to be made is strongly dependent on the setup of the microgrid. If there are many components with highly non-linear behaviour, the number of linear sections is high. As a consequence, the number of LES rises exponentially.

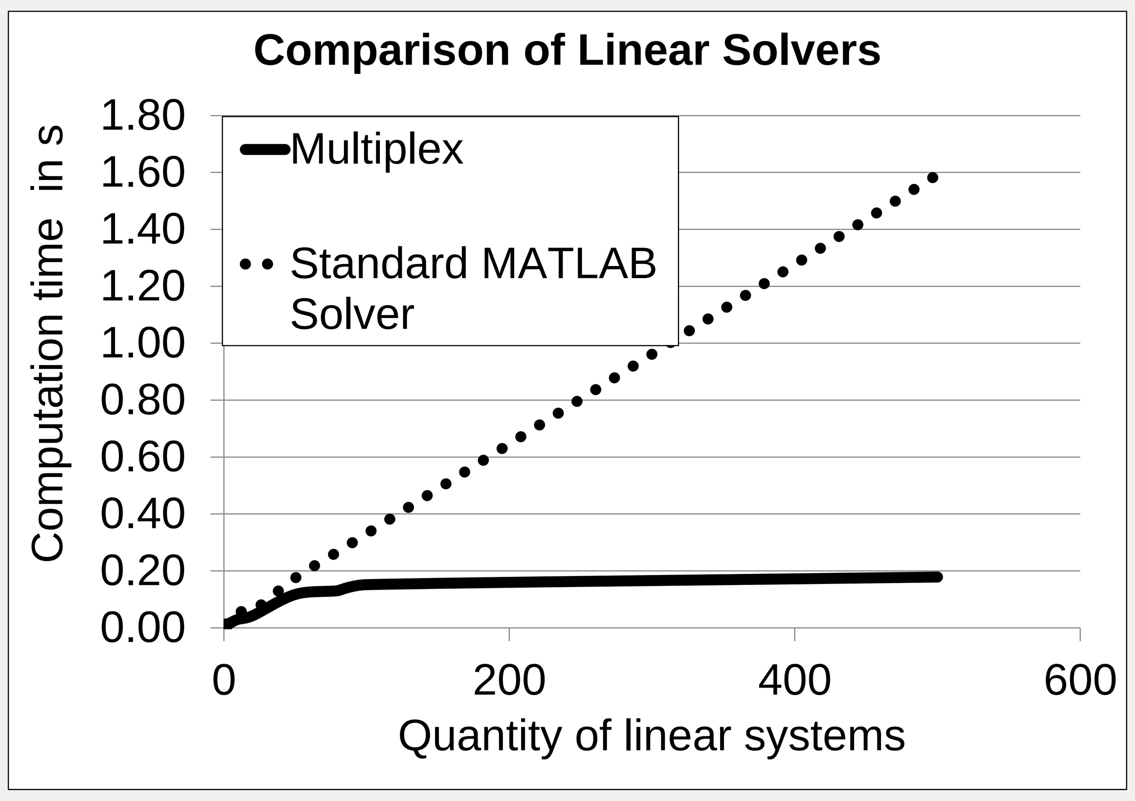

Figure 2: Comparison of linear solvers showing the effectiveness of Multiplex

Conclusion

The presented methodology:
- **addresses short-term optimisation of MGs**
- **regards any kind of component and dimension**
- **considers non-linear component behaviour by section-wise linearisation**
- **shows a high computational performance due to applicability of linear solvers**
- **includes Multiplex as a newly developed solver**
- **is deterministic**
- **loses efficiency with the number of components and level of non-linearity rising**

Further research could:
- **improve computation speed by setting sampling points individually for each transfer function**
- **improve quality of decision making compared to step-wise optimisation by introducing foresight**

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