EGU25-18057
EGU General Assembly 2025

Exploring the Potential of the Off-Grid Automation Systems in a Real Pressurized Irrigation Distribution System

Ignasius Axel Hutomo, Davide Troiani, Giacomo Ferrarese, and Stefano Malavasi
Politecnico di Milano, Civil Engineering and Environment, Italy (ignasiusaxel.hutomo@polimi.it)

Off-grid Automatic System (OAS), a smart valve patented by Politecnico di Milano, is a device that has the capability to regulate fluid flow while simultaneously recovering energy from the throttling process. The device is an evolution of several previous patents developed by the research group, designed to adapt to the operating conditions of irrigation applications. The energy recovered is used locally to enable functions that enhance water network resilience, management and sustainability, like remote control and real-time monitoring.

This paper presents a framework for assessing the feasibility of the OAS in a real Pressurized Irrigation Distribution Network (PIDS), where little to no information is available aside from geometrical features and some boundary conditions. Firstly, hydrant configurations were generated using a statistical approach based on the Clément formula integrated within the Combined Optimization and Performance Analysis Model (COPAM). Secondly, the Water Network Tool (WNTR) package was employed to simulate the hydraulic performance of the system. Thirdly, the simulation results were used to determine the minimum OAS diameter based on the Flow Coefficient (Cv) and the maximum recoverable energy of the system. Finally, the energy balance was calculated considering the minimum hours of hydrant activation and the energy consumption of the OAS across various operational modes.

This methodology was evaluated on a real irrigation network in District 10 – Capitanata PIDS in Southern Italy. The network comprises 54 kilometers of pipe serving 317 hydrant nodes. Each node irrigates 6 hectares of land, with a nominal discharge of 10 liters per second and a design pressure head of 20 meters. The upstream piezometric head exhibited an operational range of 110 meters. Average hydrant pressures ranged from 40 to 100 meters, significantly exceeding the levels required for proper operation at most network nodes. Consequently, following widely studied approaches in the literature Pressure Reducing Valve (PRV) was installed downstream within the PIDS to lower the excessive pressure and reduce water losses This intervention reduced pressures by approximately 20 meters, and the energetic sustainability of the OAS was verified also under these adjusted conditions.

This study demonstrates an average hydrant reliability of 94% across all possible configurations with 10 hours of hydrant activation. It means, on average, 94% of the potential hydrant configurations tested in this study were able to provide enough energy to power the OAS system for the whole year irrigation season. However, some nodes exhibit significantly lower reliability. Attributed to unfavorable topographic and hydrant combinations, where even prolonged

activation fails to generate sufficient energy for the OAS to achieve self-sustainability.

This study highlights the critical challenge of energy self-sufficiency for OAS particularly in the face of uncertainties in network operation. The intermittent nature of irrigation demands and the inherent variability in water pressure within the network significantly impact the energy generation potential of the OAS. The findings underscore the importance of robust system design to ensure the long-term sustainability and reliability of off-grid irrigation technologies, particularly in regions facing water scarcity and energy constraints.