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Decision support for strategic microgrid design integrating governance, business, intelligence, communication, and physical perspectives

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ABSTRACT

Microgrids are custom-designed, but their extensive design options hinder their dissemination. Consequently, microgrid-interested parties need strategic support to identify suitable design options for their use case. This paper develops a decision support artifact in the form of a decision tree for recommending the most suitable microgrid design for a project. A multi-step design science-oriented process was used. First, a morphological analysis of academic literature was conducted to deduce all possible microgrid design options and visualize them in a morphological box. Once done, 62 real-world microgrids of diverse types and locations were classified according to the morphological box. The produced dataset was used to derive five microgrid design archetypes algorithmically using cluster analysis. The dataset and their associated archetypes were then fed into a rule-mining algorithm to generate a decision tree that recommends the appropriate microgrid archetype based on up to four questions about, for instance, the microgrid's objective and the connectivity to the main grid. Furthermore, design principles for each microgrid archetype recommendation were formulated. The developed design artifact serves as applicable knowledge and a benchmark framework for researchers, as well as a comprehensive and simultaneously simplified decision-making framework for practitioners.

1. Introduction and motivation

Our goal is to facilitate the establishment of microgrids by providing strategic decision support for microgrid-interested parties (e.g., communal politicians and the energy managers of residential and commercial building complexes) before they reach out to consultants. Microgrids are delimitable distribution networks that incorporate distributed energy resources (DERs) and that balance energy generation and demand at a local level (Sachs et al., 2019). The predominant US microgrid definition (CERTS, 2019) includes the provision of both electricity and heat, whereas the more prevalent European definition (European Commission, 2012) is limited to the provision of electricity (Sachs et al., 2019). This study focuses upon the latter. Microgrids are typically classified by their application area into campus, commercial/industrial, community/utility, military, and remote (Asmus & Lawrence, 2016; Hirsch et al., 2018; Kariniotakis et al., 2014). They represent a viable option for fostering the sustainable transformation of utility networks, organizations, and communities (Sachs et al., 2019). Due to their information and communication technology (ICT)-enabled potential to integrate a significant amount of DERs safely and efficiently, they support decarbonization in the energy sector (Hirsch et al., 2018). Therefore, the establishment of microgrids should be promoted. This is consistent with the United Nations (UN) Sustainable Development Goals (SDGs). The SDGs define sustainability not only ecologically but also economically and socially (UN, 2015). In addition to energy decarbonization, microgrids offer economic benefits (Stadler et al., 2016) and can promote social benefits, particularly remote microgrids (Briganti et al., 2012). Thus, microgrids foster sustainable urban development.

According to Wouters (2015, p. 26), "[…] microgrids are tailor-made in design." This depends on the needs and objectives of the stakeholders and the surrounding environment, e.g., islanded or utility-grid-connected, and with centrally-operated or decentralized energy management. This results in an extensive array of design options that hinder the dissemination of microgrids. Accordingly, interested parties require strategic support in identifying the most suitable options. Specifically, Nakabi and Toivanen (2021, p. 1) recognized that "designing and implementing a successful energy management system for future microgrids constitutes a challenging task because of the high dimensionality and uncertainty of the microgrid components." This challenge limits the "real-world decision-making and implementation

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