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Proceeding Paper

Rethinking On-Demand Irrigation Systems Using IOT Stand-Alone Technologies †

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Abstract: The integration of Internet of Things (IoT) technologies into pressurized irrigation water distribution networks holds significant potential for optimizing water utilization, especially given the escalating concerns about scarcity and increasing demand. Nevertheless, within the irrigation domain, the utilization of specific technologies and management strategies based on IoT technologies is not yet as widespread as their well-established efficacy would suggest. The present work proposes a management strategy based on such technologies to enhance the sustainability of a case study network, using real operational data during the irrigation season.

Keywords: pressurized irrigation networks; on-demand irrigation; control valves; IoT

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1. Introduction

The current and projected water demands can benefit from the incorporation of IoT tools for equitable distribution and efficient water usage. By leveraging these technologies, it becomes possible to monitor, manage, and allocate water resources effectively, mitigating scarcity [1] concerns and promoting sustainable practices in water management. Moreover, there is an observed disparity between the inclination to employ these technologies at the farm management level [2] and their limited use at the distribution network management level. In this context, the installation of two IoT technologies patented by the Politecnico di Milano is analyzed in the present paper with reference to a specific case study. The two technologies are the GreenValve System (GVS) [3], already used in civil water distribution systems, and the Off-grid Automatic System (OAS) [4] that is under development. The two devices share the possibility of recovering energy from the flow regulation process and to use it to add functionalities to the control node. Specifically, they can be actuated remotely and can collect and communicate pressure and flow data. In the following paper, the installation of the devices in different points of interest of the network is envisaged. The scope of the installation is to manage the pressure in the network and obtain, considering the whole irrigation season, a reduction in the average pressure in the pipelines, allowing a consequent reduction of water losses in the network. The analysis also proposes the energetic balance of the devices during the irrigation season to evaluate the effectiveness of a real installation. In order to reproduce the irrigation season, real historical data from a water distribution consortium have been used.

2. Case Study and Methods

The case study used in the present work is the UFITA network. A schematic of the network is reported in Figure 1a. The network is composed of three main branches that withdraw water from a unique reservoir. Only the Central and East areas are considered in the present work, mainly because in these areas, the managers have available historical data about the use of water from each hydrant.

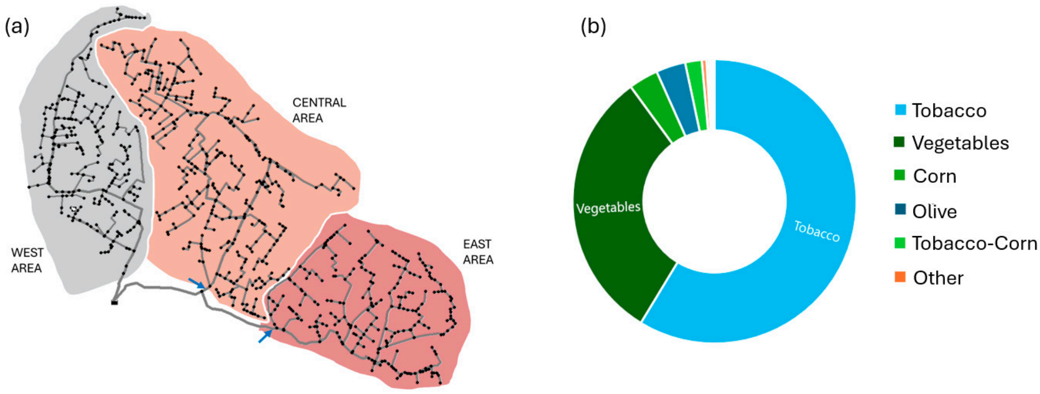

Figure 1. (**a**) Schematic of the complete network. (**b**) Crop distribution in the Central and East areas.

The Central and East branches are composed of 111 and 92 hydrants. Figure 1b reports the main crop varieties cultivated. Each hydrant of the Central and East zones is equipped with a card reader to allow the recording of water use. Using those data, the irrigation season has been simulated realistically, reproducing the behavior of the network. Figure 2a reports the statistics of contemporary active hydrants during the season and in Figure 2b, the pressure distribution of hydrants in the network is reported as a function of several months of the season. As it can be seen, the worse month is June, where the number of contemporary hydrants reaches the maximum and the pressure at delivery nodes reaches the minimum.

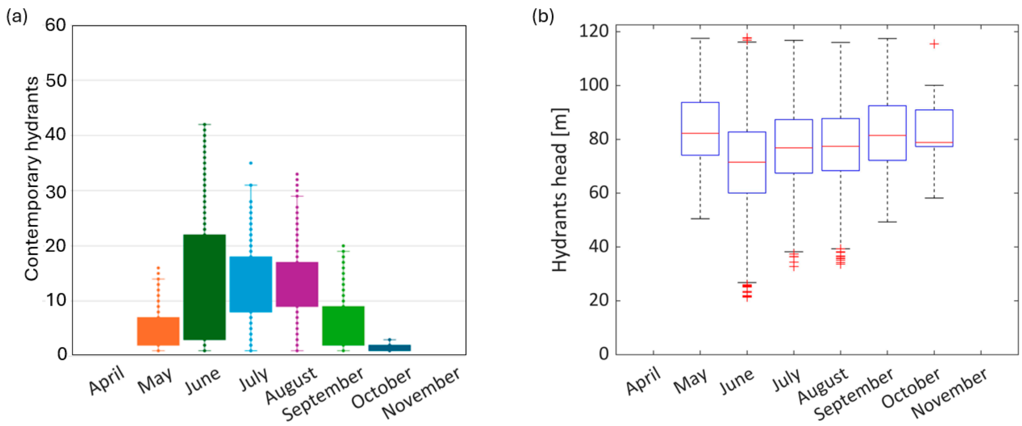

Figure 2. (**a**) Monthly contemporary active hydrants statistics. (**b**) Monthly hydrants head statistics.

As can be seen by the pressure distribution in Figure 2b, a large surplus of pressure in all the areas considered occurs. Only a few hydrants, and in a few specific configurations of active hydrants, suffer of a pressure below 25 m when a limited deficit occurs. Due to the characteristics of the network and to the surplus of pressure, the study is focused on the installation of two GVS in the main supply pipes for the Central and East zones (indicated by blue arrows in Figure 1a) to minimize the pressure on the basis of the real demand of the network. To allow the real-time knowledge of the network status, the installation of OAS in all the demand nodes of the network is proposed. The devices have been sized on the basis of the real hydraulic performances calculated after laboratory tests on scaled models. Both devices can control the flow, reducing the pressure at a certain level, and can recover energy from the regulation process. The energy recovered can be used to collect and send data and to operate the device remotely, by the farmers and by the managers. The analysis provides an energy balance of each device to verify the effective possibility of recovering a sufficient amount of energy for its functioning during the whole season.

The analysis has been performed using the hydraulic solver Epanet (USEPA, Cincinnati, Ohio) (pressure driven analysis) and its toolkit for MATLAB R2023 using a time step of half an hour for the entire season.

3. Results

Figure 3a reports the pressure distribution at the hydrants before and after the application of the GVS. It can be seen that in each hydrant, the pressure is kept above the limit of 20 m, thus sufficiently above the functional limit for the correct usage of the hydrants. It is interesting to highlight that the average pressure at the nodes in the network have been reduced by an average of 61%, indicating a substantial potential for leakage reduction in the network with a resultant reduction of the total withdrawal.

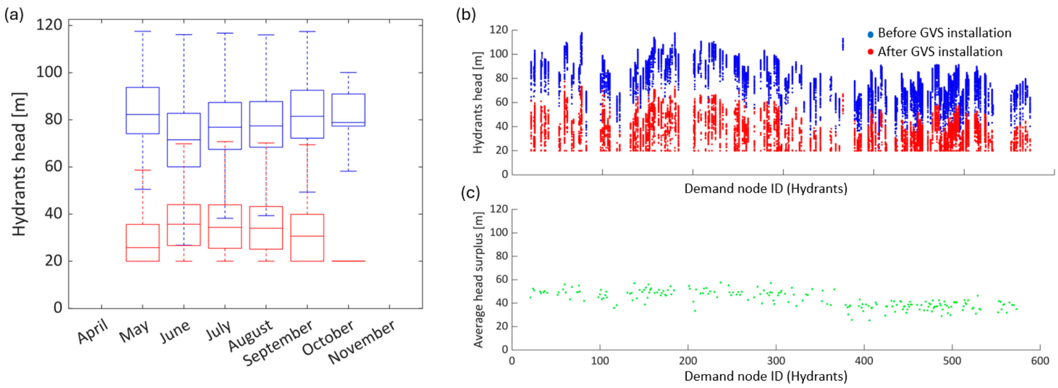

Figure 3. (**a**) Statistics of pressure at hydrants before and after the introduction of GVS. (**b**) Pressures at the hydrants before and after the introduction of the GVS. (**c**) Average head surplus at hydrants.

Finally, the new pressure distributions are used to evaluate the energy recovery with the OAS and GVS. Figure 4a reports the cumulative energy recovery capacity of the GVS in the two installation points, and in Figure 4b the cumulative energy recovered by the OAS is shown.

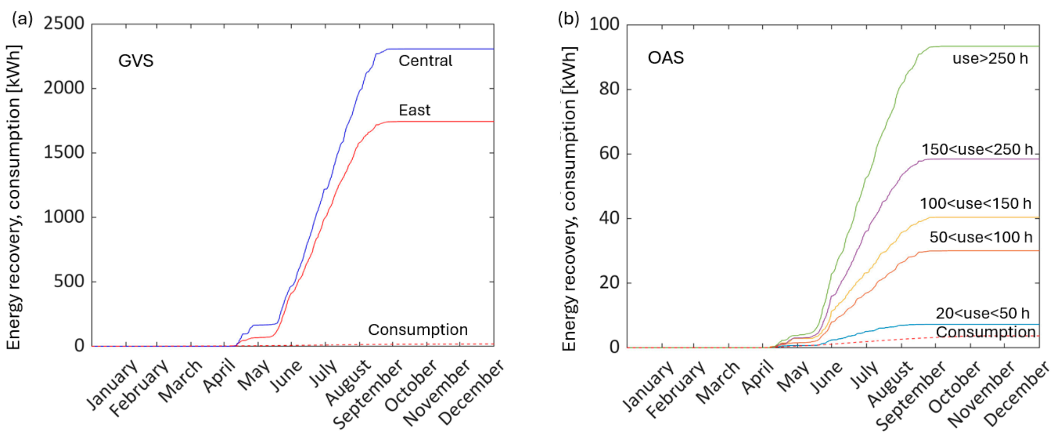

Figure 4. (**a**) Energy recovery with the two GVS. (**b**) Energy recovery of OAS system in the whole network.

In Figure 4b, the OASs are divided into classes on the basis of the number of activation hours to potentially evaluate a threshold of usage hours necessary to permit the device energetic sustainability. The energetic sustainability is guaranteed for all devices. Anyway, the most critical period for device sustainability is the off-season period, where no energy is recovered but a low but continuous consumption is present to allow for signal reception.

4. Conclusions

The series of installed devices allows the implementation of new network management strategies, improving the operational conditions of the network itself without concerns for on-demand users. Using a study case with real data from the network, the installation of two devices, the GVS and the OAS, is proposed. Both are stand-alone devices thanks to the energy that can be recovered from the flow regulation process. The GVS is used to apply a pressure management strategy based on the real-time knowledge of active hydrants. The hydrant activation information is made available thanks to the proposed installation of the OAS at the hydrant nodes. It is calculated that there is a reduction of the average pressure in the network of 61%, gaining a proportional advantage on leakage reduction. Moreover, the energetic sustainability of the system is proved by verifying the energetic balance of several devices during the season.

This study emphasizes the potential of IoT methods in agricultural settings, emphasizing their pivotal role in optimizing irrigation networks and enhancing overall water management efficiency. An economic evaluation can be the next step for an exhaustive assessment of a field installation or, for example, the selection of OAS installation points on the basis of their criticality.

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Conflicts of Interest: The authors declare no conflicts of interest.

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