8th National Congress on Civil Engineering, 7-8 May 2014
Babol Noshirvani University of Technology, Babol, Iran

Analysis of Water Distribution Systems: A critical review

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Abstract

Analysis of Water Distribution Systems (WDSs) is considered to be an essential topic for further investigation in sustainable development. It plays an important role in analysis and design of water supply, drip irrigation, and oil transmission networks. In this regard, numerous numerical techniques have been devised to analyze and obtain the pressure and velocity fields corresponding to the associated networks. This critical review of literature is intended to provide current state-of-the-art on various issues including available options to cast the Governing Equations (GEs), methods of solution proposed, interaction between state variable involved and numerical schemes used and then the network component being modeled. The literature review begins with putting the various efforts in context in reference to terminologies used in applied mathematics, and then highlights the gap in the existing literature on ways for which the initial guess can be rationalized in numerical solutions of WDSs. Finally, some conclusions are drawn on the future of trends in such analysis to make the whole process more efficient.

Keywords: Water distribution system, Literature review, Methods of solution, Network components, Analysis.

1. INTRODUCTION

An essential problem in analysis and design of water distribution networks is to quantify pressure and velocity fields with inherent spatial variability in an accurate and efficient manner. This problem has always been present, and will remain a real challenge for further investigation. The hydraulic head at nodal points represents the pressure field and the discharge in each pipe will be a measure for representing velocity field. The literature is filled with numerous attempts to cast the GEs relating these two fields and various ways to solve the GEs numerically [1-6]. This diversity of approaches reflects the importance of WDS for hydraulic engineers with new models frequently emerging from new applications.

In reference to the variation of demand at WDS nodal points and/or pump and valve manipulations, three conditions may be conceptualized in WDSs as it relates to temporal variation of these two fields. Low variation of demand make velocity and pressure fields independent of time invariably called steady or equilibrium condition. In situations such as pump turning on or off, variation in demands, and reservoir water level fluctuations, the two fields cannot be considered to be independent of time. In such situations, either extended-period simulation and/or transient analysis has to be employed to analyze and subsequently design the water distribution network under consideration. In a majority of investigations conducted to analyze and design WDS, the steady state condition is considered.

The current review paper intends to focus on steady state analysis of WDS (i.e., no temporal variation). Furthermore, for the sake of brevity and explicitness, the review would like to concentrate on approaches taken to cast the GEs and mathematical techniques adapted to solve the GEs. In particular, the review will compare and contrast each method of casting the GEs and also numerical methods devised to solve the GEs. In addition, interaction between the flow regime and nature of GEs in terms of nonlinearity will be explored in order to rationalize the initial guess required for almost all numerical solutions available in the current literature.

2. GOVERNING EQUATIONS

In any pipe network analysis, regardless of the state variables involved, the basic principles to cast the GEs are considered to be (1) conservation of mass or continuity equation at each node, and (2) energy equation in each loop. Conservation of mass implies the algebraic sum of flows leaving and entering into a typical node is zero, while conservation of energy assumes the algebraic sum of head losses around a given real or pseudo