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Decentralized control of the hybrid electrical system consumption: A multi-agent approach

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ABSTRACT

The purpose of this paper is, on the one hand, to set up management models of different elements of a self-sufficient hybrid electrical system adapted to the potentials of our isolated West African rural areas of the network, and on the other hand to set up an energy management system able to dynamically find an energy consumption policy while taking into account services requested by users, load various constraints and energy source availability.

The management strategy aims to adapt the energy consumed by consumption sources to that supplied by the renewable production sources of the system. It is based on the shift, interruption, reduction, or increase of the power requested from one or several controllable consumption sources of the system. The suggested strategy which is based on the flexibility of consumption sources has made it possible to significantly reduce the lost energy that accounts for a significant gain from an economic point of view. It improves the use of the energy produced by modifying the charge profile. Proposed strategy privileges the functioning of the critical charges.

Contents

1. Introduction

Electrical energy management includes the protection, monitoring and control of the entire electrical network. For the operator, the issue is to optimize the energy consumption costs of different production sources without any prejudice to the activity. This is done through a smart, distributed and real-time control of the whole set of parameters of the electrical system. The modern solutions to this control need consist in products and services using information and communication technologies, built around smart systems such as measurement stations and supervision and control software.

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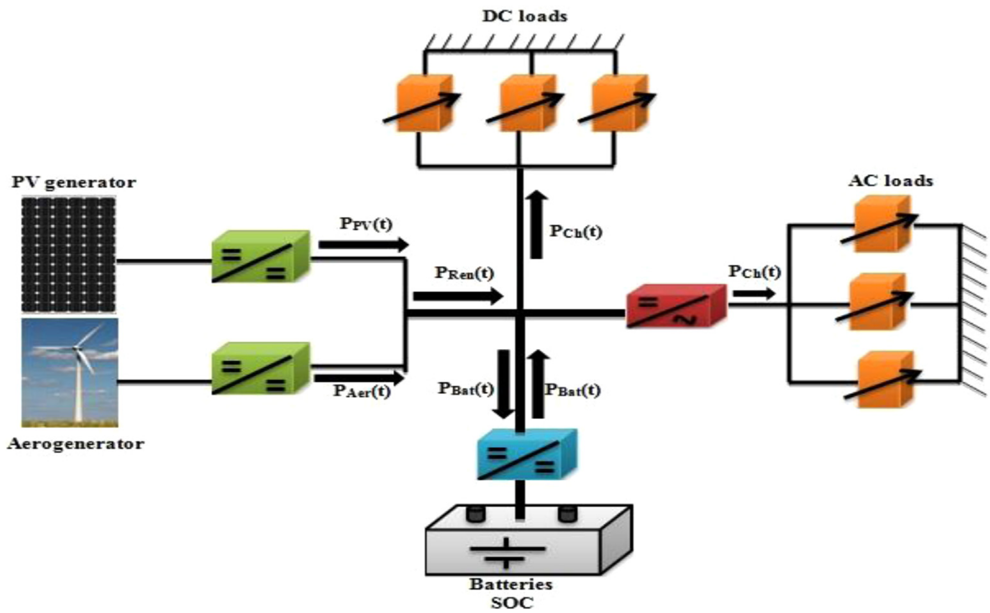

Fig. 1. The electrical system studied.

New renewable energy sources such as wind and solar characterized by strong intermittency, are increasingly integrated into our electrical systems. The user is more and more confronted with energy tariffs varying according to production sources, the day and the hour. It is within this varied and dynamic energy production and consumption context that a smart control monitoring system holds all its importance from the standpoint of both consumption and tariff (production).

Research work on the distributed control of electrical systems holds an important part of the current bibliography [1–11]. This trend has allowed the development of several distributed control systems applied to microgrids. Several architectures and methods are presented with simulations showing their efficiencies in a microgrid control.

The Multi-agent system (MAS) applied to the distributed control of electrical systems presents a major issue for the management of the complexity and flexibility of the control.

Indeed, the consumption source (CS) and production source (PS) of an electrical network are multiple, of different types, geographically distributed and maintain several forms of interactions. The balance stresses between production and consumption, taking into account local problems (shutdown, etc.) and resource availability (sunshine, wind speed etc.), require real-time decentralized control and management system permanent adaptation. A MAS for the optimization of a decentralized multi-source system management was developed in our previous research work [12]. The proposed strategy has helped obtain a decentralized management of the energy production sources of the electrical system in the face of the shifts in the demand. The model proposed has allowed the global production to be optimized in relationship with the demand profile and in function of cost minimization criteria or even greenhouse gas reduction. In the work of Monica et al. [13], the authors present a MAS designed for the real-time management of the functioning of a microgrid. The multi-agent system proposed provides a common communication interface for all the microgrid components.

In the works of Mao et al., Pipattanasomp et al, and Logenthiran et al. [14–16], the authors present a design and an implementation method for the intelligent management of electrical distribution grids.

These researches are of particular importance as they focus primarily on production while endeavoring to adapt the production sources to the demand and trying to minimize the production cost and/or reduce the amount of the greenhouse gas emissions from the electrical system.

The main questions asked in this work are:

1. Is the moment chosen by the user to ask for a given energy service appropriate?
2. Is it possible to find a better moment to launch a given service without compromising the user's comfort?
3. Is it possible to adapt the energy services requested in relation to the availability of the renewable energy sources?

This work suggests a management model of a decentralized self-sufficient electrical network. The model presents an approach aiming at adapting consumption to production. A multi-agent system, where each production and consumption source is modeled by an agent, is suggested to model the electrical system. The agents cooperate and jointly make decisions to optimize the system management both energetically and economically while taking into account the technology constraints and the resource availability. A decentralized management platform of the electrical systems is proposed to maximize the use of the energy used by the renewable sources and optimize the use of the electrical system at the energy level as well as the production cost.

Section 2 presents the methodology approach through the models of different components of the system, the mathematical formulation of the electrical system control strategy and the typology and model of the agents. The methodology approach undertaken is detailed through a behavior modeling based on a multi-agent system for a hybrid electrical system (HES). Section 3 presents and discusses the results achieved.

2. Materiels and methods

2.1. The mathematical models of system components

The electrical system (Fig. 1) studied in this work consists of a photovoltaic generator, a windmill, storage batteries and alternative current (AC) and direct current (DC) consumption sources.