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Optimizing the Design of Water Distribution Systems for Alternating Pump Flows

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Abstract: Water supply systems need to be designed efficiently, taking into account both construction costs and operating energy costs when a pump is required. Demand for water varies depending on current needs, especially for agricultural purposes, and water supply systems need to be designed accordingly. This paper presents a simple design methodology in which the total cost is equivalent to a variable demand flow using a constant flow rate. The methodology is based on the Granados system, which is a very intuitive and practical gradient-based procedure. The concepts of equivalent flow rate and equivalent volume are given and applied in a simple example to adapt it to seasonal demand. These concepts are simple in terms of calculation and simplify the process of designing hydraulic drives in the context of demand variability and can be used in several methodologies outside the Granados system. Equivalent flow rates and equivalent volumes offer solutions to design procedures that require a constant flow regime, adapting them to more realistic design situations and therefore expanding their practical scope.

Keywords: water distribution systems; optimization; design; pump operation; demand variability.

INTRODUCTION

In terms of the computational process, evolutionary programming methods such as genetic algorithms have been widely used to optimize water distribution, e.g., 1

On the other hand, demand changes are more extreme due to climate change, population migration, etc. [1], increasing variability throughout the year [2]. This seasonal change makes it more difficult for designers to correctly imagine efficient water supply systems. For these reasons, designs that can manage changes in demand are appropriate [3]. Babayan et al. [4] Enter this issue in optimizing them using standard deviations in the calculation of demand. In studies such as Granados et al. [5], safety coefficients are determined after sensitivity analysis of variables affecting demand change, especially for agricultural purposes. A different approach is used in Kapelan et al. [6], where stability is maximized by creating random flow conditions and calculating the probability of meeting the required conditions at all nodes. Babayan et al. [7] Compare the point of view of the safety factor with a certain probability-adjusted approach to random demand, and conclude that while both views have similar results, the latter is more expensive to calculate. As a suggestion for future work that will contribute to the crucial problem of optimizing the design of water distribution systems for variable pump flows, the study will focus on water sources and recyclables that can be used to balance water supply and water supply. water evaluation can also be considered. demand [8].

The aim of this study is to develop an understandable methodology that will help overcome the constraints that lead to the design of a water supply system with a changing regime of water demand and facilitate a practical approach. We propose two new design procedures that take into account variable demand, equivalent flow rate, and equivalent volume. The proposed methodology is based on a gradient-based procedure because it is very intuitive and does not require calculation, so it can be easily translated into practical terms. A practical example is given to illustrate the application.

The total value of the hydraulic impulse depends mainly on the cost of building the pipeline, the cost of building the pump station, and the cost of energy required for the pumps to operate for the entire life of the system. Other costs, such as maintenance and operation, may be overlooked because they are not directly related to pump or pipe size.

Total Cost = Pipe Construction + Pumping Station Construction + Energy

The cost of pipe construction will increase as the diameter of the pipe increases, as the cost of the pipes will increase and the excavation and installation costs will also increase due to difficulties in transportation and assembly.

The construction cost of a pump station can be considered to be relatively independent of the selected pipe, as different pump models usually have the same price and the group and stage configuration depends on the variability of demand rather than pipe characteristics.

The cost of energy depends mainly on the volume of water rising, as well as the efficiency of the head and pump. The head depends on the diameter of the pipe, because the larger the diameter of the pipe, the less the loss of the head. In this way, the use of a larger diameter reduces the cost of the pump. The relationship of pump efficiency with other factors is a variable that has not been studied in depth until recently. As a general rule, it was assumed that the larger the pump, the better its performance. Still, Martin-Candilejo et al. [9] concluded that there was a direct relationship between flow rate and pump efficiency, and examined the issue in depth: Pump efficiency is better for larger discharge flow and asymptotic for 90% reaches

Figure 1 is a cost distribution scheme depending on the pipe diameter. Since pipe diameters do not form a continuous sequence, but have discrete values on the market, the traditional way to solve the problem is to have different diameters and pumps that meet the technical requirements, and then each alternative is evaluated. at the lowest cost.

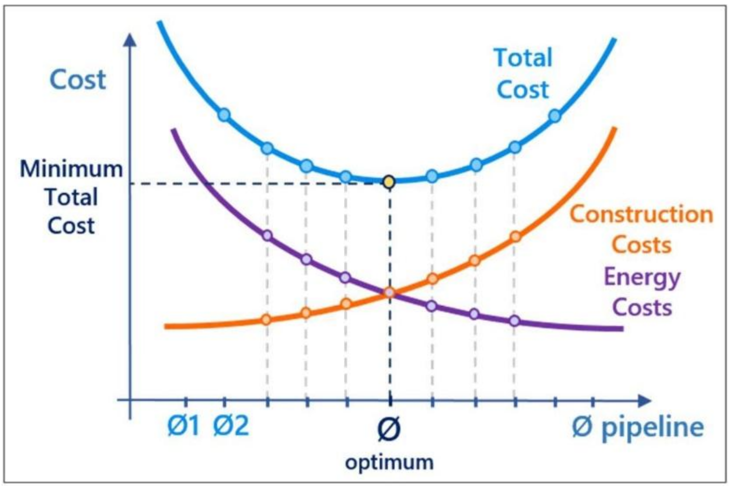

Figure 1. Simplified scheme of the costs of the water drive depending on the diameter Ø of the pipeline: As the diameter increases the construction costs rise but the head losses decrease, implying a reduction in the energy cost.[14]

The procedure proposed in this study is based on the following principle: by increasing the pipe diameter, the loss of the head can be reduced. This means saving energy costs, but also increasing construction costs. This can be studied from a unitary point of view: comparing the cost of reducing the head loss by one meter by increasing the pipe diameter so as not to raise the water by an additional meter by saving energy consumption. This is the Variation Gradient concept developed by Granados [10] as part of the Granados system pipeline optimization method. Changing the gradient only makes sense when the flow rate is constant. Therefore, for more realistic situations, this article has developed new concepts of equivalent flow rate and equivalent volume for two different procedures to design a hydraulic drive.[13.15]

The variation of the gradient [11] is defined as the value of reducing the head loss per meter by increasing the pipe diameter by Øj = Øi + 1 greater than Øi:

The theoretical position of the hydraulic drive was studied as a simple example of the application of the equivalent flow rate concept. The drive consists of two parallel pipes 500 m long. The reservoir serves agricultural purposes and has a total area of 3,000 ha. The system has no regulation at the end of the drive, as shown in Figure 5

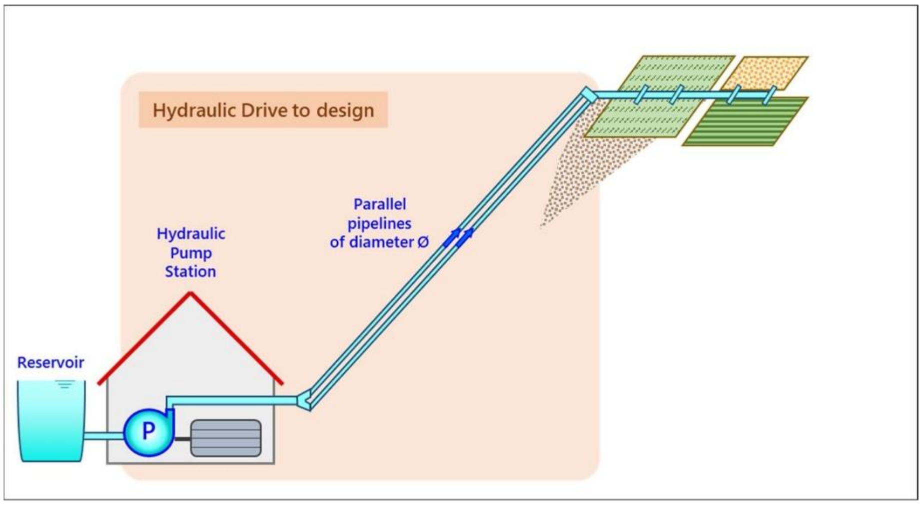

Figure 2. Case study scheme for application of the Equivalent Flow Rate concept.

The research provides a practical approach that allows the practical calculation of variable flow rates because: (a) Although the mathematical approach of the Granados system is dynamic, real computational resources allow it to work with static variables; and (b) it is efficient because it only requires a few operations to the optimum, which makes the proposed procedure very accurate in terms of calculation. The approach avoids the basic computational inconveniences of dynamic programming, which can limit its use in practical designs [12].

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