RWTH AACHEN UNIVERSITY

E.ON Energy Research Center
ACS | Institute for Automation of Complex Power Systems

Master-Thesis / Diplomarbeit:

Generation of representative distribution networks based on Complex Network theory

Erzeugung repräsentativer Verteilnetze auf Grundlage der Theorie komplexer Netzwerke

Context:

Because of the major changes undergoing in modern power systems, traditional transmission system applications (fault detection, state estimation, voltage control, etc.) are being introduced at the distribution grid level. The increasing complexity of distribution systems requires grid models to develop and validate the emerging algorithms, as well as to test and simulate the emerging applications. However, there is often an evident difficulty to obtain the required data for building such grid models, due to proprietary concerns and security issues. In this context, there is an impelling need to generate test networks which can be considered as '*representative networks*', i.e., test grids able to appropriately represent the behavior of (a set of) real distribution systems. Given their nature, these representative networks can be effectively and flexibly used for a plethora of applications, simulations and analyses in the power system domain.
Out of the different attempts developed for generating representative networks, very appealing is the approach of using Complex Network (CN) theory (Figure 1). According to this new emerging approach, the actual distribution system can be effectively seen as a graph whose nodes (vertices) and edges (links between vertices) embed different properties, both topological and electrical. The extracted CN statistical patterns can be employed to characterize the original distribution system as well as to generate representative systems, which are "statistically similar" to the original one (Figure 2). This approach offers several benefits, among which the smaller amount of data required to generate test grids and the possibility to automatize the test grid generation process paving the way for scenarios and analyses previously difficult to realize (e.g., creation of a large number of grid samples at a very little cost in the perspective of Monte Carlo simulations and uncertainty propagation techniques).

The overall goal of this thesis topic is, after familiarizing with the CN theory, the analysis and validation of an already developed MatLab algorithm for CN-based automatic generation of distribution grid models (Figure 3). Possible extensions and further refinement of the algorithm may be an added value of the activity, with the possibility to contribute to some crucial tasks within the context of an H2020 European project. Sensitivity analyses of the algorithm may be included to evaluate which are the algorithm parameters mostly affecting the results.

Your tasks (and therefore the skills you will acquire):

- Analysis of selected literature to become familiar with CN theory
- Getting in touch with a Python software (NetworkX) for manipulating CNs
- Analysis and validation of an already existing CN-based MatLab algorithm (Figure 3) by using some selected test grid models (e.g., IEEE test feeders, CIGRE test feeders, real distribution grids etc.)
- Possible refinement of the algorithm and its application to a selected test case for creating representative networks
- Possible sensitivity analysis of the algorithm performance using robust statistical methods (e.g., variance-based decomposition methods, design of experiments)

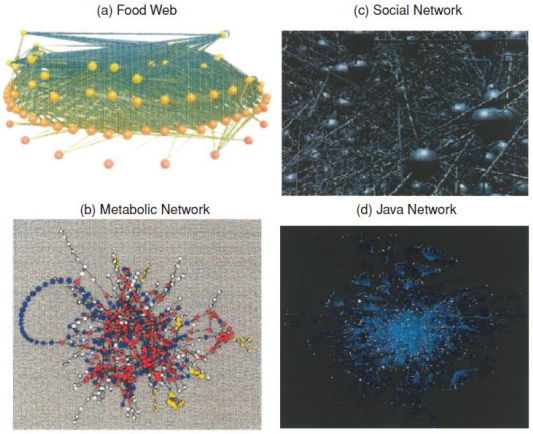

Figure 1 *Examples of CN applications in different domains [1].*
Studying the power grid under a CN perspective is the focus of this research work.

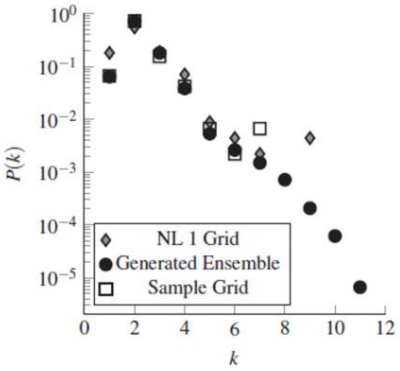

Figure 2 *Intuitive illustration of the 'statistical similarity' concept between one real distribution grid (in the figure, "*NL1 Grid"*) and a set of generated test grids (in the figure, "*Generated Ensemble"*). As it can be seen, the real grid (diamonds) and the set of generated test grids (filled circles) exhibit the same statistical distribution of P(k), a basic CN metrics [2]*

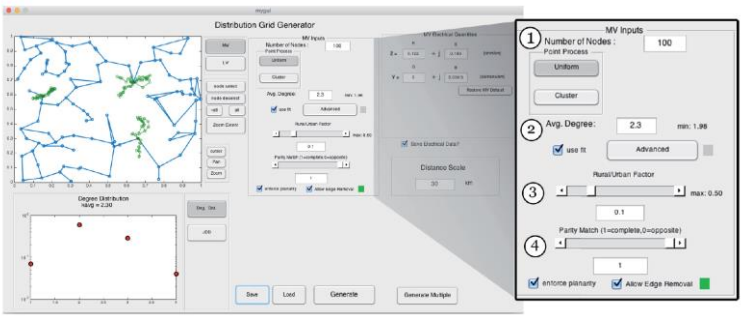

Figure 3 *Screenshot of the CN-based MatLab algorithm used to generate representative distribution networks [2].*

Your profile:

- RWTH student of Electrical Engineering (but students coming from other RWTH faculties or other universities are welcome to apply)
- Basic (but effective!) skills of MatLab and Python
- Basic knowledge about power grids and distribution systems
- General knowledge of statistics is a plus

Notes:

The supervision will be done in English.

References

[1] Xiao Fan Wang and Guanrong Chen, "Complex networks: small-world, scale-free and beyond," in *IEEE Circuits and Systems Magazine*, vol. 3, no. 1, pp. 6-20, 2003, doi: 10.1109/MCAS.2003.1228503

[2] E. Schweitzer, K. Togawa, T. Schloesser and A. Monti, "A Matlab GUI for the Generation of Distribution Grid Models," *International ETG Congress 2015; Die Energiewende - Blueprints for the new energy age*, Bonn, Germany, 2015, pp. 1-6

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