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## Renewable energy emulation concepts for microgrids



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## ABSTRACT

This paper reviews the renewable energy systems emulators proposals for microgrid laboratory testing platforms. Four emulation conceptual levels are identified based on the literature analysis performed. Each of these levels is explained through a microgrid example, detailing its features and possibilities. Finally, an experimental microgrid, built based on emulators, is presented to exemplify the system performance.

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## 1. Introduction

The importance of distributed generation (DG) in the power system is increasing. The energy produced in these facilities must

be integrated to the grid and microgrids arise as a particularly beneficial solution. A microgrid is defined as a system compounded by different micro-sources and loads, operated by an energy manager, that is able to deliver heat and electrical power in a local area [1]. This definition has been evolving as other capabilities have been included to the concept as storage systems [2] or the islanding system operation [3]. Microgrids should be

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understood as small pieces of the whole power system and each of them could be designed and operated to meet different local specifications and objectives.

A microgrid is a relatively new concept, thus different studies related with the control, operation, design and protection are being developed. Among all these projects, the ones where real microgrids are built [4] are extremely interesting for testing the theoretical developments. Microgrids as the CERTS laboratory project (Consortium for Electrical Reliability Technology Solutions) [5] or facilities developed by other research centers are defining the specifications of the future microgrid concept [6]. In a laboratory scale, other setups are being built, as for example the IREC microgrid (Catalonia Institute for Energy Research) [7] or the platform proposed by the Energy Systems Research Laboratory, Florida International University [8]. These laboratory platforms, in contrast to the large experimental projects, include emulation devices which allow us to physically represent the behavior of many different resources. Emulators in combination with real systems increase the experimental laboratory platform capabilities enormously.

Focused on the emulation devices, this paper reviews the emulation structures proposed in the literature. As a result, emulation is divided into four different conceptual groups, defined as the emulation levels. To clarify this concept, the different emulation levels' features and characteristics are explained through an example microgrid layout, also including a complete classification of the literature review. Finally, a real laboratory platform, employing two

of the emulation levels defined, is presented. Three different emulators are included in this system, one acting as a photovoltaic panel, another as a battery and another one as a couple of loads, defining the basic structure of a microgrid. Experimental results are

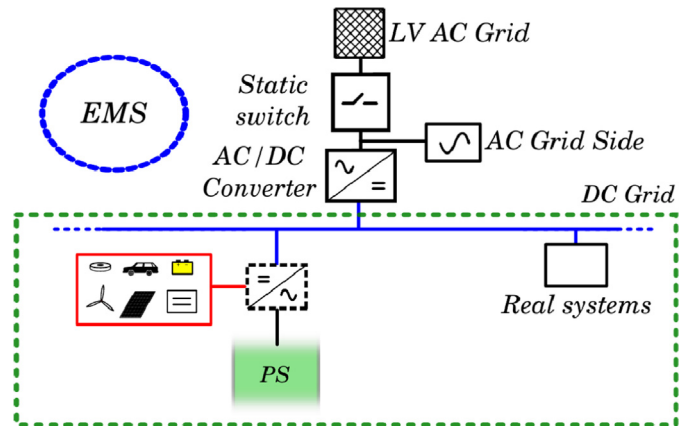


Fig. 3. Level 1 – global emulation scheme. (For interpretation of the references to color in this figure, the reader is referred to the web version of this paper.)

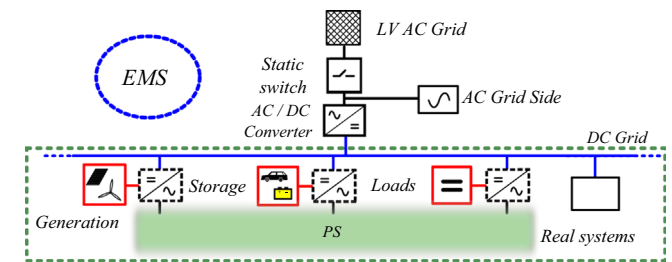


Fig. 4. Level 2 – aggregated emulation scheme.

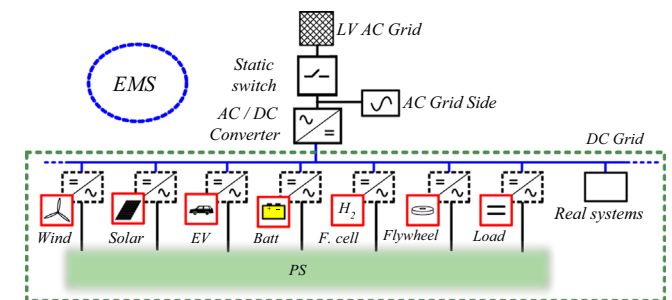


Fig. 5. Level 3 – resource emulation scheme.

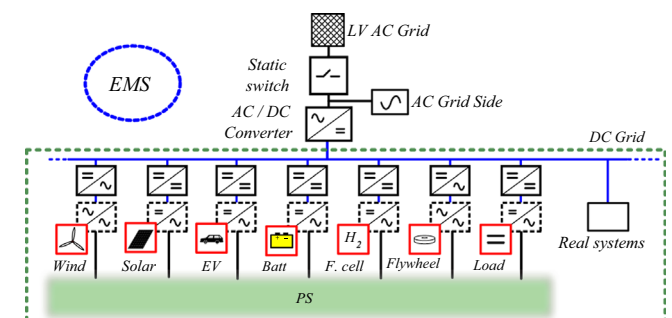


Fig. 6. Level 4 – specific emulation scheme.

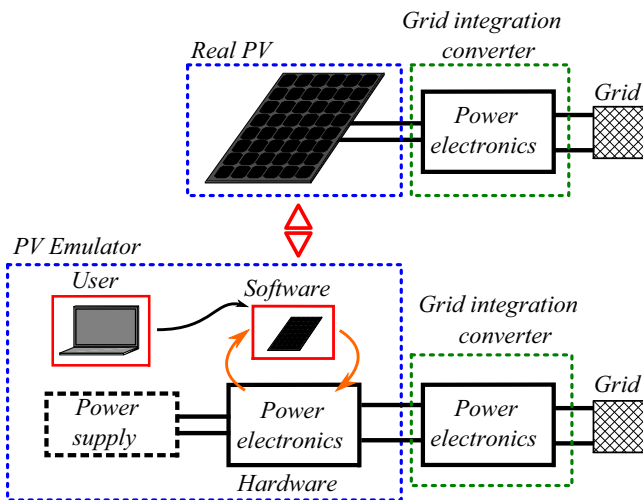


Fig. 1. Photovoltaic emulator concept.

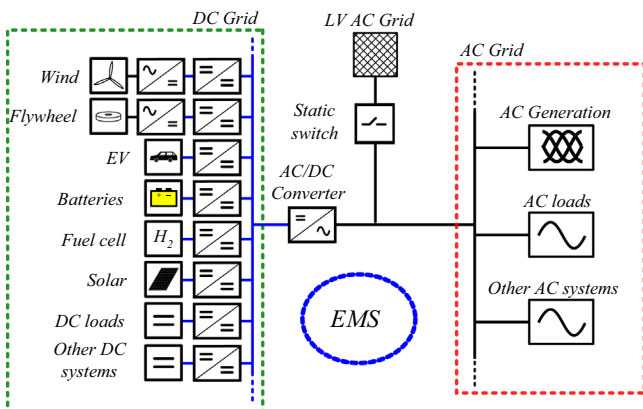


Fig. 2. Microgrid base electrical layout. (For interpretation of the references to color in this figure, the reader is referred to the web version of this paper.)

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