Techno Science
International Scientific
Journal of Technical
Sciences

Reliability of water supply systems

HARIS MEŠIĆ

THE FACULTY OF TECHNICAL STUDIES, UNIVERSITY OF TRAVNIK, TRAVNIK, BOSNIA AND HERZEGOVINA

ABSTRACT

Applying reliability analysis is very important to achieve technically and economically sustainable water management systems. The classic organisations whose task was to deliver water to consumers, regardless of the price and quality of services, are transformed into high-tech enterprises and those using computer science, where one of the dominant criteria is economic or financial sustainability. Under such conditions, the actual data on produced and distributed water, as well as accurate data on the network state become imperative, since they are the basis for making decisions regarding the water management system and economic cost effectiveness evaluation management. During the exploitation process, the consequences can be pronounced due to the water supply system functional failure. The water system is subject to external and internal influences, which reflects its ability to distribute water. Impacts are manifested by the water supply system components failure and water losses. During the water systems exploitation, various types of energy (mechanical, thermal, etc.) affect the change in their planned function project (water distribution). Reducing water losses and increasing reliability should be the goal of every water supply system, as this will lead to an improved economic and environmental performance, and certainly a better service for users. Reliability can be considered as the water supply system's ability to function in relation to the failure of one or several components. Similarly, it can be viewed as the ability of the system to provide a service at an acceptable level, despite the failure and complex operating conditions. The creation of reliable water supply systems is not possible without reliability standardisation by way of basic indicators, important for indicating technical conditions. Under the term reliability standardisation we mean a list of indicators and their markings important for assessing the water supply system accuracy. Water systems are very complex configurations with targets, constraints and a number of connections with the environment. Difficulties in planning the water systems management are numerous uncertainties; uncertainties and random effects of input sizes and the required output states. The water supply system is a stochastic system characterised by the probability or reliability of the system functioning. By doing this, the reliability analysis can establish a model for monitoring the water supply network maintenance process and, by analysing the collected data, objective decisions can be made.

Keywords: Reliability, water supply system, water losses, decision criteria, failure, indicator analysis, standardisation.

Water Systems Reliability and Management

There are two primary objectives in the projection and exploitation of the water distribution system, which are the minimum water supply costs and maximum water supply system reliability. The two objectives are in conflict, but regardless of the increase, i.e. an increase in water supply reliability, the increase in costs is almost inevitable. The problem of designing and exposing the water distribution system is its multi-functional nature. The main problem faced by engineers and government representatives involved in the design, management and maintenance of the water supply system distribution is how to bring reliability and costs to a satisfactory level.

The part of the process happening in the water supply system affects its technical characteristics. These processes temporarily change the parameters of the constituent parts (water pipes, water metres, etc.) and/or the water supply system in some limits, without progressive deterioration The most characteristic example of such processes are elastic deformations, temperature deformations, etc., where, for example, extremely low temperatures lead to freezing in certain parts of the pipeline, water metres, valves, etc., and thus prevent its functioning, the functioning of a part of the water supply system or the system as a whole. The second group are processes that, over time, lead to a progressive deterioration of the water supply system technical characteristics. The most characteristic examples are attrition, corrosion, weariness, etc.

System diagnostics

The notion of diagnostics, or diagnosis, first appeared in medical science where it has a broad meaning. It comes from the Greek word diagnosis, which denotes recognition (conclusion) and evaluation. Ea doleni con re et occullesed unt, quost landesti nonserit rehenem. This term should include all activities that are undertaken in order to assess the current state of the water supply system in order to take over the planned activities of maintaining the water supply system in the future.

Water distribution reliability and the water supply network diagnostics and maintenance are interconnected terms which determine the water supply system's technical condition as a whole. Diagnostics is an important component of the water supply system technical maintenance, since it enables the disassembly (which includes excavations, testing and other construction works) to determine the system's technical condition and to predict the resource of its safe operation in the future.

Checking (controlling) the accuracy of the water supply system or its component elements (pipelines, fittings, etc.) during the construction and exploitation period allows defective parts to be detected in time (whether pipes, bolts, etc.). Technical diagnostics in water system testing is applied in determining: the distribution state, the degree of damage or water loss and the quality of water distribution and maintenance. There are two options available for the implementation of measures: permanent ones, or permanent and periodic diagnosis.

With permanent diagnostics, diagnostic devices (e.g. flow and pressure metres) are permanently installed on the water supply system itself (water lines, nodes,...); on the basis of selected diagnostic parameters, they control the state of the most important parts of the water supply system for the time of its operation or the water distribution. As a disadvantage, there is a need for increased investments in diagnostic devices, since every major segment of the water supply system should have such devices built-in. In contrast, in the periodic diagnosis, the diagnostic measures are applied after a certain time passes in the water supply system operation, and the disadvantage is that the response related to the system malfunction is not immediate, or we cannot recognize the occurrence of a malfunction immediately after its emergence as with permanent diagnostics.

RELIABILITY STANDARDISATION

Reliability standardisation and estimation by way of certain results' a priori information indicate the actual state of the water supply system at a given moment and the default exploitation conditions. Predicting the behaviour of the water supply system in the future, depending on changes in parameters and operational conditions, engages and examines the area of anticipation (predicting technical conditions in the future). Based on the results of predicting, we can manage reliability in the operation and exploitation process through test planning and technical maintenance.

Basic reliability predicting data relate to:(1) predicting the legality pertaining to system reliability in relation to the perspective of the water supply system's water supply development, finding new materials for water supply systems, raising the parameters of the work process and other tendencies; (2) predicting the water supply system reliability based on its measured parameters, and (3) predicting the system reliability for functioning in extreme conditions.
In general, all predicting tasks can be separated according to the design, production and exploitation stages, so as to interconnect them, because special methods are needed for solving them.

Elements of the water supply system reliability theory

The water supply system functioning is the supply of chemically and bacteriologically pure drinking water to consumers with the required pressure in the distribution network, while meeting the users' needs for the water amount. If one of these components does not respond to the request, due to failure, the water system will "fall" because it does not support / meet the generally required: consumption, operating pressure and quality of the delivered water.

The water distribution system is based on, or exists on, several different key components, such as: water pipes, valves, pumps and nodes. For the system components, we say that they are mechanically independent, but also dependent on hydraulics. This practically means that the mechanical failure of the pipe or node will be reflected as a disruption to the output performance in a hydraulic sense, which affects the water quality or leads to interruptions in the water supply. Mechanical reliability is the ability to maintain components in a functional state, where proper maintenance gives the required level of functioning. Hydraulic reliability is the ability of a water distribution network to provide the required water supply or a minimum pressure to the hubs required so as to supply the required amount of water consumption. The necessary / required pressure is the pressure at which all consumption is available at all the designated points of interest, and the minimum required pressure is the one where there are no interruptions in the water supply. The minimum pressure can also be determined by the pressure that is considered to be missing from the water. The hydraulic reliability of the water distribution network can be improved if the rainwater supply is used (network stops) or if there is more than one supply source. Mechanical reliability is a function of the quality related to the built-in elements that can be improved by regular maintenance.

SYSTEM FAILURE

There are three basic conditions for all water distribution network components: full functioning, partial functioning and non-functioning. All three conditions apply to both hydraulic and mechanical conditions. From the aspect of this work, only the states of full functioning or non-functioning are important. Under the term failure of network components we mean a situation when they no longer perform their required function.

The mechanical failure can be estimated using probability or empirical formula (failure rate analysis) or by combining both modes. Failure probability is the probability that a particular component can be cancelled at a given time or a time interval (we use time dependency in the calculation). Failure probability can be applied to all components of a given type, providing the estimated number of failures. This can be estimated using different formulas or statistical approximations based on the available data for this type of system component. The empirical failure rate is based on the measurement data database, i.e. based on the collected data. The failure rate is the number of failures expected from a number of components or it may indicate the number of failures that happen during a year, by using the length of the water line (network) or the year of construction. It provides an estimate of the failure probability for a particular component or system element.

Hydraulic failure is a function or a form of mechanical failure or initial conditions, in terms of the wrong starting values in relation to the required ones. There are three types of hydraulic failure: connection failure, pressure failure (inadequate pressure) in the network and water supply cancellation, and they are all mutually dependent. A connection failure is the failure of a connection, a connection that connects two nodes, or if the pressure drops before the node reaches a value below zero. This cancellation will affect the rest of the network and lead to the next failure, which is the cessation of water supply and pressure behind the affected nodes. Pressure failure occurs when the demand for a node is greater than that available (projected, foreseen,...) for the pressure. It happens when the location of the shaft connection is farther away from the intended and the water needs additional nodes for reaching the destination resulting in an increase in speed and thus an increase in the loss of pressure (the increase in speed is directly proportional to the pressure drop). The failure of the water system depends on each connection (link) break or a reduction in the necessary pressure, and in case the node consumption / demand is not fully met.

Conclusion

Maintenance during the water supply system functioning combines a series of accompanying activities, starting with the idea and definition of the concept, the evaluation of their cost-effectiveness, realization, exploitation, up until the system failure due to use. The process of maintaining the components and elements as one of the essential parts of the water supply process has the task of preventing and eliminating system failures, primarily through rationalization and optimization of their use, increasing productivity and cost-effectiveness in the process of exploitation. An analysis of the system "life cycle" is required and presented through a systematic and analytical overview of the resources needed to support the factional process with the aim of identifying and quantifying them. One of the basic characteristics of the modern water supply systems functioning is providing a high level of their reliability.

The concept of reliability should be present in all periods of the water supply system development and use, i.e. during its entire life cycle. Failure leads to a standstill in the water system operations and causes a significant increase in the exploitation costs. The lack of adequate reliability considerations has consequences reflecting material losses and slowing down technological advances at various organization levels. Reliability predicting is a continuous process that begins with predicting on paper, based on the construction and information on earlier failures, and ends with reliability measures. It should not be considered that reliability prediction is only an end in itself. The reliability forecasting process is justified only if it proves useful in providing a more reliable end result, i.e. proper water supply.

References

1. Alegre H., Baptista J.M., Cabrera E., Cubillo F., Duaarte P., Hirner W., Merkel W., and Parena R., Perfomance Indicators for Water Supply Services, IWA Publishing, London, 2007.
2. Arenz, B. et al., Netzmeister - Technisches Grundwissen Gas, Wasser, Fernwärme. Oldenbourg Verlag, Germany, 2007.
3. Brothers, K., DMA Design One Size May Not Fit All. Proceedings of the 5th IWA Water Loss Reduction Specialist Conference, Cape Town, South Africa, 2009.
4. Andreou S.A., Marks D.H., R. M. Clark, A new methodology for modelling break failure patterns in deteriorating water distribution systems: theory, Adv. Water Res, 10(3) (1987), p. 2-10.
5. DVGW, Arbeitsblatt W 392 Rohrnetzinspektion und Wasserverluste Maßnahmen, Verfahren und Bewertung. Deutsche Vereinigung des Gas- und Wasserfaches (DVGW), Bonn, Germany, 2003.
6. Fanner, P. and Thornton, J., The Importance of Real Loss Component Analysis for Determining the Correct Intervention Strategy. Proceedings of the IWA Specialised Conference 'Leakage 2005', Halifax, Nova Scotia, Canada, 2005.
7. Janet M. Wagner, 1 Uri Shamir, 1 Member, ASCE, and David H. Marks, Water distribution reliability: Analytical methods, ASCE, 1988.
8. Kingdom, B., Liemberger, R. and Marin, P., The Challenge of Reducing NonRevenue Water (NRW) in Developing Countries. World Bank, Washington, USA, 2006.
9. Lambert, A. O., International Report: Water losses management and technique. Water Science and Technology: Water Supply. pp. 1-20, 2002.

Pouzdanost vodovodnih sistema

SAŽETAK

Primjena analize pouzdanosti je veoma važna kako bi se postigao tehnički i ekonomski održiv sistem upravljanja vodama. Od klasičnih organizacija čiji je zadatak bio da bez obzira na cijenu i kvalitet usluga isporuči vodu ka potrošačima, transformišu se u preduzeća visoke tehnologije i informatike, gdje je jedan od dominantnih kriterijuma i ekonomska ili finansijska održivost. U takvim uslovima, stvarni podaci o proizvedenoj i distribuiranoj vodi, kao i tačni podaci o kvalitetu vode postaju imperativ, jer se na osnovu njih donose odluke o upravljanju radom vodovodnog sistema kao i ocjene ekonomske isplativosti. U toku procesa eksploatacije tj. snabdijevanja vodom mogu nastati izražene posljedice zbog prestanka funkcionisanja vodovodnog sistema. Vodovodni sistem je podvrgnut spoljnim i unutrašnjim uticajima, a što se odražava na njegovu sposobnost distribuiranja vode. Uticaji se manifestuju putem otkaza sastavnih dijelova vodovodnog sistema i gubitaka vode. U toku eksploataciji vodovodnih sistema, na izmjenu njihovog projektom predviđenog funkcionisanja (distribuiranja vode) utiču razni vidovi energije (mehanička, toplotna, itd). Smanjenje gubitaka vode i povećanje pouzdanosti trebalo bi da bude cilj svakog sistema vodosnabdijevanja, jer će to dovesti do poboljšanih ekonomskih i ekoloških učinaka, a svakako i bolje usluge za korisnike. Pouzdanost se može smatrati sposobnošću funkcionisanja sistema vodosnabdijevanja u odnosu na otkaz bilo koje komponente ili više njih. Slično kao i sposobnost sistema da obezbijedi usluge na prihvatljivom nivou, uprkos otkazu i složenim uslovima funkcionisanja. Stvaranje pouzdanih sistema vodosnabdijevanja nije moguće bez standardizacije pouzdanosti po osnovnim pokazateljima, značajnim za ukazivanje tehničkih stanja. Pod standardizacijom pouzdanosti podrazumijevamo spisak pokazatelja i njihove oznake važne za procjenu tačnosti sistema vodosnabdijevanja. Vodovodni sistemi imaju dosta složenu konfiguraciju, ciljeve, ograničenja i brojne veza sa okolinom. Poteškoće u planiranju upravljanja vodnim sistemima su brojne neizvjesnosti, neizvjesnosti i slučajni efekti ulaznih podataka i potrebnih izlaznih stanja. Vodovodni sistem je stohastički sistem koji karakteriše vjerovatnoća ili pouzdanost izvršavanja sistemske funkcije. Uzimajući ovo u obzir, analizom pouzdanosti može se uspostaviti model za praćenje procesa održavanja vodovodne mreže, a analiziranjem prikupljenih podataka mogu se donijeti objektivne odluke.

Ključne riječi: Pouzdanost, vodovodni sistem, gubici vode, kriterijumi odlučivanja, otkaz, analiza pokazatelja, normiranje.

Received: December 10, 2017 / Accepted: December 15, 2017
Correspondence to: Haris Mešić, Faculty of Technical Studies, University of Travnik (Bosnia and Herzegovina)
E-mail: h_mesic@msn.com