Optimal Pressure Control and Burst Detection for Sustainable Water Management

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Abstract : Water distribution networks play a vital role in ensuring a reliable supply of clean water to urban areas. However, they face several challenges, including pressure control, pump speed optimization, and burst event detection. This paper combines insights from two studies to address these critical issues in Water distribution networks, focusing on the specific context of Kapra Municipality, India. The first part of this research concentrates on optimizing pressure control and pump speed in complex Water distribution networks. It utilizes the EPANET- MATLAB Toolkit to integrate EPANET functionalities into the MATLAB environment, offering a comprehensive approach to network analysis. By optimizing Pressure Reduce Valves (PRVs) and variable speed pumps (VSPs), this study achieves remarkable results. In the Benchmark Water Distribution System (WDS), the proposed PRV optimization algorithm reduces average leakage by 20.64%, surpassing the previous achievement of 16.07%. When applied to the South-Central and East zone WDS of Kapra Municipality, it identifies PRV locations that were previously missed by existing algorithms, resulting in average leakage reductions of 22.04% and 10.47%. These reductions translate to significant daily Water savings, enhancing Water supply reliability and reducing energy consumption. The second part of this research addresses the pressing issue of burst event detection and localization within the Water Distribution System. Burst events are a major contributor to Water losses and repair expenses. The study employs wireless sensor technology to monitor pressure and flow rate in real time, enabling the detection of pipeline abnormalities, particularly burst events. The methodology relies on transient analysis of pressure signals, utilizing Cumulative Sum and Wavelet analysis techniques to robustly identify burst occurrences. To enhance precision, burst event localization is achieved through meticulous analysis of time differentials in the arrival of negative pressure waveforms across distinct pressure sensing points, aided by nodal matrix analysis. To evaluate the effectiveness of this methodology, a PVC Water pipeline test bed is employed, demonstrating the algorithm's success in detecting pipeline burst events at flow rates of 2-3 l/s. Remarkably, the algorithm achieves a localization error of merely 3 meters, outperforming previously established algorithms. This research presents a significant advancement in efficient burst event detection and localization within Water pipelines, holding the potential to markedly curtail Water losses and the concomitant financial implications. In conclusion, this combined research addresses critical challenges in Water distribution networks, offering solutions for optimizing pressure control, pump speed, burst event detection, and localization. These findings contribute to the enhancement of Water Distribution System, resulting in improved Water supply reliability, reduced Water losses, and substantial cost savings. The integrated approach presented in this paper holds promise for municipalities and utilities seeking to improve the efficiency and sustainability of their Water distribution networks.

Keywords : pressure reduce valve, complex networks, variable speed pump, wavelet transform, burst detection, CUSUM (Cumulative Sum), water pipeline monitoring

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