Abstract of Research Project
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RESEARCH PROJECT (max 3 pages):

Introduction and state of the art

Water pipe systems have a fundamental role for our society as they provide the required amounts of potable water that are necessary to satisfy user demands. These complex infrastructures are made up of thousands of elements such as pipes, pumps, and valves, with total lengths up to hundreds of kilometres. Moreover, water distribution systems (WDSs) are usually highly looped, which increases their hydraulic reliability but also makes more difficult to monitor and manage them.
Despite their social relevance and technical complexity, most of them in Europe – and particularly in Italy – are actually composed of aged infrastructures built during the first part of the 20th century, and their structural integrity and actual degree of deterioration is often poorly known except for the increasing failure frequencies and volumes of water leakages. The progressive deterioration of pipe systems and the lack of strategies for pressure control is leading to a progressive increase in water leakages, whose costs include abstraction, treatment, and pumping. The actual leakage costs are therefore related both to resource waste and energy consumption. Hence Water Utilities must face multiple challenges including reparation of breakages, reduction of leakages, scheduling maintenance works to contrast mechanical and hydraulic decay of the pipe systems, and monitoring of drinking water quality provided to the users.
The proposed project is aimed at setting up enhanced methods and procedures based, among others, on analysis techniques, which can support Water Utilities to:
a) improve the asset management,
b) reduce water leakages,
c) improve the system real time control.
The design of DMAs represents a complex problem in real WDS, which are often designed in successive stages. Several procedures have been proposed to solve this problem [1], but there is still a need for a more detailed and rational verification by experiments [2].
Pressure control strategy through PRVs has been deeply investigated as management strategy [3], aimed at water leakages reduction avoiding very expensive pipes replacement programmes [4]. However, few experimental data are available in literature, particularly in unsteady-state conditions [5].
The transient test-based techniques have emerged in recent years and offer a powerful non-intrusive tool for detecting system defects by monitoring the pressure waves at key points in the water system [6]. However, very few field tests have been executed [7]. In addition, these techniques use models that originate in steady state theory, which may not accurately describe the complex flow behaviour in hydraulic devices, such as pumps, valves and demand connections [e.g. 5].

The transient model have been mainly developed for mains or rather simple WDSs [e.g. 8]. Effective transient model of real WDS represents a very up to date problem [9].
The approaches for real time control of pumps (particularly fixed speed pumps) [10] and PRVs [11] have been proposed mainly considering extended period steady state conditions.

Research objectives

By studying in depth the subjects outlined above we intend to set up models and tools which support Water Utility managers to improve the asset management, reduce water leakages, and improve the real time control of the system.
In particular, the firts topic regards the leakage reduction management and within this context the three objectives considered are
1. Optimal design and monitoring of DMA,
2. Pressure control devices characterization and monitoring, and
3. Defect detection.
The second topic regards the optimal real time management, and within this context two objectives considered are:
4. Characterization of the unsteady behaviour of the pipe systems
5. Optimal pressure and energy management.

Methodology

The goal of this project is to develop pioneering methodologies that will assist the design, operation, monitoring and diagnostic repair of water pipe systems. To this aim a DMA will be assembled at the Water Engineering Laboratory (WEL) of the University of Perugia, and the effect of different pressure regimes and demand patterns will be tested and simulated. The effect of some devices commonly used in water pipe systems for pressure management will be checked and analyzed. Moreover, the use of transient tests for fault detection will be examined, since leaks, blockages, bursts, deteriorated pipes, and malfunctioning devices (pumps, valves) distort wave signals. This task specifically seeks to use measured wave signals in an inverse sense to deduce the system characteristics that caused the measured response.
Finally, efficient water distribution transient models will be developed in order to characterize the transient effects due to water consumption and control devices. All these aspects will finally be included within the development of procedures for the optimal real time control. The procedures should allow for the definition of the optimal status of pumps and valves in order to minimize the pressure, and thus leakages, and energy consumption.

Expected results

<u>Applicative potentiality</u>
The effect of different pressure regimes and demand patterns close to the real ones will be tested and simulated in order to identify the most efficient and reliable decisions (e.g., sensor location, pressure regulations).
The investigation of the effectiveness of pressure control will be carried out. The conditions to achieve their maximum efficiency and the effect of the controller will be considered.
The transient test based techniques will be used to detect leaks and anomalies and the results of numerical models will be transferred to real cases studies and some field tests will be executed.
Water distribution transient modelling allows technician to get a more in deep characterization of the functioning of the system, pointing out for example critical situations which can lead to increased breakage rate.
The optimal real time control of pumps and valves allows technicians of water utilities to reduce energy consumption, losses and can determines a reduction in breakages and in ordinary and extraordinary maintenance interventions.
The scientific impact of the project is mainly due to (a) the increased knowledge of physical and chemical phenomena (e.g., hydraulic behaviour of water leakages, and transient behaviour of WDS), and (b) the advancement in the mathematical algorithms for WDS management. Scientific results will be disseminated

through usual ways (such as ISI journals, conference proceedings, workshops, professional networks) providing the scientific and experimental basis for similar researches or new developments in the same field.
The technological impact of the project is due to the experimental characterization and checking of some devices, such as PRV, smart meters, pumps that are suitable for the management of WDS, and the systems for the automatic control of such devices.
The experimental activity will help the development of numerical models and, at the same time, will provide information on the critical points of the tested configurations highlighting possible improvements; this knowledge will help manufacturer to improve production processes. The novel knowledge can also help the design of new devices for controlling or detecting water losses.

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