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Comparison of particle swarm and genetic algorithm based design algorithms for PV-hybrid systems with battery and hydrogen storage path

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Abstract

The paper describes a new optimizing design concept for autonomous power supply systems employing an enhanced particle swarm algorithm taking into account both component sizing and energy management parameters. The structure of the overall optimization problem is investigated showing high complexity and nonlinearity particularly for switching energy management strategies. The specific features of the enhanced particle swarm optimization algorithm are discussed. The new optimizing design concept is investigated for two application examples, a private household and a small agricultural holding. The performance of the enhanced particle swarm algorithm is compared to two reference algorithms, a standard particle swarm and a genetic algorithm. The enhanced particle swarm algorithm shows the highest accuracy and fastest convergence speed for both applications and for both energy management strategies.

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Keywords: autonomous power supply; hybrid storage system; battery; hydrogen; sizing algorithm; particle swarm; energy management

1. Introduction

Photovoltaic (PV) hybrid systems with battery short-term and hydrogen long-term storage path (s. Fig. 1) are well suited for the electrical power supply in off-grid applications [1-3]. For the overall technical and economic optimization of such hybrid systems two aspects are important, the determination of the optimal capacity and power rating of battery, electrolyser, hydrogen storage, fuel cell and power electronic converters [4, 5] and an appropriate energy management concept for the intelligent control of the power flow distribution [6-9]. Both tasks are strongly interconnected. This motivates to include the energy management parameters into the list of search variables, solving

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an extended, highly complex and nonlinear global optimization problem. In literature the application of metaheuristic methods like genetic algorithms [10], particle swarm optimization [11] and tabu search [12] for the optimal sizing is well known. In this paper a new optimizing design concept for autonomous power supply systems employing an enhanced particle swarm algorithm is introduced. The paper is organized in the following way. After a short introduction the principle structure of the autonomous power supply system is explained in section 2. The specific features of the optimization problem are analysed and discussed in section 3. The enhanced particle swarm optimization algorithm is explained and investigated in section 4. The new optimizing design concept is tested and demonstrated for two application examples, a private household and a small agricultural holding in section 5. Also the performance of the enhanced particle swarm algorithm is compared to two reference algorithms, a standard particle swarm algorithm and a genetic algorithm. Section 6 gives a short summary and outlook on future research topics.

2. Autonomous power supply system

2.1. Structure

The autonomous power supply system consists of an AC-coupled hybrid storage that compensates the residual load between a PV plant and the off-grid consumer. The hybrid storage system is divided in a short-term storage (lithium-ion battery), and a long-term hydrogen storage path, connected to the battery by a controllable DC/DC converter. The long-term storage path consists of an electrolyser, a low-pressure hydrogen tank and a fuel cell. The optimal nominal sizes of the components ($P_{pv,nom}$, $E_{batt,nom}$, $P_{el,nom}$ and $P_{fc,nom}$) have to be determined by the optimization algorithm. Fig. 1 illustrates the structure of the autonomous power supply system.

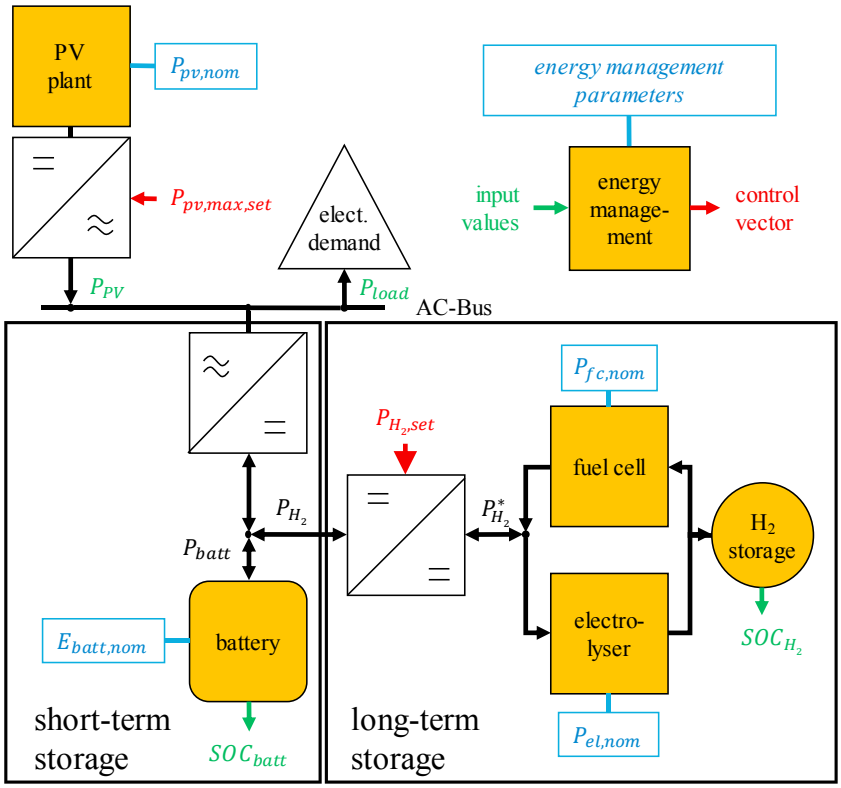

Fig. 1. Structure of the autonomous power supply system.