Doctoral Thesis

Hybrid energy transmission for multi-energy networks

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Hybrid Energy Transmission for Multi-Energy Networks

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presented by
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Summary

The extensive development of renewable, stochastic and distributed energy sources will lead to major changes in the electricity grid. Possible long term trends include a higher level of interaction between different energy carrier systems (electrical, chemical and thermal). This would facilitate storage solutions as well as the inclusion of new participants into public energy networks, e.g. new transportation technologies like hybrid or plug-in cars.

A framework for the description of these upcoming multi-energy networks has been developed in the “Vision of Future Energy Networks” project. It consists of Energy Hubs, interfaces for network participants and Energy Interconnectors, which transmit several forms of energy. Combined infrastructures for multiple energy carriers are an innovative response to future challenges including the integration of renewable sources and novel storage principles. This work aims at proposing a principle scheme for multi-energy transmission, establishing a set of models for this scheme, assessing the achievable performance of such systems under realistic assumptions and determining a suitable application range.

The interconnector principle described in this work is a novel approach to energy transmission, thus it was necessary to determine a promising variant (variant selection), the relevant physical phenomena (model), their implication on the design and operation of an interconnector and the possible application range. The spectrum of the possible energy carriers includes electricity, natural gas, hydrogen, liquid hydrocarbons, compressed air, district heating, district cooling, etc.. A promising solution with respect to the integration into future network concepts is the combination of electric and gaseous chemical energy transmission.

A set of models has been developed for this preferred variant. The specific formulation of the compressible, non-adiabatic gas flow with friction has required an adaptation of existing formulations, which yielded a numerical model. In a second step, analytical approximations have been developed, in order to derive scaling laws for the
interconnector layout.

Based on these models, the relevant operational characteristics of the interconnector system have been identified. The resulting description of the transmissible electric, chemical and thermal power has been used to derive a layout methodology for the interconnector with a given transmission capacity and transmission length.

In a final step, the layout strategy developed has been applied to different scenarios describing various transmission distances and transmissible powers. The comparison of the resulting interconnector dimensioning shows that the most promising application area for further study of the interconnector corresponds to the current medium voltage network level, i.e. the transmission of some tens of MW of electric and chemical power over a distance of some tens of km.

The layout method can now be used in infrastructure scenarios to be developed in the future within the “Vision of Future Energy Networks” project, where interconnectors will form an important part of network development strategies.
Zusammenfassung


Für diese Vorzugsvariante wurden Modelle entwickelt, welche die Beschreibung des kompressiblen, nicht-adiabatischen und rei-
bungsbehafeten Gasflusses umfassen. In einem weiteren Schritt wurden analytische Näherungen entwickelt, welche die Ableitung einer Layout-Prozedur ermöglichten.

Schließlich konnte diese Layout-Prozedur auf verschiedene Szenarien angewandt werden, welche einen breiten Bereich an Übertragungslängen und -leistungen abdecken. Der Vergleich der resultierenden Interconnector-Auslegungen ergab, dass der meist-versprechende Anwendungsbereich des Interconnector-Prinzips im Bereich einiger zehn MW elektrischer und chemischer Leistung über eine Länge von einigen zehn Kilometern liegt.

Die hier entwickelte Layout-Prozedur kann im Rahmen der in nachfolgenden Projektphasen zu entwickelnden Infrastrukturszenarrien angewandt werden.