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DESIGN OF ONE JUNCTION THREE RESERVOIR SYSTEM

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ABSTRACT: Applying mathematical models to obtain optimal solution for water transmission system has been of major concern during the last few decades. Optimization problem for water transmission system is considered as a non-linear problem during the search process to identify the decision variables (i.e. pipe diameter and cost of pipe). Flow path algorithm has been adopted to obtain the optimal design of basic unit of water transmission system. The effect of diameter of pipe on optimal design of pipe of water transmission system has been considered in this work.

KEYWORDS: Flow path algorithm, Diameter and cost of pipe, Optimization, water transmission pipelines.

I. INTRODUCTION

Water from various sources of water such as river is taken to the water treatment plant to purify and treat the raw water so as to make the suitable for drinking purpose. The treated water from water treatment plant is transported first to clear water sump; the water is transported to master balancing reservoir (MBR). Then, the water is transported from MBR to elevated service reservoir (ESR). The pipeline from clear water sump to MBR is known as trunk transmission line, and the line of water from MBR is known as trunk transmission line, and the line of water from MBR to elevated service reservoir (ESR) is known as zonal transmission line. Optimal diameters for gravity main, pumping mains and optimal cost transmission network, are determined by using the method of the Lagrange's multipliers.

A. AIM OF PROJECT: To obtain optimal design of water transmission pipelines

B. OBJECTIVES:

- The flow path algorithm process used in water transmission system
- To obtain design data for water transmission system
- To obtain the cost data for the water transmission system
- Complex system of water transmission system is converted into simple system by using flow path algorithm

C. Hazen-Williams Equation

The Hazen-Williams equation originally introduced in 1902 is empirical and dimensionally non homogeneous equation. It is the most widely used equation for the design of pressure mains. The Hazen-Williams equation is applicable for smooth turbulent flow. The Hazen-Williams equation relating velocity of flow, hydraulic mean radius and hydraulic gradient is given by:

$$V=0.849 \times C_H \times R^{0.63} \times S^{0.54} \quad (1)$$

Where, C_H =Hazen-Williams constant;
 R =Hydraulic mean depth, m;
 S =Slope of pipe,

The continuity equation is given by:

$$Q=AV \quad (2)$$

Where, Q = Flow of water, m³/s;
 A =Cross sectional area of flow, m²

Combining equations(1)&(2),Equation(1)can be written in terms of D as:

$$D = \left(\frac{Q}{0.849 \times CH \times S^{0.54}} \right) \quad (3)$$

II. LITERATURE REVIEW

- 1. B.A.Konnur,R.K.Rai, "Optimal design of water transmission network", International Journal of Engineering Research Volume No.5,Issue special1pp:250-256,8&9Jan2016.**
Water transmission network is backbone of all water supply system. A large amount of money is spent every year around the world for water supply projects. Even a fractional percentage of saving ,due to improvement in design,results in considerable saving in the overall cost of projects. The cost of such system has to be reduced to a minimum consistent with functional & safety requirement.
- 2. Prof.Prathmesh Rajendra Patil1,Prof.Pooja Gopal Gandhi2,"Optimal design of water transmission system",International Research Journal of Engineering & Technology(IRJET)Volume:07Issue:05|May22.**
The optimization is cost efficient method of design for water transmission pipelines. The design parameter which was optimized for system of water transmission pipeline shows a remarkable markdown in overall cost by finding diameter of pipe. The design of water transmission system with variable diameter of pipe will help to choose the network with optimal cost.
- 3. R.K.Rai, R.S.Tetu,"Optimal design of water transmission system with pumping",International Journal of Engineering Research VolumeNo.5.Issue special1pp:172-174,8&9Jan2016.**
The process of optimal design of three reservoir water transmission system is illustrated using an illustrated design.Design data for design containing elevation of reservoir length of pipe, flow in each pipe, cost of pipe. The determination of an optimal distribution of commercial diameter for each pipe in the network & the length of pipe which corresponds to these diameter.
- 4. N.S. Shirbhate1;R.K.Rai2,"Design of water transmission system with pumping",february26,2020.**
Flow path algorithm & Hazen William equation was developed for optimal design of three reservoir system. For optimal conditions we must choose such diameter, which together with the pumping cost will make the total annual expenses , the minimum .The optimal diameter which provides such optimal condition is known as economical diameter of pipe.
- 5. SARBU Loanl ,OSTAFE Gabriel2,"Optimal design of water supply networks",27August,2020.**
The non linear optimization model developed in this study is capable to obtain optimum design of various types of water distribution network so that all constraints such as pipe diameters, flow velocities & nodal pressure are satisfied.
- 6. Necati Gulbahar ,” Planning & design principle of Transmission line in water projects “,International Journal of Engineering Technology. Volume.2 No.1,2016.**
Identifying of the optimum diameter in a transmission line is very important .If it is taken the greater diameter the cost of line increases in that case head loss is reduced. If small diameter is selected the cost of line decreases, but thistime head loses increases that increases energy cost of motor & pump power.

III. METHODOLOGY

Optimal design of a water transmission pipeline requires cost of its components. In order to construct an objective function based on the total cost of water transmission system, the cost structure for the components of the water transmission system has to be investigated. The major components of a water transmission system are pipes and accessories. The pipes and accessories are the major components which share a substantial portion of the overall cost of water transmission system.

The cost of pipe can be obtained from current schedule rates (CSR). The cost function can be obtained in power form by

curve fitting using excel. The cost function can be used to obtain cost of pipes for a given diameter of pipe.

An algorithm for the optimal design of a water transmission system has been developed in such a way that it determines optimal diameter, optimal cost and total cost of water transmission pipelines

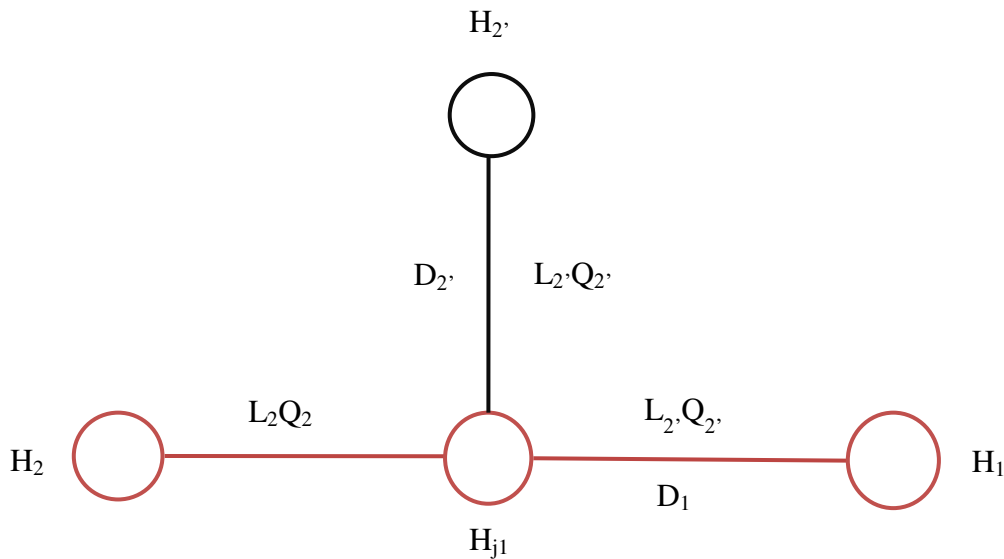


Fig. : One Junction Three Reservoir System

For the purpose of optimal design of water transmission system, the pipes, reservoirs and reservoir elevations etc. Have been assigned numbers using the following rules:

1. The pipes on the main line are assigned number 1,2,3 etc. starting from end of system;
2. The last or lowest reservoir is assigned number 1 and highest reservoir is assigned to last number;
3. The junctions on mainline are assigned number j1, etc.;
4. The intermediate reservoirs are assigned number 2' etc.;
5. The last or lowest reservoir elevation is denoted by H1;
6. Similarly, length for pipes are denoted by L1, L2, L2' etc. discharge by Q1, Q2, Q2', etc. and diameter by D1, D2,D2', etc. respectively.

➤ **Cost of pipe:**-Various types of pipes are used for the conveyance of water to the reservoirs. Generally, CI pipes are used for water transmission system because these pipes are resistant to corrosion and are durable [18Pun]. Its useful life is more than hundred years. These are of moderate cost. Also joining is easier and the service connection can be easily made in CI pipes.

The cost of pipe is given by:

$$C = K_m L_i D^m \quad (4)$$

Where,

K_m and m = Cost parameters of pipe; L = Length of the pipe, m;
 D = Diameter of the pipe, m

Three reservoir systems (TRS) is the basic unit of multi reservoir multi junction water transmission system. It consists of three pipes, three reservoirs and one junction is shown in Fig

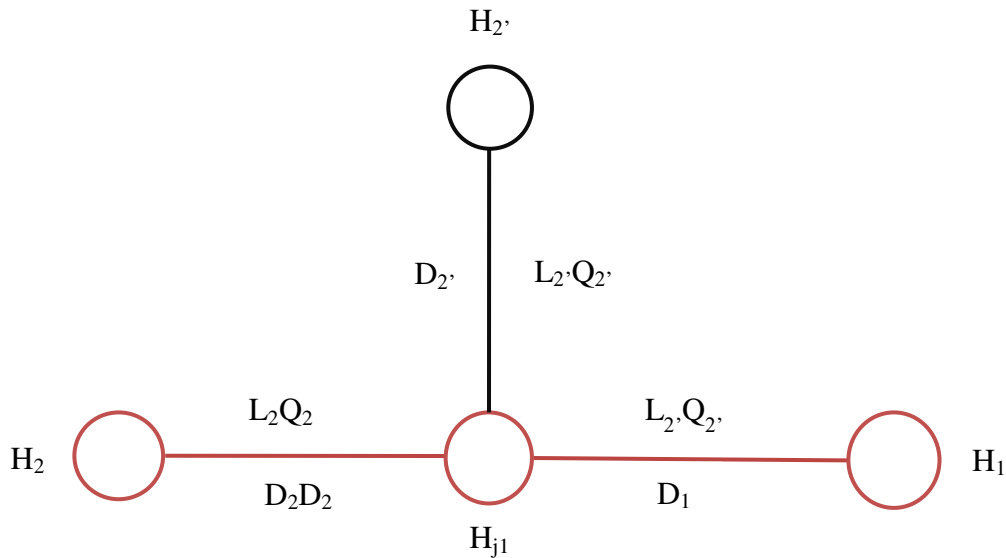


Figure : One Junction Three Reservoir System

Three reservoir system consist of two flow paths. The flow path 2-1 is shown in Fig.

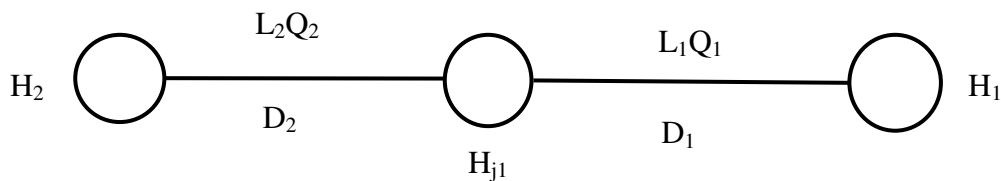


Figure : Flow Path 2-1

For flow path 2-1, the total cost of the pipe line is given by

$$C = K_m L_2 D_2^m + K_m L_1 D_1^m \quad (5)$$

The total head loss is $H_2 - H_1$, using the Equation, the head loss constraint is given by:

$$\frac{10.674 L_2 Q_2^{1.852}}{C_H^{1.852} D_2^{4.870}} + \frac{10.674 L_1 Q_1^{1.852}}{C_H^{1.852} D_1^{4.870}} = H_2 - H_1 \quad (6)$$

The Lagrange function obtained by combining Equations (3.2) and (3.3) along with Lagrange multiplier λ is given by:

$$F = K_m L_2 D_2^m + K_m L_1 D_1^m + \lambda \left(\frac{10.674 L_2 Q_2^{1.852}}{C_H^{1.852} D_2^{4.870}} + \frac{10.674 L_1 Q_1^{1.852}}{C_H^{1.852} D_1^{4.870}} - H_2 + H_1 \right) \quad (7)$$

Differentiating Equation (3.4) with respect to D_2 , and equating the results to zero, one can obtain:

$$D_2^{m+4.87} = \frac{51.982 Q_2^{1.852}}{C_H^{1.852} m K_m} \times \lambda \quad (8)$$

Similarly, one can obtain the equation for D_1 :

$$D_1^{m+4.87} = \frac{51.982 Q_1^{1.852}}{C_H^{1.852} m K_m} \times \lambda \quad (9)$$

Using Equations (3.5) and (3.6), Equation for D_1 in terms of D_2 can be written as:

$$D_1 = \left(\frac{Q_1}{Q_2} \right)^{\frac{1.852}{m+4.87}} D_2 \quad (10)$$

Substituting the value of D_1 from Equation (3.8) in Equation (3.3), one can write:

$$\frac{10.674L_2Q_2^{1.852}}{C_H^{1.852}D_2^{4.870}} + \frac{10.674L_1Q_1^{1.852}}{C_H^{1.852} \left[\left(\left(\frac{Q_1}{Q_2} \right)^{1.852} \right)^{\frac{1}{m+4.870}} D_2 \right]^{4.870}} = H_2 - H_1 \quad (11)$$

After simplification, Equation (3.12) for D_2 can be rewritten as:

$$D_2 = \left[\frac{\frac{10.674}{C_H^{1.852}} \left(L_2Q_2^{1.852} + L_1Q_1^{1.852} \times \left\{ \left(\frac{Q_2}{Q_1} \right)^{1.852} \right\}^{\frac{4.870}{m+4.870}} \right)}{H_2 - H_1} \right]^{\frac{1}{4.870}} \quad (12)$$

The flow path 2-2' is shown in Figure

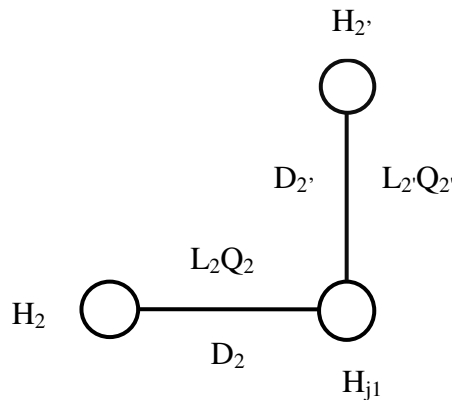


Figure : Flow Path 2-2'

$$D_2 = \left[\frac{\frac{10.674}{C_H^{1.852}} \left(L_2Q_2^{1.852} + L_{2'}Q_{2'}^{1.852} \times \left\{ \left(\frac{Q_2}{Q_{2'}} \right)^{1.852} \right\}^{\frac{4.870}{m+4.870}} \right)}{H_2 - H_{2'}} \right]^{\frac{1}{4.870}} \quad (13)$$

After calculating diameter D_2 for both flow paths, select the maximum value of D_2 and round off to the next higher value.

head loss for pipe 2 is given by:

$$h_{f_2} = \frac{10.674L_2Q_2^{1.852}}{C_H^{1.852}D_2^{4.870}} \quad (14)$$

Calculate the junction head H_{j_1} using reservoir head H_2 and head loss h_{f_2} .

$$H_{j_1} = H_2 - h_{f_2} \quad (15)$$

The head loss for other pipes can be easily calculated as follows:

$$h_{f_1} = H_{j_1} - H_1 \quad (16)$$

$$h_{f_{2'}} = H_{j_1} - H_{2'} \quad (17)$$

diameter for pipe 1 can be calculated as:

$$D_1 = \left(\frac{10.684L_1Q_1^{1.852}}{C_H^{1.852}h_{f_1}} \right)^{\frac{1}{4.87}} \quad (18)$$

Similarly, diameter for pipe 2' can be calculated as:

$$D_{2'} = \left(\frac{10.684L_{2'}Q_{2'}^{1.852}}{C_H^{1.852}h_{f_{2'}}} \right)^{\frac{1}{4.87}} \quad (19)$$

The diameters are rounded off to the next higher values at an increment of 50 mm. Thus, the optimal design of three reservoir systems can be easily obtained in only one stage.

Design procedure for three reservoir system

Three reservoir systems consist of one junction hence; the optimal solution can be obtained in single stage only. The step by step design procedure is as follows:

Step I: Determination of diameter of pipes

Three reservoir system consist of two flow paths *i.e.* flow path 2-1 and flow path 2-2'. The diameter D_2 which is common to both flow paths is calculated using Eqs. (12) and (13).

Step II: Selection of diameter

After calculating diameter, the step next is the selection of diameter. The maximum value of diameter D_2 obtain from both flow paths is selected and rounded off to next higher available size. Hence the maximum diameter is selected for the optimal design.

Step III: Computation of the head loss and junction head.

The head loss is computed by using Eqs. (14), (16) and (17) and junction head is computed using Eq. (15). From head loss and junction head, one can easily obtain diameter of other pipes and is given by Eq. (18) and (19).

Step IV: Determination of the optimal cost total cost of water transmission system

The total cost of water transmission line is given by Eq. (1)

IV.DESIRED OUTCOMES

The following are the desired outcomes on the basis of proposed methodology

1. The cost function in power form can be used to obtain the cost of pipe.
2. The approach for the calculation of diameter for various flow paths and the selection of optimal diameter is very easy; and the procedure for the optimal design of water transmission system is also very simple.
3. The method gives design in a very less time.
4. The method converts the complex system into simple system by breaking down the water transmission networks inflow path.

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