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Novel remote monitoring platform for RES-hydrogen based smart microgrid

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A B S T R A C T

In the context of the future power grids – Smart Grids (SGs) – Smart MicroGrids (SMGs) play a paramount role. These ones are very specific portions of the SGs that deal with integration of small-rated distributed energy and storage resources closer to the loads – chiefly within the distribution domain. Data acquisition and monitoring tasks are vital functions that must be developed at every stage of the grid for a proper operation. This paper presents a remote monitoring platform (RMP) to monitor an experimental SMG. It integrates Renewable Energy Sources (RESs) (solar and wind) and hydrogen to operate in isolated regime. The RMP has been developed using the open-source authoring tool Easy Java/Javascript Simulations (EJsS). The interface has been designed to be intuitive and easy-to-use, providing real-time information of all the involved magnitudes over the network. Scalability, easy development, portability and cost effective are the main features of the proposed framework. The microgrid and the proposed monitoring platform are described and the successful results are reported. The remote user executes a ready-to-use file with low computational requirements and is enabled to graphically and numerically track the SMG behaviour. These results prove the suitability of the RMP as an effective means for continuous visualization of the coordinated energy flows of a real SMG.

1. Introduction

Nowadays, the global energetic scenario is changing every day. Most of the countries are implementing politics to reduce the fossil fuel consumption and the consequent greenhouse effect, global warming and pollution. RESs, like solar, wind, biomass, geothermal, are being promoted as an increasingly efficient alternative with benefits like environmental respect, low emissions, and local availability and so on. In addition, by means of fuel cells and electrolyzers, hydrogen as energy carrier is also considered an essential tool to achieve a future sustainable energy system [1]. Among RESs options, solar and wind generators show worse predictability and can give a larger amount of power, whereas other kinds, like biomass, are man-activated sources are therefore controllable but with minor diffusion [2]. Moreover, integration with hydrogen production and storage technology improves the ability of the system to deal with energy discontinuities [3].

Notwithstanding the above, the shift towards the future framework is not only based on RESs utilization but also the incorporation of advanced communication and automation capabilities to the grids. This is the core concept of the emerging scope of SGs: intelligent networks of power generation, distribution and consumption.

Information and Communication Technologies (ICTs) constitute an enabling technology in the sense of providing communication, connectivity and data transmission ability in virtually any aspect of the current life. In the energy automation scope, these advances

Abbreviations: CCS, Centralized Control Station; DAQ, Data Acquisition Device; DPS, Decentralized Periphery Station; EESS, Electrochemical Energy Storage System; EJsS, Easy Java/Javascript Simulations; EMDL, Energy Management and Distribution Law; FLBC, Fuzzy Logic-Based Controller; HESS, Hydrogen Energy Storage System; HMI, Human-Machine Interface; HTSE, Higher Technical School of Engineering; ICTs, Information and Communication Technologies; JIL, Java Internet LabVIEW; OPC, Object-Linking and Embedding for Process Control; PCC, Point of Common Coupling; PEMEL, Polymer Electrolyte Membrane Electrolyzer; PEMFC, Polymer Electrolyte Membrane Fuel Cell; PLC, Programmable Logic Controller; PPS, Pilot Plant Server; PVG, Photovoltaic Generator; RESs, Renewable Energy Sources; RMP, Remote Monitoring Platform; SCADA, Supervisory Control And Data Acquisition; SG, Smart Grid; SMG, Smart MicroGrid; SOC, State of Charge; VI, Virtual Instrument; VNC, Virtual Network Computing; WG, Wind Generator.

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have penetrated in every monitoring issue, since the remote monitoring of power sources up to the tracking of consumers' behaviour. In fact, SGs emerged as a consequence of the convergence of energy systems and ICTs [4], and the managed data is obtained from remote sensing, control, and monitoring processes [5].

In the context of physical systems such as a building or the grid, the operative word is "smart", which is generally used to define something that has advanced control systems and technologies that allow for interconnected operability giving the capability to operate efficiently in response to external and internal communications [6]. While the traditional grid can only transmit or distribute electric power, SG is able to store, communicate and make decisions [7]. In [8] SGs are defined as a modern electric power grid infrastructure for improved efficiency, reliability, and safety with smooth integration of renewable and distributed energy sources, through automated and distributed controls and modern communication and sensing technologies. Controllers, sensors, actuators and the required data exchange with players are crucial for a successful performance of SGs [9].

From SGs standpoint, a SMG can be defined as a small scale SG which can be autonomous or grid-tied [10]. Multiple SMGs can form a network with connection to the utility grid, showing a great potential to increase the penetration of RESs [11]. SMGs are expected to significantly contribute to a more sustainable electricity delivery in the future decentralized paradigm of power systems [12]. In other words, SMGs are supposed to play a key role in the evolution of SGs, becoming prototypes for SGs sites of the future [13]. Successful operation of the SMG relies on its ability to make balance between internal sinks and sources of power [10].

As stated, SMG can operate in parallel with the grid, as an autonomous power island or in transition between grid-connected mode and islanded mode of operation [13]. In isolated regime, SMGs can manage the power flow to the pre-determined values, so they can increase the resilience of electric power system operation [14]. Until some years ago, microgrids were mainly applied to isolated communities to create stand-alone settlements for locations without the availability of the standard power supply line [2]. Although, nowadays this concept fits also in urban, rural and industrial areas, creating smart communities even in places where the energy grid is available [2]. In fact, during last years, emphasis has been placed on RESs-based SMGs due to their advantages over individual distributed generation systems in terms of stability, reliability and economics [15].

The consulted scientific literature allows asserting that SGs and SMGs are one of the most active R&D domains nowadays. In fact, severe efforts are being carried out towards development of technologies related with SG basic elements: energy generation and distribution, energy management, automation and monitoring, value-added services, information and communication infrastructure, and participatory dimension [4]. An automation and control system that implements an advanced management strategy is compulsory. The controller takes the leading role for automated operation and control of SMG while working in grid connected and islanded modes [15]. Such a challenging system is responsible of handling the energy flows and coordinating the operation of the subsystems to reach a stable and reliable power supply taking into account the intermittent nature of the RESs [16].

Fig. 1 illustrates the general diagram of a DC microgrid integrating diverse energy sources (renewable and non-renewable), hydrogen and loads, which operate around a common DC bus. The configuration around the DC bus involves the connection in parallel of multiple distributed sources and loads. A power converter together with switchgear, commonly called Point of Common Coupling (PCC), enable the connection to the distribution grid. In the figure, an additional block has been included, Automation System, in order to convert, with the proper functioning, the microgrid on a SMG, and to reflect the importance of such element and the task it performs for the correct operation of the SMG.

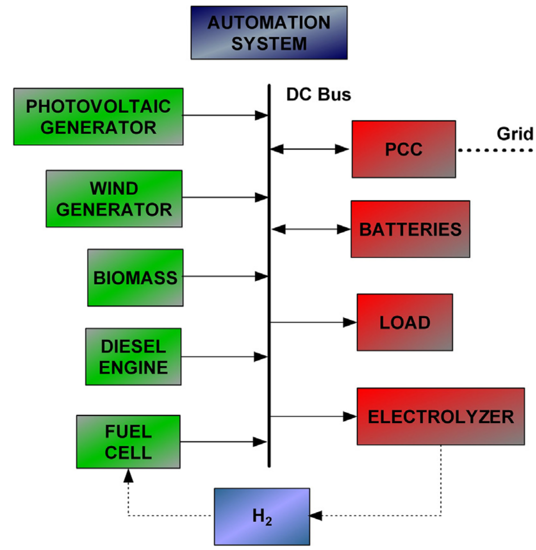

Fig. 1. Block diagram of a general DC SMG.

Apart from the automation and control functions, critical tasks are data acquisition and monitoring, necessary for all kind of technical and scientific process [17]. In the energy scope, monitoring systems have greatly grown because of the recent environmental awareness and energy shortages [18].

It should be noted that during last years the number of R&D projects related to SMGs has noticeably increased as reported in [19]. However, many of these projects are based on simulation/emulation environments, whereas the physical facilities are scarce. In this sense, experimental tests and demonstrative projects are highlighted as fundamental means to derive new methods and tools to address the challenging issues of future energy grid [20].

This paper presents a Remote Monitoring Platform (RMP) to monitor an experimental SMG. This platform provides a general framework to implement remote monitoring systems for SMGs. Particularly, a Programmable Logic Controller (PLC) is used to automate the SMG and to provide the information for the RMP using a communication link based on the Object-Linking and Embedding for Process Control (OPC) standard [21].

Our proposal relies on the utilization of an experimental pilot scale facility to act as benchmark for remote access. The remote user is able to observe in real-time the SMG behaviour. The monitored DC SMG is based on distributed RESs and hydrogen integration. This SMG is a complex system that involves electrical and chemical processes of different nature operating together. From the point of view of systems integration, the RMP aim is to offer a comprehensive environment to observe and understand the interaction between the various sources and sinks under an energy management strategy.

The remainder of the paper is as follows. Section 2 is devoted to carry out a brief review of monitoring systems applied to microgrids and the software EJsS. Section 3 deals with an overview of the monitored SMG from the perspective of both power components and automation elements. The applied energy management law is also explained. Section 4 deals with the description of the developed RMP. In Section 5, experimental results are reported. Finally, the main conclusions of the work are presented in Section 6.