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ANALYSIS OF WATER DISTRIBUTIONNETWORK USING EPANET

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Abstract : Water is a basic need of all living beings in the world. The demand for water is increasing day by day. A plumbing system is a system of engineering hydraulics and components that provide water supply. For the development of a nation, water supply networks are very important for the development of a territory because apart from supplying water for human consumption, they serve many purposes. The water network plays a virtual role in maintaining and providing a desirable quality of life to the public, a major component of which is reliability of supply. It is difficult to provide rural residents with safe water in sufficient quantity, quality and at a satisfactory pressure head while reaching an economic constraint. EPANET software is used to design and analyze a multi-village supply system considering technical sustainability. EPANET is a computer program that performs long-term simulation of hydraulic behavior in a pressurized pipeline network. Analyzing a complex hydraulic network is a time-consuming and equally tedious task. The analysis of an illustrative nine-loop hydraulic network is therefore performed by the Hardy Cross method using the Hazen-William equation. The analytical solution for the nine-loop hydraulic network is obtained using electronic spreadsheets in MS-Excel and subsequently by modeling the same hydraulic network in the EPANET computer software.

***IndexTerms* - Analysis, EPANET, Hardy Cross method, Hazen-William equation, MS-Excel.**

I. Introduction

A water distribution system is a hydraulic infrastructure consisting of elements such as pipes, reservoirs, reservoirs, pumps and valves, etc. It is crucial to provide potable or potable water to end users; efficient water supply is therefore of paramount importance when designing a new water supply network or expanding an existing one. The calculation of flows and pressures in a complex network has been a major challenge and interest for those involved in the design, construction and maintenance of public water distribution systems. The analysis and design of pipe networks is a rather complex problem, especially when the network consists of a series of pipes, as is often the case in the water distribution systems of large metropolitan areas. In the absence of significant fluid acceleration, the behavior of the network can be determined by a sequence of steady-state conditions, which form a small but vital component in assessing the adequacy of the network. Such an analysis is needed whenever a significant change in consumption or delivery pattern or an added function such as water delivery, addition of auxiliary pumps, pressure control valves or storage tanks will change the system. Many methods have been used in the past to calculate flows in a pipe network, from graphical methods to the use of physical analogies to the use of mathematical models.

Network analysis methods have been developed and implemented on the computer during the last fifty years. Of all the methods available, the first and probably the most widely used method of analysis is the Hardy Cross Technique. This method makes corrections to the initial guess value by expanding the first-order energy equation in terms of a selection factor for the flow in each loop. In certain cases, the Hardy Cross method was found to converge very slowly or not at all. This leads to the design of specific measures to improve convergence and a constrained model for the design of minimum cost water distribution networks. This methodology attempted to account for uncertainties in required requirements, required pressure heads, and pipe roughness coefficients. An optimization problem was formulated as a nonlinear programming model, which is solved using the generalized reduced gradient method. It shows that uncertainties in future requirements, head requirements and pipe roughness can have a significant impact on optimal design and cost. Further, the reliability of the water distribution system can be calculated by treating the demand, pressure head, and pipe roughness as random variables. Water consumption and pipe roughness coefficient can also be assumed to follow a probability distribution, and then a random number generator was used to generate random variable values for each node and pipe. It leads to a hydraulic simulation and calculates the pressure heads at the demand nodes if the requirements are met. Finally, hydraulic reliabilities of nodes and systems can be calculated using EPANET.

II. OBJECTIVES

1. Analyze existing water distribution using EPANET and design some measures if the current network does not meet current and future demand;
2. Study the water distribution network of loops;
3. Collect pipeline report and network connection report;
4. Analyze data using EPANET software; and
5. For checking the discharge and pressure head in the loop network.

III. HAZEN-WILLIAMS FORMULA

The Hazen-Williams equation is the most used empirical equation, which can be expressed as:

$$V = 0.85C_H R^{0.63} S^{0.54} \quad (3.1)$$

Where, CH= Pipeline Hazen-Williams Coefficient S = Slope of hydraulic head (m/m) which is equal to the ratio of pressure loss to pipe length. The CH value for cast iron pipe for design purposes is 100 (Manual, 1999).

Substitution, $V = 4Q/(\pi D^2)$, $C_H = 100$, $R = D/4$, and $S = hf/L$ in Eq. (3.1) and after some algebraic manipulations the equations can be obtained.

$$h_f = \frac{10.68 L Q^{1.852}}{C_H{}^{1.852} D^{4.87}} \quad (3.2)$$

$$h_f = K Q^{1.852} \quad (3.3)$$

Where, K = Pipe resistance coefficient and is given by:

$$K = \frac{10.68 L}{C_H{}^{1.852} D^{4.87}} \quad (3.4)$$

The Hazen Williams formula expressed in the forms of the above equations can be used to calculate the head loss in a pipeline flowing under pressure.

IV. METHODS OF BALANCING HEAD

In this method, based on the knowledge of inflows and outflows from the system, the flows in all pipes of the network are distributed in such a way as to satisfy the continuity constraints at all nodes. When the inflows and outflows are explicitly known, this will involve assigning as many flows as there are in the primary loop system. The requirement that the sum of the head losses around the primary loop be zero leads to a system of many equations. The solution of a well-determined system of nonlinear equations is influenced by a systematic relaxation known as the Hardy Cross method. In the Handy Cross head-balancing method, a trial-and-error process, the necessary flux correction formulas for assumed flows are algebraically consistent by arbitrarily assigning positive signs to clockwise flows and associated head losses and negative signs to counterclockwise flows and associated loss of head. .

1. Assume clockwise flow is positive and counterclockwise flow is negative; and negative counter-clockwise flow signs and associated pressure losses; and

2. Assign a positive sign to pressure drops for flows toward the coupling and a negative sign to flows away from the coupling.

The overall procedure for the Hardy Cross balancing head loop network analysis can be summarized as follows:

Step 1: Number all nodes and pipe connections. Also the number of loops. Adopt the sign convention that pipe discharge is positive if it flows from a lower node number to a higher node number, negative otherwise. Apply the nodal continuity equation to all nodes to obtain initial pipe discharges.

Step 2: Obtain pressure in other pipes, repeat until all pipe flows are known. If there are more than two pipes with an unknown If the discharges assume arbitrary discharges in all but one pipe, use the continuity equation to obtain the discharge in the other pipes. The total number of pipes with arbitrary discharges should be equal to the total number of primary loops in the network. Calculate the corresponding K using Eq.3.4

Step 3: Assume the loop pipe flow sign convention to apply loop discharge corrections.

Step 4: Take the value of CH.

Step 5: Calculate ΔQ for existing pipeline flows using the equation and apply algebraic pipeline corrections.

Step 6: Use a similar procedure in all loops of the pipe network. Repeat step 5 until the discharge corrections in all loops are relatively very small, i.e. within the permissible limits of ± 0.2%, or the sum of the pressure losses in the closed is relatively very small, i.e. within the permissible limit of ± 0.150 m. When the corrections are less than the permissible boundary limits, the predicted flows are correct and the iterations are terminated.

V. STEPS FOR ANALYSIS USING EPANET

1. Draw a network representation of the distribution system.
2. Edit the properties of the objects that make up the system.
3. Describe how the system works.
4. Select a set of analysis options.
5. Perform hydraulic/water quality analysis. And

6. View the analysis results.

VI. Analysis of Hydraulic Network

The hydraulic network contains single source and nine loops as shown in Fig.6.1. In this, pipes B-G, C-F, H-G, G-F, F-E, G-J, F-K, I-J, J-K, K-L, J-O and K-N, are common to loops 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8 and 8-9 respectively. The corrections in discharges ΔQ1, ΔQ2, ΔQ3, ΔQ4, ΔQ5, ΔQ6, ΔQ7, ΔQ8 and ΔQ9 were applied to find discharge in the pipes. Required data for the analysis of the hydraulic network containing flow and resistance for pipes are given in Table 6.1.

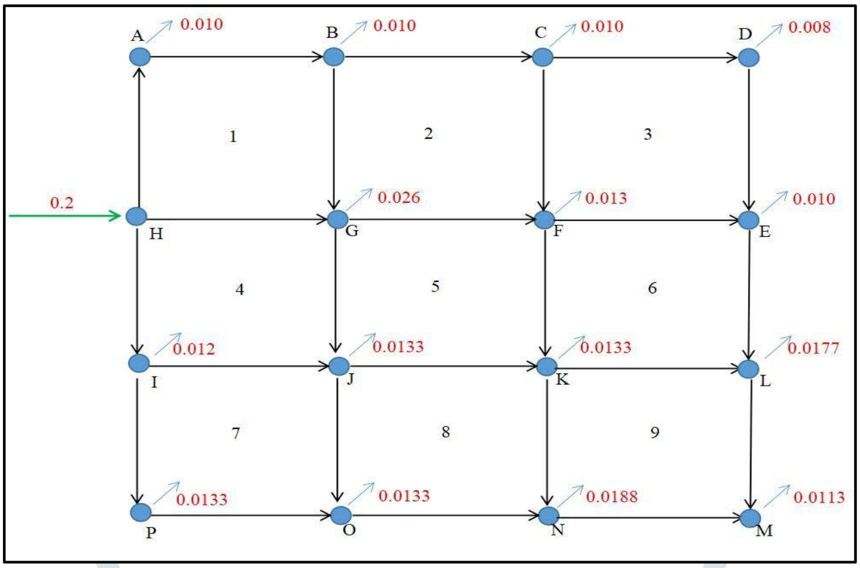

Fig.6.1: Nine loop Example with demands in (m3 /s)

Table 6.1: Flow, Length and Diameter of Pipes for HN

Node	Nodal Flow,m3/sec	Pipe	L,m	Dia,mm	Pipe Flow,m3/sec
A	0.010	AB	150	50	0.060
B	0.010	AH	150	50	0.070
C	0.010	BC	150	50	0.030
D	0.008	BG	150	50	0.020
E	0.010	CD	150	50	0.010
F	0.013	CF	150	50	0.013
G	0.026	DE	150	50	0.002
H	0.200	HG	150	50	0.060
I	0.012	HI	150	50	0.070
J	0.0133	GF	150	50	0.030
K	0.0133	GJ	150	50	0.024
L	0.0177	FE	150	50	0.017
M	0.0133	FK	150	50	0.010
N	0.0188	EL	150	50	0.009
O	0.0133	IJ	150	50	0.020
P	0.0133	IP	150	50	0.038
		JK	150	50	0.0207
		JO	150	50	0.010
		KL	150	50	0.010
		KN	150	50	0.0074
		LM	150	50	0.0013
		PO	150	50	0.0247
		ON	150	50	0.0214
		MN	150	50	0.0100

VII. Analysis of Hydraulic Network Using Hardy Cross Method

The relevant calculations required for iteration 1 and 4 for hydraulic networks (HN) 1 are listed in Table 7.1

Table 7.1: Relevant calculations required for iteration 1 and 4

ITERATION 1									
LOOP 1 (ABGHA)									
PIPE	D	L	K	Q	$h_f=KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
AB	0.05	150	368170.9080	0.060	2009.9515	62040.5039	-0.0134	0.0466	22.3339
BG	0.05	150	368170.9080	0.020	262.7586	24331.4509	-0.0134	0.0066	67.0016
GH	0.05	150	368170.9080	-0.060	-2009.9515	62040.5039	-0.0134	-0.0734	22.3339
HA	0.05	150	368170.9080	0.070	2674.0593	70747.9697	-0.0134	0.0566	19.1433
					2936.8180	219160.4283			

LOOP 2 (BCFGB)									
PIPE	D	L	K	Q	$h_f=KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
BC	0.05	150	368170.9080	0.030	556.7728	34371.4426	0.0013	0.0313	4.3796
CF	0.05	150	368170.9080	0.013	118.3239	16856.6080	0.0013	0.0143	10.1067
FG	0.05	150	368170.9080	-0.030	-556.7728	34371.4426	0.0013	-0.0287	4.3796
GB	0.05	150	368170.9080	-0.020	-262.7586	24331.4509	0.0013	-0.0187	6.5693
					-144.4347	109930.9440			

LOOP 3 (CDEFC)									
PIPE	D	L	K	Q	$h_f=KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
CD	0.05	150	368170.9080	0.010	72.7863	13480.0173	0.0037	0.0137	36.9951
DE	0.05	150	368170.9080	0.002	3.6945	3421.1176	0.0037	0.0057	184.9754
EF	0.05	150	368170.9080	-0.017	-194.4647	21185.2177	0.0037	-0.0133	21.7618
FC	0.05	150	368170.9080	-0.010	-72.7863	13480.0173	0.0037	-0.0063	36.9951
					-190.7702	51566.3701			

LOOP 4 (HGJIH)									
PIPE	D	L	K	Q	$h_f=KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
HG	0.05	150	368170.9080	0.060	2009.9515	62040.5039	0.0030	0.0630	5.0175
GJ	0.05	150	368170.9080	0.024	368.2991	28420.4159	0.0030	0.0270	12.5437
JI	0.05	150	368170.9080	-0.020	-262.7586	24331.4509	0.0030	-0.0170	15.0524
IH	0.05	150	368170.9080	-0.070	-2674.0593	70747.9697	0.0030	-0.0670	4.3007
					-558.5673	185540.3403			

LOOP 5 (GFKJG)									
PIPE	D	L	K	Q	$h_f=KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
GF	0.05	150	368170.9080	0.030	556.7728	34371.4426	0.0002	0.0302	0.6179
FK	0.05	150	368170.9080	0.010	72.7863	13480.0173	0.0002	0.0102	1.8538
KJ	0.05	150	368170.9080	-0.0207	-280.0442	25055.1603	0.0002	-0.0205	0.8956
JG	0.05	150	368170.9080	-0.024	-368.2991	28420.4159	0.0002	-0.0238	0.7724
					-18.7842	101327.0361			

LOOP 6 (FELKF)									
PIPE	D	L	K	Q	$h_f=KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
FE	0.05	150	368170.9080	0.017	194.4647	21185.2177	-0.0018	0.0152	10.5818
EL	0.05	150	368170.9080	0.009	59.8834	12322.6771	-0.0018	0.0072	19.9878
LK	0.05	150	368170.9080	-0.010	-72.7863	13480.0173	-0.0018	-0.0118	17.9890
KF	0.05	150	368170.9080	-0.010	-72.7863	13480.0173	-0.0018	-0.0118	17.9890
					108.7756	60467.9295			

LOOP 7 (IJOPI)									
PIPE	D	L	K	Q	$h_f=KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
IJ	0.05	150	368170.9080	0.020	262.7586	24331.4509	0.0084	0.0284	42.0040
JO	0.05	150	368170.9080	0.010	72.7863	13480.0173	0.0084	0.0184	84.0080
OP	0.05	150	368170.9080	-0.0247	-388.4403	29125.1557	0.0084	-0.0163	34.0113
PI	0.05	150	368170.9080	-0.038	-862.5985	42040.3260	0.0084	-0.0296	22.1074

					-915.4938	108976.9499			

LOOP 8 (JKNOJ)									
PIPE	D	L	K	Q	h_f=KQ$^{1.852}$	1.852KQ$^{0.852}$	Δ Q	Q_C	%EQ
JK	0.05	150	368170.9080	0.0207	280.0442	25055.1603	0.0007	0.0214	3.1609
KN	0.05	150	368170.9080	0.0074	41.6741	10429.7975	0.0007	0.0081	8.8420
NO	0.05	150	368170.9080	-0.0214	-297.8350	25775.2559	0.0007	-0.0207	3.0575
OJ	0.05	150	368170.9080	-0.010	-72.7863	13480.0173	0.0007	-0.0093	6.5431
					-48.9030	74740.2310			

LOOP 9 (KLMNK)									
PIPE	D	L	K	Q	h_f=KQ$^{1.852}$	1.852KQ$^{0.852}$	Δ Q	Q_C	%EQ
KL	0.05	150	368170.9080	0.010	72.7863	13480.0173	0.0010	0.0110	10.0630
LM	0.05	150	368170.9080	0.0013	1.6637	2370.1192	0.0010	0.0023	77.4077
MN	0.05	150	368170.9080	-0.0100	-72.7863	13480.0173	0.0010	-0.0090	10.0630
NK	0.05	150	368170.9080	-0.0074	-41.6741	10429.7975	0.0010	-0.0064	13.5987
					-40.0104	39759.9514			

ITERATION 4									
LOOP 1 (ABGHA)									
PIPE	D	L	K	Q	h_f=KQ$^{1.852}$	1.852KQ$^{0.852}$	Δ Q	Q_C	%EQ
AB	0.05	150	368170.9080	0.046	1212.7396	49173.7739	0.0000	0.0457	0.0000
BG	0.05	150	368170.9080	0.006	25.4883	8318.4975	0.0000	0.0057	0.0000
GH	0.05	150	368170.9080	-0.074	-2988.1019	74455.9261	0.0000	-0.0743	0.0000
HA	0.05	150	368170.9080	0.056	1749.8740	58209.0442	0.0000	0.0557	0.0000
					0.0000	190157.2417			

LOOP 2 (BCFGB)									
PIPE	D	L	K	Q	h_f=KQ$^{1.852}$	1.852KQ$^{0.852}$	Δ Q	Q_C	%EQ
BC	0.05	150	368170.9080	0.031	602.7576	35649.4644	0.0000	0.0313	0.0000
CF	0.05	150	368170.9080	0.014	141.4123	18297.1821	0.0000	0.0143	0.0000
FG	0.05	150	368170.9080	-0.029	-512.4720	33085.1099	0.0000	-0.0287	0.0000
GB	0.05	150	368170.9080	-0.019	-231.6979	22963.2618	0.0000	-0.0187	0.0000
					0.0000	109995.0183			

LOOP 3 (CDEFC)									
PIPE	D	L	K	Q	h_f=KQ$^{1.852}$	1.852KQ$^{0.852}$	Δ Q	Q_C	%EQ
CD	0.05	150	368170.9080	0.014	129.8108	17590.6354	0.0000	0.0137	0.0000
DE	0.05	150	368170.9080	0.006	25.4242	8308.8591	0.0000	0.0057	0.0000
EF	0.05	150	368170.9080	-0.013	-123.9999	17223.9022	0.0000	-0.0133	0.0000
FC	0.05	150	368170.9080	-0.006	-31.2350	9134.1281	0.0000	-0.0063	0.0000
					0.0000	52257.5248			

LOOP 4 (HGJIH)									
PIPE	D	L	K	Q	h_f=KQ$^{1.852}$	1.852KQ$^{0.852}$	Δ Q	Q_C	%EQ
HG	0.05	150	368170.9080	0.063	2200.7471	64683.5590	0.0000	0.0630	0.0000
GJ	0.05	150	368170.9080	0.027	458.4230	31431.4739	0.0000	0.0270	0.0000
JI	0.05	150	368170.9080	-0.017	-194.2292	21173.4099	0.0000	-0.0170	0.0000
IH	0.05	150	368170.9080	-0.067	-2464.9408	68146.6894	0.0000	-0.0670	0.0000
					0.0000	185435.1323			

LOOP 5 (GFKJG)									
PIPE	D	L	K	Q	h_f=KQ$^{1.852}$	1.852KQ$^{0.852}$	Δ Q	Q_C	%EQ
GF	0.05	150	368170.9080	0.030	563.1610	34552.3068	0.0000	0.0302	0.0000
FK	0.05	150	368170.9080	0.010	75.3047	13692.6221	0.0000	0.0102	0.0000
KJ	0.05	150	368170.9080	-0.0205	-275.4175	24863.8713	0.0000	-0.0205	0.0000
JG	0.05	150	368170.9080	-0.024	-363.0482	28233.2863	0.0000	-0.0238	0.0000
					0.0000	101342.0865			

LOOP 6 (FELKF)

PIPE	D	L	K	Q	h_f=$KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
FE	0.05	150	368170.9080	0.015	158.0980	19260.5386	0.0000	0.0152	0.0000
EL	0.05	150	368170.9080	0.007	39.6320	10191.4847	0.0000	0.0072	0.0000
LK	0.05	150	368170.9080	-0.012	-98.8650	15519.3334	0.0000	-0.0118	0.0000
KF	0.05	150	368170.9080	-0.012	-98.8650	15519.3334	0.0000	-0.0118	0.0000
					0.0000	60490.6900			

LOOP 7 (IJOPI)									
PIPE	D	L	K	Q	h_f=$KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
IJ	0.05	150	368170.9080	0.028	501.4820	32756.7931	0.0000	0.0284	0.0000
JO	0.05	150	368170.9080	0.018	224.0905	22613.2800	0.0000	0.0184	0.0000
OP	0.05	150	368170.9080	-0.0163	-180.8630	20490.1737	0.0000	-0.0163	0.0000
PI	0.05	150	368170.9080	-0.030	-544.7095	34026.8181	0.0000	-0.0296	0.0000
					0.0000	109887.0650			

LOOP 8 (JKNOJ)									
PIPE	D	L	K	Q	h_f=$KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
JK	0.05	150	368170.9080	0.0214	296.6550	25728.2244	0.0000	0.0214	0.0000
KN	0.05	150	368170.9080	0.0081	48.7529	11210.3830	0.0000	0.0081	0.0000
NO	0.05	150	368170.9080	-0.0207	-281.1934	25102.4086	0.0000	-0.0207	0.0000
OJ	0.05	150	368170.9080	-0.009	-64.2145	12724.9662	0.0000	-0.0093	0.0000
					0.0000	74765.9822			

LOOP 9 (KLMNK)									
PIPE	D	L	K	Q	h_f=$KQ^{1.852}$	$1.852KQ^{0.852}$	Δ Q	Q_C	%EQ
KL	0.05	150	368170.9080	0.011	86.8775	14623.3981	0.0000	0.0110	0.0000
LM	0.05	150	368170.9080	0.0023	4.7964	3857.6156	0.0000	0.0023	0.0000
MN	0.05	150	368170.9080	-0.0090	-59.8500	12319.5109	0.0000	-0.0090	0.0000
NK	0.05	150	368170.9080	-0.0064	-31.8239	9212.9527	0.0000	-0.0064	0.0000
					0.0000	40013.4773			7

VIII. Analysis of Hydraulic Network Using EPANET

From the given procedure, the results of the analysis will be in the Project option under which Graphs and Tables can be displayed for links and nodes involving various parameters.

IX. Input

An illustrative example was modeled in EPANET and is shown in Fig.9.1

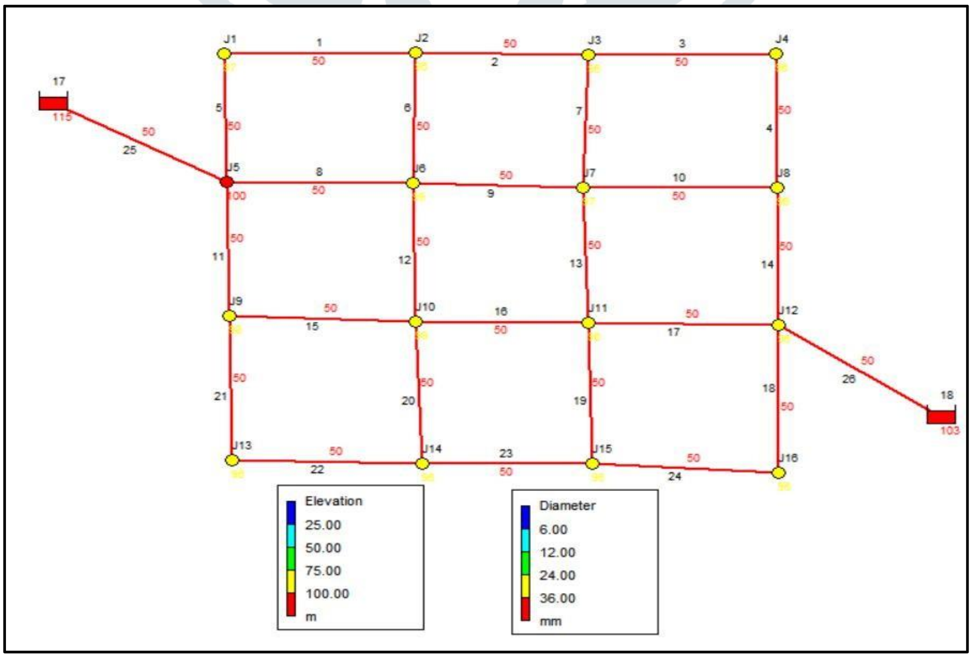

Fig.9.1: Illustrative example of HN using EPANET

X. Output

The results obtained are described below:

Table 10.1 and 10.2 show the result obtained for all pipes and nodes in the network. In the pipes As a result, the output includes flow rate, pipe velocity and unit head loss. In nodes results output includes height, altitude and pressure.

Table 10.1: Pipe Results

Network Table - Links

Link ID	Length m	Diameter mm	Roughness	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor	Status
Pipe 1	150	50	100	0.45	0.23	2.96	0.054	Open
Pipe 2	150	50	100	0.41	0.21	2.40	0.055	Open
Pipe 3	150	50	100	0.25	0.13	1.00	0.059	Open
Pipe 4	150	50	100	0.24	0.12	0.94	0.059	Open
Pipe 5	150	50	100	0.46	0.24	3.09	0.054	Open
Pipe 6	150	50	100	0.04	0.02	0.03	0.078	Open
Pipe 7	150	50	100	0.14	0.07	0.35	0.064	Open
Pipe 8	150	50	100	0.67	0.34	6.08	0.051	Open
Pipe 9	150	50	100	0.43	0.22	2.71	0.055	Open
Pipe 10	150	50	100	0.33	0.17	1.59	0.057	Open
Pipe 11	150	50	100	0.62	0.32	5.31	0.052	Open
Pipe 12	150	50	100	0.25	0.13	0.98	0.059	Open
Pipe 13	150	50	100	0.24	0.12	0.90	0.060	Open
Pipe 14	150	50	100	0.56	0.29	4.36	0.053	Open
Pipe 15	150	50	100	0.34	0.17	1.75	0.057	Open
Pipe 16	150	50	100	0.43	0.22	2.63	0.055	Open
Pipe 17	150	50	100	0.61	0.31	5.05	0.052	Open
Pipe 19	150	50	100	0.04	0.02	0.04	0.076	Open
Pipe 20	150	50	100	0.15	0.08	0.39	0.064	Open
Pipe 21	150	50	100	0.27	0.14	1.12	0.059	Open
Pipe 22	150	50	100	0.26	0.13	1.02	0.059	Open
Pipe 23	150	50	100	0.39	0.20	2.28	0.055	Open
Pipe 24	150	50	100	0.42	0.21	2.57	0.055	Open
Pipe 18	150	50	100	0.41	0.21	2.44	0.055	Open

Table 10.2: Node Results

Network Table - Nodes

Node ID	Elevation m	Base Demand LPS	Head m	Pressure m	Quality
Junc J1	97	0.010	109.10	12.10	0.00
Junc J2	96	0.010	108.65	12.65	0.00
Junc J3	96	0.010	108.29	12.29	0.00
Junc J4	96	0.008	108.14	12.14	0.00
Junc J5	100	0	109.56	9.56	0.00
Junc J6	99	0.026	108.65	9.65	0.00
Junc J7	97	0.013	108.24	11.24	0.00
Junc J8	96	0.010	108.00	12.00	0.00
Junc J9	98	0.012	108.76	10.76	0.00
Junc J10	99	0.0133	108.50	9.50	0.00
Junc J11	96	0.0133	108.11	12.11	0.00
Junc J12	96	0.0177	107.35	11.35	0.00
Junc J13	96	0.0133	108.60	12.60	0.00
Junc J14	96	0.0133	108.44	12.44	0.00
Junc J15	96	0.0188	108.10	12.10	0.00
Junc J16	96	0.0113	107.72	11.72	0.00
Resvr 17	115	#N/A	115.00	0.00	0.00
Resvr 18	103	#N/A	103.00	0.00	0.00

XI. Result And Discussion

The results of the analysis of the nine-loop hydraulic network analyzed by the Hardy Cross method. For this method, acceptable results were obtained in the 4th iteration meeting the criteria of $\Sigma hf \leq 0.150$ m; acceptable results were obtained in the 3rd iteration meeting the criteria of $\Sigma hf \leq 0.0001$ m.

11.1 Junction Report

The hydraulic network of nine loops consists of 16 junctions. Results for an illustrative nine-loop problem are obtained using EPANET software. The pressure is determined using the Hazen-Williams approach. For the elevation of the reservoir equal to 15 meters, none of the nine intersections shows a vacuum height. Vacuum height means that the hydraulic drop line lies below the delivery level. This problem can be overcome by increasing the diameter of the supply pipe or by providing auxiliary pumps. Other connections show fluctuations in pressure head.

11.2 Pipe Report

The nine-loop hydraulic network consists of 16 pipes. Following are some of the findings of the study. The error between the actual flow rate and the flow rate calculated using the EPANET software is compared. The actual flow rate is almost the same as the flow rate obtained using EPANET. The head loss calculated by EPANET is almost equal to the actual head loss.

XII. Conclusion

The above study revealed that; EPANET software saves time and has no limitations on the number of nodes, the number of pipes or pumps that are modeled and analyzed in it to easily solve complex networks. As increasing the number of iterations, the head loss value approaches zero and for verification the obtained answers are used to equalize the flows at each point. Results obtained using Hardy cross method and the EPANET software are almost the same.

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