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Optimization of energy management of a photovoltaic system by the fuzzy logic technique

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Abstract

The efficiency of a photovoltaic system depends mainly on its energy management which takes in charge the storage and the distribution of the energy produced by the photovoltaic system in order to feed the load and to avoid any shortage of energy.
Our project concerns the energy management of a Stand Alone Photovoltaic System. This is done by elaborating an algorithm based on the fuzzy logic technique which allows us to optimize the management of the storage system, ensuring a longer battery life, and the energy distribution available from the photovoltaic array and the batteries. It appears from the first results obtained that the fuzzy logic control maintains the battery voltage almost stable at the end phase of charge.

Key words: Stand-Alone Photovoltaic Systems (SAPVS), Energy Management, Battery, Fuzzy Logic, Fuzzy Controller.

1. Introduction

Climate change and oil shortage have prompted the ever-growing awareness about the need to use non pollutant energy. This favourable economic background conducted to an impressive growth rate of the photovoltaic industry in the last decade and it is expected to continue in the upcoming years. In this context, the number of PV installations increases year after year. As the initial cost is high, the users need to be ensured that the PV system installed will be reliable and energetically efficient [1]. The mastering of the performance of a Stand Alone Photovoltaic System (SAPVS) is done through the control and management of the energy of the system. The energy management of a PV system must both allow to:

- Produce a maximum power from the photovoltaic generator,
- Protect the battery against overcharge and deep discharge.
- Satisfy the energy needs of the user by avoiding energy shortage.

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We aim by our study to design and implement an energy management algorithm for SAPVS. After the modelization of the storage stage, we introduce a new technique, namely fuzzy logic which we use to design a fuzzy controller for batteries. That will allow us to optimize the management of the storage system ensuring a longer battery life and minimizing the potential malfunction of the elements constituting the photovoltaic system.

2. Energy management for Stand Alone Photovoltaic System (SAPVS)

A SAPVS consists of a photovoltaic generator composed of one or more solar panels, a set of batteries for electric energy storage, one or more DC-DC converters to provide the appropriate supply voltages for the batteries and continuous loads and a DC-AC converter for powering other AC devices [2], [3].

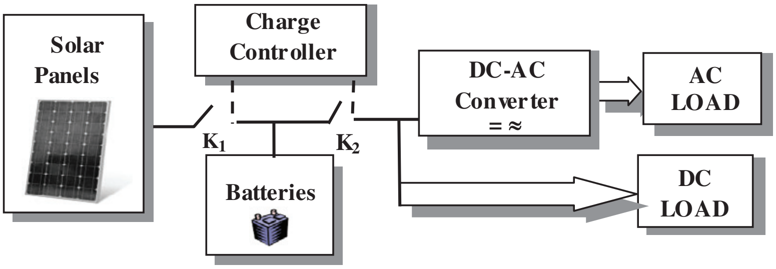

Fig. 1 A Stand Alone Photovoltaic System configuration

Due to the non-availability of permanent solar energy, for various reasons: weather, time of day, season etc..., the use of batteries as buffer of energy is required to guarantee continuous supply energy. In order to avoid any energy shortage and ensure a longer battery life, an energy management strategy is essential in a SAPVS.

3. Energy storage for SAPVS

3. 1. Electrical model of battery

For the storage stage of photovoltaic system, both types of electrochemical storage battery as lead-acid (Pb acid) and nickel-cadmium (Ni-Cd) batteries are commonly used. Thanks to their sturdiness and stability, the lead-acid batteries are the most used in PV installations [4].

In order to study the operation of the battery, we have used a battery model shown on the figure 2 which is mainly based on:

- The relation between the state of charge (SOC) and the charging current (I_B) [4, 5].
- The variation of the voltage (V_B) according to the current and the state of charge (SOC) [4].
- The variation of the capacity (C_B) versus the current [4].

The models used for each stage of the battery model (figure 2) are described by the following mathematical equations:

The capacitor model:

$$C_B(t) = \int_{t=0}^{t} I_C(t)dt + C_{B,i} \tag{1}$$

$C_B(t)$ is the capacitor of the battery in (Ah) at a time t, $C_{B,i}$ the initial capacitor of the battery in (Ah).
Where: