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Original Articles

Experimental design and genetic algorithm optimization of a fuzzy-logic supervisor for embedded electrical power systems

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Abstract

The embedded power systems are nowadays developing at high pace. Hybrid-electric vehicles, full-electric vehicles, airplanes, ships, high-speed trains, all share a common point – the embedded electrical power system. This paper aims to present an optimization methodology of a fuzzy-logic supervision strategy. The optimization objectives are to minimize the DC-link voltage variations, and to increase the system efficiency by reducing the dissipated power. For that, a methodology involving the experimental design and genetic algorithm will be presented. The simulation and experimental results are validating the proposed procedure.

Keywords: Embedded electrical power system; Energy storage; Fuzzy logic; Optimization; Experimental design; Genetic algorithm

1. Introduction

Numerous arguments to increase efficiency on every level of energy consumption are well known by all: exhaustible raw material for energy generation, high costs of exploitation, pollution agents due to burning of carbon based fuels and the famous CO_2 green gas effect that concerns us maybe the most nowadays. All these issues are pushing researchers to find more ways to reduce consumption by increasing efficiency. One of the solutions is to electrify the transportation sector, being considered between the biggest consumer and polluter of our planet. Electrification in this area comes natural when we look at the advantages: greater efficiency, increased reliability, better dynamics and sometimes a little cost [11].

One of the most important elements of an embedded electrical power system is the energy storage device. This element plays different roles depending on the application: main power source, auxiliary power source, power leveling or power peak shaving [8]. Thus, for each application, a supervision technique must be implemented. In this paper, a study is made on an embedded power system equipped with a supercapacitor energy storage device having the role of

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power smoothing and peak-shaving. The objective of the paper is to present an optimization methodology of a fuzzy-logic supervision strategy [1,8,9]. This methodology is, firstly, validated with the help of simulations and, secondly, by experiments on the test bench.

2. System under study

In Fig. 1, a DC power distribution system is presented. This system consists of one or several independent unidirectional power sources, one or several unidirectional or bidirectional loads, and a hybrid storage and dissipation system. The rated voltage of DC bus is 270 V, but the acceptable tolerance is between 250 and 280 V according to accepted standards [8,9].

The unidirectional power sources could be generators driven by prime movers (hybrid vehicles) or a battery that should not recharge during short periods due to aging issues (electric vehicles). The storage and dissipation systems are power-controlled. The power reference will be determined by the supervision system [8–10]. A systematic methodology to design a fuzzy-logic supervisor is presented in [1], allowing to design a multi-objective supervision strategy. Currently, two graphical tools are used to design the control of a complex system, i.e. Petri nets and grafcets. These tools enable to build graphically and step by step the control system, so as the analysis and the implementation of control functions are easier. These tools are well suited for sequential logical systems. However, they are not well adapted for hybrid systems, which include random and continuous variables. The proposed methodology is an extension of this graphical approach to include fuzzy and unknown data [1]. The type and form of the membership functions (MF) for fuzzy-logic supervisor were chosen empirically. This article proposes a methodology that reduces the empiricism when developing this kind of supervision.

The power management objectives considered in our supervision strategy are presented in Table 1. Two levels of power management strategies are considered as shown in Fig. 1. The first level determines the total absorbed or generated power reference of the hybrid system, P_{ref} by measuring generator power P_{gen}, DC-link voltage V_{DC}, state of charge (SoC) of the storage system and the output power of the storage system P_{stor_out}. The second level splits the P_{ref} in two parts: the power to be stored, P_{stor_out}, and the power to be dissipated, P_{dissi_ref}.

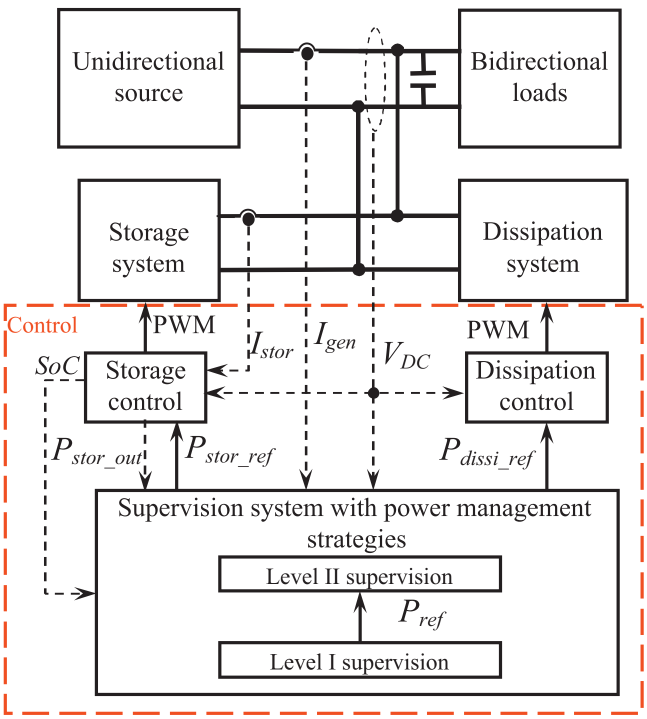

Fig. 1. System under study and supervision architecture.