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# METHODOLOGY OF SIMULATION, MODELING AND EXAMINATION OF RING-TYPE WATER SUPPLY NETWORKS

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A b s t r a c t: In this paper, the methodology of simulation, modeling and examination of ring-type water supply networks is discussed. On the way from water supply to water consumption, some obstacles may encounter that need to avoided. An example of an obstruction may be a defect in a section point (consumer) through which the water cannot flow. Ring-type water supply networks consists of a number of closed rings surrounding the consumers while supplying them with water through sections. In this paper, a problem situation will be simulated and the results discussed.

**Key words:** modeling; simulation; ring-type water supply networks

## МЕТОДОЛОГИЈА НА СИМУЛАЦИЈА, МОДЕЛИРАЊЕ И ИСПИТУВАЊЕ НА ПРСТЕНЕСТИ ВОДОВОДНИ МРЕЖИ

А п с т р а к т: Во овој труд се зборува за методологијата на симулација, моделирање и испитување на прстенести водоводни мрежи. На патот од местото на водоснабдување до местото на користење на водата можат да настанат одредени опструкции кои треба да се избегнат. Како пример за опструкција може да се наведе дефект во некоја гранка од мрежата (потрошувач) низ која водата не може да тече. Прстенестите водоводни мрежи се состојат од голем број затворени прстени кои ги опкружуваат потрошувачите за време на водоснабдувањето. Во овој труд се симулира една прстенеста водоводна мрежа со проблем и се дискутираат резултатите.

**Клучни зборови:** моделирање; симулација; прстенести водоводни мрежи

## 1. INTRODUCTION

The methodology of examination is a set of planning activities in order to conduct the examination in a way that is foreseen or developed, in order to achieve the goals of the examination. The methodology of examination in general consists of:

• subject, that is, a description of the purpose of the examinations;

• measured quantities and the method of their measurement (including the required accuracy of the instrument and the complete test installation);

• description of the test installation (if a special installation is examined) or the method of installation of the measuring instruments;

• examination regimes, that is, conditions under which the examinations and measurements should be performed;

• the examination procedure, that is, the method of carrying out the measurements and collecting the results;

• way of presenting the results of the measurements (and possibly also the criteria for their evaluation).

The results are usually shown in the form of a test report.

A measuring system is a set (usually a chain) of measuring instruments and auxiliary equipment that provide measurement, display and storage of the measured quantity. The measurement system can also include the processing of measurement results.

A test installation is a set of devices that create conditions to perform the test. It does not include the measuring system, but the devices that control the testing process.

In order to carry out a successful test, it is necessary to have appropriate measuring instruments and additional components to implement a measuring system.

The measuring system takes a signal that is proportional to the measured value through the sensors. The transmitters often need to be activated by electricity, and certain components, i.e. instruments from the measuring system, are responsible for that. The signal received from the transmitter is conditioned if necessary amplified, filtered and processed in other ways. The next stage in the path of the measurement signal is its transfer to components for storage or display. Recently, the measuring systems are almost regularly controlled by computers and appropriate application software.

The linearity, that is, the non-linearity of the instruments, results from the ratio of the input and output signal in the instrument. The most advantageous are the instruments that are linear due to the simple establishment of a connection between the input and the output. If the instrument is non-linear, it is necessary to know exactly the characteristics of such non-linearity. Even then, there is a complex process of taking the non-linearity into account, especially if it is not of the same character throughout the measurement range. Another significant characteristic of measuring instruments is their sensitivity expressed through the ratio of the output to the input value. Instruments with higher sensitivity are preferable to use because they give higher output for lower input signal levels. It enables the measurement of very small physical quantities with relatively small errors. The accuracy of individual measuring instruments is one of the most important characteristics. A measurement system composed of instruments with higher accuracy will ultimately give a value of the measured quantity with less error.

In water distribution networks, other than the nodes and links some additional controlling elements are used for smooth functioning of the system networks. Among the control elements such as check valves, flow-control valves and pressure reducing valves which is used to control the direction of flow through them, regulate the flow to a constant value, and reduce the water pressure to a required value respectively [7].

In the professional practice the conventional design of an urban water supply and distribution system is based on a number of simplifying assumptions, the most critical of which are:

a) The design discharge is based on the expected average demand of the estimated future population.

b) Empirical multipliers are used for estimating the maximum water demand.

c) The system is solved for steady state operation with the expected maximum demand.

d) The type of materials to be used is decided prior to the analysis of the system.

e) Pipe roughness and local energy losses are estimated using bibliographic data.

f) The internal diameters of the pipes are predetermined irrespective of the type of coating (e.g. internal coating in steel pipes has different depth if it is of epoxy resin or cement).

g) Energy losses are calculated with the expected maximum water demands concentrated at the nodes, uniformly and simultaneously distributed.

The major problem in this type of design is that all of the parameters involved are considered constant and reliable throughout the life cycle of the system [6].

## 2. DESCRIPTION OF THE SIMULATION MODEL AND MEASUREMENT SYSTEM

Hydraulic systems are widely used in modern machinery due to the many advantages they possess such as fast system response, sensitivity to significant loads, high power density and superior stability. The hydraulic system is often a core component of engineering equipment in control and power transmission systems. However, the hydraulic system can be easily damaged by exposure to the sun, dust particles or unstable operating conditions such as heavy load, cavitation or hydraulic shock. Therefore, such systems are prone to failures and if certain initial abnormalities are not located and eliminated in time, they may develop into a functional disability of the system and even lead to a dangerous condition and a complete collapse of the system. For this purpose, it is extremely important to promptly diagnose and eliminate such problems [1, 2, 3].

However, the appropriate diagnostics of hydraulic systems still remains a challenge. Compared to common mechanical and electrical systems, hydraulic system faults are often hidden and obscure. Therefore, it is difficult and complex to obtain information about errors and to find the relationship between the characteristic of the error and the cause of that error. According to this, it can be concluded that it is extremely important to investigate the key technologies and methods for performing quality diagnostics and management of hydraulic systems [4, 5].

For this purpose, a small simulation model (Figure 1) and a measuring system were made, which will serve as a basis for further tests. The purpose of the simulation is to examine the behaviour and the possibilities of measuring and controlling the flow and pressure in a certain node of the ring-type water supply network in the case of a system failure. The simulation was done in the software package PipeFlow Expert.

The measuring system consists of monitoring the pressure and the flow transmitters in the ring-type water supply network. The simulation installation consists of interconnected pipes in the form of four rings with valves which give us the possibility of flow control in each node.

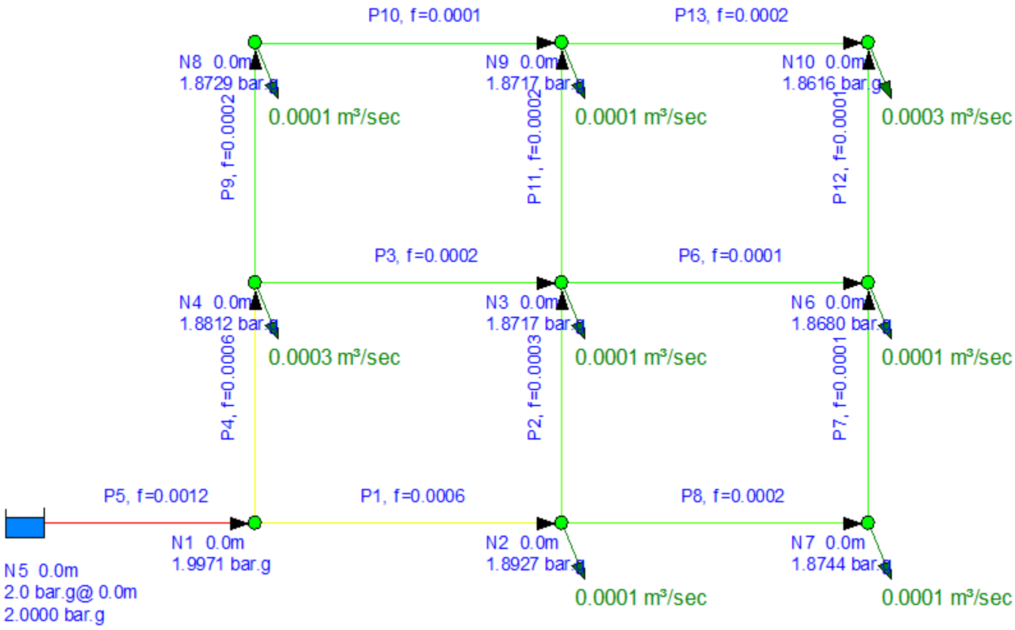


**Fig. 1.** Simulation model

## 3. SIMULATION OF NORMAL OPERATION MODE

For the simulation of normal operation mode, the following settings of the ring-type water supply network were made:

• diameter of the pipes in the ring-type water supply network (PVC pipe $D_{N15}$);

• diameter of pressure line from pump (reservoir) to node N1 (PVC pipe $D_{N40}$);

• pipe length $L$ = 1 m;

• pressure in tank (pump) $p_R$ = 2.0 bar (constant);

• flow in critical consumers $Q_{N4} = Q_{N10}$ = 0.0003 $m^3$/s = 18 lit/min;

• flow in normal consumers $Q$ = 0.0001 $m^3$/s = 6 lit/min;

• geodetic placement of consumers (elevation) = 0.0 m;

• minimal required working pressure in the critical nodes N4 and N10 of ring-type water supply network $p_R$ = 1.5 bar.

From the obtained results (Figure 2), it can be concluded that the ring-type water supply network works correctly under normal conditions and the critical nodes $N_4$ and $N_{10}$ in the ring-type water supply network receive the required flow $Q_{N4} = Q_{N10}$ = 0.0003 $m^3$/s = 18 lit/min and required pressure $p_{N4}$ = 1.8812 bar and $p_{N10}$ = 1.8616 bar which is bigger than the required pressure $p_R$ = 1.5 bar.

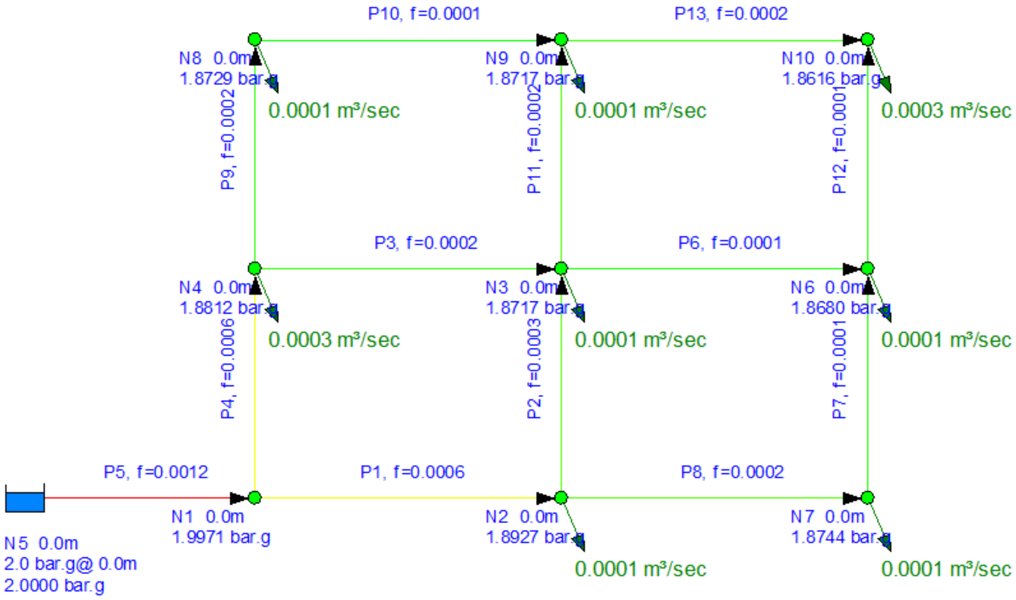


**Fig. 2**. Ring-type water supply network normal operation mode

## 4. SIMULATION OF FAILURE MODE

For the simulation of the failure mode, it was taken into account that in the system there are two broken pipes ($P_4$ and $P_{13}$). From this simulation it can be seen how the system is performing without any external regulation. The results are shown on Figure 3.

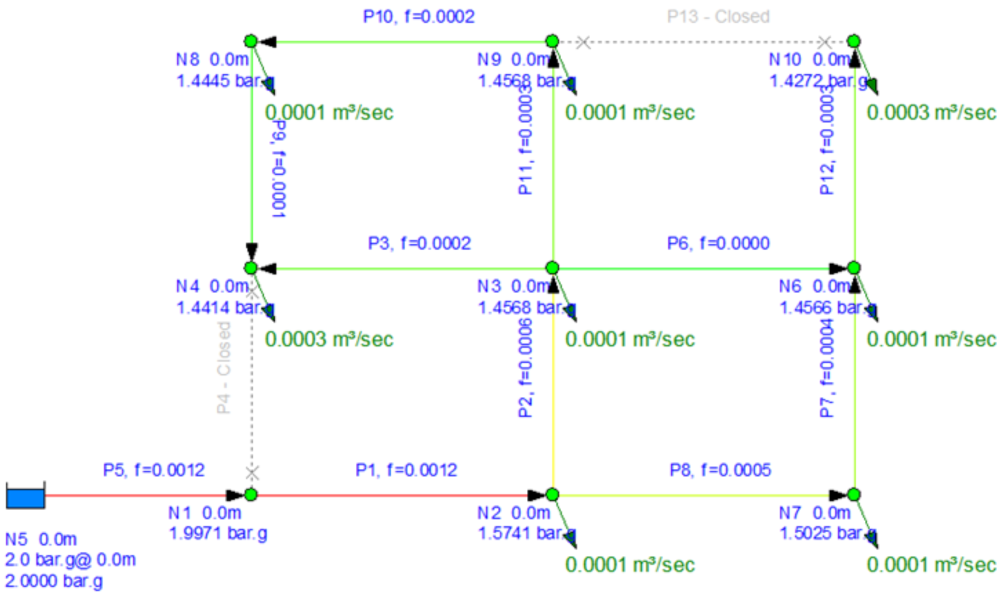


**Fig. 3** Simulation of failure mode

From the obtained results, it can be concluded that the ring-type water supply network doesn't works correctly under abnormal conditions and the critical nodes $N_4$ and $N_{10}$ in the ring-type water supply network receive the required flow $Q_{N4} = Q_{N10} = 0.0003\ m^3/s = 18$ lit/min and but not the required pressure $p_{N4} = 1.4414$ bar and $p_{N10} = 1.4272$ bar which is smaller than the required pressure $p_R = 1.5$ bar. This means that for such problems in the ring-type water supply networks it is need some kind of regulation in order to achieve the requested parameters.

## 5. SIMULATION WITH REGULATION IN FAILURE MODE

For the simulation with regulation in failure mode, it was taken into account that in the system there are the same two broken pipes ($P_4$ and $P_{13}$) but it is needed something to be done in order to achieve the requested parameters in the critical nodes N4 and $N_{10}$ of the ring-type water supply network (required flow $Q_{N4} = Q_{N10} = 0.0003$ m$^3$/s = 18 lit/min and the minimal required pressure $p_R = 1.5$ bar).

From this simulation it can be seen how the system is performing with external regulation. The results are shown on Figure 4.

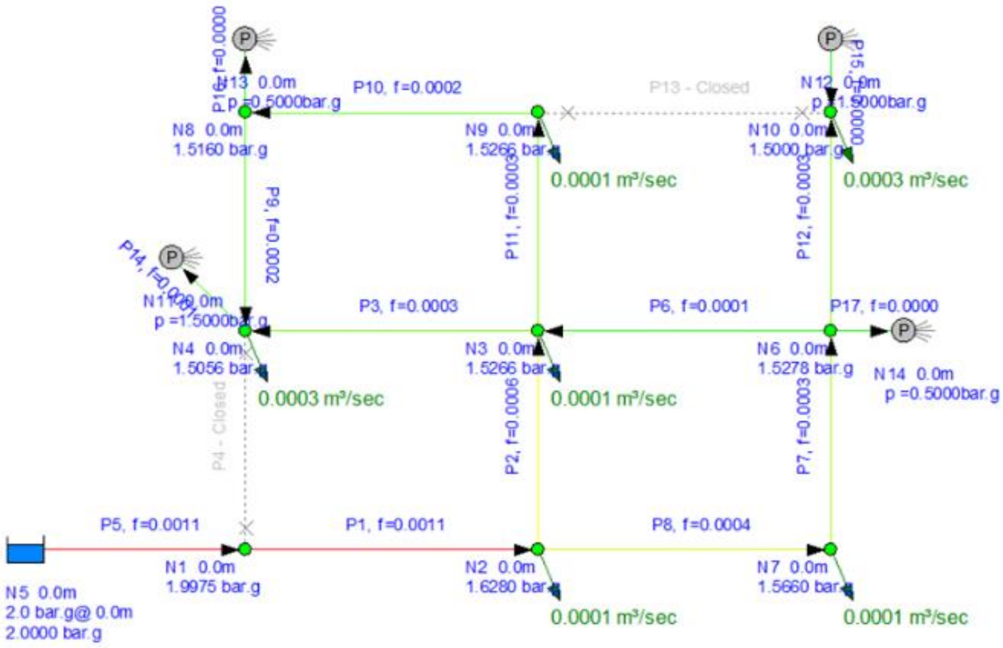


**Fig. 4.** Simulation with regulation in failure mode

From the obtained results, it can be concluded that the ring-type water supply networks can work correctly also under abnormal conditions and the critical nodes N4 and N10 in the ring-type water supply networks can receive the required flow $Q_{N4} = Q_{N10} = 0.0003$ [m$^3$/s] = 18 [lit/min] and the required pressure $p_{N4} = 1.5056$ [bar] and $p_{N10} = 1.5000$ [bar] which is bigger than the required pressure $p_R = 1.5$ [bar]. This means, that for such problems in the ring-type water supply networks it is needed some kind of regulation in order to achieve the requested parameters. In this case a regulation of the flow and the pressure in the nodes N8 and N14 was done in order to achieve the requested outcome.

## 6. PRACTICAL EXPERIMENT TO PROVE THE CONCEPT

After receiving positive results from the simulation, a small ring-type water supply network was built in order to prove the concept and confirm the obtained results from the simulation (Figure 5).

**Fig. 5.** Practical experiment

The experimental ring-type water supply network was equipped with manometers and pressure gauges to monitor the pressure in every node of the network, then hand valves to control the flow in every part of the system and a proportional valve in order to fine tune the parameters in the critical nodes. The control and monitoring of the system was done with specially developed software for this purpose. This algorithm was coded and developed in LabVIEW from scratch.

## 7. RESULTS AND DISCUSSION

Once again three different situations were examined: the normal operation mode, failure operation mode and the regulated failure mode. The results as expected were the same as in the simulation. With this knowledge can be concluded that it is possible to regulate the ring-type water supply networks in such a way that it can obtained the required parameters in some critical nodes.

## 8. CONCLUSIONS

Data collection and analysis is vital to any complex system. Without sufficient or good quality data it is not possible to make decisions about the state of the system. On the other hand, this can save us a lot of money if, based on the data, we can predict when a machine or system would break down and act preventively.

With the constant development of science and technology, mechanical engineering is also constantly developing and changing, from traditional mechanical engineering to modern electronic-mechanical engineering - mechatronics. And the level of automation of the systems has continued to improve and is entering a new phase of development. Recently, artificial intelligence technology has been increasingly combined with mechanical and electronic engineering.

Deep learning (artificial intelligence) is an area that opens up huge opportunities because it allows us to extract a lot of knowledge from raw data. The basis of deep learning is data analysis. In this age of internet and internet of things, data is everywhere and if we can extract it efficiently, we can achieve a lot. The goal of this project is to study the possibilities of applying artificial intelligence in the management and control of ring-type water supply networks.

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