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Adaptation of pressurized irrigation networks to new strategies of irrigation management: Energy implications of low discharge and pulsed irrigation

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ABSTRACT

This paper analyzes the consequences of adopting new on-farm irrigation management strategies (low discharge rates, long irrigation times and high frequencies) in an existing on-demand and sectorized pressurized irrigation system in eastern Spain. The sectorized behavior of the network was analyzed using two criteria: (i) the operating sectors obtained in a first stage by arranging the hydrants depending on their altitude respecting the pumping station and (ii) the operating sectors obtained by means of an optimization process. The Simulated Annealing combinatorial metaheuristic optimization technique was employed to find the best solution. Random on-demand patterns were generated using a Montecarlo simulation. The hydraulic requirements of the network were analyzed in every scenario by the Epanet 2.0 engine. The effect on energy consumption, power requirements and energy costs was assessed taking into account the electricity tariff billing structure. It was found that reductions in emitter discharge (q_e) and Energy consumption (E)-Energy Cost (EC) savings are not inherently related to each other. Certain amounts of E and EC could be saved when the number of sectors and operating time parameters were properly selected. Pulsed irrigation in the current scenario showed an energy saving potential of 10.67, 6.43 and 6.99% for power capacity, E and EC, respectively.

1. Introduction

In many Mediterranean countries traditional irrigation schemes have been modernized during the last two decades. This updating of the irrigation facilities consisted of substituting ancient open-cannals-based transport, distribution, and surface watering systems by pressurized piping systems (Plusquellec 2009) in an attempt to achieve several advantages: (a) reduce water losses during transport and application, (b) overcome topographic constraints, (c) avoid uncontrolled water withdrawals, and (d) invoice the exact amount of water consumed on each farm (Lamaddalena and Sagardoy, 2000; Daccache et al., 2010a,b,c). In addition, pressurized irrigation networks make it possible to implement new and more efficient on-farm irrigation systems, mainly drip and sprinkler irrigation. This entire process has derived in an increase of the water use efficiency but simultaneously it involves a notably increase in energy consumption (IDAE, 2008), especially in sprinkler irrigation. Many studies can be found in the literature aimed at assessing the behavior of pressurized irrigation networks in order to improve their energy consumption (Fernández García et al., 2013, 2014, 2016; Díaz et al., 2009; García-Prats et al., 2012; González Perea et al., 2014; Jiménez-Bello et al., 2010, 2015; Rodríguez Díaz et al., 2007, 2012; Tarjuelo et al., 2015). The large number of these studies is an indication of the importance of this issue.

Drip irrigation has been traditionally recommended for row crops, vines and trees (Brouwer et al., 1988) although its many proven advantages has meant that its use has been extended to almost all types of crops. Its most significant advantages include: (i) higher water use efficiency (Daccache et al., 2010a,b,c), (ii) lower energy requirements than other pressurized irrigation systems and (iii) higher yields and better quality of harvested crops (Vyrlas and Sakellariou, 2005). The increased use of drip irrigation is seen as one way of improving the sustainability of irrigation systems around the world (Cote et al., 2003). The potential efficiency of drip irrigation is generally accepted to be around 90%, however we should not lose sight of the fact that this value is not an inherent property of the system, but a function of its management (Smith et al., 2010).

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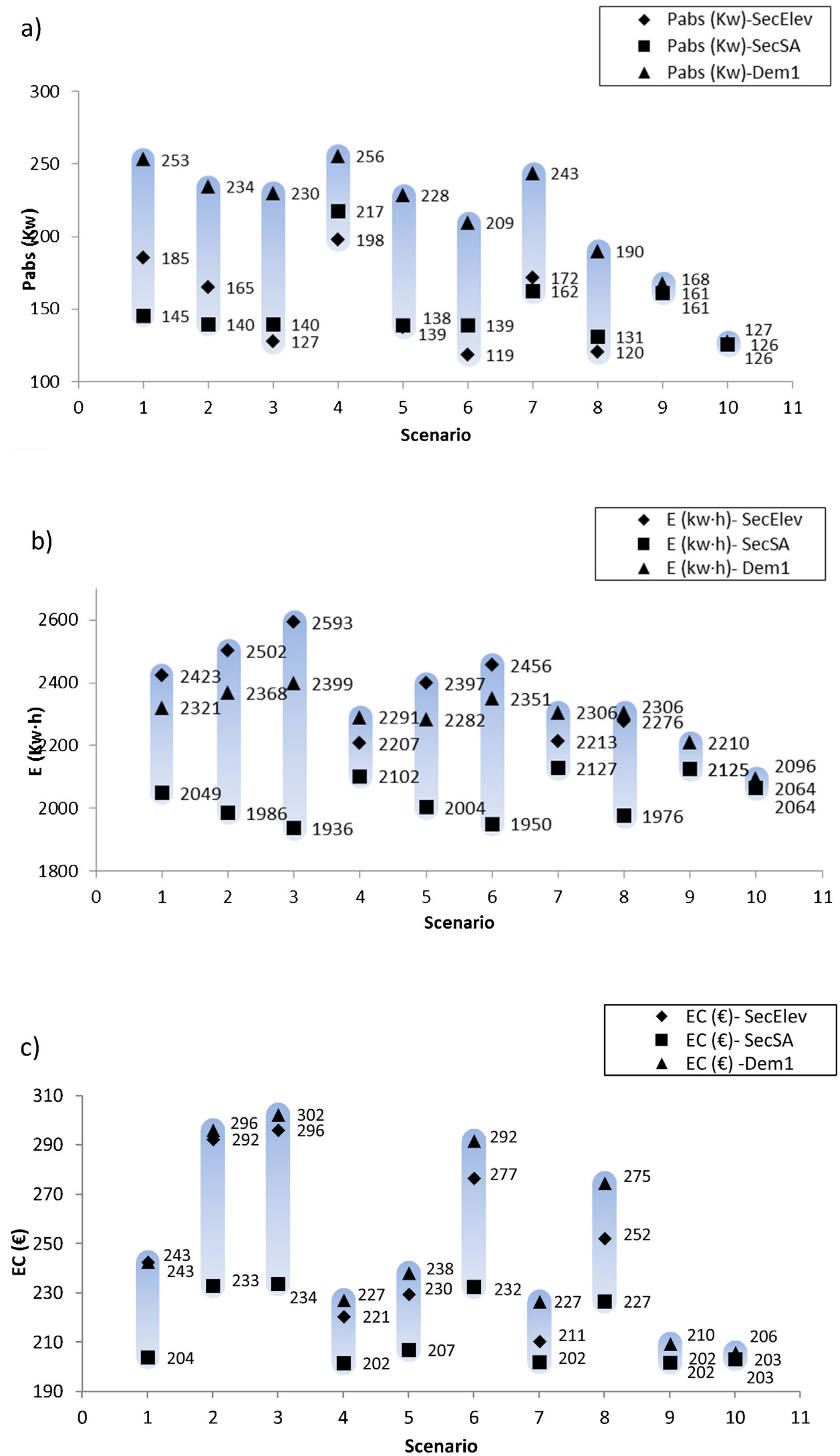

Fig. 1. Evolution of P_{abs} (kW), E (KW h) and EC (€) in different scenarios of continuous irrigation. P_{abs} = power capacity; E = energy consumption for one day of irrigation in the peak month and EC = electricity costs for the same period in the different scenarios.