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Automatic Power Supply from Different Sources for E-Vehicles

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Abstract

The paper presents a designed Automatic Power Supply from Different Sources for E-Vehicles for the online operation of an experimental low voltage microgrid equipped with a battery storage system and two power supplies: A PV module emulator, connected to a low voltage ac node. The connections of the electrical energy sources to the common ac bus make use of power inverters with specific functionalities. The ac node feeds electrical active and reactive load emulators able to reproduce programmable profiles. The automatic PMS provides the microgrid monitoring in both grid-connected and islanded operating conditions. The paper describes the structure and functionalities of the PMS as well as a specific experimental investigation aimed assessing the electrical charging.

Index Terms—*Battery, digital microcontroller, electrical microgrids, PV, power management system (PMS), E-Vehicles*

I. INTRODUCTION

Distributed generation (DG) may result in enhanced continuity of service and in increased customer participation to the electricity market [1], [2]. These opportunities are certainly supported by allowing the operation of a small portion of distribution networks (both on medium & low voltage levels) in islanded conditions. The literature on the subject defines micro-grids as small-scale power systems equipped with embedded generators and suitable control systems able to supply local electric and thermal demands in islanded operation. In this definition, micro-grids are also designed connect seamlessly to the public distribution network and, after that, disconnect when appropriate [3][7]. In household applications, the above mentioned capability to operate in islanded mode is permitted by the presence of electric energy storage devices and by the implementation of automatic scheduling systems that make use of communication and aggregation features allowing the operation & control of micro-grids as single entities. Within this context, there is a general interest for the udi- libation of kilowatt class fuel cells in residential applications. Indeed, compared with other conventional small generators, FCs, and in particular the PEM ones, promise higher cogenerate performance, clean and silent operation, and cost-effective supply of electric power. Recently, research provided a review of different architectures of systems powered by PEM FCs, also in combined use with other power supply and energy storage units, in order to build so-called hybrid systems. Various electric energy management approaches have been proposed in the literature in order to handle the characteristics of different power generators and storage systems. With reference to integrated PEM FCs and battery systems for E-vehicle applications propose a cascade control of FC-current, battery current, and battery state of charge with a limitation function of the dc link voltage. Concerning residential applications, hybrid electric energy storage systems composed by regenerative FCs integrated with batteries or ultracapacitors, have been compared in order to assess the criteria for the exploitation of the different electrical energy and power density values of the components. Additional research efforts appear to be needed in order to develop automatic power systems suitable for residential applications able to take into account the specific technical characteristics, and constraints, of the above mentioned sources, namely, integration of different electric and thermal generation systems, reduced size storage resources, and continuity of supply. For this purpose, an experimental micro-grid has been developed at the author's laboratory. The micro-grid includes a PEM FC able to provide 4.5kW electric and 4.7kW thermal outputs a 0.6-kW PV emulator, and a 4.2kW-100Ah lead-acid battery storage system. All these devices are connected to a common 230V ac bus through inverters with specific characteristics. The inverter of the PEM FCs allows setting its power production taking into account the FCs limitations and requirements. One of the PV emulators tracks its maximum power operating point, while the 4.2-kW bi-directional converter of the storage system implements a voltage-frequency control of the ac bus when the micro-grid is disconnected. A PMS has been developed and implemented into an embedded microcontrollers for the automatic operation of the experimental micro-grid in standalone conditions. The PMS has been conceived to estimate and control the battery SoC as this quantity represents one of the most critical operation elements for the microgrid continuity of supply in islanded operating conditions. The paper aims at describing the above mentioned PMS with particular focus on its implementation into a dedicated real time microcontroller equipped with a field programmable gate array (FPGA). Moreover, it presents the results of the experimental investigation aimed at assessing the dynamic characteristics of the standalone microgrid under various initial SOC values, electrical load profiles, and load rejection maneuver. The structure of the paper is the following: Section II provides some details on the characteristics of the PEM FCs system. Section III describes the PMS functionalities developed to control the FCs output with reference to standalone operating conditions of the microgrid. Section IV presents the experimental results obtained during the PMS actions for different load profiles. Section V presents the results of the PMS and micro-grid transient response following a sudden and complete disconnection of the electric load. Section VI concludes the paper with final remarks. In order to keep the adequate water content in the stack mem- brane, a gas to gas porous medium humidifier is used. It humidifies the inlet air stream by using the water vapor produced by the hydrogen oxidation and released at the stack cathode. The humidification process requires neither electric energy nor heat from external sources. The cooling subsystem is aimed at removing the reaction heat by demineralized water fed by means of a pump into the stack. It allows keeping the internal temperature within the range between 60C and 70C. A three-way valve is positioned at the outlet (W1 in Fig. 2) and it is used to control the water temperature, depending on the system operating conditions, by regulating the water flow to the heat ex- changer to the radiator (stream w3 and w5). When the operating conditions require a fast increase of the stack temperature, all the cooling water is bypassed into the tank. The electric scheme of the FC with internal auxiliaries and connection to the external single phase 230V ac bus. The FCs dc voltage output, characterized by the non-linear voltage-current relation given by the stack polarization curve [10], varies between 50V and 70V and it is converted to 230V ac by an inverter. As provided by the manufacturer, the

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inverter of the FCs. Is designed & controlled to operate only in grid connected mode. For the specific application in the experimental microgrid, its standard anti islanding protection, based on a continuous evaluation of the network impedance, has been disabled and the allowed frequency deviation range increased to 1.25Hz. Some of the electric auxiliaries, namely the air blower and the cooling fan are connected to an internal 230V ac bus. The other auxiliaries are supplied by dc buses at various voltage levels through the ac bus by means of a rectifier unit connected to the secondary winding of a transformer. The FCs auxiliaries characterized by the largest electrical power consumption are the air blower 530W, the cooling fan 35W, and the cooling water pump 25W. The system efficiency is affected by the losses of the main inverter and of the rectifier of the auxiliaries. The function of the automatic PMS have been developed taking into account the following peculiarities of the experimental microgrid, namely: 1) the maximum power provided by the PV array is lower than the maximum electrical power input absorbed by the battery during the charging phase. 2) the FCs is requested to operate only when the system is disconnected from the external distribution system. The PMS control has been developed with a state chart structure & the relevant main operating modes

II. HEADINGS

1. Abstract
2. Introduction
3. *Battery State of Charge Estimation*
4. *Experimental Validation of the SoC Estimation*
5. *Control Strategy and Limiters of the Battery Voltage*
6. Conclusions

III. CONCLUSIONS

The realized PMS, described in the paper, allows the reliable standalone operation of a kW class residential micro-grid fed by a controllable FCs and a Photovoltaic unit. It allows following both load and PV production variations by acting on the power control of the FCs. The main objectives of the PMS actions is the control of the battery state of charge, which is estimated by using an accurate algorithms developed for this purpose, this feature represents one key aspect of the developed system compared to existing one, as it allows limiting in an effective way the number of startup and shutdown maneuvers of the FCs. The estimation of the battery state of charge is also a crucial parameter for the management of the energy flows in a standalone system equipped with multiple power supply and electro chemical batteries. The action of the PID regulators has been designed/tuned in order to be adequate to avoid the intervention of the protection relays of the battery inverter also for the case of critical load rejection operation.

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