EXTENDED ABSTRACT

Introduction

Water supply systems are responsible for 2-3% of the world's energy consumption. Energy inputs to water systems are primarily in the form of electricity for extracting and pumping water. Therefore efficient energy management is important for water companies to meet economic and environmental targets. The water supply system of Athens is an extended, complex and highly energy intensive hydrosystem and consists an ideal field to implement energy efficiency measures.

The scope of this postgraduate thesis is to analyze the energy aspect of management in this hydrosystem. The main goal is to assess the influence of specific energy in the activation (operation) of pumping stations and boreholes.

Thesis outline

The thesis is organized in eight sections:

- Chapter 1: Introduction
- Chapter 2: Facts about energy consumption in water companies, the term of energy efficiency and summary of most promising areas for intervention within water supply systems.
- Chapter 3: Brief description of the water supply system of Athens.
- Chapter 4: Brief description of the decision support system for the management of the Athens water resources system.
- Chapter 5: Description of major economic and energy aspects that management policy takes into account.
- Chapter 6: Analysis of methodology and description of examined scenarios.
- Chapter 7: Analysis of the results for optimized scenarios.
- Chapter 8: Conclusions and suggestions for future research

A short description of the Athens water supply system

The Athens water supply system is a particularly large and complex hydrosystem that extends over an area of around 4000 km^2 and includes surface as well as groundwater resources. It incorporates four reservoirs, 350 km of main aqueducts, 15 pumping stations, 100 boreholes

and four water treatment plants (WTP). The system is run by the Athens Water Supply and Sewerage Company (EYDAP).

The system's main objective is to provide water to the Greater Athens area through the WTP, which lie in the surroundings of Athens. In addition, the water resource system provides water for irrigation, water supply of nearby towns and also environmental preservation (1.0 m^3/s) downstream of the Evinos dam.

Management of Athens water supply system

Optimizing the management of Athens water supply system is a real challenge. In fact the system must provide water of sufficient quantity and high quality for about 4 million people who live throughout the Greater Athens area. Moreover, from 2000 EYDAP has operated under a new status and has to make decisions under free-market criteria. Therefore, the management policy has to effectively accomplish the objectives of sustainability, reliability and economy.

To derive optimal management policy, EYDAP since 2000 has used a decision support system for the management of the hydrosystem. The main target of management policy is to optimize annual average failure probability and total energy consumption. The adopted reliability level was set to 99% on an annual basis (only one failure of the system to meet the target is allowed in 100 years), a value that provides a high level of safety. Pumping costs are related to the use of boreholes and pumping stations along the Yliki aqueduct.

The core of the DSS is *Hydronomeas,* the module performing the system simulation and optimization. The basic characteristics of Hydronomeas is that provides all results in probalistic terms and incorporates all natural, operational, environmental, economic and administrative aspects of water resources management.

Economy and energy aspects of management policy

The operational cost is estimated in terms of mean energy consumption on an annual basis. So far operational costs have been incorporated into the model in the form of specific energy values (consumed energy at pumping stations and boreholes per discharge unit). The conveyance cost is introduced in terms of energy consumption (GWh/hm^4 for pumps and kWh/m^3 for boreholes)

The estimation of specific energy is based on the analysis of the available historical data, concerning both discharge and energy consumption data. Although this is the most important economic issue, several other issues could be introduced (e.g. activation of backup resources, maintenance costs of pumping stations), in order to provide better approach for the total operational cost.

Description of the examined scenarios

In the framework of the 2008-2009 Master Plan of the Athens water supply system three basic scenarios were studied. These scenarios aimed at evaluating the real potential of the system and finding the suitable policy which, ensuring a 99% reliability level maximizes the system release, and also keeping the total pumping energy as low as possible.

The first scenario (Scenario B1) refers to the actual present configuration of the system whereas the other scenarios (Scenario B2 & Scenario B2) refer to a future configuration, after the implementation of a number of projected works. In the second scenario leakages were considered reduced by 50%. In the third scenario restore of the interconnection between Mornos and Yliki aqueducts was considered. For each one of the aforementioned scenarios specific energy was increased by 25%, 50%, 75%, 100% and reduced by 25%, 50%, 75%.

Optimization was based on steady state simulations with synthetic inflow series of 2000 years length, which were generated through the stochastic simulator Castalia taking into account phenomena of persistent droughts. A particular management policy was considered for groundwater resources, which are regarded as backup resources. Two thresholds were imposed, the upper one to forbid the usage of groundwater if the active shortage of the system is more than 40% of the total active capacity, and the lower one to enforce their usage if the storage is less than 25% of the capacity. Between these thresholds, the usage of groundwater depends on economic criteria. For all scenarios the objective was the minimization of the average operating cost, by keeping the reliability level up to 99%.

For the purpose of this thesis, we considered that operation of pumps and boreholes is described by mean activation probability. Mean activation probability is calculated by dividing the number of months where energy consumption was nonzero to the number of simulated years.

Conclusions

When the specific energy is increased at the pumps, the mean activation probability is initially reduced and then remains steady at that value. Therefore a minimum limit of operation for the pumps is needed for the system in order to meet the desirable target of reliability. The initial decrease of probability works as a counterbalance to the increasing energy consumption

Decreasing specific energy has significant impact in the operation of the following pumping stations: Kremmada-Kleidi, Kioyrk-Menidi, Viliza-No10 and No3-Frear A. The most promising pumping station for intervention is Viliza-No10. The mean activation probability of pump No3-Frear A in this case depends mainly on economic criteria.

On the other hand mean activation probability of boreholes displays a small range of values and the change of energy doesn't appear to affect the activation of boreholes. The mean activation probability is augmented only by a small percentage when specific energy is changed. Furthermore, the activation of the boreholes depends on the management policy that was considered for the groundwater resources.

The elimination of water losses due to leakage along the Mornos aqueduct (according to Scenario B2) doesn't contributes much in energy savings.The mean energy consumption along the Yliki aqueduct due to pumping water will be reduced about 35 GWh on annual basis due to the implementation of the projected works, as more water would be transferred via gravity. Moreover the mean energy consumption (Scenario B3) is increased due to the intense exploitation of groundwater resources and increasing activation of pumping stations along Marathon aqueduct.

Finally the analysis that was conducted in this thesis can be useful in implementing energy efficiency measures in the Athens water supply system in order to quantify possible energy savings.