

The new strategy of energy management for a photovoltaic system without extra intended for remote-housing

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Abstract

This paper proposes a new strategy used to optimize the demand side management for a stand-alone photovoltaic system (SAPS) without ancillary source in desert regions. It is based on developed load profile, actual weather conditions and energy storage. The intended objectives are house energy comfort and economic size of the system. The first objective was achieved by reducing the loss power supply probability (LPSP), which leads to the reduction of load shedding. The second objective is attained by reducing the batteries replacement through the improvement of the life cycle of batteries. The size of an experimental SAPS without load management was used for case study.

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1. Introduction

Despite the fact that electricity is considered as a fundamental key element in contemporary societies, official statistics state that almost over one and a half billion person worldwide do not have access to electricity (Ruijven et al., 2012; Doll and Pachauri, 2010). Most of those people live in rural areas and countries in voice of development – largely in Africa and South-East Asia (Giannini et al., 2011). Scattering and low populations density prevents the national power network from expanding in rural zones. The usual solution of electricity production such as diesel generators, does not provide a real autonomy of installations because of fuel delivery problems (isolation), and the equipment maintenance (occasional sandstorms and

high temperature). The use of wind generators in most of desert regions in Algeria (for example in Ghardaia, 32°29'N, 3°40'E, 450 m) is less beneficial than the photovoltaic (PV). It is important to note that the annual mean wind velocity in Ghardaia is below 4 m/s (Chellali et al., 2011). The wind speed below 4 m/s is less used (Infield, 1997), because it greatly influences the performance of the wind farm production (Djami and Merzouk, 2011).

The Algerian energy strategy recommends an increase of renewable energies contribution (Aksas and Gama, 2011). Renewable energies for electricity production represent 0.028%, according to the production report in 2005. The objective is to reach a renewable energies contribution of 5% by year 2015 and 40% by year 2030, through the photovoltaic, solar thermal and wind generators (Algerian Ministry of Energy and Mines, 2011; Hattabi et al., 2010). In this sense, the insertion of a PV system has an impact on development, economy and environment of desert regions.

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In the world, the residential electrification covers more than 60% of the electrical installations (Chaabene et al., 2007). Usually, the power consumption profile rarely correlates PV production (Fig. 1). To solve this problem, the energy storage is necessary for exploitation of an intermittent production based on photovoltaic solar energy. In the context of remote area power supply, a storage device is a crucial element in the SAPS (Chaabene et al., 2007; Arun et al., 2009; Semaoui et al., 2012). This device provides technical and economical solutions to the use of autonomous PV systems. In addition, as a contribution to the enhancement of life quality of several remote residents, an integrated solution based on an autonomous energy system is elaborated recently by these authors (Dufo-López and Bernal-Agustin, 2005; Kaldellis et al., 2010; Posadillo and López Luque, 2008; Tascikaraoglu et al., 2012).

To improve the reliability of PV systems, the energy management has been the subject of many research papers. Recently, for the grid-connected systems, the objective has been to help intensive penetration of photovoltaic production into the grid by proposing a peak shaving service by adding a storage system (Riffonneau et al., 2011; Vallé et al., 2007; Lu et al., 2010). For the PV systems with extra or hybrid systems (PV/Diesel generator or wind generator, etc.), (Yamamoto et al., 2003) proposed a method to control photovoltaic-diesel hybrid generation system using the prediction of solar irradiation to improve the efficiency of the system. To ensure power supply of habitat, (Wang et al., 2008) designed an overall power management strategy to manage power flows among the different energy sources and the storage unit in the hybrid PV system.

Energy management in a SAPS is still a contemporary research in the photovoltaic field. According to (Kaiser, 2007), the Fraunhofer-Institute of Solar Energy Systems has developed a new generation of battery-management system, which improves the storage lifetime and reliability of batteries. This battery-management system allows for new operating strategies not possible with conventional battery systems. (Barca et al., 2008) presented an optimal energy management method for stand-alone photovoltaic system. Their method exploits a predictive state of charge model to implement the control algorithm. Zhu and Liao

(2009) proposed an energy management control strategy for stand-alone PV system. Their strategy was based on the control of the un-directional DC–DC converter and bi-direction DC–DC converter. (Qi et al., 2009) presented an energy management method that integrates maximum power tracking control, load power tracking control, fast charge with variable current and discharge control for battery.

Concerning load management, (Al-Alawi and Islam, 2004) used demand side management with use the diesel generator, to smooth out the daily peaks and fill valleys in the load curve to make the most efficient use of renewable energy resources. Using predictions concerning wind speed and power, (Lujano-Rojas et al., 2012) discussed a load management strategy for the optimal use of renewable energy in a system with wind turbine, battery bank and diesel generator. In the same line, (Clastres et al., 2010; Missaoui et al., 2011) proposed an optimal household energy management system which could contract to provide ancillary services. Their management system anticipates the operating plan for the following 24 h period. This management is based on data forecasts (weather, local demand, electricity prices, etc.) and a PV-based system multi-source. According to (Riffonneau et al., 2011) the load management strategy used for grid connected PV system is based on forecasted data of weather and energy cost.

In this paper, a new optimal management strategy of loads was proposed, for an optimal use of renewable energy in a stand-alone photovoltaic system without ancillary source in isolated desert regions. This new management strategy based on developed load profile, actual data (not forecast data) of weather (ambient temperature and irradiance) and state of charge (SOC) of batteries. The core strength of this new management strategy is the predictive control of washing machine according to $SOC(t)$ at 23h55. The traditional architecture of houses in desert regions in Algeria allow us to add the control aspect of lighting taking into account the daylight duration variation during year and all respecting the visual comfort. Hence, the aim is to investigate the impact of flow energy management of housing on the system reliability and replacement of storage device. The approach of this study is illustrated in case study.

2. Experimental PV system description

2.1. Application site

This study focuses on a housing located in Ghardaia region (M'Zab Valley), at 600 km south of the capital Algiers. This region is famous for its architectural and social specificities. Ghardaia is ranked by the UNESCO among the world patrimony (Ali Khodja, 2008). Since the 11th century, the citadels of M'Zab Valley form an extraordinary homogeneous cohesion marking, in the desert, a sedentary and urban civilization revealing an original culture. For centuries, M'Zab Valley conserves practically

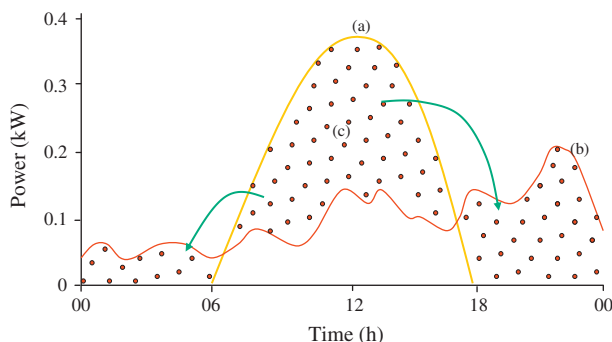


Fig. 1. Power distribution during daylight. (a) PV production, (b) consumption, (c) energy stored.

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