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Analysis Model of Physical Leakage Flow Based on Blind Source Separation Theory

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Abstract

A new physical leakage flow analysis model is established based on blind source separation theory (BSS). The model simultaneously considers the correlation and uncertainty between water consumption and physical leakage flow, takes constraints independent component analysis (CICA) algorithm in BSS, respectively establishes reference vector of water consumption and physical leakage flow to obtain the waveform information of physical leakage flow. The standard deviation and mean of the two flows are respectively calculated based on water balance analysis report and minimum night flow, to achieve the amplitude reduction of physical leakage flow. This analysis model is the application of the high-order statistical information of water distribution network operation data with high simulation accuracy.

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Keywords: *Water distribution network, physical leakage flow, blind source separation, constraints independent component analysis, amplitude reduction.*

Water distribution network leakage has caused huge waster of water resource and energy, in which physical leakage is a major component. It is significant to establish a physical leakage flow analysis model to analyze the physical leakage state and guide leakage control.

The typical models for single leakage point include orifice flow model[1], FAVAD model[2], index model and

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pressure-driven node flow model, etc. The expression of index model is simple, such as formula(1) and it is widely applied to engineering for higher fit of relationship between physical leakage flow and head. The factors like pipe material, leakage hydraulic conditions, soil hydraulic conditions, funnelled size and shape, etc, can enormously impact on the leakage coefficient and index but difficult to fully informed for pipes laying underground. Thus, the parameters in formula(1) is difficult to confirm. In addition, leakage index value is in widely range of 0.5~2.5, which can lead to the complex relationship between single leak physical leakage flow and water head.

$$q_l = \alpha h^{\beta} \tag{1}$$

Where q_l is the physical leakage of single leakage point; α is leakage coefficient of the leakage points; β is leakage index of the leakage point; h is the head in pipes.

In tradition simulation models, physical leakage flow in water supply network is mainly regarded as the sum of physical leakage flow for all leaks based on the index model of single leak. According to the difference of dealing with leakage coefficient and index and complexity of model solve degree from low to high, the model is mainly developed into equivalent leak index model,consistent leakage model, night minimum flow model (also called leakage coefficient value classification model),leakage coefficient ratio value model[3], BABE model. There models have strong subjectivity of parameter selection and are lack of reliable data verification, which cause the simulation for physical leakage flow is not accurate.

In addition, according to recent study, the viscoelasticity of pipes leads to physical leakage flow in the process of step-up is smaller than step-down with same head, which means the relationship between single funnelled physical leakage flow and head is uncertain[4]. Whereas, most physical leakage flow analysis models of water distribution network are established for a certain relation with the head as independent variables and unable to simulate above uncertainty.

This paper has built a new method to accurately simulate the physical leakage flow analysis model, that can effectively solve or avoid the complexity of physical leakage flow and water head and reflect the uncertainty of them.

1. Applicability of blind source separation theory to solve the physical leakage

1.1. Basic questions of physical leakage in water distribution network

According to the water balance analysis offered by IWA, water supply volume amount is consist of four parts: the sale of water, free water supply, carrying water leakage and physical leakage. Because all water points can not be real-time metering flow, physical leakage flow can not be certain at any moment but be counted in total water supply flow with other flow.

Total supply flow is divided into physical leakage flow Q_L and water flow Q_Y and establish the basic formula (2) in this paper, in which the physical leakage flow corresponding to the physical leakage amount and the water flow corresponding to the sale of water ,free water supply and carrying leakage amount.

$$Q_Z = Q_Y + Q_L \tag{2}$$

1.2. Applicability of blind source separation theory analysis

Physical leakage flow and water flow are regarded as two source signals, and other observed data like flow and head, is acted as mixed signal in operation. When source signal changes and it is not clear to make sure how to reflect mixed signal through a certain inherent rule, the method of basing on observed signal and little apriori information, such as the statistical distribution characteristics of total water flow, to isolate the source signal can be clear. Thus,

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