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CRITERIA, OBJECTIVES AND METHODOLOGIES FOR WATER NETWORK PARTITIONING

Armando DI NARDO(*), Michele DI NATALE(*), Anna DI MAURO(*)(**), Giovanni Francesco SANTONASTASO(*) & Carlo GIUDICIANNI(*)

(*) Università della Campania "Luigi Vanvitelli" - Dipartimento di Ingegneria - via Roma, 29 - 81031 Aversa (CE), Italy
(**) Med.Hydro s.r.l., spin-off - via Roma, 29 - 81031 Aversa (CE), Italy
Corresponding author: armando.dinardo@unicampania.it

EXTENDED ABSTRACT

Le reti idriche di distribuzione sono infrastrutture caratterizzate da un'articolazione piuttosto complessa e ramificata, da dimensioni molto elevate (reti magliate con migliaia di nodi) e da ridotta accessibilità (tubazioni interrate). Ciò ne rende particolarmente difficile la gestione da parte delle *Water Utilities*, che generalmente gestiscono da poche migliaia a milioni di utenti.

L'applicazione del paradigma del "*divide et impera*" alle reti idriche, facilitando la stima dei bilanci idrici, la ricerca delle perdite ed il controllo delle pressioni, è una valida tecnica per migliorare sia la gestione che la manutenzione.

L'interesse mondiale verso la riduzione dell'enorme quantità di acqua sprecata all'interno delle reti idriche trova un valido alleato nella distrettualizzazione delle reti idriche, riconosciuta a livello internazionale come best practice per l'individuazione delle perdite.

La distrettualizzazione di una rete idrica consiste nella sua suddivisione in sottoinsiemi (distretti) delimitati da organi di sezionamento e controllo idraulico (dispositivi per la misura delle portate). Il sezionamento della rete, già introdotto da tempo in molti paesi, ha principalmente due scopi:

- semplificare il computo dei bilanci idrici, consentendo una stima più affidabile dei consumi, e l'applicazione delle tecniche di localizzazione delle perdite idriche;
- migliorare la gestione dell'intero sistema di distribuzione, attraverso il monitoraggio continuo di alcune grandezze idrauliche, al fine di prevenire situazioni di crisi, programmare operazioni di manutenzione e di facilitare la riduzione delle perdite idriche.

La possibilità di suddividere la rete in distretti rappresenta una moderna tecnica di organizzazione dei sistemi idrici urbani che offre nuove prospettive di progettazione, protezione, gestione e manutenzione, favorendo la trasformazione delle tradizionali reti acquedottistiche in *Smart Water Network*, in accordo con la sempre più crescente spinta verso il concetto di *Smart City*.

Infatti, alla tradizionale filosofia, seguita da sempre nel settore delle costruzioni idrauliche, di avere una rete fortemente magliata al fine di migliorarne l'affidabilità nelle diverse condizioni di esercizio, si contrappone una filosofia di parzializzazione della rete, il che determina inevitabili perdite di prestazione globale e parziale del sistema. Infatti, il problema fondamentale della distrettualizzazione è rappresentato dalla perturbazione nei confronti della rete idrica sia in termini di prestazioni che di qualità delle acque. Intervenire con operazioni di manovra e di chiusura di valvole in un contesto complicato quale quello delle reti di distribuzione cittadine, spesso accresciutesi senza alcuna progettazione preventiva, comporta sia problemi di ordine tecnici che economico. Tuttavia, i notevoli benefici di tale tecnica sono evidenti; infatti, la gestione delle reti di distribuzione viene migliorata favorendo la ricerca delle perdite, la gestione delle pressioni, la protezione della qualità dell'acqua, etc.

Nella memoria vengono proposte alcune indicazioni metodologiche legate alla distrettualizzazione cercando di evidenziarne vantaggi e svantaggi, rilevandone anche le differenti problematiche connesse alla loro realizzazione.

Inoltre verranno riassunte le principali tecniche recentemente proposte in letteratura finalizzate a trovare il miglior partizionamento che consenta di ottimizzare sia i costi, sia le prestazioni idrauliche che la robustezza topologica della rete, nonché la protezione della rete e quindi la qualità della risorsa acqua.

A tal proposito gli autori hanno sviluppato uno specifico software (SWANP 3.0 - *Smart Water Network Partitioning and Protection*) per la distrettualizzazione delle reti idriche di distribuzione, che implementa i principali algoritmi di clustering e di ottimizzazione e consente di ottenere distrettualizzazioni automatiche offrendo indici di prestazione innovativi (resilienza energetica, topologica e di qualità dell'acqua) per il confronto dei diversi *layout* di rete ottenuti. Inoltre, il software implementa un tool per la protezione delle reti idriche da contaminazioni accidentali ed intenzionali, definendo il layout di sensori di qualità che massimizza le prestazioni del monitoraggio (tempi di rilevamento, popolazione contaminata, probabilità di rilevamento).

Il software SWANP 3.0 consente di effettuare le verifiche idrauliche in *Demand and Pressure Driven*. In conclusione, la presente memoria ha lo scopo di mostrare i criteri, gli obiettivi e le metodologie per il partizionamento delle reti che permettono di individuare nella distrettualizzazione una delle strategie più efficaci e propedeutiche allo sviluppo di una gestione intelligente dei sistemi di distribuzione idrica.

ABSTRACT

Water distribution networks are complex infrastructures characterized by very large dimensions (meshed networks with thousands of nodes) and reduced accessibility (generally they are buried underground). These peculiarities make it particularly difficult to manage and show numerous criticalities; at the same time, water distribution networks represent one of the main subsystems of smart cities.

The paradigm "divide et impera" is a valid technique to improve the management and facilitate the maintenance, the water balance estimation, the water leakage detection and the pressures control. On this side, Water network District Metering (WDM), a method developed in England, and already implemented in many countries, represents a modern technique to organize urban water systems, offering new perspectives for design, management and maintenance. The WDM is recommended as one of the best practice to limit the huge amount of dispersed water in urban networks, simplifying water leakage detection, carrying out pressure management, improving water system management and monitoring of district hydraulic data. On this subject, the authors developed a specific software (SWANP 3.0) for water network partitioning that integrates the main optimization algorithms.

This paper shows the main aspects of water network partitioning summarizing the principal recently proposed techniques in the literature aimed to find the best partitioning layout from an economic and performance point of view.

Keywords: *water network partitioning, leakage detection, pressure management, District Meter Areas*

INTRODUCTION

Water distribution networks (WDNs) show a deep structural and managerial backwardness. The most common problems are the following: degradation due to the obsolescence of pipes and hydraulic devices (gate valves, control valves, flow meters, etc.); low hydraulic performances (insufficient pressures, reduced resources during summer, poor water quality, etc.); high percentages of leakages both physical and administrative (Cascetta *et alii*, 2005a, 2005b); bad design of network expansion resulting from irregular city grows.

The United Nations devoted the year 2003 (United Nations, 2003) to the problem of water in the world, in particular to the areas of the planet affected by water scarcity, where it would be necessary to build intake structures while at the same time, exist regions characterized by wealth of water resources. Some cases required actions to minimize waste and optimize resources. These goals can be achieved only through the upgrade of novel and effective water management strategies. It constitutes a crucial challenge for all industrialized countries; in fact, the Organization for Economic Co-operation and Development (OECD), in its last summit on environmental issues, focused the attention on the waste of water resources for the major industrialized countries. The OECD estimated that water losses in urban water networks account for around 30% (for the 30 most industrialized countries), exceeding the optimum economic level of 10% and 20% (OECD, 2002).

A valid and efficient strategies to better manage water distribution networks, especially regarding the water losses, is the Water Network Partitioning (WNP), based on the paradigm of "divide and conquer" which exploits the property that complex system can be better analysed if it is possible to split them in many sub-parts. This strategy in WDNs was introduced in the 1980 in the UK (Water Authorities Association and Water Research Centre, 1985; *Wrc/WSA/WCA Engineering and Operations Committee,* 1994; Water Industry Research Ltd., 1999); it consisted in dividing the network into permanent subsystems, called as DMAs (District Meter Areas), by inserting gate valves and flow meters along properly selected pipes, in order to improve water and pressure management, losses identification and protect users from accidental and intentional contamination (Grayman *et alii*, 2009; Di Nardo *et alii*, 2015a).

WNP provides a series of interventions on the water distribution network that require a careful economic planning by the managing authority; furthermore, it envisages the use of modern monitoring systems (remote control, etc.) which no longer have a prohibitive cost and which, to be implemented, only await a new management policy (Cascetta, 1997). An important aspect to take into account is that, the criterion of the WNP is in contrast to the general design criteria of the water distribution networks, according to which the redundancy of the paths is the main characteristic to guarantee. The introduction of the concept of districts and water sectors is in opposition to the traditional criterion followed in the field of the hydraulic constructions (Milano, 1996); design a multi-meshed network in order to improve its efficiency under different operating conditions. The partitioning could provide hydraulic performance deterioration of the system (Di Nardo *et alii*, 2016b); in fact, it is carried out in almost all cases on networks already designed and implemented with the traditional criteria, so system efficiency could be partially and/or globally compromised. Anyway, the introduction of the paradigm "divide et impera" for the water distribution networks promotes innovation in the management of water networks introducing the concept of Smart WAter Network (SWAN) as a key subsystem of the notion of Smart City.

It is evident that having a network divided into smaller *k* sub-regions makes it easier the study and the management of the system (Water Industry Research, 1999; Di Nardo & Di Natale, 2011). In details, depending on the objectives, the sub-parts can or must be interconnected generating different partitioning criteria both physical and virtual (Cascetta *et alii*, 2005b).

The definition of an optimal partitioning layout is a crucial and arduous problem; anyway, nowadays it is possible thanks to the development of new monitoring and control technologies and to the recent growth of computational power used by simulation software, that provide new opportunities to the traditional approach of analysis, design and management. Therefore, WNP represents a crucial task not only for the technicians of the sector but also for the scientific community, because it modifies some fundamental criteria followed in the design of water systems.

In this paper, the authors put together various indications of literature, proposing some methodological suggestions related to water network partitioning, highlighting their advantages and disadvantages. Furthermore, the main methodologies and techniques recently developed to obtain automatic district metering of water networks are listed.

DISTRICT METERING ADVANTAGES

The paradigm of "*divide and conquer*" applied to SWAN was introduced in the 1980 in the United Kingdom. It consists in dividing a large network into smaller subsystems, called DMAs (District Metered Areas), inserting both gate valves and flow meters in order to improve:

- the management of the water distribution network;
- the water balance to detect water leakage;
- the water pressure control;
- the water quality protection from accidental and intentional contamination.

In the sections below will be synthetically described the main benefits obtained with the application of WNP.

Management improvement

The main benefits of Water Network Partitioning are represented by the definition of DMAs that allows to control smaller parts of the entire water system (paradigm of divide and conquer).

DMAs simplifies the monitoring and the management, with reference to the problems that will be exposed in the following paragraphs (location of water losses, pressures management, protection of water from accidental or intentional contamination) and provides the possibility to obtain several information for each district, such as, demand distribution, urban destination, type of users, break frequency, pressure levels, water quality, etc. All valuable information to improve management, quality and cost of service.

Water balance

The water balance and the evaluation of network integrity presuppose the exact definition of the different components of the volumes to estimate the water losses, and to compare water networks of different countries.

An important aspect to highlight is that, on the subject, it subsists not only technical and scientific problems but also difficulties related to the drafting of an international "standard terminology".

On this side, IWA made a fundamental contribution (Lambert & Hirner, 2000) to define water balance components and to compare the performance of the systems using evaluation indices equal for all countries (Lambert *et alii*, 1999). Water balance is crucial to evaluate the efficiency of a water distribution system. It is clear that, theoretically, it is possible to carry out a water balance on the entire distribution network, but this operation is practically impossible due to many problems, essentially linked to the difficulty of identifying users' consumption (civil, industrial, commercial, etc.), authorized or not consumption, and the synchrony of all measures (or to report them at the same time interval). The practical application of the water balance is a very complex operation, both for scientific and technical reasons and for economic and management reasons.

One of the main problems is represented by the evaluation of the volumes involved in the water balance, which is not always easy to determine and are often estimated rather than measured (AWWA, 1997). Several conditions make water balance difficult, in particular: *spatial*, linked to the dislocation of the water meters; *temporary*, linked to the synchrony of the time intervals in which evaluate the water balance; *operational*, related to the different operating conditions of the network.

To overcome the problems related to the lack of measures about users' consumption, some methodologies were developed initially in England (Wrc/WSA/WCA, 1994; UK Water Industry, 1999); they allow to estimate (and not to measure!) the volumes to be included in the water balance equation to assess real and apparent losses. The two most used techniques are the following:

- *MNF (Minimum Night Flow):* the most used methodology to control water network integrity is the continuous measurement of the minimum night flow (MNF), which is conducted on a smaller portion of the network for a period necessary to obtain statistically significant data. The method consists in installing suitable flow meters, equipped with a totalizer, in order to detect the volumes of water that flow during the night. The measurement of the minimum night flow is used both as a financial statement method, aimed to assess flow components to highlight water losses, and as a network monitoring methodology, comparing the MNF measured with a reference MNF, appropriately chosen in the literature in relation to the characteristics of the case study and representative of a good working condition and operation of the network. If the measured value of the MNF is higher than the reference one, it might be convenient to start a leakage detection activity. The balance is essentially executed at a time between midnight and four, when users' consumption is minimal and leakage affect the incoming flow in the distribution network, or in a district, as consumptions are almost constant; in fact, the method to work needs that water loss is "visible" with respect to consumption. The application of MNF method requires the possibility of temporarily or permanently installing flow meters and gate valves, which obviously alter the "normal" operation of the water network.

- *Minimum flow consumption or zero consumption technique*: the minimum consumption measurement method is a short term technique, which ends in one night, based on the analysis of the flow rate that feeds a portion of the network with the main purpose to identify leaks. The method provides also information about consumption distribution and infrastructure conditions. The method consists in evaluating flow rate at a point in the network, previously insulated with gate valves, for the whole duration of the test and comparing it with the one introduced from the outside, suitably measured by a mobile laboratory. The difference between the totalized output volumes and those entered must be zero in the absence of leakage, considering as hypothesis that users' consumption is zero during the night. Also this methodology can be applied only to limited portions of the network, both to limit water balance to a sufficiently restricted area to be able to estimate consumption, both to avoid the inevitable disservices that the closure of gate valves can provoke to the users of the neighbouring parts of the system distribution.

It is evident that both methodologies require a sectorization of the network, and therefore water network partitioning become fundamental to obtain reliable water balances, and to provide useful indications also on water losses localization.

Water pressure management

Water network partitioning supports the pressure management for each district since the pressure control can reduce the leakages.

In this regard, it should be noted that water leakage $Q^{Leakage}$ in the pipelines increases with increasing pressures P according to the relation (Khaled *et alii*,1992; Lambert, 2000):

$$Q^{Leakage} = cP^{\gamma} \quad (1)$$

in which the values of the coefficients c and γ depend on the pipelines characteristics and the type of leak while P is expressed in meters of water column.

Therefore, it is evident from (1) that the placement, in suitable points of districts, of the pressure reducing valves, allows the establishment of water loads at nodes able to reduce water losses. This pressure reduction inevitably reduces the network hydraulic efficiency; in this regard, optimization algorithms are need for the optimal placement of the valve, in order to reduce the pressure at nodes (and therefore the water losses of the district), but at the same time, preserving the hydraulic performances of the system and guarantying the minimum level for the users. Water network partitioning allows to adjust pressure values in the different areas of the network, taking into account the different needs of the urban areas served as already shown in different international experiences.

Water distribution system protection

Water Network Partitioning can be an effective way to protect water system from intentional contamination according to the dual-use value criteria (Di Nardo *et alii*, 2015a).

In previous studies, the authors investigated how different layouts of permanent DMAs can reduce the risk of contamination for the network and limit the effects of a malicious act. The positioning of gate valves and flow meters was optimized with a multi-objective function in order to minimize the alteration of hydraulic performance due to partitioning and to minimize the effects of intentional contamination. The malicious attack was assumed to be perpetrated with cyanide finding the worse insertion point for each network layout. The analysis was carried out on a real water distribution network comparing different sectorization scenarios. The simulation results showed the effectiveness of the optimization approach with a significant reduction of risk for users.

PHYSICAL AND VIRTUAL DISTRICT METERING

The main problem of Water Network Partitioning is represented by the perturbation on the water distribution system that can be affected both in terms of performance and water quality.

Operating by manoeuvring and closing valves in a difficult and complicated context like urban distribution networks, causes many technical and economic problems. In this paragraph two types of District Metering design criteria are described, related to two different techniques of partitioning. Generally, it is possible to define a "physical district metering" and a "virtual district metering".

In the first case, the adjective "physical" refers to the real action that DMAs - through the isolation valves and measurement devices - performs upon the urban water distribution system by altering its functioning, in terms of hydraulic performances and water quality, as reported in Figure 1.

In the second case, the adjective "virtual" means that the system district metering only occurs in terms of measuring the hydraulic characteristics (flow, pressure, etc.) of a partitioned area without activating any interception device, hence not harming its functioning. Thus, virtual "district metering" is carried out by partitioning the network through the installation of devices metering flows and bidirectional volumes along the pipes selected to limit the district, as reported in Figure 2.

Physical district metering gives more opportunities than its virtual counterpart, because it allows the monitoring, managing and optimizing of the operation of the system and, the reduction of leakages by Water Pressure Management (WPM) thanks to district isolation valves. In addition, physical district metering can also be used to protect water networks from accidental or intentional contamination.

On the other hand, this methodology is complicated to achieve because, by intervening in a physical way on the system, it is necessary to verify the variations of the system respect to the initial conditions, through hydraulic simulation and calibration techniques (Di Nardo & Di Natale, 2011).

The main goals that can be achieved through district metering design are: a) minimize the alteration of hydraulic performance b) minimize the number of flow meters (the best management condition occurs when a single meter is installed for each district) in order to simplify the computation of water balance (Twort *et alii*, 2000; Cascetta *et alii*, 2005a).

OPTIMIZATION TECHNIQUES FOR WATER NETWORK PARTITIONING

The literature offers empirical suggestions for water network partitioning based on DMAs characteristics (number of users, pipes length, etc..) (Butler, 2000; Water Industry Research Ltd., 1999); or 'trial and error' approaches used with hydraulic simulation software (Cascetta *et alii*, 2006). Nevertheless, these suggestions and approaches are very difficult to apply to large water supply systems; in the last ten years, many optimization techniques have been proposed, based on graph and network theory, that have significantly improved water network partitioning.

Several suggestions about DMA size can be found in the technical literature: in Water Authorities Association and Water Research Centre (1985) a DMA has to include 1,000 - 3,000 properties, while in Butler (2000) a permanent district has to contain 2,500 - 12,500 inhabitants with 5-30 km of water network, UK Water Industry Research recommends a number of properties between 1,000 (small DMA) and 3,000 (medium DMA) and up to 5,000 (large DMA). These guidelines cannot be easily extended to large water supply systems, since they are based on empirical considerations, and sometimes on a small number of case studies. Different optimization methodologies lead to define automatic procedures for water network partitioning (or sectorization) respect to which the authors have provided a significant contribution.

Generally, the procedures are divided in two phases (Di Nardo *et alii*, 2015b; Perelmann *et alii*, 2015):

1) clustering, aimed at defining the shape and the dimensions of the network subsets, based on different theories aimed to minimize the number of connections (or other characteristics like diameter, length, conductance, etc.) balancing the number of nodes (or other characteristics like flow, pressure, etc.) for each district, as shown Figure 3.

This phase can be obtained with different techniques and algorithms proposed in the literature, often developed in other disciplines for different classes of problems. In particular, the most effective methodologies are based on the following techniques:

a) *graph algorithms* (Jacobs & Goulter, 1989; Savic *et alii*, 1995; Tzatchkov *et alii*, 2006) starting from the representation of the water network as a simple weighted graph considering $G=(V,E)$, where V is the set of n vertices (or nodes) and E is the set of m edges (or pipes). Subsequently, it is defined the matrix of connectivity *A nxn* and the matrix of weights *W nxn* (matrix of the intensity of the connections between nodes). Then, the application of different techniques of graph theory, in particular related to the search for minimum paths (weighted and not), allows to obtain groupings of nodes on which then it is possible to apply the next dividing phase. Through these techniques it is possible to quickly identify the districts in the subsequent dividing phase and to guarantee a minimum service levels compatible with original network reliability (Di Nardo & Di Natale, 2011; Di Nardo *et alii*, 2014a). The "least important" or "most redundant" sections are identified and at the same time the number of sections on which is needed to insert gate valves and/or meters is reduced.
b) *multilevel partitioning* (Di Nardo *et alii*, 2015b) that starting

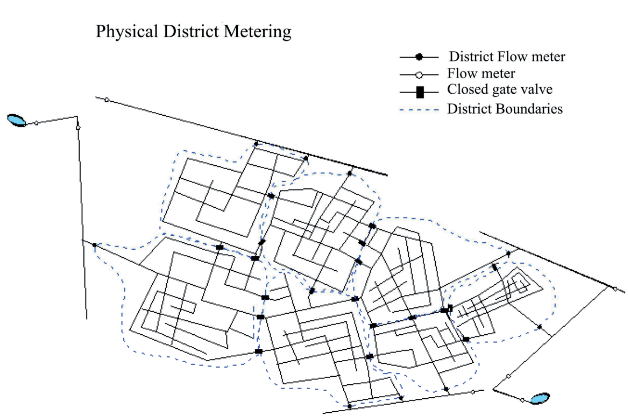

Fig. 1 - Physical District Metering

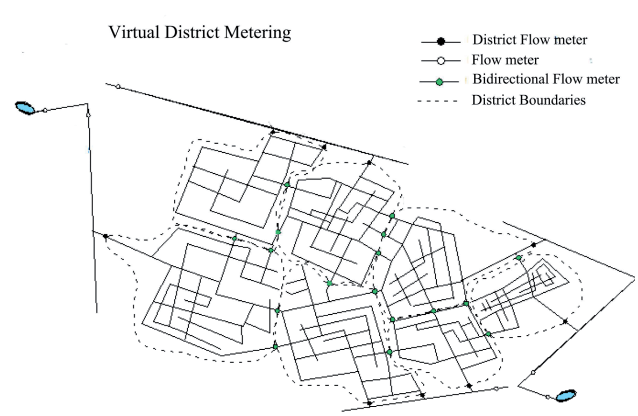

Fig. 2 - Virtual District Metering

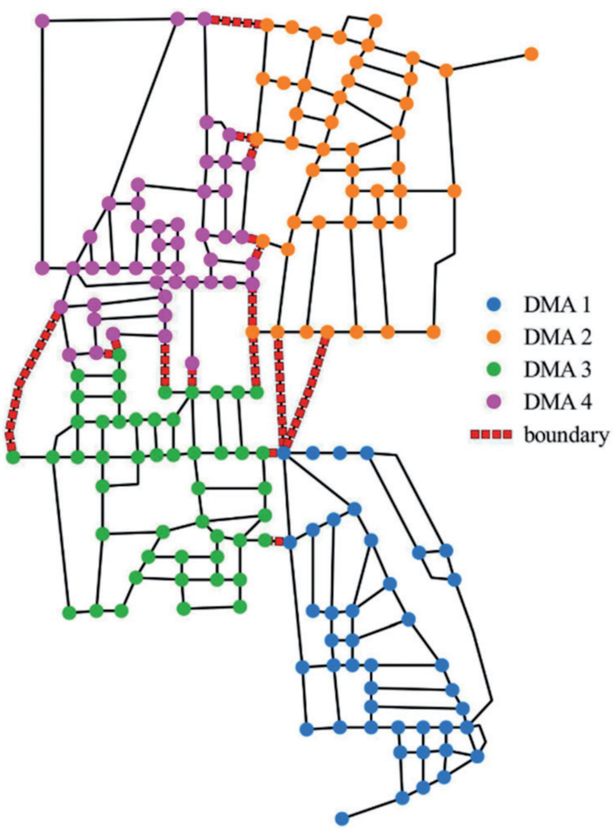

Fig. 3 - Clustering phase

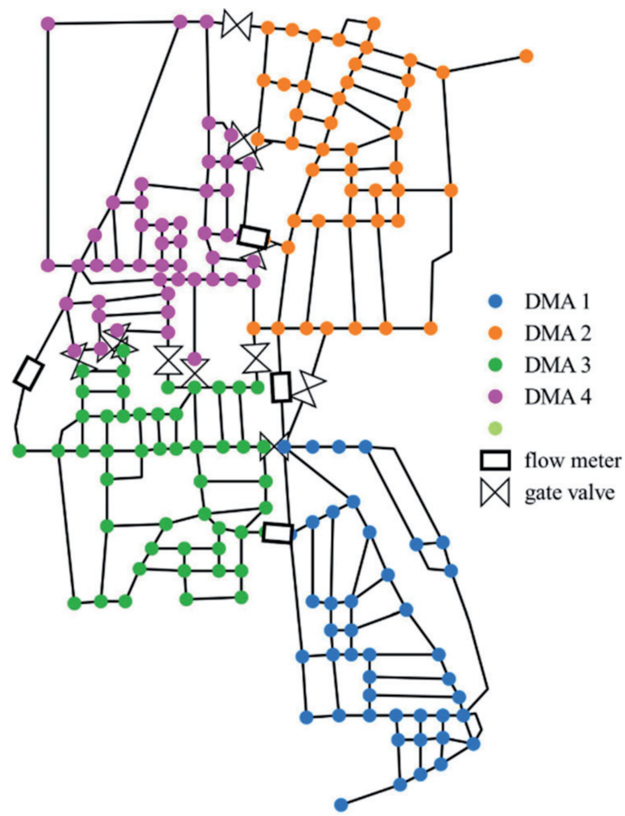

Fig. 4 - Dividing phase

from techniques implemented in informatics tools allows to obtain automatically water network clustering minimizing the number of links between districts. In fact, for simulation that need huge computational power like, for example, simulations based on finite element methods, parallel computation can be used and, in this case, it is necessary to distribute the finite element mesh among different processors. This distribution, in order to improve performance, must be made according to two main rules: 1) an equal number of finite elements has to be allocated to each processor for balancing the workload; 2) a minimum number of adjacent elements between processors has to be found for reducing communication overhead. This problem can be assimilated to partitioning of a computational mesh in k-way or in k-processors that will perform each computational process. The mesh is commonly schematized by a graph with vertices correspondent to individual computational processes (e.g., finite elements) and with links correspondent to their connections. Starting from this schematization of the mesh, partitioning techniques of a graph in k- way were developed in Computer Science for the optimal allocation of a computational mesh in parallel or distributed computing architectures. The proposed methodology is based on the similarity between a calculation mesh and a water distribution network, in particular on the analogy between the districts design criteria and those of parallel computing system, in other words: the balancing of the load of calculation to be assigned to different processors can be compared with the balancing of the number of nodes (or the flow rates) to be assigned to each water district, and the minimization of the connection elements between two processors corresponds to the minimization of the pipe closures.

c) *community structure*, is a bottom-up hierarchical algorithm based on the measure of network density to define clusters. These algorithms identify sub graphs in an iterative manner, aggregating nodes time by time and then the groups of nodes, minimizing the density between groups and maximizing the density within each group. Density therefore becomes a measure of the quality of the clustering process, where for density it means the number of connections between nodes. As metric for density measurement are generally adopted modularity and centrality of segments (Newman, 2000; Di Nardo *et alii*, 2015b).

d) *spectral approach*, developed in the last few years (Herrera *et alii*, 2010; Di Nardo *et alii*, 2016a) starts from considering the network as a simple graph $G=(V,E)$, where V is the set of n vertices vi (or nodes) and E is the set of m edges. Subsequently, it is defined the matrix of connectivity A nxn and the matrix of weights W nxn (matrix of the intensity of the connections between nodes). In this case, methodologies and algorithms of complex networks theory are adopted (Boccaletti *et alii*, 2006), assuming water distribution networks as complex systems, constituted by thousands of elementary units (nodes and stretches), connected to form meshes (loop), strongly geographically bound (Boccaletti *et alii*, 2006). Starting from the adjacency matrix A, it is defined the diagonal matrix of the degrees D nxn (matrix of the degree of connection of each single node), and therefore the Laplacian matrix of the graph L=D-A, whose spectrum defines important characteristics of the network. In detail, if k is the number of clusters in which the network has to be divided, the first k eigenvectors of the Laplacian define a new representation of the nodes that facilitates the identification of the subsets (Fiedler, 1973). It is shown that, the obtained clustering layout minimizes the number of infra-clusters pipes and simultaneously balances the number of nodes for each clusters (or the sum of the weights if the graph is weighed).

2) dividing, aimed at physically partitioning the network, by selecting pipes for the insertion of flow meters or gate valves using recursive bisection procedure (Ferrari *et alii*, 2014) or optimization technique (Di Nardo *et alii*, 2016b) with the objective of identifying the optimal layout that minimises the economic investment and the hydraulic deterioration, as shown in Fig. 4. Ones obtained the set of N_{ec} of boundary pipes, it is necessary to choose which of them must to be closed with N_{bv} gate valves or, equally, must to be used for installing $N_{fm}=(N_{ec} - N_{bv})$ flow meters.

This choice was made comparing, through appropriate Performance Indices (IP), a subset of possible combinations $N_{cs}<N_c$ of the binomial coefficient:

$$N_C = \binom{N_{fm}}{N_e} \qquad (2)$$

The subset N_{cs} has been identified with an heuristic technique based on the dissipated power in the pipes, discarding the N_c-N_{cs} combinations that had a higher dissipated power with respect to the original network; in practice, only a subset of N_{cs} combinations corresponding to the pipes with the lower dissipated power were considered (Di Nardo & Di Natale, 2011).

The authors developed in Python the software SWANP3.0 (Di Nardo *et alii*, 2014b, Di Nardo *et alii*, 2016c) for the automatic clustering and dividing of a water distribution network, implementing different clustering algorithms and different objective functions for the physical dividing phase (Fig. 5).

The software therefore allows to compare solutions coming from different methodologies, and at the same time, give the possibility to select the optimization criterion for the specific case study.

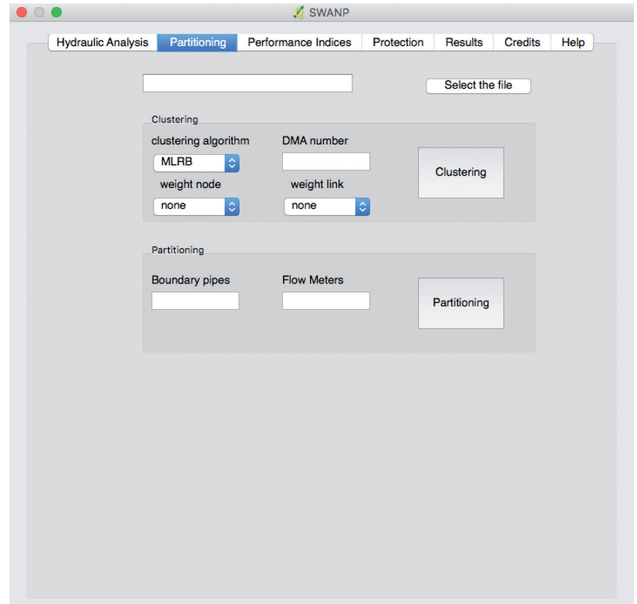

Fig. 5 - Partitioning Section of SWANP GUI

CONCLUSION

Water network partitioning has been successfully applied in many English companies, and also in some other countries, to locate and reduce water losses. However, it still needs to be improved especially due to the complexity of the design of WDNs. Only recently, a series of innovative methodologies proposed in the scientific literature, allow to obtain automatic partitioning that minimize the alterations of hydraulic performances.

The techniques for defining the best water network partitioning layout are numerous and each one allows to take into account specific topological and/or hydraulic aspects, in order to optimize the solution from an economic and functioning point of view. The common goal of these procedures is to obtain optimal configurations of the districts while preserving the reliability of the network in different operating conditions, guaranteeing the minimum level service for the users.

The authors developed the first software SWANP 3.0 specifically dedicated to the automatic partitioning of a water distribution network, implementing different clustering and dividing criteria and using numerous performance indices to choose the best configurations. The software provides to the decision-maker different solutions, comparing network layouts with some hydraulic and protection performance indices, integrating two different algorithms based on multilevel and multiagent techniques for water network partitioning, and a novel algorithm based on a multi-objective function, for water network protection from intentional contamination based on backflow attack model.

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