iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: VIII Month of publication: August 2022

DOI: https://doi.org/10.22214/ijraset.2022.46287

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

Exploration of Pressure Driven Method in Hydraulic Modelling of Water Distribution Network

Ms. Sonali Gaikwad[1], Dr D.K. Rajmane[2], Dr.S.D.Khandekar[3]
[1]PG Student, [2]Associate Professor, [3]Professor, Department of Civil Engineering, Sinhgad College of Engineering , Pune, Maharashtra, India

Abstract: A water supply network is assessed on its efficiency and capability to cater to the demand of consumers. There are two approaches for analysing a network viz. Demand Driven Approach (DDA) & Pressure Driven Approach (PDA). It assumes that the demands at all nodes are always satisfied, irrespective of the available nodal pressure. But many a times, in an operational network, certain situations such as pipe burst, pump failure, fire demand, supply shortage etc. arise. These situations cause pressure deficiency or even negative pressures. Such lower pressures cause water shortage at delivery points or sometimes even supply disruption. This is where DDA fails. PDA is comparatively a new approach. But it is capable of simulating pressure deficient conditions and analysing their effects on the network. Though, not for designing, but it can be efficiently used to simulate different conditions, analyse their effects and determine solutions to mitigate hazards. This paper compares DDA & PDA by analysing a looped network.
Keywords: Water distribution network, Hydraulic modelling, Pressure driven analysis, Demand Driven analysis, NHFR.

I. INTRODUCTION

Water supply systems are built with the primary purpose of delivering water from source to consumer. A typical water supply system consists of a source, intake structure, pumps, water treatment plant, clean water storage reservoirs, pipe network, and other appurtenances like different kinds of valves, flow meters, pressure gauges etc. Once the water is filtered, treated and purified at treatment plants, it is pumped to elevated service reservoirs. Water distributionnetwork includes transportation of water from service reservoirs to consumer ends. Further, the network is divided into number of zones depending upon population, consumer type, topology of the region, capacity of service reservoir. The zone is further divided into multiple District Metered Areas (DMAs). DMAs ensure equitable supply of water throughout the zone and better water management. The aim is to distribute water to all the consumers in equal quantitiesand in adequate pressure ranges. The performance evaluation of a network is done on the basisof its capacity to cater demands of consumers and the residual pressures at consumer ends. Hence, for efficient working of the network, proper layout and correct hydraulic design are very important. This process of designing a network is known as Hydraulic Modelling. It is comprised of engineering, mathematical and geo-spatial design of the network. An efficient hydraulic model allows minimum head losses in the network and hence maintains maximum pressures.

II. OBJECTIVES OF PROJECT

1) To analyze a water distribution network in Water GEMs.
2) To study Demand Driven and Pressure Driven Approach and apply it on a benchmarknetwork.

III. LITERATURE REVIEW

Various studies have been performed on analysis of water distribution networks and Pressure Driven Analysis (or Pressure Dependent Demands). Certain papers are related to the importance of Pressure dependent demand function in water network analysis and use of PDD function in software like water GEMS, water CAD, EPANET. In this report, literature review covers most of the papers regarding with design, analysis and research parameters of design of water distribution network and pressure dependent demand approach.

IV. METHODOLOGY

The study started with learning basics of Water Supply Engineering and Principles ofHydraulics and their application.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII August 2022- Available at www.ijraset.com

Different methods and approaches for analyzing a network are studied. A looped network is analyzed with 1 manual method i.e. Hardy-Cross Method and two softwares i.e. Water GEMS and Tal Tantra by IIT Bombay. The same network is then analysed by Demand Driven and Pressure Driven Approaches. For comparison of DDA and PDA, pressure deficient condition of pipe burst, and supply shortage are considered in the analysis, and its effects are studied. For simulation of various scenarios, WaterGEMS has been used.

V. CASE STUDY

In this project the case study – I network is chosen from "Modeling Pressure Deficient Water Distribution Networks in EPANET" 16th Conference on Water Distribution System Analysis, WDSA 2014, Procedia Engineering 89 (2014) 626 – 631, as shown in Fig 3.5. This network isused by many researchers and the data is available for this network. In this project work, Hardy-Cross method is used for analysis of this benchmark network. For software analysis, WaterGEMS Connect Edition Update 1 is used. WaterGEMS is based on Global gradient algorithm. The results of both the methods are compared for validation ofthe software. Following are the details of benchmark network.

The network consists of 13 nodes, 21 pipes and 2 sources. The total system demand is 0.874 m^3/s.

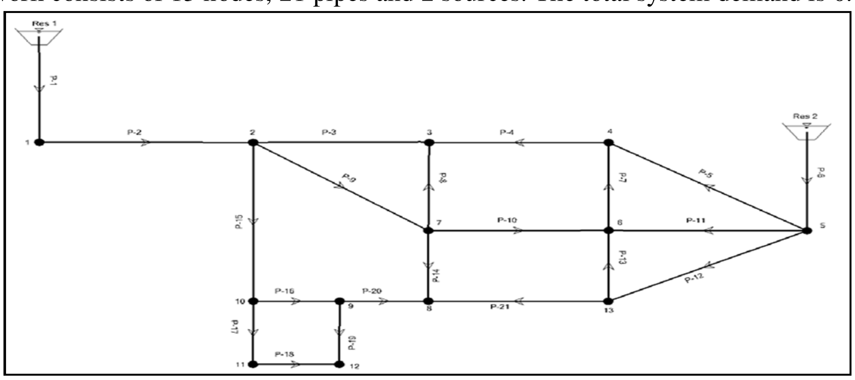


Fig.1 Benchmark Network

The network is simulated for following cases:

A. DDA – Normal Network (All pipes open)

1) Hardy- Cross Method

2) Water GEMS Analysis

Table 1. Details specifying characteristics of network pipes

Pipe No	Pipe Length (m)	Diameter (m)	Hazen-Williams Coefficient	Pipe no.	Length (m)	Diameter (m)	Hazen-Williams coefficient
1	609.60	0.762	130	11	883.92	0.305	110
2	243.80	0.762	128	12	1371.60	0.381	108
3	1524.00	0.609	126	13	762.00	0.254	106
4	1127.76	0.609	124	14	822.96	0.254	104
5	1188.72	0.406	122	15	944.88	0.305	102
6	640.08	0.406	120	16	579.00	0.305	100
7	762.00	0.254	118	17	487.68	0.203	98
8	944.88	0.254	116	18	457.20	0.152	96
9	1676.40	0.381	114	19	502.92	0.203	94
10	883.92	0.305	112	20	883.92	0.203	92
				21	944.88	0.305	90

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII August 2022- Available at www.ijraset.com

Table 2. Details specifying characteristics of network junctions and sources

Node ID	Elevation(m)	Demand (m^3/s)	Node ID	Elevation(m)	Demand (m^3/s)
1	27.43	0.0	8	31.39	0.091
2	33.53	0.059	9	32.61	0.0
3	28.96	0.059	10	34.14	0.0
4	32.00	0.178	11	35.05	0.030
5	30.48	0.059	12	36.58	0.030
6	31.39	0.190	13	33.53	0.0
7	29.56	0.178	RES 1	60.96	N/A
			RES 2	60.96	N/A

Table 3. Results of Flows in Hardy-Cross, & WaterGEMS(Flow values in m^3/s)

Label	Flow Initital	WaterGEMS	Hardy-Cross	% Flow Variation HC	% Flow Variation JT
1	0.631	0.626	0.631	-0.89	-0.23
2	0.631	0.626	0.631	-0.89	-0.80
3	0.307	0.337	0.34	-0.89	-0.62
4	0.188	0.22	0.224	-1.82	-0.54
5	0.02	0.018	0.015	16.67	-11.11
6	0.243	0.246	0.243	1.22	2.66
7	0.03	0.06	0.06	0.00	-4.28
8	0.06	0.058	0.058	0.00	-13.75
9	0.178	0.151	0.153	-1.32	-0.25
10	0.035	0.01	0.012	-20.00	-7.11
11	0.087	0.085	0.083	2.35	2.23
12	0.077	0.086	0.086	0.00	9.31
13	0.058	0.035	0.034	2.86	3.95
14	0.045	0.021	0.021	0.00	4.76
15	0.087	0.079	0.078	1.27	1.28
16	0.049	0.046	0.045	2.17	2.21
17	0.038	0.033	0.033	0.00	-0.02
18	0.008	0.003	0.003	0.00	-0.19
19	0.022	0.027	0.027	0.00	0.02
20	0.029	0.019	0.02	-5.26	-5.21
21	0.017	0.051	0.05	1.96	16.91

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII August 2022- Available at www.ijraset.com

Comparison of Hardy-Cross & Water GEM

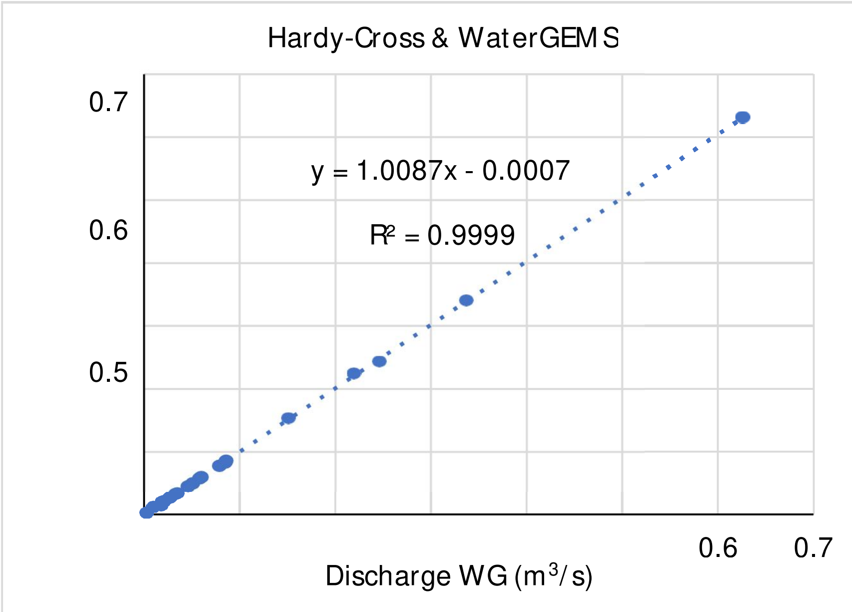


Fig .2 Scatter plot for discharge in pipes in Hardy-Cross & WaterGEMS

Fig 2. shows scatter plot for discharge in pipes in Hardy-Cross and WaterGEMS, the value ofR^2 is 0.9999 which implies that values of flow by Hardy-Cross and WaterGEMS are almost matching.

B. Comparative Analysis

Comparative analysis is done for cases mentioned earlier. The results are shown in Table 3and Fig 2. It shows comparative analysis between pressure heads and Flows at junctions forNormal Network and Pressure deficient network (Pipe-3 Burst), with DDA.

Table 4. Pressure head at junction

Pressure Heads at Junctions (m)			
Junction	DDA		PDA
	Normal	Pipe-3 Burst	Pipe-3 Burst
1	32.27	32.94	32.94
2	25.66	26.59	26.59
3	27.17	6.58	11.04
4	23.07	3.57	8.04
5	24.69	12.4	15.26
6	18.73	4.22	8.66
7	20.73	7.71	11.47
8	17.87	5.75	9.56
9	20.18	17.4	18.37
10	20	18.36	19.00
11	14.51	12.42	13.07
12	12.75	10.37	11.25
13	18.81	6.07	9.55

Remarks: It is the basic concept of DDA, that even if the pressure heads decrease at junctions,the actual flows at all junctions remain same as that of target demand. Fig. 3.17 show pressureheads in all three conditions. However, with drop in pressures, actual flows at junctions shouldalso drop.

Table 3 and Fig. 2 show comparative analysis of pressure head and actual flows at junction in Pipe-3 burst condition, with DDA and PDA.

Table 5. Comparison of DDA & PDA – Flows at junctions

Pipe 3 Burst Condition					
Junctions	Target Demand (m^3/s)	Actual Flow at Junctions (m^3/s)		Demand Shortage (m^3/s)	
		DDA	PDA	DDA	PDA
1	0.000	0.000	0.000	0.000	0.000
2	0.059	0.059	0.088	0.000	-0.029
3	0.059	0.059	0.057	0.000	0.002
4	0.178	0.178	0.146	0.000	0.032
5	0.059	0.059	0.067	0.000	-0.008
6	0.190	0.190	0.161	0.000	0.029
7	0.178	0.178	0.174	0.000	0.004
8	0.091	0.091	0.081	0.000	0.010
9	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000
11	0.030	0.030	0.031	0.000	-0.001
12	0.030	0.030	0.029	0.000	0.001
13	0.000	0.000	0.000	0.000	0.000

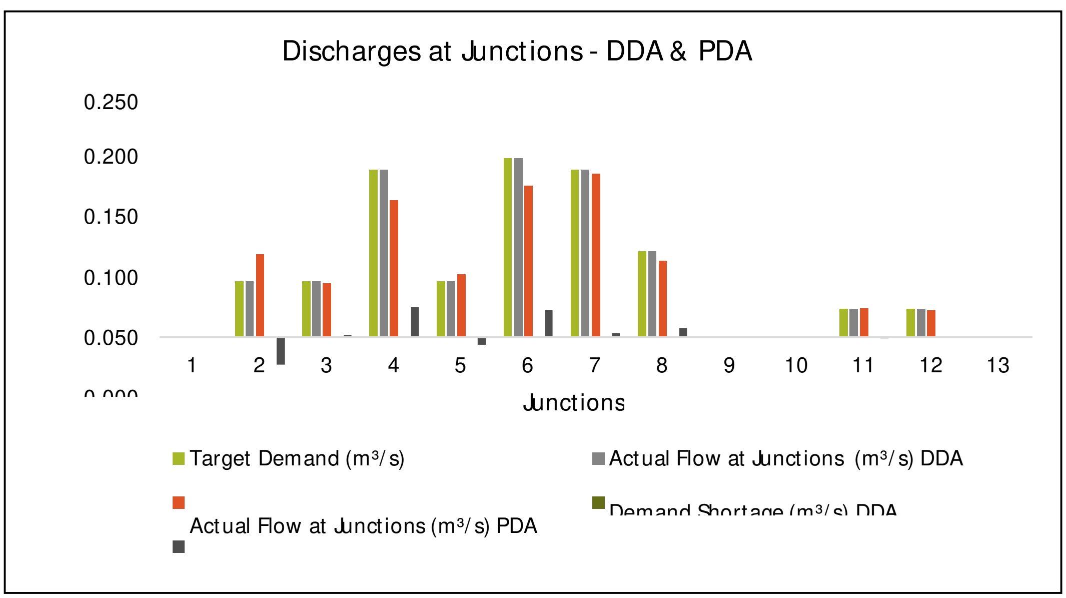


Fig 3. Comparison of DDA & PDA for Flows at junction

REMARKS: It can be seen from above table 3 and Fig.5 that, Demand Driven Analysis isnot capable of simulating pressure deficient conditions and it can lead to wrong results for such situations.

1) Total demand in the network is 0.874 m^3/s
2) In Pipe-3 Burst condition and Demand Driven Analysis, even when the pressure heads drop,the actual discharges at junctions = 0.874 m^3/s. It implies that there is no demand shortage in pipe burst condition and all the demands are fully satisfied.

In Pipe-3 Burst condition and Pressure Driven Analysis, when the pressure heads at junctionsdrop, the discharges at

a) junctions also decrease. The actual discharges at junctions = 0.834 m^3/s. It implies that there is shortage of 0.040 m^3/s in pipe burst condition and the demands at pressures lower than reference pressures aren't satisfied fully.
b) In Pipe-3 Burst condition, 7 junctions have pressure heads less than reference pressure and discharges less than their actual demands.
c) It implies that Pressure Driven Analysis is better than Demand Driven Analysis forsimulating Pressure deficient conditions.

VI. CONCLUSIONS

1) Demand Driven Analysis is good for designing a water distribution networks, but it fails to simulate and analyze various pressure deficient conditions in the network.
2) In this project work, the Hardy-Cross analysis and WaterGEMS analysis of a looped benchmark network, gave almost same results for flow in pipes.
3) Theoretically, Pressure Driven Analysis gives more realistic results in pressure deficient conditions, than Demand Driven Analysis.
4) On simulating pipe burst condition in Benchmark Network, around 85% junction's pressure head dropped below Reference Pressure i.e. 12 m which causes shortage in flow by 0.040 m^3/s.
5) From study, it can be inferred that Pressure Driven Analysis gives more realistic results in pipe burst situation, than Demand Driven Analysis i.e. Demand Driven Analysis failed to analyze this condition properly.
6) Further, from Pressure Driven Analysis of Benchmark Network, it can be inferred that Reference Pressure is an important parameter while analyzing network by Pressure Driven Approach.

REFERENCES

[1] M. A. H. Abdy Sayyed, R. Gupta, T. T. Tanyimboh, (2014), "Modeling Pressure Deficient Water Distribution Networks in EPANET", Procedia Engineering 89, 626 – 631.

[2] Mrs. Vaidya Deepali R., Mali Sandip T.(2019), "Pressure driven approach in water distribution network analysis: A Review", The International journal of analytical and experimental modal analysis.

[3] Muley M. R., Kadu M. S., Dahasahasra S. V., (2016), "Managing disasters using Pressure Dependent Demand Analysis-Case study of Shirpur town", Civil EngineeringInfrastructures Journal, 49(2): 339 – 346.

[4] P. Sivakumar, R. K. Prasad, (2014), "Simulation of Water Distribution Network under Pressure Deficient Condition", Springer Science Business Media Dordrecht, 11269- 014-0677-0

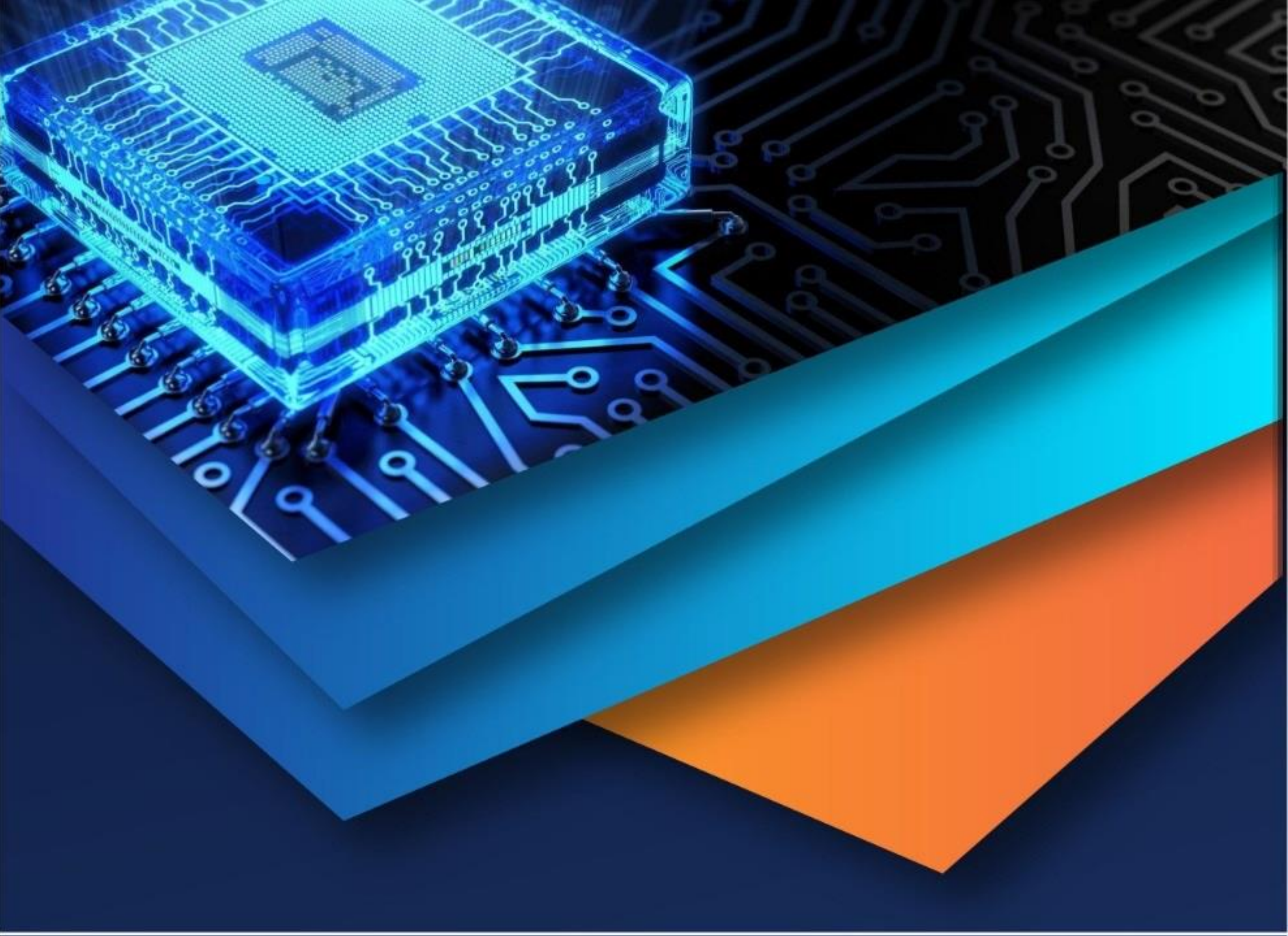
[5] Rajesh Gupta, (2015), "History of Pressure dependent Analysis of Water Distribution Networks and its Applications", World Environmental and water resources congress.

[6] Tom Walski, Devin Blakley, Matthew Evans, Brian Whitman, (2016) "Verifying pressure dependent demand modelling", XVIII International Conference on Water Distribution Systems Analysis.

[7] Tom Walski, Zheng Yi Wu, Daniel Bowdler, (2002), "Efficient Pressure Dependent Demand Model for Large Water Distribution System Analysis", 8th Annual International Symposium on Water Distribution System Analysis.

[8] Zheng Wu, Rong H. Wang, Thomas M. Walski, Shao Y. Yang, Daniel Bowdler, Christopher C. Baggett, (2014), "Extended Global Gradient Algorithm for Pressure Dependent Water Distribution Analysis", ASCE, 0733-9496, 135:1,13.

[9] Zheng Yi Wu, Thomas Walski, (2006), "Pressure Dependent Hydraulic Modelling for Water Distribution Systems under Abnormal Conditions", IWA World Water Congressand Exhibition.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

SJIFactor TOGETHER WE REACH THE GOAL IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY