Design of NDA Water Distribution Network using EPANET

A Saminu, Abubakar, Nasiru, L Sagir

Abstract- This study presents the use of EPANETsoftwarein the design of the N.D.A water distribution network. EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network, EPANET is designed to be a research tool for improving our understanding of the movement and fate of drinking water constituents within distribution systems. It can be used for many different kinds of applications in distribution systems analysis. In this paper it was used to carry out the hydraulic analysis of the distribution network in the study area. The results obtained verified that the pressures at all junctions and the flows with their velocities at all pipes are feasible enough to provide adequate water to the network of the study area.

Keywords: Epanet, Analysis and Water Distribution Networks.

I. INTRODUCTION

Water distribution system is a hydraulic infrastructure consisting of elements such as pipes, tanks reservoirs pumps and valves e.t.c. It is crucial to provide water to the consumers; effective water supply is of paramount importance in designing a new water distribution network or in expanding the existing one. It is also essential to investigate and establish a reliable network ensuring adequate head.

Computation of flows and pressures in network pipes has been of great value and interest for those involved with designs, construction and maintenance of public water distribution systems. Analysis and design of pipes networks create a relatively complex problem, particularly if the network consists of range of pipes as frequently occurs in water distribution systems of large metropolitan areas. In the absence of significant fluid acceleration, the behavior of a network can be determined by a sequence of steady state conditions, which form a small but vital component for assessing the adequacy of a network. Such an analysis is needed each time changing pattern of consumption or delivery are significant or, added features such as supplying of water, addition of booster pumps, pressure regulating valves or storage tanks, change the system. This study aimed at performing the hydraulic analysisof NDA water distribution network using Epanet Software.

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1.1 PROJECT AREA

The project area is the NDA (Nigerian Defence Academy) permanent site Kaduna, which is sited along Mando road, Afaka Kaduna and Lagos expressway. The area survey sites is seen to have gentle slope, few out crops covered by farmland, interspersed with shrubs and scattered trees. The area can be accessed by motor vehicles, motorcycles and foot traverses. The NDA permanent site drainage pattern comprises of four main rivers, which are seasonal rivers, Gora, Debu, Doka and river mashi (U Tukur NDA 2006) [1]. Among the entire rivers only river Gora is the major river which runs southwards at the lowest part of the general area. NDA permanent site is mainly populated by officers, soldiers, civilian staffs and cadets. The total population of NDA is approximated to be 6935persons (U Tukur NDA 2006).

II. LITERATURE REVIEW

The analysis of hydraulic problems has reviewed considerable attention in the past. This is almost entirely due to the available computer facilities which make it less tedious, iterative calculations were amenable to a quick solution. In addition, obtaining a solution to these problems has important economic and design significance.

Many methods have been used in the past to compute flows in network of pipes such methods range from graphical methods to the use of physical analogies and finally to the use of mathematical models. These methods of network analysis have been developed and implemented on the computer over the last fifty years.

One of the first and probably the most widely used method of analysis is the Hardy Cross Technique (1936) [3]. This method makes corrections to initial assumed value by using a first order expansion of the energy equation in terms of selection factor for the flow rate in each loop. The process is of course repetitive and is dependent on the accuracy of the initial given which must be reasonably good. If an aimer is to be obtained, reportedly, however the method is suitable for both hand calculation, and also a number of digital programs have been prepared for network flow analysis suing this procedure. In certain cases it has been found that the Hardy Cross method converges very slowly or not at all. This lead Mc corale and Deliany (1960) [4] to suggest special measures to improve convergence.

The method described by Newton and Peter (1963) [5] has also been used by Gludice (1965) and Pitchal (1966) for studied for hydraulic networks. The method has been extended by Shanny and Howard (1968) [6] to include various hydraulic components in the network. Epp and Fowler (1970) [7] late reported an approach to solving hydraulic network problems utilizing the Newton-Rapson method and have offered some details pertaining to a general digital computer program available for this problems.

This method adjusts the flow rate in all the loops simultaneously. Convergence using Newton-Rapson approach is much quicker than that obtained using Hardy Cross analysis. This is especially important when analyzing networks involving large number of pipes.

Direct electrical analogues are also used for hydraulic network analysis developed by Mcllroy (1950) [8]. This and other available direct analog services are described in a proper Mcpherson (1962) [9]. Although, electrical analog are accuracies and no process of convergence exist; equipment and trained operation are required to meet there devices which makes their method of analysis impractical in any situations.

Uri Shamir of Israel and Chuck Howard of Canada (1968) [10] demonstrated that the method could also be used to accommodate systems with pumps and valves and also showed how the method could be used to solve for other unknowns. In 1969, Alvin Flower and a graduate student named Robert Epp developed a new approach to network analysis at the University of British Columbia that applied the Newton-Raphson method to simultaneously solve for the flow adjustment factors associated with the original "loop" method of Cross (1936). This had the net benefit of significantly improving the convergence characteristics of the original algorithm.

III. METHODOLOGY

3.1 MATERIALS

The materials used for this study includes; topographical map, then water distribution parameters such as; water demand, N.D.A population, and also distribution network parameters such as; elevations, pipe diameter, pipe length, finally EPANET software.

3.2 METHOD

The demand was obtained after considering the population of the study area as 6935, also the study area falls under the category of urban settlement, as a result of this development, the standard from the Federal Ministry of Water Resources manual on water demand was used, for this research 180 L/C/D was considered. We obtained a demand at particular junction by dividing (the total population by the number of junctions and multiplying by 180L/C/D).

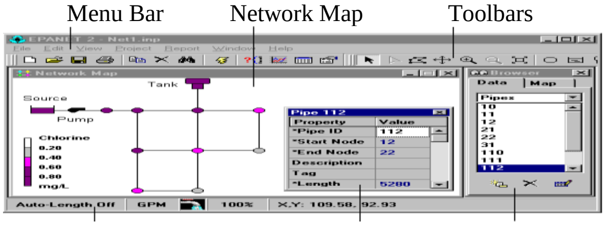
After that, the following steps were carried out to analyze the NDA water distribution network**:**

1. Draw a network representation of your distribution system or import a basic description of the network.
2. Edit the properties of the objects that make up the system
3. Select a set of analysis options
4. Run a hydraulic analysis

E P A N E T' S W O R K S P A C E

The basic EPANET workspace is pictured below. It consists of the following userinterface elements: a Menu Bar, two Toolbars, a Status Bar, the Network Mapwindow, a Browser window, and a Property Editor window.

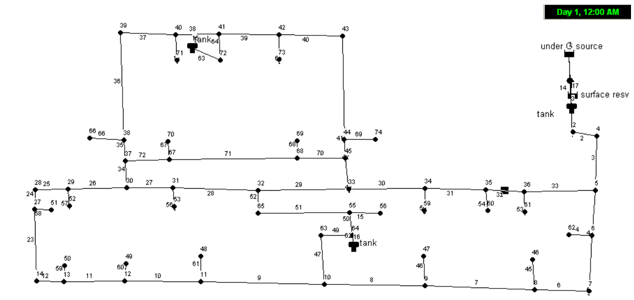
Menu Bar Network Map Toolbars



Status Bar Property Editor Browser

IV. ANALYSIS/RESULT

In this research the distribution network of NDA Kaduna was obtained and analyzed. It consists of 63 pipes of different materials, 57 junctions, 3 tanks and 2 source reservoir from which water is pumped to the surface reservoir and later distributed to the network, as shown below:



KEY
water tank
pump
node/junction
reservoir
pipe

FIGURE 1: THE NDA PIPELINE WATER DISTRIBUTION NETWORK

The analysis of any water distribution network includes determining quantities of flow and head losses in the various pipe lines, and resulting residual pressure at various demands in the network junctions .**The results obtain for the network of NDA study area are described below:**

4.1 NETWORK TABLE – NODES (JUNCTIONS)

	Demand	**Head**	**Pressure**
Node ID	(LPS)	(m)	(m)
Junc 2	0.31	399.51	49.51
Junc 4	0.28	399.06	59.06
Junc 5	0.27	398.19	8.19
Junc 6	0.25	397.76	29.76
Junc 7	0.31	396.87	29.87
Junc 8	0.35	396.02	51.02
Junc 9	0.31	395.10	55.10
Junc 10	0.22	394.51	59.51
Junc 11	0.24	394.49	46.49
Junc 12	0.25	393.10	44.10
Junc 13	0.31	392.01	42.01
Junc 14	0.24	391.74	29.74
Junc 27	0.25	390.12	10.12
Junc 28	0.23	389.96	1.96

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Node ID	Demand (LPS)	Head (m)	Pressure (m)
Junc 29	0.33	389.70	10.70
Junc 30	0.26	389.39	39.39
Junc 31	0.27	389.40	2.40
Junc 32	0.25	389.53	10.53
Junc 33	0.33	389.53	36.53
Junc 34	0.32	391.06	3.06
Junc 35	0.28	392.57	13.57
Junc 36	0.33	394.06	6.06
Junc 37	0.34	386.43	25.43
Junc 38	0.35	385.03	25.03
Junc 39	0.36	383.04	18.04
Junc 40	0.33	382.56	21.56
Junc 41	0.34	382.56	21.56
Junc 42	0.26	383.06	23.06
Junc 43	0.28	385.01	24.01
Junc 44	0.27	385.69	5.69
Junc 45	0.25	388.69	11.69
Junc 46	0.31	395.69	52.69
Junc 47	0.26	394.88	54.88
Junc 48	0.26	394.27	49.27
Junc 49	0.23	389.13	49.13
Junc 50	0.24	388.22	41.22
Junc 51	0.25	386.61	16.61
Junc 52	0.24	385.37	18.37
Junc 53	0.30	382.66	15.66
Junc 55	0.26	405.58	55.58
Junc 56	0.23	405.36	45.36
Junc 59	0.26	384.72	29.72
Junc 60	0.22	388.93	32.93
Junc 61	0.23	390.08	50.08
Junc 62	0.25	397.76	52.76
Junc 63	0.23	407.81	61.81
Junc 64	0.27	414.64	71.64
Junc 65	0.24	392.70	42.70

Node ID	Demand (LPS)	Head (m)	Pressure (m)
Junc 66	0.33	373.83	23.83
Junc 67	0.32	386.43	35.43
Junc 68	0.26	387.22	35.22
Junc 69	0.28	382.08	27.08
Junc 70	0.27	380.96	25.96
Junc 71	0.32	371.06	12.06
Junc 72	0.27	378.29	19.29
Junc 73	0.32	371.56	11.56
Junc 74	0.25	379.83	19.83
Resvr 1	-143.92	400.00	0.00
Resvr 17	0.00	450.00	0.00
Tank 3	133.28	500.00	15.00
Tank 15	-0.06	505.00	15.00
Tank 16	-5.16	498.00	10.00

4.2 NETWORK TABLE - LINKS (PIPES)

Link ID	Flow (LPS)	Velocity (m/s)	Unit Headloss (m/km)	Friction Factor
Pipe 1	15.78	0.50	21.30	0.331
Pipe 2	15.47	0.49	20.47	0.331
Pipe 3	15.19	0.48	19.74	0.331
Pipe 4	7.33	0.41	26.42	0.452
Pipe 5	6.83	0.39	22.94	0.452
Pipe 6	6.52	0.37	20.91	0.452
Pipe 7	5.86	0.33	16.89	0.452
Pipe 8	5.29	0.30	13.77	0.452
Pipe 9	4.08	0.06	0.13	0.231
Pipe 10	3.58	0.20	6.33	0.453
Pipe 11	3.10	0.18	4.75	0.453
Pipe 12	2.55	0.14	3.22	0.453
Pipe 23	2.31	0.13	2.64	0.454
Pipe 24	1.81	0.10	1.62	0.454

Pipe 25	1.58	0.09	1.24	0.455
Pipe 26	1.01	0.06	0.51	0.456
Pipe 27	-1.09	0.06	0.59	0.456
Pipe 28	-1.66	0.09	1.37	0.454
Pipe 29	-2.13	0.12	2.23	0.454
Pipe 30	-5.95	0.34	17.42	0.452
Pipe 31	-6.53	0.37	20.98	0.452
Pipe 32	-7.03	0.40	24.31	0.452
Pipe 33	-7.59	0.43	28.34	0.452
Pipe 34	1.85	0.24	21.94	0.777
Pipe 35	1.62	0.21	16.88	0.778
Pipe 36	0.94	0.12	5.71	0.780
Pipe 37	0.58	0.07	2.18	0.783
Pipe 38	-0.07	0.01	0.00	0.076
Pipe 39	-0.62	0.08	2.49	0.782
Pipe 40	-1.20	0.15	9.28	0.779
Pipe 41	-1.48	0.19	14.09	0.778
Pipe 42	-2.00	0.25	25.70	0.777
Pipe 43	-3.49	0.20	6.01	0.453
Pipe 44	0.25	0.01	0.00	0.031
Pipe 45	0.31	0.06	2.77	1.143
Pipe 46	0.26	0.05	1.95	1.146
Pipe 47	0.99	0.13	6.27	0.780
Pipe 49	0.76	0.10	3.69	0.781
Pipe 50	0.52	0.10	7.66	1.136
Pipe 51	0.03	0.01	0.00	0.117
Pipe 52	-0.21	0.04	0.87	0.759
Pipe 53	0.23	0.12	49.67	3.553
Pipe 54	0.22	0.11	45.47	3.555
Pipe 55	0.26	0.13	63.38	3.548
Pipe 56	0.30	0.15	84.25	3.542
Pipe 57	0.24	0.12	54.05	3.551
Pipe 58	0.25	0.13	58.62	3.549
Pipe 59	0.24	0.12	54.05	3.551
Pipe 60	0.23	0.12	49.67	3.553
Pipe 61	0.26	0.05	1.95	1.146
Pipe 62	0.03	0.17	244.14	2.369
Pipe 63	0.06	0.33	1377.77	3.803
Pipe 64	-0.21	0.11	42.36	3.557
Pipe 65	0.32	0.16	95.80	3.540
Pipe 66	0.33	0.17	101.85	3.539
Pipe 67	0.27	0.14	68.32	3.546
Pipe 68	0.28	0.14	73.44	3.545
Pipe 69	0.25	0.13	58.62	3.549
Pipe 70	1.24	0.16	9.93	0.779
Pipe 71	0.70	0.09	3.19	0.781
Pipe 72	0.11	0.01	0.00	0.047
Pipe 13	0.32	0.16	95.80	3.540
Pipe 15	0.23	0.05	1.36	1.020
Pump 14	133.28	0.00	-100.00	0.000

V. CONCLUSION

The main focused of this research is to analyze the water distribution network and identify deficiencies (if any) in it is analysis, implementation and its usage. At the end of the analysis it was found that the resulting pressures at all the junctions and the flows with their velocities at all pipes are adequate enough to provide water to the study area. In addition, the following situation were observed in the distribution pipe line network which in future can cause inadequate supply of water to the area are:

1. It was observed that the pipes connected to the tanks as distribution pipes to the other pipes have smaller diameters.
2. It was observed that the network on the topographical map does not have a widercoverage of water distribution to some parts of the area; this as well, can cause water crisis as a result of rapid expansion of the area in future.

5.1RECOMMENDATIONS

It is recommended that the foregoing observations made should be carefully studied, by replacing the appropriate diameters to the distribution main and as well expanding the distribution network in order to obtain a proper coverage in the area, doing this will save the consumers in having the water shortages in future.

REFERENCES

1. U Tukur (2006) “Design of NDA water treatment sedimentation tank” submitted to department of civil engineering NDA Kaduna.
2. AWWA (2005). M32- Computer Modeling of Water Distribution Systems. Denver, CO., 159 pp. Cesario, L. (1995). Modeling, Analysis, and Design of Water Distribution Systems, American Water Works Association
3. Cross, H. (1936). “Analysis of flow in networks of conduits or Conductors.” Engineering Experiment Station, University of Illinois, Bulletin No. 286

4. Mc Corale and denial (1960). pipeline network flow analysis J, Mer water works association 41, 422 – 428 1949
5. Martin, D.W. and Peters, G. (1963). "The application of Newton's method to network analysis by digital computer." Journal of the Institute of Water Engineers, 17, 115-129.
6. Shamir, U. and Howard, C.D.D. (1968). "Water distribution systems analysis." Journal of the Hydraulic division, ASCE, 94, Proc. Paper 5758, 219-234.
7. Epp R., and A.G. Fowler, Efficient code for steady-state flows in networks, J. Hydraulics Di v., Proc. Amer. Soc • Civil Engineers, 96 (HYl), 43-56, 1970
8. Mcllroy M. S. pipeline network flow analysis J, Mer water works association 41, 422 – 428 1949
9. McPherson M.B.~ E.C. Bolls, Jr., D.A. Brock, E.B. Cobb, H.A. Cornell, J.E. Flack, F. Holden, F.P. Linaweaver, Jr., R.C. McWhinnie, J.C. Neill, and R.V. Alson, Priorities in distribution research and applied development needs, J.Amer. WaterWorks Association, 66(9), 507 - 509, 1974.
10. Shamir U., and C.D. Howard, Water distribution system analysis, J. Hydraulics Dfv., Proc. Amer. Soc. Civil Engineers, 94 (HYl),219-234, 1968.
11. Todini, E. and Pilati, S. (1987). "A gradient algorithm for the analysis of pipe networks." *Computer Applications in Water Supply,* Research Studies Press Ltd. Taunton, UK., 1-20.
12. Rossman, L.A. (1993). "EPANET, Users Manual." Risk Reduction Engineering Laboratory, U.S. Environmental Protection Agency, Cincinnati,Ohio.
13. Alperovits, E. and Shamir, U. (1977). "Design of optimal water distribution systems." Water Resources Research, Vol. 13(6), pp. 885-900.
14. [Gessler, J., *Optimization of pipe networks*, Proc. of the Ninth International. Symposium on Urban Hydrology, Hydraulics and Sediment Control, Univ. of Ky., Lexington, July 27-30, 1982.
15. Wood, D.J and Charles, C.O.A. (1972). "Hydraulic network analysis using linear theory." Journal of the Hydraulic division, ASCE, 98, Proc. Paper 9031, 1157-1170.
16. Jeppson, R. W., and A. L. Davis, (1976). "Pressure Reducing Valves in pipe Network Analysis," ASCE Journal of the Hydraulic Division, 102(HY7):987.
17. Wood, D.J. (1980). User's Manual - Computer Analysis of Flow in Pipe Networks Including extended Period Simulations, Department of Civil Engineering, University of Kentucky, Lexington, kY.
18. Wood D J, Algorithms for pipe network analysis and their reliability. University of Kentucty, Water resources Research Institution Research report No. 127 1981
19. Mays, L.W. (2000). Water Distribution System Handbook, L. W. Maysed.,McGraw Hill, New York. Pg409 - 482, pg 469.