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Water efficiency indicators studies and energy applied to real water distribution system of south of Minas Gerais - Brazil

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Abstract: The indicators applied to water distribution systems help in its diagnosis and support the management actions. Hydraulic and energy-related indicators can relate energy consumption, input flow, pressures and demand to identify systems and tools to minimize energy costs and maximize hydraulic reliability. This study was carried out in a real system, in a city of the south of Minas Gerais, Brazil. With the available data, the main water and energy efficiency indicators were calculated based on Alegre al. (2014). Among those main parameters, the value of PH4 - Utilization of pumping capacity, 98.4%, Op23 - Water losses per branch, 55.90 m³/branch/year, Op 24 - Water losses per pipeline length, 8.57 m³/km of conduit/days. Op26 - Apparent water volume loss at system entry, 0.65%. The results indicate that the system as a whole has a reasonable behavior compared to other case studies regarding water and energy efficiency.

Key words: Water Distribution Systems, Indicator, Leakage, efficiency hydric

1. INTRODUCTION

Around the world, water and energy crises have recently taken place in the national and international media. The subject is important and worrying because it is two basic elements of the daily life of the population, water, and energy.

In this work, the focus is the water distribution systems losses at and the pumping stations energy, we will relate are mainly due to the existing losses and the inadequate operation, involving control of pressure levels, pump operation among others factors.

The method used is the study of the network either by visiting the sanitation companies or by hydraulic and electrical measurements parameters, thus generating some indicators for a better understanding and diagnosis of the system.

The author´s calculated important indicators for a better hydroelectric management of the sector under study taking into account the measures of flow, pressure, level, elevation of altimetry and electricity consumed.

Indicators are important tools that in the case of its application in water distribution systems have large applicability since they can diagnose systems and compare it with others. This allows managers to find problems and set up changes that can allow the water and energy best uses and so financial gains.

We will study in water distribution system of a mountainous city in the south of Minas Gerais, Brazil.

The indicators made calculated in the literature. However, some authors stand out in the field of study.

According to Alegre et al. (2004), the performance indicator (ID) is an instrument commonly used to test water distribution parameters at companies. His work specifies various indicators, wich highlighting the following items:

a) Indicators of water resources, Human resources indicators, Infrastructure indicators, Operational indicators, Service Quality Indicators , Economic and Financial Performance Indicators.

b) Another important and current document on Brazilian studied indicators was the SNIS (2015), which presents an extensive range of information and indicators capable of providing a comprehensive view to get consistent assessments of service performance across the country.

Cabrera et al. 2010 proposed work on the water balance and the energy-water in water distribution system. The analysis allowed us to represent all the energy of the system, which shows the importance the energy balance. This balance aims to get performance indicators and test the system from the energy point of view, thus identifying improvement actions to improve the efficiency of the system.

Vilanova (2012) presented work which had the initiative to develop a set of indicators of hydraulic and energy efficiency, allowing to compare the current situation of an optimal condition system, referring to components, physical and operational, more relevant in the hydraulic and energy context. The best condition to give the lowest energy and water consumption, taking into account the limits and operational requirements of the studied system. In this context, four indicators were proposed: optimum pumping operation indicator, hydraulic energy recovery indicator, available hydraulic load indicator and water efficiency indicator.

2. METHODOLOGY

With the choice of the municipality in a study developed a partnership. With the help of professionals from the water supply company, he defined a target sector, whose main need is the sectorization.

Propose the following studies from here:

- Determination of topographic dimensions using GPS equipment;
- Obtaining flow data using ultrasonic flowmeters;
- Compression data;
- Survey of the energy data of the pumps.

For this, before the field work, several trainings were carried out with the GPS equipment, flow and pressure meters, besides their calibrations and laboratory measurements.

Figure 1 illustrates the work done. Step 1 begins with the search for cities with the desired profile, where the company of interest forms a partnership and its place was near the region South of Minas Gerais, Brasil. In step 2, the longest and most laborious; Develops several trainings with the equipment. Also in this step he collected the field data. In step 3, the analysis of data from the field campaigns took place, as well as the establishment of indicators with their respective calculations.

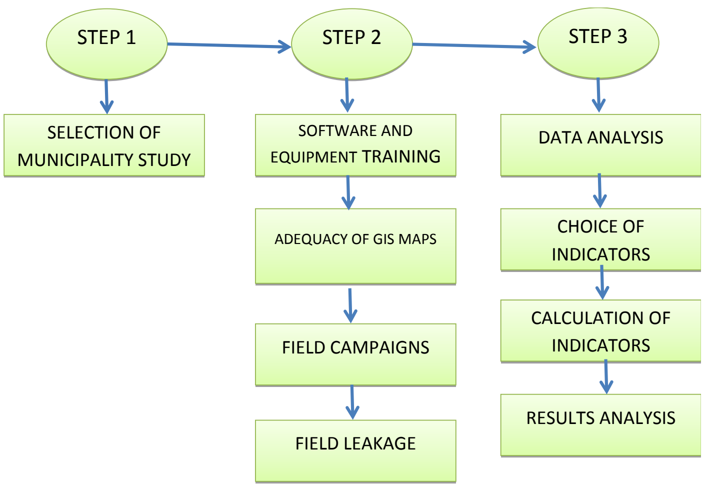

Figure 1. Workflow of work (adapted by Soares, 2016)

Figure 2 (Goulart, 2015) generated through the EPANET program, express well-defined topographic zones and help define nodes to receive the pressure meters. The node choices were important because they were low, medium and high-pressure regions.

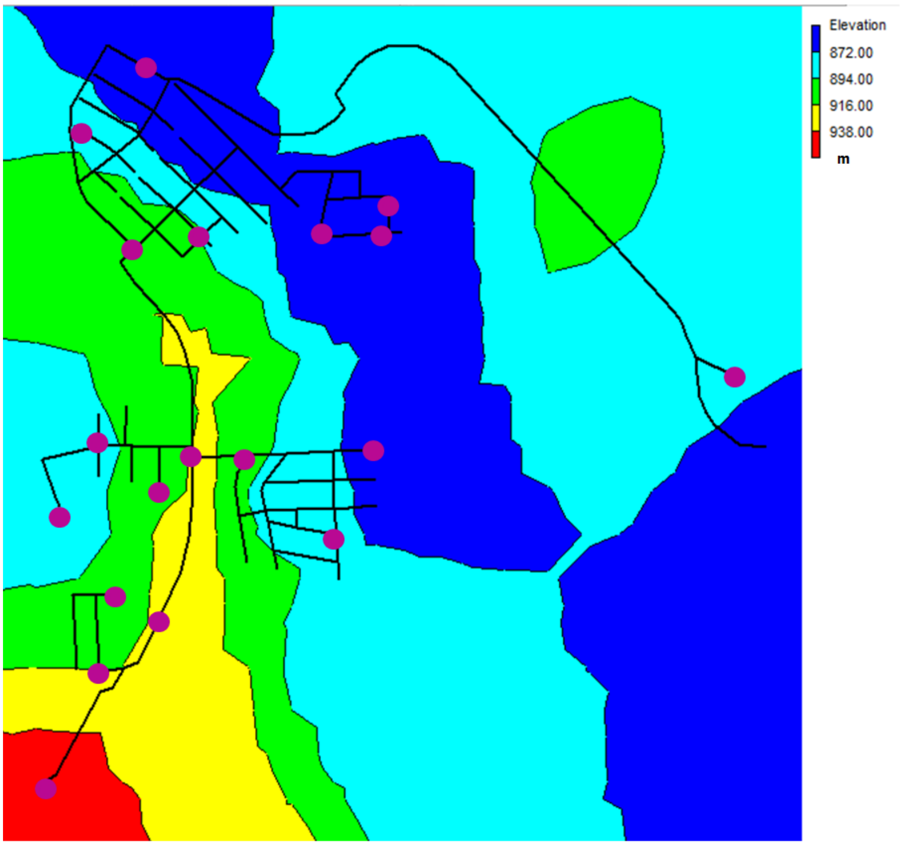

Figure 2. Location of the nodes of the houses that received the pressure gauges (Goulart, 2015)

2.1 Indicators choices

Evaluating the current literature, made an analysis to choose the indicators used. Alegre et al. (2004) was the main reference consulted and shows several existing indicators and method of calculation.

The focus indicators of this work follow:

A) Ph4 - Pumping capacity utilization (%).
B) Ph5 - Standard energy consumption (kWh / m³ / 100m).
C) Ph6 - Reactive energy consumption (%).
D) Ph8 - Valve density (n / km).
E) Ph 14 - Automation Degree (%).
F) Ph15 - Remote control Degree (%).
G) WR1 - Use of water resources inefficiency (%).
H) Op23 - Water losses per branch (m³ / branch / year).
I) Op 24 - Water losses per pipeline length (m³ / km / day).
J) Op26 - Apparent water volume loss at system entry (%).
K) Op 27 - Actual losses per branch (l / branch / day).
L) Op 28 - Losses by length of conduit (l / km of conduit/day).
M) Op29 - Leakage infrastructure indicator.
N) Fi46 - Financial indicator of water not billed in terms of volume (%)
O) Op39 - Water indicator not measured (%).
P) Minimum loss indicator (l / extension / day).

3. RESULTS

A) Ph4 - Utilization of pumping capacity (%).

Figure 3 it is possible to observe the values of the daily consumption in kWh referring to the pumps of the reservoir R3, during the week of the field campaign. The ordinate chart represents consumed energy.

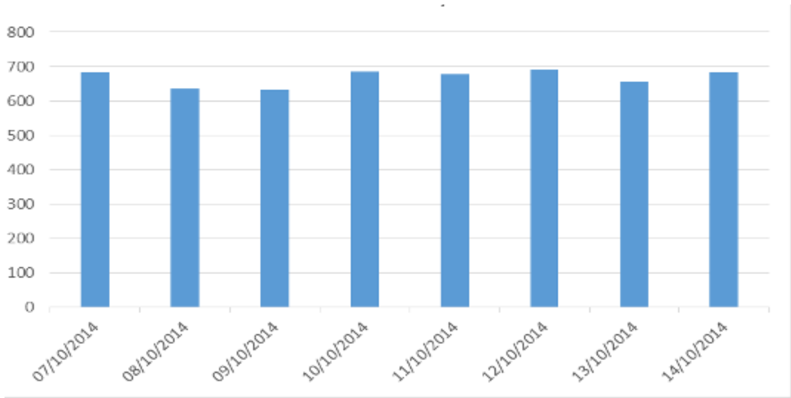

Figure 3. Daily energy consumption, with a maximum consumption of 683,297 kWh on 12/10/2014 (Soares, 2016)

Figure 4 shows the power in kW used by the pumps of the reservoir. In ordinate present power demand in kW.

The two charts are of high relevance, as its shows the pump consumptions, values used to calculate the Ph4 indicator.

$$Ph\ 4 = D\ 2 / (C\ 7 \times 24) \times 100 \quad (1)$$

D2 - Maximum daily energy consumption for pumping (kWh)), ie the number of hours of engine operation on the day of greatest energy consumption during the reference period X nominal power.

D2 = 683,297 kWh x 28,55% (value proportional to the sector).

D2 = 195.08 kWh.

C7 - Maximum pumping capacity of lifting stations (kW).

C7 = 28.77 kW x 28.55% (value proportional to the sector).

C7 = 8.21 kW.

Ph4 = 98.9%.

Thus, it was concluded that 98.9% of the pumping capacity was used on the day of greatest energy consumption.

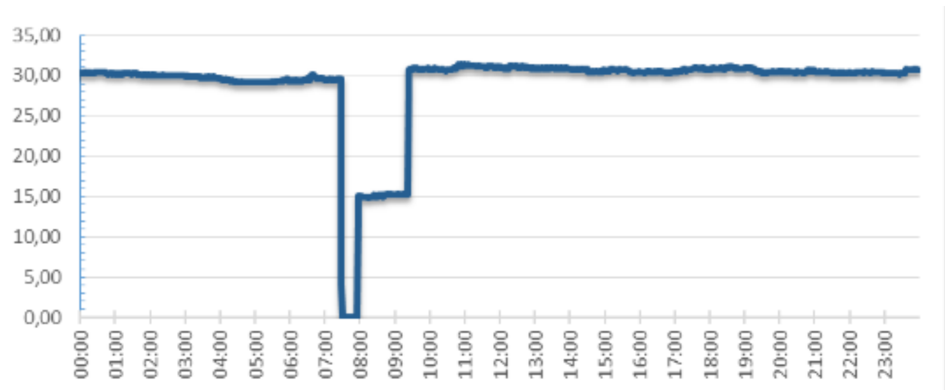

Figure 4. Curve giving an average power of 28.77 kW. (Soares,2016)

B) Ph5 - Standard energy consumption (kWh / m³ / 100m)

$$Ph5 = D1 / D3 \quad (2)$$

D1 - Energy consumption in pumping.
D3 - Uniformity factor (m^3x100m) ie the volume pumped in the period x gauge height / 100.
H - Total lifting height (gauge) of the system [m].
D3 = 54,39 x 125,43 / 100 = 68,22 (m^3x100m).
Ph5 = 0,40 kWh/m^3/100 m.

C) Ph6 - Consumption of reactive energy

$$Ph6 = D4 / D1 \times 100 \quad (3)$$

D1 - Energy consumption in pumping.
The average reactive energy consumption measured by the contracted company was 33401,702 kVar / min or 2004102,12 kVar / hour
D4 - Consumption of reactive energy, according to contracted company was on the average equal to 5780,22 kVar.
D1 - Energy consumption for pumping at the lift station. 655 kWh.
where kWh and kVar are equivalent and their admission ratio.
Ph 6 = 30.59%.
The result of Ph6 by more than 30% shows that the excessive spending of this reactive energy increases the energy invoice at the end of the month, generating a considerable financial loss.

D) Ph8 - Valve density (n / km)

$$Ph8 = C22 / C9 \quad (4)$$

C22 - Sectional valves. 8 records.
C9 - Length of distribution network (km). 8,698 km.
Ph8 = 8.698 / 8 = 1.08 records per km.
This indicator verifies the ability to isolate a sector if it needs to intervene in the network.

E) Ph 14 - Automation degree (%)

$$Ph14 = C16 / C15 \times 100 \quad (5)$$

C15 - Control unit. 2 units.
C16 - Unit with automatic control. 2 units.
Ph14 = 100%. That is, the sector was fully automated.

F) Ph15 - Remote control rating (%)

$$Ph15 = C17 / C15 \times 100 \quad (6)$$

C15 - Control unit. 2 units.
C17 - Unit with remote control. 0 units.
Ph15 = 0%. That is, there is no system-wide remote control in the industry that would help monitor the real-time industry.

G) WR1 - Use of water resources inefficiency

WR1 = A19 / A3x100 (7)

A19 - Actual losses (m^3). 26599,61 m^3 / year.
A3 - Water in the system inlet (m^3). 95795,61 m^3 / year.
WR1 = 27.77%.
This indicator reveals the inefficiency in the use of water resources in the sector under study, which was around 27.77%.

H) Op23 - Water losses per branch (m^3 / branch / year)

Op23 = (A15x365 / H1) / C24 (8)

A15 - Water losses (m^3). 27225.18 m^3 / year = 74.59 m^3.
C24 - Number of extensions (nº) .487 extensions.
H1 - Reference period (day).
Op23 = 55.90 m^3 / branch / year.

I) Op 24 - Water losses per pipeline length (m^3 / km / day)

Op24 = (A15 / H1) / C8 (9)

A15 - Water losses (m^3). 27225.18 m^3 / year = 74.59 m^3.
C8 - Length of the conduits (Km). 8,698 km.
H1 - Reference period (day).
Op24 = 8.57 m^3 / km of conduit / day.

According to Alegre et. al (2014) this indicator is applied because it has a density of extensions greater than 20 / Km (in this case they gave 56 extensions per Km).

J) Op26 - Apparent water volume loss at system entry (%)

Op26 = A18 / A3 x 100 (10)

A3 - Water at the system inlet (m^3). 95795,61 m^3 / year.
A18 - Apparent losses (m^3). 625.87 m^3 / year.
Op26 = 0.65%.

K) Op 27 - Actual losses per branch (l / branch / day)

Op27 = A19 x 1000 / (C24 x H2 / 24) (11)

A19 - Actual losses (m^3). 26599.31 m^3 / year = 72.87 m^3 / day.
C24 - number of extensions (number). 487 extensions.
H2 - System pressurizing time. Same as 24 h.
Op27 = 149.63 l / extension / day.

L) Op 28 - Losses by length of conduit (l / km of conduit / day)

Op28 = A19 x 1000 / C8 x H2 / 24 (12)

A19 - Actual losses (m^3). 26599.31 m^3 / year = 72.87 m^3 / day.
C8 - Length of the conduit. 8,698 km.
H2 - System pressurizing time. Same as 24 h.
Op28 = 8377.80 l / km of conduit / day.

According to Alegre et. al. (2004), this indicator does not apply because it has a density of extensions greater than 20 / Km (in this case they gave 56 extensions per Km).

M) Op29 - Leakage infrastructure indicator

Op29 = Op27 / (18 x C8 / C24 + 0.7 + 0.025 x C25) / (D34 / 10) (13)

Op27 - Actual losses per branch. 149.63 l / extension / day.
C8 - Length of conduits. 8,698 km.
C24 - Number of extensions. 487 extensions.
C25 - Average length of extensions. 4m (estimated).
D34 - Average operating pressure. 31.3 mca = 306.76 kPa.
Op29 = 4.36
Well maintained systems tend to have values close to 1.

N) Fi46 - Financial indicator of water not billed in terms of volume

Fi46 = A21 / A3 x 100 (14)

A3 - Water in the system inlet. 95795,61m^3 / year
A21 - Unbilled water. (2016). 27,225.18 m^3 / year
Fi46 = 28.42%
That is, 28.42% is the volume of unbilled water.

O) Op39 - Water indicator not measured

Op39 = (A3-A8-A11) / A3 x 100 (15)

A3 - Water in the system inlet. 95795,61m^3 / year.
A8 - Billed consumption measured. 68570,43 m^3 / year.
A11 - Unbilled consumption measured. 0.
Op39 = 28.4

4. CONCLUSIONS

In this paper performance indicators of water distribution systems. The application studied a city in the southern of Minas Gerais, Brazil. This city is within the research of NUMMARH - Nucleus of Simulation Modeling in Environment and Hydric Resources of the Federal University of Itajubá, Brazil. The indicators applied to a real system used as main reference the work of Alegre et al. (2004). The main conclusion of this work is the usefulness of this tool as a method to analyze the behavior of different systems. Because the indicators studied provided much information on the hydraulic structure under study. The NUMMARH group is currently studying other cities and intends to propose new indicators in future studies.

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