DEVELOPMENT OF A MODIFIED HARDY-CROSS ALGORITHM FOR TIME-DEPENDENT SIMULATIONS OF WATER DISTRIBUTION NETWORKS

Selami Demir*, Kaan Yetilmezsoy and Neslihan Manav

Faculty of Civil Engineering, Department of Environmental Engineering, Yildiz Technical University, 34349 Yildiz, Besiktas, Istanbul/Turkey

ABSTRACT

The Hardy-Cross method that has been widely used in steady-state analyses of water distribution networks was modified in this study. The modified methodology involves the steady-state solutions of the system at various instants. The methodology suggests bringing these steady-state solutions together to form a time-dependent simulation result. A spreadsheet solution was also developed for the modified Hardy-Cross algorithm. Microsoft Excel™ macros were used to implement the newly developed algorithm. The computer program is able to perform both steady-state and time-dependent analyses. It offers the use of Darcy-Weisbach or Hazen-Williams equations for the calculation of frictional losses. Both Jain and Colebrook-White equations can be used in the analyses. The computer program can also account for minor losses through the pressure pipes. The program was tested for an example water distribution system along with EPANET calculations. The modified Hardy-Cross method was proved to be an accurate tool for time-dependent simulation of water distribution networks. This study represents the development of this accurate, modified algorithm based on steady-state Hardy-Cross Method. This newly developed methodology can easily be used for both educational and professional purposes.

KEYWORDS: Hardy-Cross, water distribution system, steady-state, time-dependent simulation.

INTRODUCTION

The demand for water needed to serve agriculture, industry, sanitation, and domestic consumption increases continuously along with population and economic growth. However, with increasing development and urbanization, water flow rates and other hydraulic requirements associated with water distribution systems have been estimated to increase on both national and local scale. Lin et al. [1] have reported that expansion and construction of new water supply areas have made the water distribution network become even more complicated and resulted in numerous problems of water allocation, water supply safety, operation and management. Therefore, managing the water distribution systems in a sustainable and integrated manner is necessary to meet the growing demand of water for drinking, industrial and other necessities. In this regard, there is an urgent need to develop well-designed and optimized solution methods to achieve better control of water distribution systems. For this purpose, several investigators have conducted studies on the calculation of complex water distribution networks using different solution approaches. However, most have limited use when working with high-dimensional hydraulic data.

The present day water distribution networks are complex and require huge investments in their construction and maintenance. Therefore, in order to develop a continuous strategy for the management of water distribution systems, hydraulic parameters should be attentively controlled routinely for the duration of the testing, and network quality should also be verified under various operating conditions. However, engineers may not have enough time to monitor all hydraulic parameters under different operating conditions. Hence, a number of modification attempts to the standard solution methods for development of a powerful algorithm may help to assess both steady-state solutions and particularly time-dependent simulations of water distribution systems when the nodal demands change on a daily basis.

Water distribution systems may be laid down in two ways: in loopal networks and in branching structures. From a view point of operational concerns, branching distribution systems, also called dead-end systems, may lead mainly to operational problems in the aspect of system pressure, especially places near the dead-ends. In order to overcome this problem, pipes may be laid down in a loopal manner, which is the most commonly used construction method throughout the world. This way, it is easier to sustain much higher operational pressures all over the distribution system.