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Analysis of Water Distribution Network Using Epanet for Normal and Leakage Condition and Its Effect on Pressure

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Abstract: Water distribution network is a system of engineered hydrologic and hydraulic component which supplies water from the source to the required area. In the design of water distribution network, it is crucial that the network supplies the forecasted demands with enough residual heads at all nodes of the network during the entire design period. However with the increasing change in future scenario, either the nodal demands change or the water distribution network falls short to meet the increasing demands. Therefore, we require a proper analysis of water networks to strengthen them for future. In situations like this, softwares play a major role in analyzing water distribution network to make it work as per the design. The present study is an effort to analyze the water supply network using available software, it proposes hydraulic simulation model for water distribution network analysis and comparison of results.

Keywords: EPANET, Hydraulic component, Hydraulic Simulation, Water Distribution Network etc

I. INTRODUCTION

Water distribution network is a system of engineered hydrologic and hydraulic component which supplies water from the source to the required area. These systems have to cater to the varying water demands that take place in a day , which is highest during the day as water is used for personal hygiene, cleaning, food preparation , & washing clothes while the water distribution is lowest during the night. With increasing change in Future Scenario; it has become quite difficult to make water available to end masses due to insufficient head to meet the increasing demand, also due to climatic changes like unreliable rains and other conditions that reduce the water availability at source. Water distribution system consists of elements such as pipes, tanks, reservoirs, valves and pumps to make water available to the end user. Therefore efficient design of water supply schemes is of utmost importance in expanding an existing water network or proposing a new one. It plays an important role in modern world as its efficient service is directly related to the well-being of the population. In order to promise a good service in a sustainable way the water distribution network performance should be evaluated. Hence analysis related with the computation of flow, pressure and design of pipes is crucial. It is needed when there is a changing pattern for consumption or when the demands are significant.

II. OBJECTIVE OF STUDY

The aim of this project is, "To Analyze the water distribution network using EPANET for normal and leakage condition and to study it's effect on pressure". A framework for WDN has been prepared to help understand the water resources distribution problems. To full-fill the aim of the project, the following objectives have been defined:-

1) To simulate Water Distribution Network for normal and leakage condition
2) To study the effect of Leakage on pressure and discharge

III. METHODOLOGY

Methodology is the core part of a study and that is what drives the project to the conclusion. After a lot of discussion on water distribution network, we have considered a network from a paper and have analyzed it with different patterns of distribution and comparing its results at the end. Below is a process which has been adopted for the project. The first step of the methodology of the given research is to study the water distribution system and its working. For the study purpose no. of literature has been considered. In the next step, we have studied the different methods of EPANET software and its different methods of analysis.

Later on, the modeling of case study has been done with different network patterns. After that, the results were compared with the results from paper which has been considered for study.

IV. METHODS OF ANALYSIS

A. Hardy Cross Method

The Hardy Cross method is an application of continuity of flow and continuity of potential to iteratively solve for flows in a pipe network. In the case of pipe flow, conservation of flow means that the flow-in is equal to the flow-out at each junction in the pipe. Conservation of potential means that the total directional head loss along any loop in the system is zero (assuming that a head loss counted against the flow is actually a head gain). This method is applicable to system in which pipes form closed loops. The out-flows form the system is generally assumed to occur at the nodes junction. Hardy Cross developed two methods for solving flow networks. Each method starts by maintaining either continuity of flow or potential, and then iteratively solves for the other.

B. Newton Rhapson Method

Newton Rhapson Method is a method for finding successively better approximations to the roots (or zeroes) of a real-valued function. It is a powerful numerical method for solving systems of nonlinear equations. The idea of the method is as follows: one starts with an initial guess which is reasonably close to the true root, then the function is approximated by its tangent line (which can be computed using the tools of calculus), and one computes the x-intercept of this tangent line (which is easily done with elementary algebra). This x-intercept will typically be a better approximation to the function's root than the original guess, and the method can be iterated.

V. EPANET

The EPANET software developed by the USA Environmental Protection Agency is adopted because it is for general public and educational use and it is available free on-line. It has the capacity to analyze unlimited number of pipes and tanks. EPANET has become a popular tool in analyzing complex and simple water distribution networks in both the developed and developing countries of the world. 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 of the study area. The results obtained are verified and observed 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. [3]

VI. EANALYSIS OF NETWORK

The analysis considered here is based on a network taken from paper presented by Damian Sala et.al, wherein they have used a new technique of identifying leakage for a small scale water network known as Virtual Distortion method which is widely used in mechanics. The Current study uses EPANET to analyze and study the pressure variations in a network. Calibration of the network has been achieved by running an analysis for the network considered in the paper. The results obtained are close to the experimental work carried out by the author.

The network taken into consideration is an experimental work carried out by Damian Scala et.al wherein an experimental setup of water network in loop formation has been created in which one half of the network has been raised than the other half to allow for proper circulation of water through gravity. The current thesis is an attempt to analyze the network considered in the experimental work mentioned above and carrying out trails in EPANET with making changes to the network and analyzing it under normal and leakage conditions for different combinations

VII. CALIBRATING THE NETWORK:

Calibration is a comparison between a known measurement (the standard) and the measurement using your instrument. Typically, the accuracy of the standard should be ten times the accuracy of the measuring device being tested. However, accuracy ratio of 3:1 is acceptable by most standard organizations. The goal of calibration is to minimize any measurement uncertainty by ensuring the accuracy of test equipment. Calibration quantifies and controls errors or uncertainties within measurement processes to an acceptable level.

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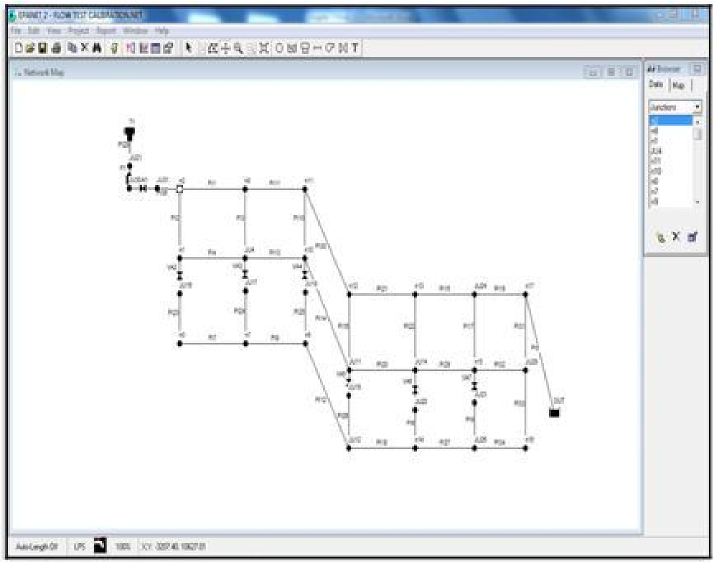
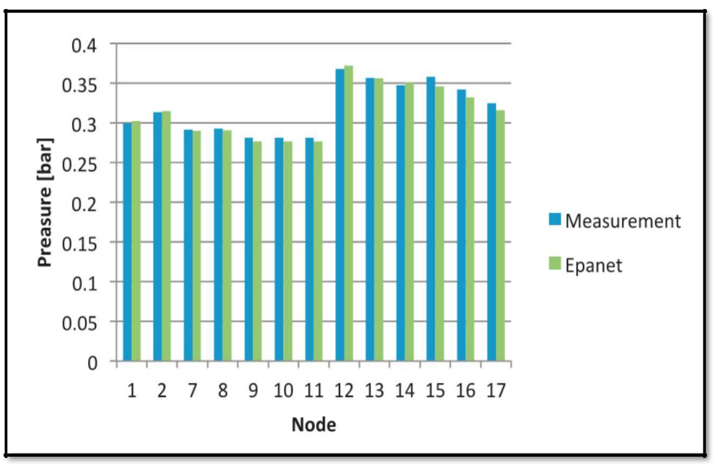
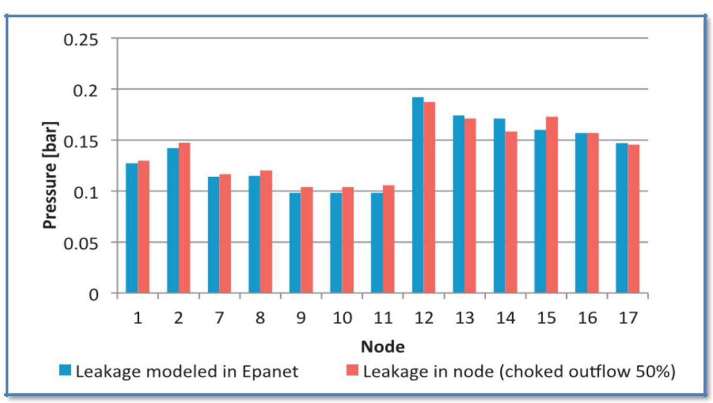
In summary, calibration is vitally important wherever measurements are important, it enables users and businesses to have confidence in the results that they monitor record and subsequently control. The figure below shows the network drawn in EPANET for calibration purpose. The network was first drawn in CAD to avoid any errors in length and then scaled to Epanet to proceed with network creation and adding appurtenances. Before importing the network skeleton from CAD, certain network defaults and hydraulic defaults have been set , which is then applied for the entire analysis if the network.



EPANET Network Calibration



Results from paper – Source – Ref [1]



Results from paper – Source – Ref [1]

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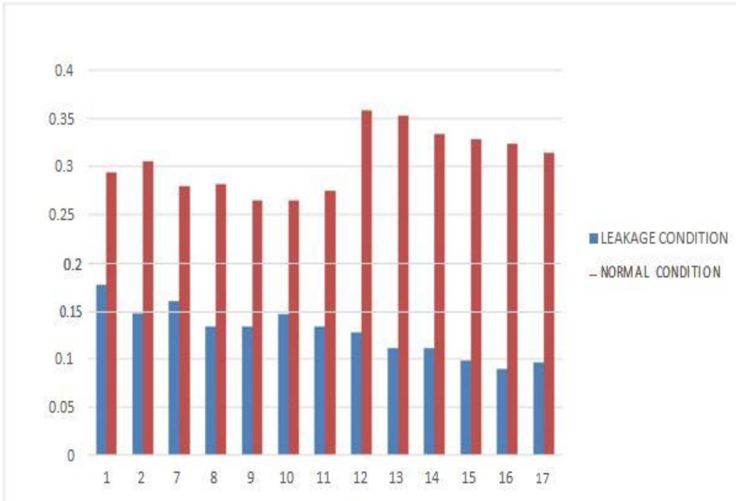

Results from calibrating the network

NORMAL CONDITION			
Network Table - Nodes			
	Head	Pressure	
Node ID	m	m	bar
1	2.99	2.99	0.29
2	3.11	3.11	0.30
7	2.85	2.85	0.28
8	2.87	2.87	0.28
9	0.27	2.7	0.26
10	0.27	2.7	0.26
11	0.28	2.8	0.27
12	3.65	3.65	0.36
13	3.6	3.6	0.35
14	3.4	3.4	0.33
15	3.35	3.35	0.33
16	3.3	3.3	0.32
17	3.2	3.2	0.31

LEAKAGE CONDITION			
Network Table - Nodes			
	Head	Pressure	
Node ID	m	m	bar
1	1.32	1.32	0.13
2	1.43	1.43	0.14
7	1.17	1.17	0.12
8	1.17	1.17	0.12
9	0.92	0.92	0.09
10	0.97	0.97	0.10
11	0.92	0.92	0.09
12	1.92	1.92	0.19
13	1.78	1.78	0.18
14	1.73	1.73	0.17
15	1.61	1.61	0.16
16	1.58	1.58	0.16
17	1.48	1.48	0.15

Observations for network under normal & leakage condition

VIII. CASE STUDY

Methodology adopted in the study is that for an area in Poland and they have carried out experimentation as well as software analysis for the purpose of leak identification in water distribution network. Below is an attempt to study the work carried out by the author as well applying the leak to the system worked out in EPANET to understand how pressure varies with it.

A. Experimental Water Network from Paper

The most essential part of the water network was the design and construction of water distribution network. It is composed of 12 rectangular grids, each one of 1.1m x 3m in plan made from 0.75 inches of PVC pipe. There is a 1m difference in the height level in the network with the supply part placed higher to allow more gravitational flow through network.

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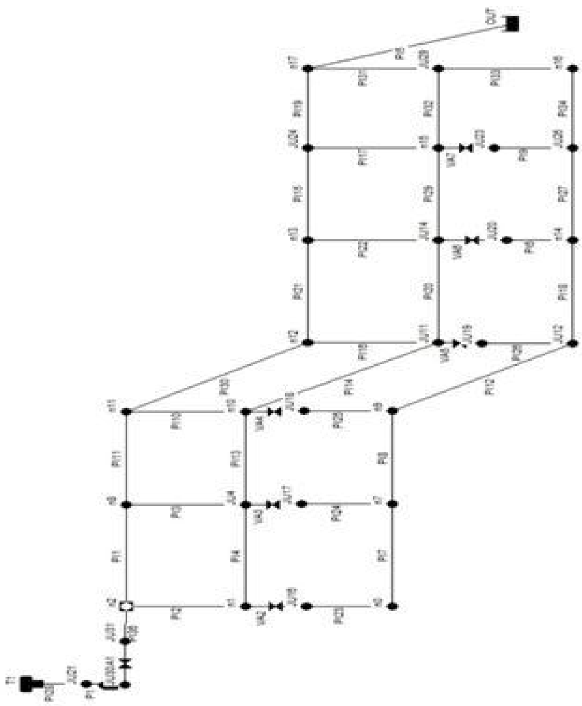
Experimental Model

In any scenario, the usual approach for designing a water distribution network is to study the base elevation of the area, the length of the network into consideration, supply elevation and the losses involved in it. A network is then analyzed and a pump of a certain pump rating curve is needed to supply water for the required head in a network.

This study is an attempt to study the pressure variation in a normal water supply network and also in a leakage situation. The network into consideration is taken from the paper described above. Study is carried out to introduce leakage in the network and learn the corresponding pressure variation. Trials are carried out to test the network under different network patterns and conditions



EPANET Model

B. Trials on EPANET

Once the calibration of network was over, different trials were carried out to understand the behavior of the network under normal and leakage condition. After much analysis and discussion, it was concluded to modify the network and study the behavior of the network under different combinations of loop and branch and how it affects the pressure at different regions of the network.

Since the parent network comprised of only loops, we decided to go with network modification as follows:

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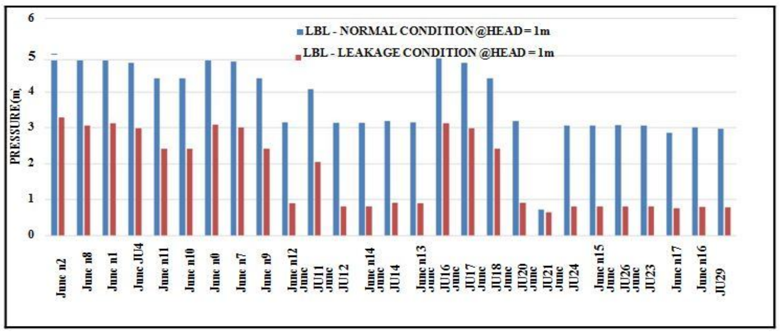
1) *Trial 1 – Loop – Branch- Loop Network*
   a) Normal Condition
   b) Leakage Condition
   c) Varying head Condition

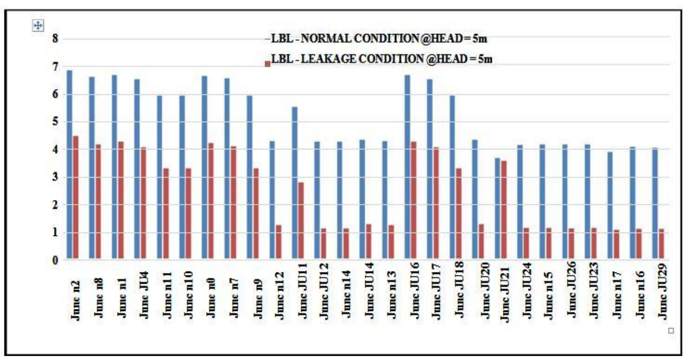
2) *Trial 2 – Branch Loop-Branch Network*
   a) Normal Condition
   b) Leakage Condition
   c) Varying head condition

3) *Trial 3 – Analyzing the network for varying head condition*

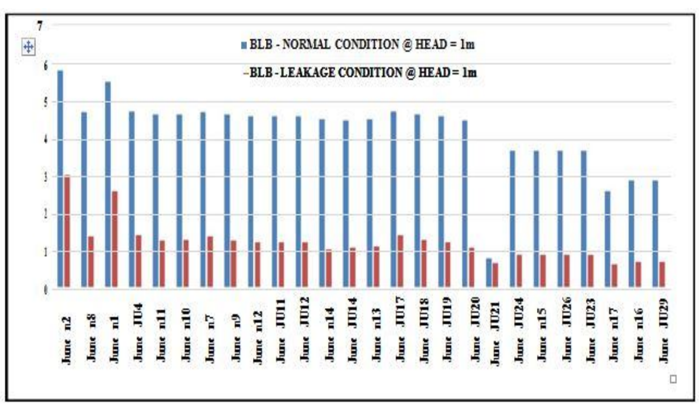
IX. RESULTS



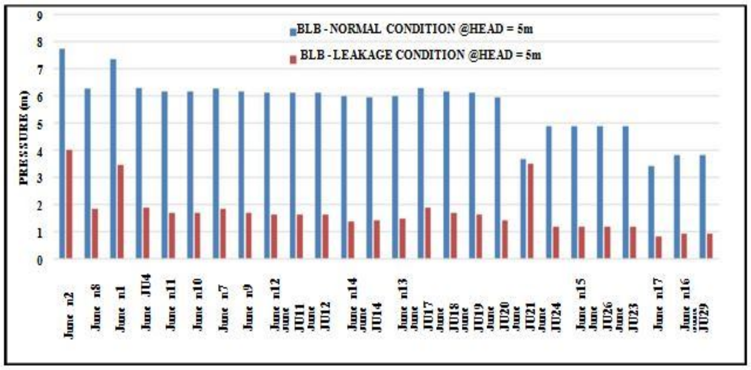
Results from Trial 1 i.e Normal & Leakage Condition @ Head = 1m



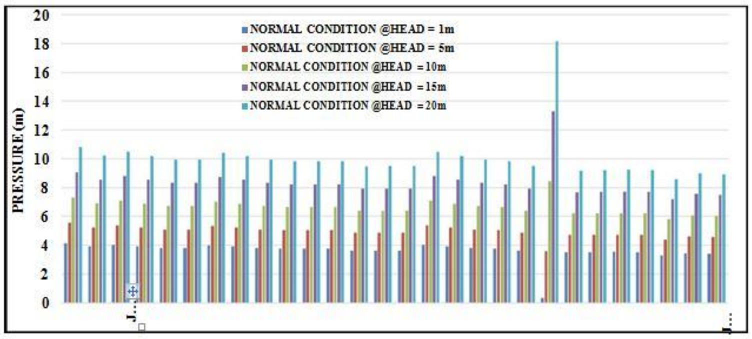
Results from Trial 1 i.e Normal & Leakage Condition @ Head = 5m



Results from Trial 2 i.e Normal & Leakage Condition @ Head = 1m



Results from Trial 2 i.e Normal & Leakage Condition @ Head = 5m



Results from Trial 3 i.e Normal Condition

X. CONCLUSION

This study is an attempt to understand the behavior of a water distribution network with respect to pressure under different conditions explained in the earlier chapters. Carrying out different simulations for normal, leakage and varying head conditions clearly show the pressure variation across the network. From the above results we can observe that the pressure variation for a Branch-Loop-Branch (BLB) under normal conditions are better than that of Loop-Branch-Loop network (LBL); this is due to the network configuration taken into consideration for BLB. As a loop network is sandwiched between two branches, water is always in loop and is able to supply the water on both branches.

Further we can observe that for leakage condition under varying pressure, the LBL network shows good amount of pressure as compared to BLB network. Since in the former, there is a branch connecting two loop networks and the leakage taken into consideration in Junction 24 is a part of a loop network. Hence even though we see leakage in Junction 24 the loop network doesn't become redundant as water is always in circulation in the network.

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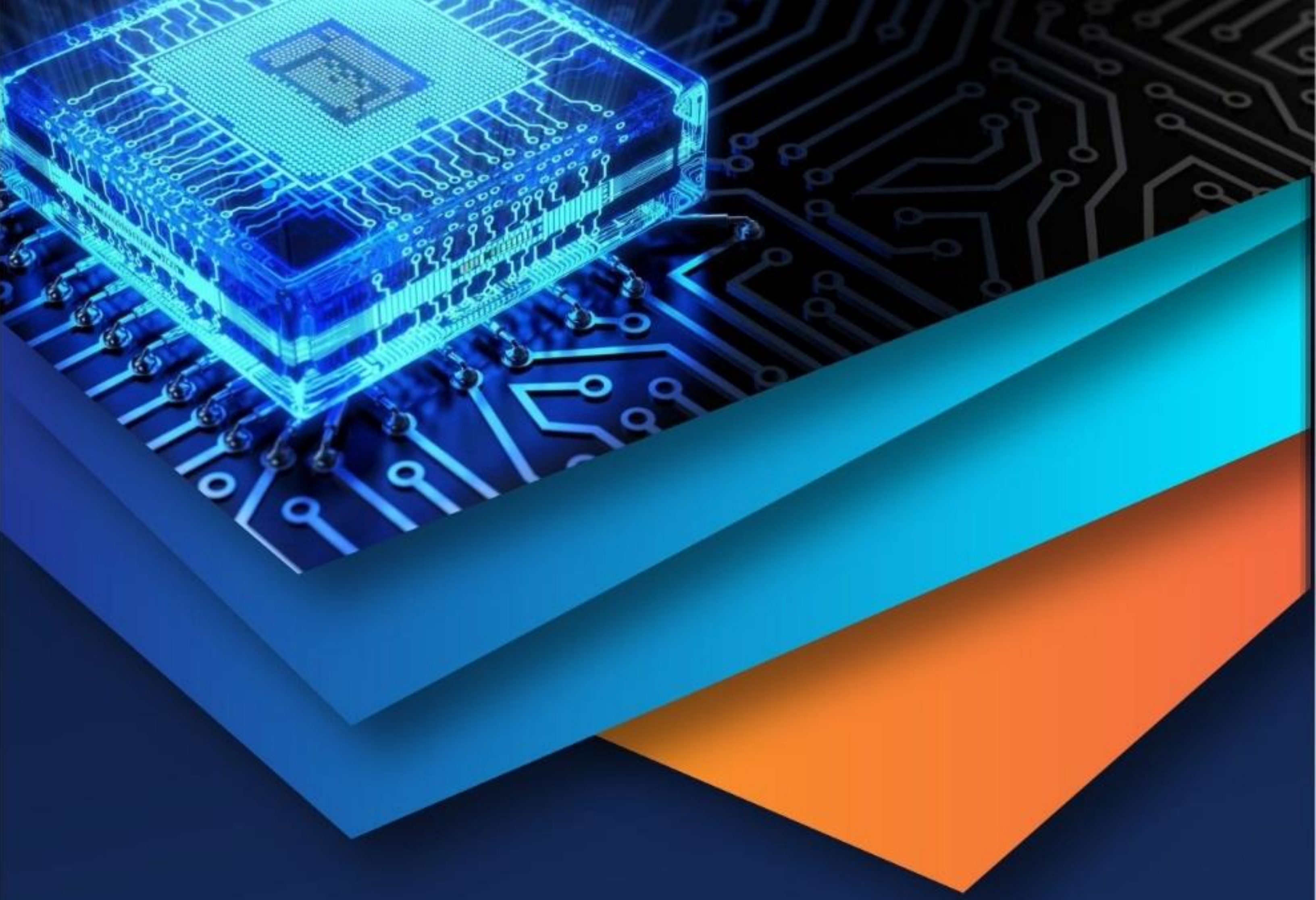

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