Technologies for Interoperability in Microgrids for Energy Access

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***Abstract*—Photovoltaic (PV) microgrids have been one of the technological solutions to the lack of energy access in last-mile communities. As PV technology gains popularity, more industry players enter the electricity market, resulting in interoperability issues. Interoperability is an important feature of an electricity system as it improves system reliability. It is also essential for microgrid scalability as it enables adaptable integration with one another, other decentralized solutions, or with the centralized grid. The purpose of this paper is to examine the current state of technology for PV microgrid interoperability. We discovered that the literature on interoperability in the context of microgrids is primarily limited to information and communication technologies. We classified the identified technologies into a five-layer microgrid architecture.**

Keywords—energy access, interoperability, microgrid, photovoltaic

I. Introduction

Photovoltaic (PV) microgrids have become a prominent decentralized solution as they are powered by renewable energy, supported by digital technologies, and located closer to consumers. As PV technology gains popularity, more new actors, including industry players, enter the electricity market, offering competitive products rather than relying on centrally governed energy access initiatives. This raises the issue of interoperability.

The purpose of this paper is to examine the current state of technology for interoperability applied in PV microgrids. We reviewed 79 Scopus-indexed publications in the field of energy to identify these technologies and classify them into a five-layer microgrid architecture.

II. Facets of Interoperability

Interoperability can be defined as "the ability of two or more networks, systems, devices, applications, or components to interwork, to exchange and use the information to perform required functions" [1]. Practitioners consider two domains: the *physical domain*, which relates to hardware and firmware requirements that enable compatibility, and the *communication domain*, which involves the exchange, collection, distribution, analysis, and utilization of data and information [2]. Ensuring devices or systems coexist and are able to interoperate requires electromagnetic compatibility (EMC) to be fulfilled.

III. Technologies for Interoperability

We adapted the three-dimensional microgrid architecture [3] consisting of five interoperable layers, two networks, and two roles on the actor domain (Fig. 1) to map several technologies proposed in the reviewed papers. The physical layer constitutes the physical components of the electricity system where data are acquired from meters and energy management systems. The information and communication technologies (ICT) layer addresses data relay through communication protocols. This layer is indispensable for interoperability as it allows information exchange. The control layer has the function to collect information from the other layers, make predictions based on data, and take decisions in microgrid operation. The market and business layer deals with business models and market operations, such as managing Peer-to-Peer (P2P) trading and determining the amount of energy quota. The regulation layer includes legal framework and regulation, e.g. standards relevant to microgrid design, operation, and interoperability [3]. This layer is critical in the context of energy access for the adoption of microgrids, especially concerning the arrival of the main grid. EMC applies to the physical, ICT, and control layers, and is a prerequisite for interoperability.

Several situations prompting interoperability include the introduction of modular and hybrid systems, the arrival of the grid in villages with already installed microgrids, and the technological advancement allowing integration of various distributed generation solutions which necessitates effective cooperation among units and systems from different vendors.

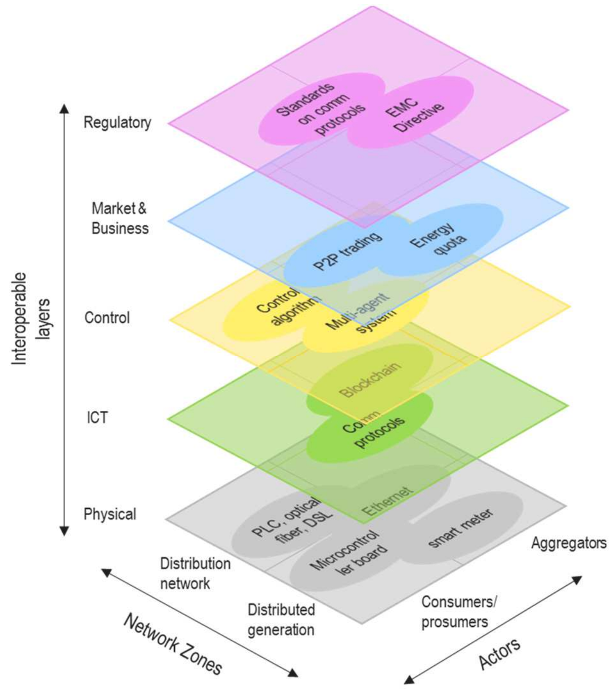

Fig. 1. Technologies for interoperability on the five-layer microgrid architecture. Adapted from [3].

IV. Conclusion

Microgrid interoperability is predominantly observed in smart grid and grid integration applications. The focus lies on the technologies within the ICT and control layers. Physical interoperability was not critically discussed, even though physical components must be electrically interoperable before communication for data exchange can take place.

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