

# **A literature review of microgrids: a functional layer based classification**

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**Abstract—** Operation of distributed energy resources and resilience related problems are becoming of most importance in the pursuit for a more sustainable electricity delivery. Microgrids (MGs) could contribute significantly to both issues and may play an important role in the new decentralized paradigm of power systems. This paper proposes a hierarchical organizational scheme of MGs with a clear distinction of the Microgrid, Nanogrid and Picogrid concepts, and addresses a detailed technical literature review to identify and classify MGs main features and design alternatives. Definitions; descriptions of MGs, Nanogrids, Picogrids; operation modes; business models and communication protocols are dispersed in the literature. In order to gather clearly all the existing information, this review has been organized according to four functional layers, inspired by the ones commonly used in Smart Grid architecture description. For each one and whenever possible, the paper classifies the outcomes of the review in a table kind of format that helps summarizing the different MGs' options. Regarding the first layer, the paper describes the different physical devices involved in MGs, such as generators, converters, electric vehicles (EV) and energy storage systems (DS) and the DC levels that are being discussed. For the second layer the paper addresses a review of the communication protocols currently used or proposed. Then, the intelligence layer is analyzed concerning any decision making issue related to operation and planning of the MGs as well as any other aspect that may be relevant for taking advantage of MGs potentiality. In the last layer, the paper reviews different business models adapted to a future where MGs will be deployed. Finally, the paper ends with an exhaustive review of the practical MG experiences in place worldwide, classified according to the issues presented previously, and a brief discussion of the key points to be addressed in the MGs deployment.

**Index Terms—** Microgrid; Communication Protocols; Microgrid Testbeds; Aggregation Types; Business models; Distributed Energy Resources; Electric Vehicle; Demand Response.

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