

Modeling Leakage in Water Distribution System Using EPANET

Ashwini Gajbhiye¹, P. Hari Prasad Reddy² and A. P. Sargaonkar³

¹M.Tech Scholar

¹Dept. of CE, NIT Warangal, Telangana

^{2,3}Dept. of CE, NIT Warangal, Telangana

E-mail: ¹ashwinigajbhiye400@gmail.com, ²ponnapuhari@gmail.com, ³ap_sargaonkar.neeri.res.in

Abstract—Water distribution system is a basic yet very crucial unit in every urban habitat. The primary task for water utilities is to deliver water of the required quality & quantity to individual customers under sufficient pressure. But this system of engineered hydrologic as well as hydraulic components is subject to faults in the form of loss of water, the most important losses being leakages. In this paper, hydraulic modeling of the water distribution system of study area is carried out. Also, leakages in the water supply system are identified and the effect of loss of water on the system pressure is studied. This is done with the help of EPANET software.

Keywords: Water distribution system, EPANET, Leakages, Emitter Coefficient

1. “Introduction”

Water is a very basic necessity of life. The demand of water is continuously increasing due to increase in population, industrialization, urbanization and improved standard of living. It is estimated that half of the India’s population will live in urban areas by 2050 [10]. The distribution of drinking water in distribution networks is a technical challenge both in quantitative and qualitative terms. This is because a huge quantity of treated potable water is lost in its transit within the distribution system as apparent and real losses. Apparent losses or background losses are losses obtained from utility operation, meter inaccuracies, data errors, unauthorized and illegal use. Real losses are the physical losses from the distribution network which include leakage, storage overflows and unaccounted usage of water [2]. The water supply in most Indian cities is only available for a few hours per day, pressure is irregular, and the water is of questionable quality. The reason for such a fluctuation is predominantly the leakages in the system. Hence, analysing the network by stringent continuous or periodic monitoring and performance evaluation of its hydraulic parameters is the need of the hour. Various public domain softwares like EPANET, Branch and Loop as well as commercial softwares like Aquis, WaterGEMS, WaterCAD, etc. are available for hydraulic modeling of water distribution system. The choice of water distribution network software is based on the availability of the data, time, financial

implications, resources, applicability and overall purview of the project

[9]. However, the use of EPANET software is very common for studies. The algorithm used in EPANET software to solve the flow continuity and head loss equations that characterize the hydraulic state of the pipe network is based on Newton-Raphson iteration method for solving the simultaneous equations which are derived from the flow and head loss in the network [1]. In a study, an attempt has been made to develop a water distribution system for a city in Punjab, India, using EPANET software for assessment of the hydraulic parameters [4]. Network analysis of water distribution system in rural areas was done & effective design and distribution of network of pipes using EPANET tool was highlighted in a study [6]. A study on hydraulic modeling of water supply network of Bagalkot city of Karnataka, India, analyzed the water distribution network and the deficiencies with respect to minimum pressure, velocities and flow the system were identified [8]. In yet another study, water demand analysis of municipal water supply for Chennai city was done using EPANET software to delineate the areas within the municipality that are unserved and underserved [2].

2. “Material and Methodology”

Reshimbag, the study area, is located in the heart of Nagpur city of Maharashtra, India. The water distribution network considered for study is spread over 2.74 Km² area, bounded by Latitude 21°7’22” N and 22°8’17” N and Longitudes 79°5’17” E and 79°6’32” E, and has pipeline length of about 65.5 Kms. The official residential population is 25750 people according to Census data of 2011. The water supply scheme was laid in 1980 and has been under operation since then. The total number of pipes in the network is 1262 and only water is supplied from a single Elevated Service Reservoir.

2.1 Continuous supply simulation

The hydraulic simulation of the water distribution system of the study area is done by using EPANET. EPANET, in general operates under “Demand-driven” assumption -

wherein, the nodal demands are assigned fixed values and the problem is to find pipe flows and nodal pressures that are hydraulically consistent with the nodal demands [7]. For this, hydraulic head loss within the pipes is calculated using the Hazen-Williams formula [1],

$$h_f = 10.69 * \left(\frac{Q}{C}\right)^{1.852} * L * D^{-4.87} \quad (1)$$

here, h_f = head loss (m), L = pipe length (m), D = pipe diameter (m), Q = flow rate in the pipe (m³/s), and C = Hazen-William or Roughness Coefficient. For model application, the water supply network map, node map and elevation map in the form of shape files were generated in ArcGIS10.3 and georeferenced using WGS84 UTM-Zone 43 projection [5]. The data from attribute table from the shape files was used to create the Input file (.inp) for setting up the hydraulic model in EPANET. The roughness coefficients were assigned according to pipe material and age.

2.1.1 Theissen's polygon method of calculating nodal demand

Using the shapefile of nodes of the study area, Theissen's polygons were generated around each node in the ArcMap 10.3 and a polygonal shape file was created. This polygon shape file along with the nodal shape file was overlaid together in Google Earth. Number of houses in each polygon was counted. Assuming an average of 5 persons for each household, number of households in the each polygon was multiplied with 5 to generate population to be assigned to each node. The obtained population was multiplied with the demand per capita. As per the CPHEEO manual, the per capita demand of 155 LPCD (135 LPCD + 15% of 135 LPCD for Unaccounted for Water) was considered. Water demand for each node was then calculated by multiplication the obtained population and per capita demand.



Figure 1: Theissen's polygons and nodes (Google Earth view)

The Input data presented above in section was used to setup EPANET model of the water distribution system of the study area and 24 hourly simulations were carried out. The results are presented in Section 4.

2.2 Continuous supply simulation with leakages

In EPANET, emitters are used to simulate leakage in a pipe connected to the junction. Emitters are devices associated with junctions that model the flow that is discharged to the atmosphere. The governing equation is given below:

$$q = c * h^N \quad (2)$$

here q is the leakage flow rate; c is the leakage coefficient; h is the pressure head and N the leakage exponent.

Results of water audit of the study area carried out by the authorities indicated that 40% of total water supplied is lost in the network which can be attributed to leakages in the system. However, the exact location of points of leakage was not known. To identify the leaking nodes, following two approaches were used.

2.2.1 Rule based leakage identification

In this approach of data analysis, a set of four rules was created in terms of age, diameter, length and service connection for every single pipe and pipes were classified accordingly.

Rule 1: Old pipes are more prone to leakage than newer pipes. All the pipes of age 36 years were classified as leakage prone pipes.

Rule 2: Smaller diameter pipes are more prone to leakage because they are prone to failure if high pressures are encountered. All the pipes of age 36 years whose diameters were less than 100 mm were classified as leakage prone pipes.

Rule 3: Longer length pipes are more prone to leakage than smaller pipes. The pipes which are longer than 50 meters in length were considered to be more prone to leakage.

Rule 4: More the number of service connections, more the leakage possibility. The pipes which had more than 2 service connections were classified as more leakage prone.

In this way, 66 pipes were classified that satisfied all the four rules & the respective nodes of the classified pipes were identified.

2.2.2 Water quality based leakage identification

In this approach, water quality monitoring data was used and the locations in the study area where residual chlorine was found to be less than 0.1 mg/l were identified. These points with extremely low residual chlorine were indicative of contamination of water. Contamination of water is indicative of leakage.

The shape file was created from the points obtained by using the methods described in Section 4.2.1 and 4.2.2. A Layout map was created using ArcMap 10.3 as shown in Figure 2.

From the Figure 2, 10 nodes were identified which were at a high risk of failure and hence were used to denote leakage in the system in the EPANET model.

Emitter coefficients were applied at 10 nodes and 24 hourly simulation were carried out. The value of emitter coefficient was modified for successful 24 hourly simulation depending on the results of net inflow. The results are presented in the next section.

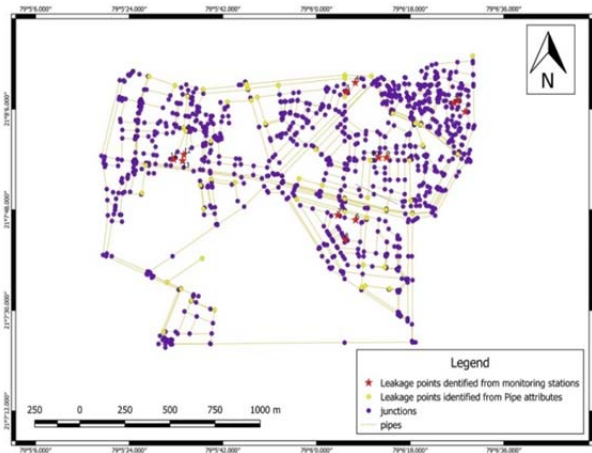


Figure 2: Layout Map of identified leakage points

3. “Results and Discussion”

In this section, the results obtained from the methodology discussed in Section 2 are presented and discussed.

3.1 Results of continuous supply simulation.

The simulation carried out by using the Input file was successfully run. The result for pressure and flow in the system is presented in Figure 3.

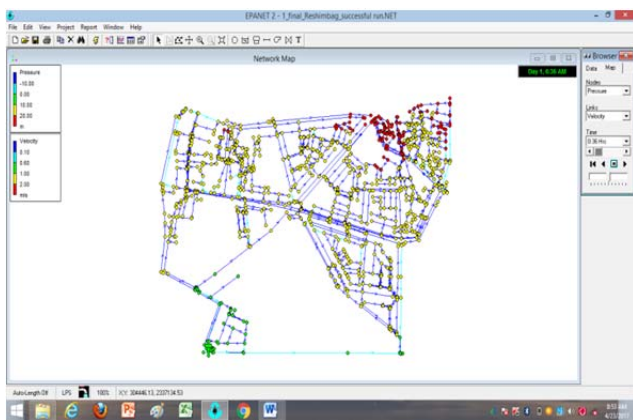


Figure 3: Simulation results of pressure and velocity at 0.36 Hrs.

The obtained result of pressure at nodes in the model was compared with the actual pressure measurements of the study area. The results were found concurrent. The net inflow of the tank was 44.43 LPS as per the water demand. The system was found to be operating under sufficient pressure.

3.2. Results of continuous supply simulation with leakage.

The results of 24 hourly simulation of leakages is shown in Figure 4. It shows the result of 10 % leakages in the system with emitter coefficient (c) value of 0.1 applied at 10 nodes.

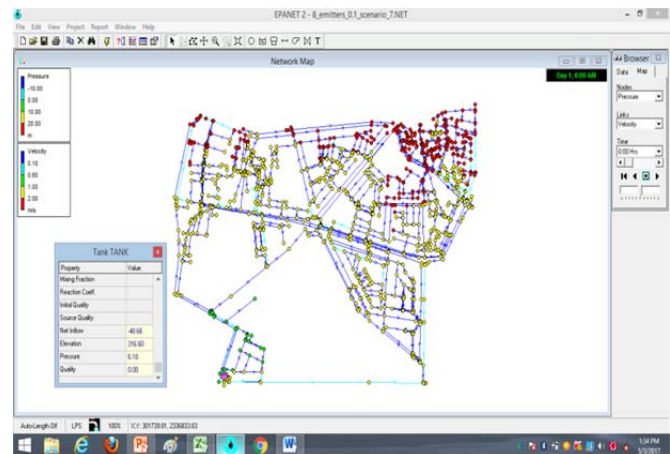


Figure 4: Simulation results of pressure and velocity considering leakage

It can be seen that the Net Inflow in the system has increased to 48.66 LPS when leakage is introduced. Also there is variation in pressure at nodes as the pressure at that point was little less than that of pressure obtained on the same point during the simulation with no leakage.

4. “CONCLUSION”

The hydraulic modeling of water distribution system of the study area was successfully simulated using EPANET. The validation of the model was done real time using pressure data of the study area. The system was found to be operating under sufficient pressure. Leakage identification in the water distribution system of the study area resulted in shortlisting of 10 points of high probability of failure in the system. It was observed that EPANET cannot model the leakages in water network independently. EPANET simulations are demand-driven, and the program does not include a specific functionality to model water leakage, which is pressure-driven. The model was not able to simulate 40% leakage in the system, which is the real life situation. However, a scenario having 10% leakages in the system was successfully run in EPANET. If the percentage of leakage was more than 10%, then the system encountered negative pressure and could not simulate for 24 hours. If the percentage of leakage was less than 10%, there was no deviation in the system pressure. Hence, it can be concluded that allowable leakage in the system is 10% using the EPANET model.

“REFERENCES”

- [1] Adeniran, A. E., & Oyelowo, M. A. (2013). An EPANET analysis of water distribution network of the University of Lagos, Nigeria. *Journal of Engineering Research*, 18(2), 69-83.
- [2] Arunkumar, M., & Mariappan, V. N. (2011). Water demand analysis of municipal water supply using EPANET software. *International Journal on Applied Bioengineering*, 5(1), 9-19.
- [3] Bireka, L., Petrovica, D., & Boylanb, J. (2011). A fuzzy logic based approach to leakage forecasting in water industry. *The 31st Annual International Symposium on Forecasting*, (pp. 1-12).
- [4] Gupta, I., Khitoliya, D. R., & Kumar, D. S. (2013). ‘Study of water distribution network using EPANET.’ *International Journal of Computational Engineering Research*, Vol. 3(6), (pp.: 58-62).
- [5] Mohapatra, S., Sargaonkar, A., & Labhasetwar, P. K. (2014). ‘Distribution network assessment using EPANET for intermittent and continuous water supply.’ *Water resources management*, Vol. 28(11), (pp.: 3745-3759).
- [6] Ramana, G. V., Sudheer, C. V., & Rajasekhar, B. (2015). ‘Network Analysis of Water Distribution System in Rural Areas using EPANET’. *Procedia Engineering*, Vol. 119, (pp.: 496-505).
- [7] Rossman, L. A. (2000). EPANET 2: User’s Manual.
- [8] Shivalingaswami, S. H., Vijaykumar, H. & N. S. Patil (2016). ‘Hydraulic modeling of water supply network using EPANET.’ *International Research Journal of Engineering and Technology*, Vol. 3(3), (pp.: 1022-1027).
- [9] Sonaje, N. P., & Joshi, M. G. (2015). ‘A review of modeling and application of water distribution networks (WDN) soft wares.’ *International Journal of Technical Research and Applications*, Vol. 3(5), (pp.: 174-178).
- [10] Yadav, S. M., Singh, N. P., Shah, K. A., & Gamit, J. H. (2014). ‘Performance evaluation of water supply services in developing country: A case study of Ahmadabad city.’ *KSCE Journal of Civil Engineering*, Vol. 18(7), (pp.:1984-1990).