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Power management of a photovoltaic/battery pumping system in agricultural experiment station

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Abstract

This paper focuses on dynamic modeling, simulation, control and energy management in an agricultural experiment station located at Sahline–Tunisia consisting of a 1.5 kW photovoltaic panel (PV) and a 25 A h Lead Acid battery storage supplying an induction motor coupled to a centrifugal pump as mechanical load. The cost-optimally design and the new suitable power management approach are the two main objectives. An iterative optimization approach namely, the Deficiency of Power Supply Probability (DPSP), the Relative Excess Power Generated (REPG), the Energy Cost (EC) as well as the Total Net Present Cost (TNPC) have been developed in order to find the optimal configuration of PV/battery. To reach the second object, three new supervisory controllers are designed, a neuro-fuzzy controller, a fuzzy controller and an algorithm controller. In order to show the effectiveness of the first one, a comparison of the three controllers is proposed. The principal objectives of the three supervisory controllers are: (i) the design of an adequate tracking system maximum power point (MPPT) to extract the maximum power which is given by the theory of conservation of energy, (ii) the insurance of the control speed needed for the vectorial control of the induction motor, (iii) the regulation of the water in the tank which is taken as a second storage system and finally (iv) the insurance of the correct operation for all the conversion string in order to optimize the quantity of water pumped.

Keywords: Water level regulation; Supervisory controller; Neuro-fuzzy; Optimization

1. Introduction

Energy plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. Energy is an important factor in all the sectors of any country's economy. In the recent years, the diminishing supplies of fossil fuels and their impact on the environment have encouraged a growth in sustainable energies such as wind and solar power; such a significant growth was seen by the photovoltaic industry.

Solar power generation is experiencing a remarkable growth in terms of installed power and energy generation in many countries. Autonomous photovoltaic panels are intermittent sustainable energy sources which require energy storage to balance generation and demand, as photovoltaic generation depends on time and weather.

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Traditionally batteries are the most common storage technology for photovoltaic systems (Gibson and Kelly, 2010; Kaldellis et al., 2012; Steffen and Weber, 2013). Standalone photovoltaic systems are often used in remote areas, away from the national grid for water irrigation system (Bouzidi, 2011; Corrêa et al., 2012; Glasnovic and Margeta, 2007; Hamidat et al., 2003; Hegazy and Abou Hashema, 2013; Meah et al., 2008).

Many works dealt with the choice of the drive system to interact with the PV source; PV pumping systems based on DC machines, AC machines (Corrêa et al., 2012; Meah et al., 2008), the type of pumps to use and the ways to control and optimize the whole system. In fact, several control schemes are modeled and described as scalar control, vector control of the induction machine (Khiareddine et al., 2013; Mimouni et al., 2004) and DTC control (Rekioua and Matagne, 2012).

Various algorithms have been developed over the years (Ben Salah and Ouali, 2011; Mazouz and Midoun, 2011; Shaiek et al., 2013) in order to determine the maximum power point such as Perturb and Observe Technique, Incremental Conductance Technique, Hill Climbing Control, Curve Fitting Method, Sliding Mode Controller, Fuzzy Logic Technique, Artificial Neural Networks,

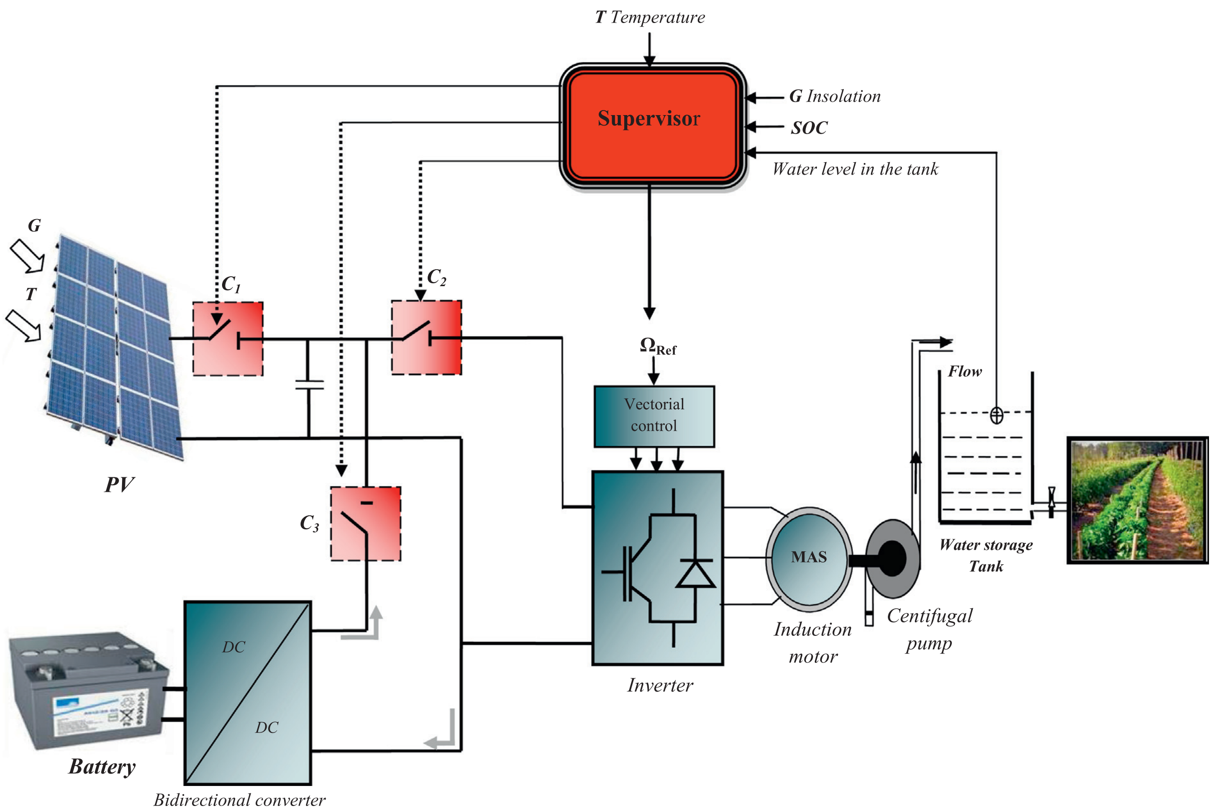

Fig. 1. Schematic diagram of photovoltaic pumping system with battery storage.

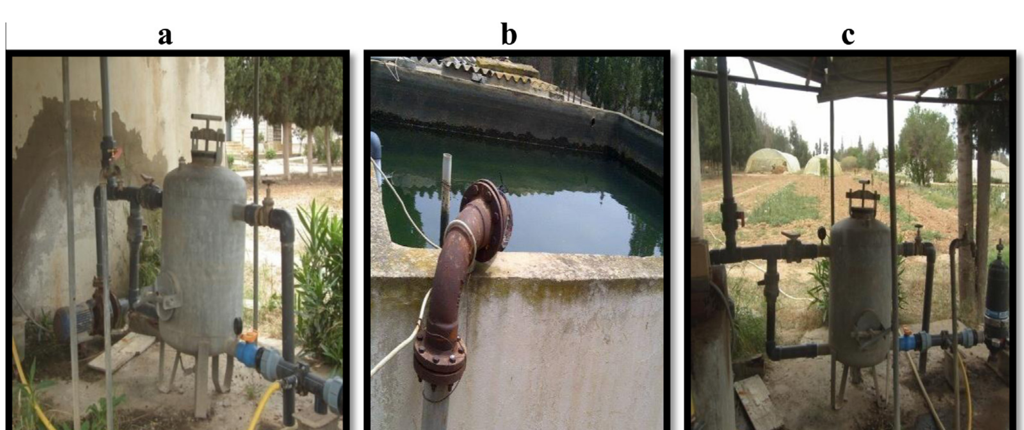

Fig. 2. Pumping system: (a) the motopump, (b) general view of the tank and (c) greenhouse.