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Use of software to model the water and energy use of an irrigation pipe network on a golf course

J.F. García-González[a,*], M.A. Moreno[b], J.M. Molina[c], A. Madueño[d], A. Ruiz-Canales[a]

[a] Water and Energy for a Sustainable Agriculture, Engineering Department, Miguel Hernández University of Elche, Orihuela 03312, Spain
[b] Regional Center of Water Resources CREA, Albacete 02071, Spain
[c] Engineering and Agricultural Equipment Department, Technical University of Cartagena, Cartagena 30203, Spain
[d] University of Seville, Aerospatial Engineering & Fluids Mechanical Department, Seville 41013, Spain

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ABSTRACT

Generally, most pressure irrigation systems require efficient management of water and energy, particularly in systems installed on golf courses. Golf courses have high water requirements throughout the year because the grass has to be maintained in optimum conditions for adequate play development and for aesthetic reasons. Thus, the duration and frequency of irrigation varies to obtain the optimum water supply. The primary objective of this paper is to study the improvement of irrigation management on a golf course by modelling the irrigation network and pumping station. The simulation results are related to the individual and simultaneous opening of sectors, the water and energy consumption, and the efficiency of the pumping station. Several water and energy consumption patterns have been obtained and quantified. These patterns are related to the opening of individual and simultaneous sectors in the golf course pipeline network. The results indicate that the water and energy consumption are increased with the simultaneous opening of sectors, but the efficiency and the irrigation time are decreased.

1. Introduction

Golf course irrigation systems are typical areas that demand water and energy for sports and other leisure purposes. In Spain, these systems are less important than agricultural systems (Rodriguez Diaz et al., 2007). Most advances in the research management of irrigation systems for golf courses are related to the maintenance of the grass, specifically regarding fertilization (O'Neill et al., 2014) and irrigation (Silva et al., 2010). However, not enough research has been completed about the specific tools for adequate water and energy management in golf course irrigation systems. These additional research topics can contribute to other advances that change the environmental perception and enhance public awareness about this sector.

Currently, several applied technologies can be further developed for water and energy management in golf courses irrigation systems. There is extensive research about water and energy consumption modelling in agricultural irrigation systems that can be easily adapted to golf courses use. In this way, several alternatives for the reduction of water and energy consumption and the associated costs have been developed (Abadia et al., 2008; Moreno et al., 2007, 2009; Rodríguez Díaz et al., 2011; Jimenez-Bello et al., 2010; Bagirov et al., 2013). Some tools are related to the support of decision-making about investment in infrastructures (Khan et al., 2010), the management of pumping stations (Lamaddalena and Khila, 2013), the sustainability of the systems (Carrillo Cobo et al., 2014) and various other areas in energy management (Reca et al., 2014).

Furthermore, EPANET® (Rossman, 1999), is a public domain tool used for modelling the water distribution in pressurized irrigation networks, analysing the dynamic components (pressure, speed and pressure drop, among others) and the quality of the irrigation water. This model has been applied to many types of pipe networks (Cabrera-Bejar and Tzatchkov, 2012), water and energy demand scenarios (Mendez et al., 2013; Gorev and Kodzhespirova, 2013), calibrations and simulations (Mendez et al., 2013; Farina et al., 2014; Liu and Yu, 2013) and pumping stations (Bagirov et al., 2013). This last aspect of modelling the water and energy consumption in pumping stations (Arrouf and Ghabrour, 2007; Miron et al., 2013) has been additionally incorporated with alternative software like MATLAB® (matrix laboratory). Moreover, several applications for

* Corresponding author at: Engineering Department, Miguel Hernández University of Elche, Orihuela 03312, Spain. Tel.: +34 966749639; fax: +34 966 74 97 18.
E-mail address: ppgg.bigastro@gmail.com (J.F. García-González).

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irrigation have been developed with this tool (Moreno et al., 2012). Again, there are currently no similar tools available specifically for golf course irrigation systems.

One of the main uses of these models and tools is the implementation in a SCADA (supervisory control and data acquisition) system. These devices are a system operating with coded signals over communication channels to control remote equipment (typically using one communication channel per remote station). The supervisory system may be combined with a data acquisition system by adding the use of coded signals over communication channels. This system combination may be used to acquire information concerning the status of the remote equipment for display or recording functions. With these devices, it is possible to remotely monitor, supervise and control the irrigation and pumping station systems on a golf course. The applications of the SCADA have been extended from only one sector to others, like in agriculture and sports. There are varied examples of SCADA use in the management of agriculture irrigation systems. Uses are related to decision making (Alminana et al., 2010), management of irrigation companies (Aquije et al., 2009), irrigation scheduling (Molina and Ruiz, 2010), optimal management of water resources (Sweigard, 2003; Gensler et al., 2009) and canal management (Figueiredo et al., 2013).

The objective of this paper is to study the employment of two software tools for the modelling of two systems in a golf course: the irrigation network and the pumping station. Firstly, the study addresses the adequate simultaneous opening of valves by commercial software based on the modelling of the pipeline network (mainly the distribution of the water levels, pressures and flows varying with demand conditions). Additionally, the optimal selection is developed, a selection that combines the pumps of the pumping station to minimize the energy consumption in the same golf course. In this case, the model calculates the efficiency of the pumping station of the golf course by considering the frequency of pumping station discharge during the irrigation season (Moreno et al., 2007). The use of these software tools is based on techniques applied previously in agricultural systems (Moreno et al., 2010; Rodríguez-Diaz et al., 2009; Planells et al., 2007). This methodology is partially based in EPANET®. Also presented are the implementation and results of water and energy demand and the consumption model of a pumping station based in MATLAB®. These techniques are adapted to an irrigation system in a case study of a golf course located in the Alicante province in the Valencian Community in Southeast Spain. Additionally, these tools can be integrated in a SCADA system used to automate and remotely control systems for irrigation network management. These technologies enable the real-time optimization of water and energy consumption (Molina et al., 2011).

2. Materials and methods

2.1. Study area

This study has been developed for a golf course located at the Alicante province in Southeast Spain. This golf course has been in operation since 1998. The annual average rainfall for the area is 237.06 mm and the annual average evapotranspiration (ET_0) is 1042.65 mm; therefore, the annual contribution of water irrigation to the golf course is 805.59 mm (the data were acquired from a weather station located on the golf course). The irrigation water for the golf course comes from a wastewater treatment facility associated with the residential complex at the course. The golf course lakes are used as reservoirs.

The case study is of a golf course with 18 holes and a total area of 45 ha, including the driving range. The irrigated area is roughly 40 ha, depending on the playing area (the green, the ante green, the tee, the fairway and the rough), the time of year, and the duration and frequency of irrigation.

The irrigation system is a mesh network of pipelines with diversions to mesh subnetworks of emerging sprinklers. The minimal working water pressure is 3.5 kg cm^{-2}. In this system, 1785 sprinklers of 30 varied models are used.

The pumping station consists of four pumps that supply a maximum water pressure of 9 kg cm^{-2}, with synchronized flows of 30, 110, 160 and 220 m^3 h^{-1}. The operational sequence and the number of working pumps depend on the water demand.

To activate the sprinklers, a weather station with remote control and radiofrequency is included in the system. The activation of the sprinklers depends on the evapotranspiration demands as monitored by a central irrigation programmer. This programmer controls the time for the start of irrigation in every sprinkler group. Sprinklers are interconnected in groups of two or three units. Every group of sprinklers is a sector that is automatically and simultaneously opened. There are three timers that control the beginning of the irrigation cycle for each sector. Every timer controls 17 sectors by means a of 24 V signal. One timer is used to command the sectors that control the irrigation in the tee and greens areas. The other timers are used to send the signal for the beginning of the irrigation process to the sectors controlling fairway irrigation. The programmer continuously measures the flow of the sprinklers. Depending on this flow, the pumps are activated. While the irrigation demand is increasing, the pumps are activating with the objective of maintaining the pressure of the hydraulic system at the constant value of 7.5 kg cm^{-2} (working pressure). When there is demand on the system, the pressure decreases under the working pressure. At this moment, the timer waits for 30 s to check if the initial pressure is reached. If, after the waiting period, the pressure in the network is not reached, the pumps are automatically started by the previously cited order. In this case, the inner pressure of the network is maintained. When the pressure of the network surpasses the working pressure, the pumps are turned off in the inverse order. Again, the working pressure is reached. With these pressure variations, there is obvious variation of the energy demand of the electric network. Additionally, an associated energy cost for the energy demand is included in this study.

Before irrigation starts, all groups of sprinklers (sectors) are kept closed by the computer that manages the irrigation. The role of pump #1, the jockey pump, is to pressurize the irrigation network. When a signal is sent to the pump to open a sector and the head pressure is less than 7.2 kg cm^{-2}, pump #2 is started. This second pump includes a variable frequency drive (VFD). The VFD device is installed to maintain the head pressure of 7.5 kg cm^{-2}. If this pump is not capable of maintaining a minimal head pressure of 6.9 kg cm^{-2}, then pump #3 is started at 100% capacity. Thanks to the VFD, the pressure of 7.5 kg cm^{-2} is reached in the irrigation system. If the system needs maximum flow, pump #3 and pump #4 start simultaneously.

Additional modelling data gathered pertains to the energy and water consumption. The administrative staff of the golf course has provided monthly energy and water data and the corresponding costs for the study period. Firstly, the monthly energy consumption and the total cost of each invoice during this period are obtained. Additionally, the monthly water requirements of the irrigation system of the golf course, obtained as the difference between evapotranspiration (ET_0) and rainfall (P), are collected. These data are obtained from the weather station located on the golf course.

2.2. Energy analysis of the optimal point of the pumping station operation

The modelling of the pumping station was made with software, Model for Analysis of Energy Efficiency at Pumping Stations