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Review Of Water Distribution System Modelling By Epanet 2.0 And The Decision Variables For Optimal Design

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Abstract: In a water distribution system portable water must be available with sufficient pressure head and flow velocity, while maintaining the standard quality and minimization of losses. The current study aims at the review of the use of EPANET 2.0 for the water distribution system modelling. The factors that can serve as the decision variables while aiming at an optimal design have been reviewed. A review of the studies pertaining to the performance evaluation and the leakage modeling of a designed network was done. It was found that EPANET 2.0 is a great tool in cases where modest degree of accuracy along with cost efficiency is required. To obtain an optimal design solution, the decision variables for the hydraulic design need to be constrained to standard values, the cost efficiency has to be validated and efficiency of performance has to be estimated.

Keywords: Water distribution system modelling; EPANET 2.0; WaterNetGen; JALTANTRA; optimal design

1. Introduction

The growing need of portable water has made it extremely important to have a well-designed and efficient system of water distribution to meet the requirements of the population to be served in terms of the adequate pressure head, flow availability, and quality of the water; while ensuring the minimization of losses at the same time. The most efficient, reliable and less time consuming technique available for which is the use of modelling softwares. In the current study the design of WDS (water distribution system) by EPANET by various researchers for different areas would be reviewed. To arrive an optimal solution of the design rather than just modelling a water distribution network, review of the studies pertaining to factors deciding and evaluating the optimality of the design has been included. The studies pertaining to adherence to standard values of various parameters like water pressure available, water age, residual chlorine would be reviewed. The current study also includes the review of performance evaluation of WDS by means of various indices and the leakage analysis and modelling of a WDS. Its also attempted to review the use of JALTANTRA web system for cost optimization of the WDS.

2. Review of Literature

A review has been carried out for various freeware and licensed software used for modelling of WDS. It has been laid down that the licensed softwares offer versatility, precision and flexibility compared to freeware ones. It was however concluded that the software selected to be used depends upon various factors including overall cost, complexity of the system, precision level required and data available. A review of the performance analysis of the WDS has also been carried out. The deterministic approach takes into account the available discharge and peak demand with the uncertainties as constants

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whereas the probabilistic approach quantifies the uncertainties by using probability distributions instead of fixed values in assessing the risk [1].

A study has been carried out to review various modelling softwares like EPANET, Watercad, Water gems, Branch, Watsys, Pipe 2014, etc. The study of use of these softwares in various WDS design projects has also been included. It has been concluded that these softwares differ from each other in various aspects like functionality, compatibility to different computational systems, graphical user interface, searching and optimizing algorithms, languages and programs used in their design. Furthermore , it has been studied that design of WDN requiring fair level of accuracy can be done by using free ware softwares but the projects requiring great precision and speed must be modelled by licensed softwares [2].

A review was carried out to lay down the importance of EPANET software in design of the WDS. It has been shown that the software has been successfully used to model the WDS for different study areas by various researchers and obtained fairly good results along with maintaining the cost efficiency of the design. Further it has been concluded that EPANET is easy to work with, cost efficient software compared to the other softwares [3].

The design of the WDS for an area named Kathgarh region in Himachal pradesh has been carried out using EPANET. Results for pressure at the nodes and flow in the pipes have been obtained in form of color coded diagrams, contour plots and time series plots. The maximum pressure head at two of the nodes is greater than 80m, posing a risk of burst of the pipes and the valves. Moreover, the flow velocity in nine of the links is less than the standard value of 0.25m/s, posing a risk of deposition in the links [4].

Analysis and design of WDN using EPANET for chirala municipality in prakasam district of Andrapradesh has been carried out. The review of the earlier used softwares like pipe ++ has also been carried out. Results have been obtained for node pressures and pipe flows in form of color coded diagrams. The minimum pressure head of 14m available at the nodes is sufficient to provide water at the second story level of the buildings. However, the velocity of flow in some links is lower than 0.25m/s, posing a risk of sediment deposition [5].

An outline of the necessity and use of EPANET for the efficient design of WDN for kadappa village in Andrapradesh has been presented. Results have been obtained in form of tables and color coded diagrams. It has been concluded that the residual pressure head at all the nodes is greater than 7m and the pipe diameter of 63.5 mm is sufficient for providing the requisite pressure. Furthermore the system can withstand a population increase of 5% [6].

The utilization of EPANET for design of WDS for a small area in vettom panchayat has been studied. T he results obtained by the software for the network have been validated by performing the manual analysis by Hardy cross method. The pressure head at all the nodes is sufficient enough to provide the water at the third story level of a building as per the Indian standards. Flow velocity in all the links of the network is less than the standard lower limit, such that the deposition of sediments might take place [7].

EPANET has been used for design of WDS for Nigerian defense academy.A review of the methods like Hardy Cross technique, the approaches utilizing Newton-Rapson method, direct electrical analogues; used for analysis of hydraulic problems has been carried out. The pressure head in majority of the nodes is deficient (less than 7m), such that the water might not be available even at the first story level of a building. The flow velocity is also very low, posing a risk of deposition [8].

Water distribution network for CUET campus (leading engineering university of Bangladesh) has been modelled using EPANET 2.0 software to check the reliability of the present water distribution network for present and future demands as per the future master plan of CUET. The adequacy of the WDN for the present demand has been verified and the modifications to meet the future demand have been proposed [9].

The validity of the current local guide line criterion for the minimum pressure head equal to 24 m has been investigated by scrutinizing the hydraulic models for 14 different towns in 5 municipal areas of the south Africa. A new guideline for minimum residual pressure head equal to 12m for low income group and 15 m for high income group, based on the results of this study have been laid down [10].

The relation between water pressure and water age has been studied in a WDS in Greece by using the EPANET 2.0 and the MATLAB soft wares. The optimum solution for reducing the operating pressure and water age simultaneously has been obtained [11].

The study analyzed the probable causes of chlorine decay in the WDS of Gabarone city, Botswane by considering the pipe wall conditions and the distribution system water quality. An experimental approach based on estimation of biofilm growth and chlorine decay reaction rate constants was used to assess the pipe wall chlorine decay [12].

This study delineates the introduction and application of technical performance indices (TPI) in order to work out the operational efficiency of a distribution network and point out the elements of poor performance. The deficiencies in various existing TPI have been studied and new indices to overcome the shortcomings of the earlier used ones have been proposed. The performance analysis tools obtained have been applied to a WDS generated with the help of Waternetgen, which is an extension of the EPANET 2.0. The performance evaluation includes the nodal pressure performance map, network slack map for minimum pressure, minimum pressure constraint violations map, demand required but not satisfied map [13].

A new application called as the Waternetgen has been designed as an extension to EPANET tool. It has been laid down that the Waternetgen can be used to automatically generate the WDN with hundreds of nodes and pipes within a few minutes. The software also allows to select the commercial diameters such that the final network satisfies the constrains of defined minimum diameter, maximum velocity and minimum pressure [14].

The incorporation of the local performance indices like discharge surplus index, in the Waternetgen has been carried out. The local performance indices have been tested on an existing WDN in city of santaram by using demand driven analysis and the more realistic pressure driven analysis. The results of the simulations obtained through use of both the approaches have been discussed and thus the real use of the local performance indices for the WDN has been investigated [15].

An explanation of the approach that has been incorporated in the Waternetgen to carry out the simulation of the WDN with pressure deficiencies has been laid down. The pressure driven analysis has been briefly described and the approach incorporated in the Waternetgen has been illustrated by the PDA of C-Town network model by Waternetgen. The leakage taking place in the pipes has been explained and the modelling for the same has been incorporated in the Waternetgen and illustrated by analysis of the C-Town network [16].

The use of pressure reducing valves (PRV) in reducing the leakage and improving the performance of an existing WDN has been presented. The location of PRV is determined after carrying out the analysis by EPANET and Waternetgen. Use of two PRV on the basis of the results obtained from the analysis, in terms of technical performance indices (TPI) for pressure and velocity, operation index (OI) for pipelines has been suggested. The leakage analysis and the performance analysis in terms of TPI has been carried out before and after the installation of PRV. The comparison of results has shown a significant improvement in the parameters after installation of the two PRV [17].

An experimental setup was used to validate that the orifice flow is the best way to model the leakage flow in case of leaks with high OS number (orifice head loss/ soil head loss), as it is in most of the cases. The results have been used to propose an appropriate orifice equation to model the leakage flow. Furthermore it was described that by application of computer modelling to a real world WDN the effectiveness of pressure reduction for leakage management can be modelled [18].

The deficiencies in various cost optimization techniques have been pointed out and a linear integer programming based optimization tool called Jaltantra has been developed, which not only aids in sizing the pipe diameters but also the components like pumps, tanks and valves, in order to delineate the cost optimal model of a WDS, quickly and precisely [19].

The study delineates the importance of the inclusion of the tank configuration as one of the decision variables along with pipe diameters for the cost optimization of a WDN with tanks serving as the demand nodes for primary network and the source for the secondary network. A linear integer program model has been described which integrates the tank configuration to pipe diameter selection problem [20].

3. Discussions

From the study done above it can be concluded that the choice of the use of type of software, whether free or licensed depends upon the precision required, cost consideration and speed of computation required. The licensed softwares offer higher degrees of most of the requisites. However, the use of freeware softwares like EPANET has been recommended where the project needs to have modest degree of accuracy accompanied by the cost effectiveness and ease of use. Pressure head at the nodes, the velocity of flow in the pipes, residual chlorine at the nodes and the water age are the key parameters having close interdependence and are vital for the optimal hydraulic performance of a WDS. The cost optimality of the network is another factor of due importance and is dependent on the components of the network like pipes, pumps, elevated storage reservoirs and valves. The performance evaluation indices are serving as a great tool to augment the assessment of the efficiency of performance of a WDS. Leakage losses in form of node and pipe losses (background and burst leakage) are known to reduce the efficiency of performance of a designed network and such losses can be modelled by using WaterNetGen, which is freely available as an extension to the EPANET.

4. Conclusions

- The design of a WDS must be aimed at obtaining an optimal solution by setting out the objective functions, decision variables and constrains rather than just evaluation of pressure heads and flow velocities.
- Water quality simulation and analysis including the residual chlorine concentration and water age at different nodes needs to be given due consideration while designing a portable WDS for an area.
- The leakage modelling of the designed network needs to be carried out to access the amount of leakage discharge in the proposed network so that suitable measures may be employed to minimize the losses.
- To augment the assessment of the efficiency of performance of the designed network, due consideration must be given to the performance analysis of the network by computing the TPI for pressure and velocity.
- The check for cost optimality of the proposed network must be carried out by using the cost optimization tools like JAL-TANTRA.

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