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A new approach to model development of water distribution networks with high leakage and burst rates

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Abstract

Modelling real distribution networks can be particularly difficult if they are so leaky that the types of leak and their nature can hardly be determined from scarce field measurements. In this context, a new approach to model development of such WDNs is proposed. The method is based on leakage estimation from MNF and the burst frequency of AZPs. After applying it to a real DMA in Mauritius, the resulting calibrated model from EPANET is found to approach the actual status of the network very closely in terms of overall real losses, coefficients of discharge, nodal flow and pressure.

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1. Introduction

In many African and sub-Sahara African countries, the state of the water distribution network (WDN) is such that corrective maintenance is carried out only when there are pipe bursts and heavy leaks. Monitoring water losses through flowmeters and pressure sensors is quite costly within an old infrastructure which just needs replacement. However, replacement is a long term process which requires a lot of investment. The only of way of alleviating the problem in the short term, is to adopt a proper pressure control strategy in order not to further damage the old existing pipes and avoid excessive water losses since it is now well established that the rate of leakage depends on pressure. System analysis techniques (modelling, simulation and optimisation) are now widely accepted within the water utility industry as a mechanism for reducing the spatial and temporal complexities of water distributions. The

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present work focusses on model development of heavy leaking WDN using Rossman's [6] Epanet software. The idea is to develop a model which can be used for pressure management rather than to locate exactly the leaks in the networks. The method developed here is a sustainable one which is valid even when the old infrastructure is replaced since leakage is inherent in any WDN. The research has been carried out taking into account the relevant burst frequency of pipes of the average zone points in the DMA as well as the minimum night flow in order to quantify the leakage rate at specific locations.

1.1 Background leakage

According to Torricelli's theorem, the rate of leakage Q_l is proportional to the square root of the pressure head H in a pipe.

$$Q_l = C_l A_l \sqrt{2gH} \tag{1}$$

where
C_l= the discharge coefficient
A_l= leak area
g=acceleration due to gravity
H= total head at the point of leak

Several researchers have conducted tests on orifice in pipes and the hydraulics is now very well understood. The rate of leakage is in fact proportional to the square root of the head at that particular leak point according to Hikki [7], Greveinstein and Van Zyl [2] irrespective of the pipe material and size of hole, thereby confirming the relationship:

$$Q_l \, \alpha \, H^{0.5} \tag{2}$$

However, leaks are not always of orifice type and therefore other shapes like circumferential and longitudinal cracks were investigated. A more general form of the leak equation which is proposed by Lambert [7] is:

$$Q_l = C\,H^N \tag{3}$$

where
C is the leakage coefficient
N is the leakage exponent

Rewriting the leak flow equation 1 according to FAVAD:

$$Q_l = C_d \sqrt{2g}\,(A_0 H^{0.5} + m\,H^{1.5}) \tag{4}$$

where
A_0 is the initial leak area
m is the slope of the head-area curve

This relationship, however as it is, can only be applied if we know the leak characteristics (A_0 and *m*) of the network beforehand and one leak is unlikely to be similar to another. Therefore, the use of this equation is limited and cannot be readily applied to a distribution network. Furthermore, the equation above predicts a maximum value of *N* of 1.5 and therefore does not explain the higher values of 2.79 for example found in field tests.

1.2 Real loss estimation using minimum night flow

P.Cheung et al. [1] used the Minimum Night Flow measurements in order to calculate the real losses of a DMA. They showed that the MNF method and the calibration process yield similar results in terms of leakage estimation.

The Daily Real loss Volume DRLV is given by

$$DRLV = F_{nd} \times Q_{mn} \tag{5}$$

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