Optimization of Water Distribution Network for Dharampeth Area
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Abstract— Distribution of water supply of a city is very essential for occupants residing in it. In the water supply network the systematic planning and approach is required for designing. It comprises of 60-70% of the total investment in the system which includes choosing appropriate diameter of pipes. The design of water distribution network comprises of various intricate programs, search methods, conventional techniques and algorithms. The analysis of water distribution is also carried out in the field by traditional methods which involve complexity in solving the equations. The design of any water distribution network requires minimum cost of project, maintaining the pressure head and velocity of flow as a constraints. Therefore, there is a need to develop a simple optimization technique so that an average user can easily understand and implement it. In this study, water distribution network has been designed for Dharampeth area of Nagpur comprises traditional design method of Loop software which is used in designing water distribution network. The non-linear programming (NLP) model was further formulated in this study to carry out the comparative analysis of the results obtained using Loop software and proposed NLP model. Findings of this study indicate that the NLP model showed 5-6% reduction in cost as compared to traditional Loop software. Thus, the proposed model provides economical solution and can be effectively implemented for the design of water distribution network in urban areas.

Key words: Optimization, Nonlinear programming method, water distribution network design

I. INTRODUCTION

In India the demand of each occupant is increasing day by day as his/her requirements. The water demand is at its high rate in term of its consumption which involves number of public and private sectors. The important unit consuming water is the industrial setup which is growing at its faster rate. The demand of water is at high peak due to increasing population. The design of water supply layout should be i to provide proper way so that it fulfills the desires of each individual existing in it. In most of the cases the design of water supply network consumes amount of energy to pump, transport and supply water to the distribution network fulfilling demand of each consumer nodes. If concentration of rainfall is less for long duration for certain period, problem will be faced in supplying water to the occupant as per demand. On one hand it is essential to provide quality of water to users. On the other hand, it is necessary to provide quantity of water so that the consumer may fulfill his demand .If you have a water shortage, it will affect occupant’s life and the industrial development of a city. The economical condition of city depends on the source of water which decides the future demand of harmony between states and between countries and at the most among the each individual living in the environment. Design and analysis of pipe networks are important factor as it deals with conventional and traditional methods

II. PROPOSED METHODOLOGY

In the present study the Dharampeth area of Nagpur has been considered for the design of urban water distribution network (WDN). The design of water network is carried out by Loop software. The survey of the area has been physically carried out on site to determine the elevation, length of pipe. The population of study area is carried out by various method forecasting population. The required demand of water is calculated for the projected population of 2045. The Programming of loop software provides a cost of project in the design. The traditional method of Non Linear programming has been used in optimizing the cost of the project. The model consist of excel sheet which is solved by NLP method. It has been prepared by including various parameter such as headloss which is calculated manually by using formula. The model provides the total cost of the project which is compared with the cost obtained by Loop software.

III. STUDY AREA

The study area is the region of Dharampeth which fall under the westward area of Nagpur. The Dharampeth region is urban area whose requirement is high which can be achieved by proper networking. The existing network of Dharampeth is running for 24 * 7 fulfilling all the requirements of hydraulic constraints. The area considered under the design covers 0.64 sq.km. It is an urban area. The location of area is from the Ramnagar Tekdi to the Shankar nagar chowk. The source of water for the distribution network is from ground reservoir. The study area is located at the favourable
elevation. The source node of reservoir is at high elevation which fulfills the demand of consumer at each node.

IV. DESIGN OF WATER DISTRIBUTION NETWORK

The design of water distribution network in this research is carried out by Loop software. Loop software is the program which involves various parameter for designing of water network. The loop software can solve up to 1000 pipes. The parameters such as elevation; length of pipeline has been input to the software which designs the network giving output in terms of diameter of pipeline. The software satisfy the constraints such as pressure head which is considered greater than 7m except the source node which is at high elevated area. The second constraints is velocity of flow which is assumed less than 3m/sec. The software includes the Newton Raphson Method which solves the iterative procedure upto 5 iterations. The number of 12 loops are formed in designing of network.

A. Water Demands for Dharampeth Area

The demand for water is based on the population of the area. The present population of Dharampeth area is found to be 30,000 for 2015 year. The population of the area is collected from the NMC and Dharampeth zone office. The populations of last 5 decades have been collected from the NMC department and it is used to find the population of further three decades. The population is calculated by using forecasting method. The Geometric method is found to be more efficient in estimating the population of 2045. As this method has provided the maximum population as compared to other methods.

FORECASTED POPULATION FOR 2045

<table>
<thead>
<tr>
<th>Area</th>
<th>Arithmetic method</th>
<th>Geometric method</th>
<th>Incremental increase method</th>
<th>Decrease method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dharampeth Region</td>
<td>41211</td>
<td>50184</td>
<td>44680</td>
<td>50218</td>
</tr>
</tbody>
</table>

From the table it is observed that the forecasted population obtained by Geometric increase method is giving maximum population.

PROJECTED WATER SUPPLY DEMAND IN MLD

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Existing demand MLD</th>
<th>Projected water supply demand in MLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dharampeth region</td>
<td>3.37</td>
<td>5.55</td>
</tr>
</tbody>
</table>

Table 1: Population and water Demand

Now the demand of water can be achieved as population is known, as per Indian standard 150 lpcd (litre per capita day) is considered. The existing demand of water is calculated by using multiplying factor and 25% has a major and minor losses. The demand of water for 2015 is found to be 3.37MLD. Similarly the demand for the further three decades have been calculated.

B. Designing Pipeline Network

For the design of water distribution network the following input parameters:

Input parameters:
- Discharge: lps
- Length: meter (m)
- Elevation: meter (m)

Fig. 2: Study Area

Fig. 3: Designed diameter obtained by Loop software

The input parameter on updating in software provides the diameter of pipeline. The velocity of flow is also calculated.

The network of water includes 36 pipes and 25 nodes. The length of each pipe has been input into the software. Similarly the elevation of the ground has been input into the program. The software also provides the hydraulic gradient in terms of meter.
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Fig. 4: Cost of commercial Diameter

The flow in each pipe has been calculated and is used as input parameter for obtaining the design of network. The software also shows the details of pipeline with the pressure head greater than 7m. The nodal details are also obtained in the output. It also includes the cost analysis of network.

The cost analysis is calculated as per DSR rate. The price of 12 commercial available diameters is provided with per length.

The roughness constant is 140 for CI pipe material.

The cost of design project is calculated with the cost of DSR C.

V. FORMATION OF MATHEMATICAL MODEL

The formation of mathematical model basically aims at the optimizing the diameter of pipeline so as to minimize the cost of project. The model formation is done by assuming certain parameter as pressure head greater than 7m and velocity of flow should be less than 0.3 meter. The mathematical method includes NLP method to optimize the diameter of the study area.

The objective of the model is to reduce the total cost of the given network:

\[ C_T = \sum_{i=1}^{N} C_i D_i L_i \]

Where,

- \( C_T \) is the total cost of the pipeline network,
- \( N \) is the total number of pipes in the network,
- \( C_i \) is the cost of pipe
- \( D_i \) is the cost per unit length

For the model formulation the following parameters are calculated:

- Headloss: m/km
- Discharge: litre per second (lps)
- Pressure Head: meter (m)

VI. SOLVER

MS Excel solver has been used for optimization of the water distribution network. The solver involves the participation of some parameters which act as constraints in solver. The list of available commercial pipe diameters with their cost per unit length was provided and was used as decision Variables in the Optimization Process. The important in solving the parameter is the pressure head which should be at least 7m except at the source node of reservoir.

Fig. 6: Microsoft solver Excel

VII. HEADLOSS

It is pressure drop as a fluid flows through a pipe. It is calculated by using Hazen William’s equation

Where,

\[ L=\text{Length of pipe (m)} \]
\[ Q=\text{Flow in pipe (cubic m/s)} \]
\[ C=\text{Hazen William Coefficient i.e. (140)} \]
\[ D=\text{Diameter of pipe (m)} \]

VIII. MATHEMATICAL MODEL
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**Table 2: Optimised Diameter**

The result shows that the NLP method helps in minimizing the diameter of pipe material which leads in optimization of water distribution network.

**A. Cost Comparison**

<table>
<thead>
<tr>
<th>LOOP SOFTWARE</th>
<th>NLP</th>
<th>TOTAL SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS. 85.92 Lacs</td>
<td>RS.84.56 Lacs</td>
<td>RS.4,85,295 Lacs</td>
</tr>
</tbody>
</table>

SAVING - 5.75 %

**B. Diameter Comparison**

![Fig. 9: Pipe Diameter and comparisons](image-url)
X. CONCLUSION

1) The optimization of water distribution network is an intricate task.
2) In this study, a water distribution network was designed using conventional Loop software.
3) A traditional method of non-linear programming model was used to optimize the cost of water supply network.
4) Saving of around 5.75% can be obtained in design cost of the water distribution network calculated using conventional method ensuring the pressure head and velocity constraints.

Therefore, NLP model shows the potential application and can be effectively implemented for economic design of water supply system without involving any complexity.

REFERENCES