A CASE STUDY IN WATER AND WASTEWATER SYSTEMS' ENERGY EFFICIENCY

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***Abstract* – World economy is closely related to energy and to how it contributes to the modernization of the society, by raising the standard of living and the degree of civilization of the population. In this context, water supply systems are attractive for energy efficiency, occupying an important place in the hierarchy of energy consumers. The purpose of this paper is to present some important aspects of a case study that must be considered in order to respond to specific requirements of water supply systems and it also shows a few measures that can be implemented with or without investments in order to reduce costs and energy consumption.**

Keywords – energy efficiency, water suplysistems, reactive energy

I. INTRODUCTION

A significant part of the global energy consumption is represented by the water supply, at an international level. Taking into account the fact that during the 20th century the population of the world tripled and water use for human purposes multiplied six times (Figure 1), this energy consumption, used throughout the entire water supply process, involves a high cost, but however, costs can be minimized with and/or without reducing energy consumption [1], [2], [8]. If we only refer to the reduction of energy consumption, this could be reduced by at least 25% by improving the energy efficiency performances in the case of several water supply systems worldwide [6]. In the water industry, most of the energy costs are represented by electricity consumption for pumping water [7]. The technological scheme of a water supply and collection system and wastewater treatment system is shown in Figure 2 [3].Most of the water used in households and industry (even 90% in certain areas) is returned to the sewage treatment plants.

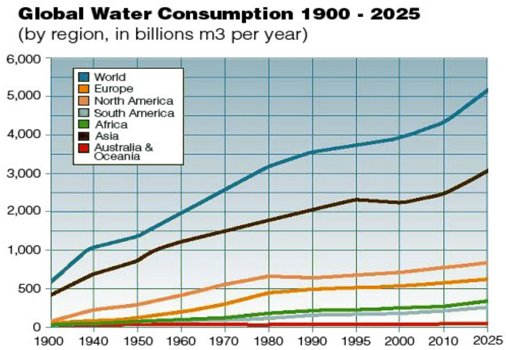

Fig.1. Global water consumption 1900- 2025 [14]

If we take into account that in North America the average residential water use is of approximately 1,583.00 m3 per person per year and in Europe is somewhere around 300 m3 per person per year, there is a need to educate the population to reduce the unnecessary water consumption (in recent years the consumption has decreased because of the rising prices, but also because of ecological awareness) [8]. In Romania an inhabitant consumes about 321.5 m3 per year [9].

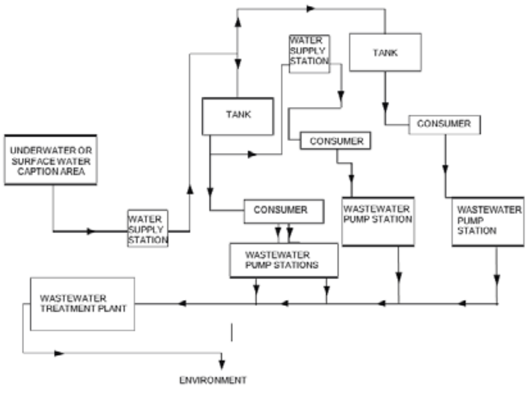

Fig. 2.Diagram of water supply and collection/ wastewater treatment system [3]

The main purpose of a water supply system is to supply water that is being used for drinking, cooking, and not only for the residential consumers, but also for the industrial consumers. One of the main requirements to be met by such a system is to be able to distribute the necessary amount of water to meet the full demand from the consumers. Another important requirement is that a water supply system must provide confidence and that the consumers can benefit from water at any time of the day, 365 days a year.

In order to understand the importance of such a system and especially how important its optimal operation is, we may associate it with the human circulatory system. As the heart pumps the blood through the arteries, veins and capillaries in order to supply oxygen to all the body parts, a pumping station sends the water to the end consumers through the pipelines [4].

II. CASE STUDY

Following a complex analysis performed on the general contour of energy consumption of a local public water supplier and sewerage service provider, a number of aspects that deserve to be taken into consideration in order to minimize costs and reduce energy consumption were noticed. As you can see and in Figure 2, there are two directions of analysis, both equally important: the drinking water supply system and the wastewater system. The following table shows the current distribution of energy consumption per component of the annual energy balance.

Table1.Annual energy balance of the water supply systems

	Electricalquantity	Symbol	[%]
1	Total activeenergyconsumed from the network	Ec	100.00%
2	Losses in transformer	ΔTr	0.72%
3	Losses in powercables	ΔEca	0.55%
4	Electrical and mechanicallosses in motors	ΔEm	12.18%
5	Mechanical and hydrauliclosses in pumps	ΔEp	26.17%
6	Usefulpumpingenergy	Eu	58.30%
7	Other consumers		2.26%

With regard to the drinking water supply system, one of the first problems identified is related to the compensation of the reactive energy. In the case of certain transformation stations that supply the pumping stations, it was found that there was a partially achieved compression, below the value of the neutral power factor (0.9), having values between 0.85-0.89 (figure 3). This situation can be explained by the dimensioning of the compensation steps corresponding to a normal operating regime in which all the pumps supplied from the same network point do not work. However, at peak mode, when all the pumps come into operation (the case from the measurement period), the existing capacitor batteries compensate only partially for the power factor. A solution to remedy such a situation is to supplement the existing capacitor batteries for the peak mode and to periodically check the capacitors and their correct functioning in the case of the transformation stations where this situation exists, of the partial compensation, to minimize the costs with the reactive energy. Also, in the case of the stations where there was found a lack of compensation equipment, it is recommended that they be fitted, preferably reactive energy compensation batteries, in automated steps, also to avoid the costs of the inductive reactive energy consumed by the pumping units.

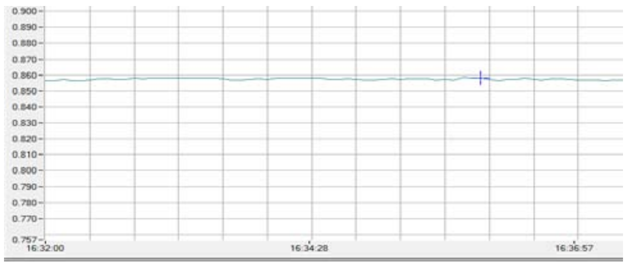

Fig. 3. The evolution of the powerfactoron the general powersupply of the transformer station

Another situation where costs related to reactive energy are generated is the existence of a fixed capacitor battery of 15kVAr connected to the pumping station general panel, value higher than the reactive power consumption of a single pump (about 10.5 kVAr). For the single-pump operation mode, a predominant operating mode, the battery is not useful, as it generates reactive energy costs in both situations: if it is connected, it will inject reactive energy into the network (capacitive mode) and if it remains disconnected, the inductive reactive energy consumption of the pump shall be recorded at a power factor of approximately 0,81 ... 0,82. For this reason a solution could be to replace the existing capacitor with fixed capacitor batteries of 7.5 kVAr connected to the supply circuit of each pump.

In the case of a boosting station, some cost-generating situations were also found. An example of such a situation is in the case of a boosting station equipped with 3 Wilo pumps of 15 kW operated by frequency converters. In this situation, the presence of capacitive reactive power circuits at the single-pump operation of about 2.0 ... 2.5 kVAr was found for very short periods of time due to the frequency converter (Figure 4) [13].

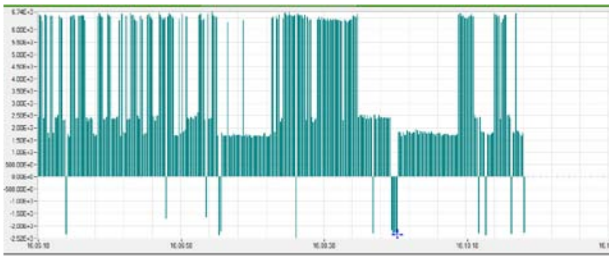

Fig. 4. Reactivepoweron the supply of a 15 kW Wilopump from a pumping station

In the case of the submersible pumps from the capture wells, a number of aspects have to be observed, aspects which require attention concerning the way of choice and at the same time concerning their operating mode in accordance with the necessary pumping height in the network. The scheme of the technological process of water capture at the level of a well is presented in Figure 5. Within the actual balances drawn on the outline of the pumps from the wells, their useful components (ie the useful powers expressed as a hydraulic effect) were calculated starting from the value of the pressure from the collecting pipeline, as the resulting value of pump discharge pressures after the restrictor valves. For this reason, the values obtained for the hydraulic efficiency of the pumps are lower than the catalog data or other analyzed situations. This situation occurs due to the fact that a large part of the capture pumps are pumps that achieve a pumping height much higher than the height of the network (which is approximately 25 m).

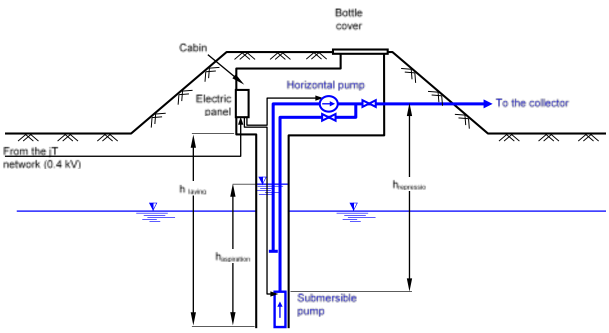

Fig. 5. The schematicdiagram of a water capturewell

It is recommended to replace the pumps with a high pumping height (over 45 m) with pumps delivering the same flow, but at lower pressures corresponding to the height of the network. It is also possible to analyze the solution of equipping the pumps with frequency converters so that the operating curve of the pump can be changed, as explained in the figure above.

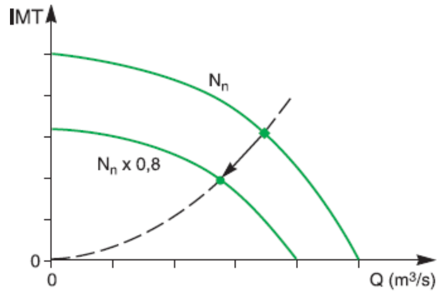

Fig. 6. The characteristics of a centrifugalpump for twodifferentspeeds [13]

This solution also allows for multiple adjustment possibilities in situations where network pressure drops occur because of the increase of the consumption at certain time intervals or of certain consumers connected to it (in particular industrial consumers), losses currently covered by handling the restrictor valves and thereby diminishing the additional hydraulic strength introduced by these by increasing the flow section.

At another pumping station the pumps are powered by frequency converters, which ensures a high level of energy efficiency related to those. The capacitor batteries are auto-stepped (controlled by VARlogic), providing a power factor over 0.95 inductive. It was found that both 1600 kVA transformers are under voltage, since the maximum power absorbed by the entire station at the same time does not exceed 450 kVA, which is why it is recommended to disconnect a transformer from the voltage and operate only with a transformer, so that savings will be made by reducing the idling losses related to a transformer (Table 2).

Table2.Annual savings estimated by de-energizing a transformer

Name of the measure	Estimatedannualsavings			Investmentcosts
	MWh	[tep]	[Thousand lei]	[Thousand lei]
Removingpower from a transformer and operatingonly with a power transformer at the pumping station so thatsavingswill be made by reducing the idlinglosses of a transformer	13.14	1.13	5.20	Itdoesnot involve investments

With regard to the sewage system, this is also an important source where energy efficiency can be achieved. For instance, in the case of a wastewater treatment plant, from the beneficiary's daily consumption records one can notice situations where, because of the reduced consumption of reactive energy of the station, values of capacitive reactive energy were recorded at the level of the general counter. In this situation, by analyzing the possibilities of supplementing the step of compensating the reactive energy consumed by the transformer, with a lower capacity step, meant for the low charge modes of the station and implicitly inductive reactive energy consumption of the smaller transformer, one can make savings.

Another situation encountered on the general supply of a treatment plant is that the capacitor batteries existing in the transformer station (3 fixed steps x 15 kVAr) are not connected and do not perform the reactive energy compensation. In any case, they should be coupled and decoupled manually, but taking into account the amount of reactive power consumed at one time. At peak consumption mode, the existing steps are sufficient to compensate for the power factor corresponding to a value above the neutral power factor, but there are situations when all three steps (3x15 = 45 kVAr) make over-compensation, which is why it is recommended to install step-compensated capacitor batteries with varlogic automatic regulator. The evolution of reactive power consumption consumed by the network is shown in the image below.

Fig. 7. Reactivepoweron the general powersupply of the wastewater treatment plant general transformer station

An interesting situation is observed in the wastewater pumping stations where, due to a low number of users, the water level in the pond increases very hard and the operation of the pumps is often short and very rare. Generally equipped with two pumps, the waste water pumping stations often operate only with a pump and the hourly average values calculated for the electrical measurements measured during load operation (pump is in operation - Table 3) and during empty operation (pump stopped - Table 4) can be seen in the following tables [3].

Table 3.Hourly average values for electric quantities measured in load conditions

Electrical quantity	P_m [kW]	Q_m [kVAR]	S_m [kVA]	I_m [A]	$\cos\varphi_m$
Average hourly value	6.26	4.27	7.58	10.77	0.826

Table4.Hourly average values for electric quantities measured in non-load conditions

Electrical quantity	P_m [kW]	Q_m [kVAR]	S_m [kVA]	I_m [A]	$\cos\varphi_m$
Average hourly value	0,18	-0,45	0,67	0,94	0,669

As can be seen in Table 4, in the case of the empty operation (no waste water pump works), reactive capacitive energy values are recorded, a situation that is due to the frequency converters that are permanently under voltage. Since this situation generates additional costs, it must be eliminated, and a solution could be to automatically disconnect the frequency converter from the network, when the pump is stopped and when the minimum level indicator in the tank transmits the command [3].

III. CONCLUSIONS

As important energy consumers, water supply systems are attractive for energy efficiency and cost savings, the entire water supply process requires energy consumption and this consumption reaching 2-3% of the world energy consumption [10], [11], [12]. Taken into account the fact that the water consumption increases as a result of changes in lifestyle and eating habits in recent years, energy consumption in the water supply systems is also increasing [9].In this paper there have been presented some measures that can be implemented with or without investments in order to reduce the costs and/or the consumption of energy. Thus, if they were implemented within the analyzed water supply system, it would save about 230 thousand lei annually, also taking into account the savings achieved by reducing the energy consumption by approximately 410 MWh per year. Of the total economy, about 30% could only be achieved by implementing measures to compensate for reactive energy consumption, such as replacing existing capacitor batteries, resizing them, or installing such equipment.

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