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Suitable Models and Methods for the Steady-State Analysis of Multi-Energy Networks

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Abstract : The motivation for the development of this paper lies in the need for energy networks to reduce losses, improve performance, optimize their operation and try to benefit from the interconnection capacity with other networks enabled for other energy carriers. These interconnections generate interdependencies between some energy networks and others, which requires suitable models and methods for their analysis. Traditionally, the modeling and study of energy networks have been carried out independently for each energy carrier. Thus, there are well-established models and methods for the steady-state analysis of electrical networks, gas networks, and thermal networks separately. What is intended is to extend and combine them adequately to be able to face in an integrated way the steady-state analysis of networks with multiple energy carriers. Firstly, the added value of multi-energy networks, their operation, and the basic principles that characterize them are explained. In addition, two current aspects of great relevance are exposed: the storage technologies and the coupling elements used to interconnect one energy network with another. Secondly, the characteristic equations of the different energy networks necessary to carry out the steady-state analysis are detailed. The electrical network, the natural gas network, and the thermal network of heat and cold are considered in this paper. After the presentation of the equations, a particular case of the steady-state analysis of a specific multi-energy network is studied. This network is represented graphically, the interconnections between the different energy carriers are described, their technical data are exposed and the equations that have previously been presented theoretically are formulated and developed. Finally, the two iterative numerical resolution methods considered in this paper are presented, as well as the resolution procedure and the results obtained. The pros and cons of the application of both methods are explained. It is verified that the results obtained for the electrical network (voltages in modulus and angle), the natural gas network (pressures), and the thermal network (mass flows and temperatures) are correct since they comply with the distribution, operation, consumption and technical characteristics of the multi-energy network under study.

Keywords : coupling elements, energy carriers, multi-energy networks, steady-state analysis
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