Aspects of Energy Efficiency in Water Supply systems

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Abstract

Water supply systems are massive consumers of energy, which is consumed in each of the stages of the water production and supply chain: starting from pumping the water to the water treatment plant, along the treatment process and while distributing the water via the network.

Energy efficiency may be achieved by improving the pump station design, system design, installation of Variable Speed Drives to pumps, and operating pumps efficiently. Leakage reduction would bring to significant savings in power consumption.

A most effective tool in loss reduction is pressure modulation which by adjusting night pressures to the reduced demand, reduces excess night pressure and leaks.

A main factor in energy management is time of day power tariffs. Such rates policy creates a major change in the pumps operation concept. Major savings can be achieved by shifting the pumps operation from the Peak period to the Mid and Off-peak period. Such operation strategy would increase night pressures and consequently the water loss.

These two control strategies are therefore in conflict. A combined solution is attained by applying Energy Management operation schedules on the backbone system and isolating the distribution areas as pressure controlled DMAs.

Introduction

Water supply systems are massive consumers of energy, which is consumed in each of the stages of the water production and supply chain: starting from pumping the water to the water treatment plant, along the treatment process and while distributing the water via the network.

Energy is lost due to various reasons: Inefficient pump stations poor design, installation or maintenance, old pipes with high head loss, bottlenecks in the supply network, excessive supply pressure, and inefficient operation strategies of the various supply facilities. Other major cause for energy waste is excess supply due to water leaks or due to inefficient use of water. When the worldwide water loss average is estimated to be 30%, it means that the very same portion of energy is lost. Given the above causes, energy consumption savings might get to 20% - 30% of the current consumption.

Pump Stations

The working point of a pump is the intersection point of the water system resistance curve and the pump H-Q curve (Figure 1). Efficient operation is achieved when the Efficiency curve is at its maximum point. However, system demand changes daily and seasonally. The working point for a fixed speed pump would shift from this optimal point to non-efficient working points and might reach to shut-off. To handle operation against these varying conditions, different pump units combinations will be operated or pumps will be operated against partially closed valves to reduce through put.

Variable Speed Drive (VSD) for pump provides significant flexibility and improves the operation efficiency. (Figure 2). VSD for centrifugal pumps enables maintaining fixed pressure v.s changing flow conditions or inversely, flow v.s pressure. This flexibility reduces the number of pump starts and stops and consequently the number of water hammers in the distribution system and the number of pipe breaks. It would also enable more efficient operation of the pump units.

The optimal design and operation of a pump station requires combination of:

- Number and size of pump units

- Pump curve slope adjusted to required operation condition
- Variable Speed Drive

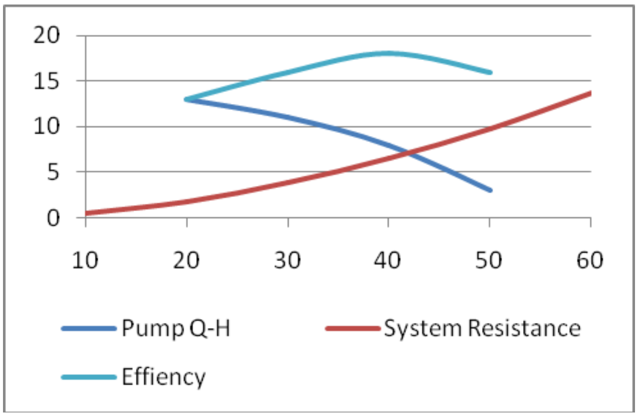


Figure 1 Working points of pump

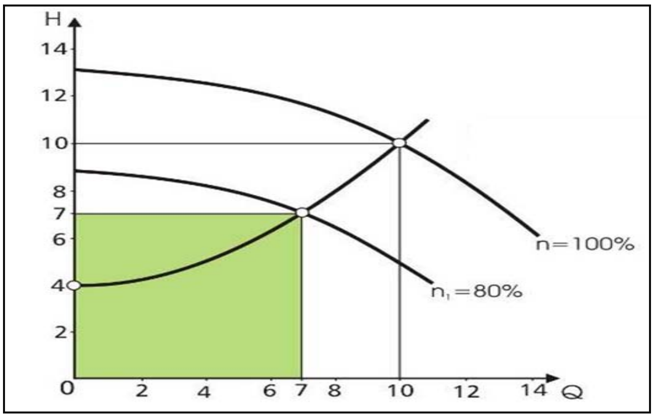


Figure 2 Variable Speed Drive

Pump Stations Scheduling

Common controls

Pump stations and other controlled facilities are usually operated applying one or a combination of the following strategies:

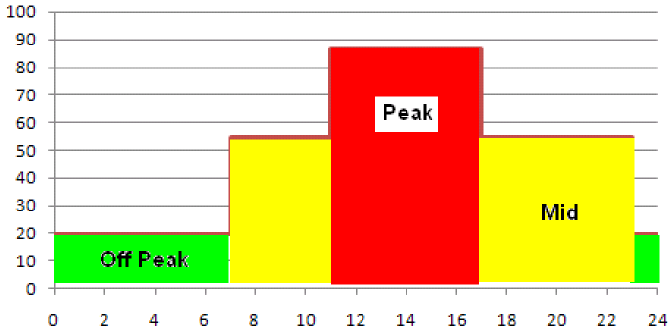
- Pressure control: Pumps are started according to variations in suction pressure. Increase in demand would reduce the network pressure and trigger for pump start up. A pump is stopped when pressure increases due to reduction in demand.
- Level Control: Pumps are started and stopped according to reservoir water level variations
- Time controls: Pumps are started and stopped on fixed hours of the day.

Power Tariffs Impact on Operation Considerations

In most countries, Time of Day energy tariffs are applied. Figure 3 illustrates a week day tariffs profile in the summer season in Israel. The peak tariff gets to 4 times as much the off peak tariff.

This rates policy creates a major change in the pumps operation concept. Major savings can be achieved by shifting the pumps operation from the Peak period to the Mid and Off-peak periods. In any point of time the future change in costs is known. On Off-peak period our goal would be to utilize the pumps to the maximum, knowing that any delay in supply would cost much more later on. As opposed to the common operation strategies mentioned above, which mainly respond to the changing conditions, efficient operation is realized by planning the operation in advance.

Figure 3 Time of day energy tariffs



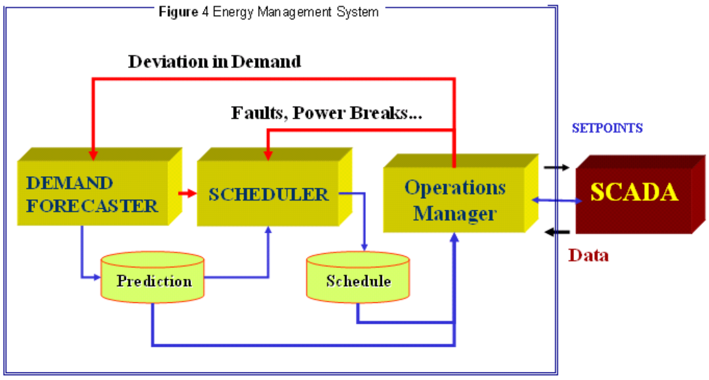
Energy Management System

An Energy Mangement System, also called Decision Support System comprises two main componenets:

- Demand Forecaster : A module which predicts the water demands profile for the planning period, typically 24 hours.

– Scheduler: The Scheduler's goal is to generate a daily schedule for the operation of the water system pumps and other controlled facilities, as Pressure or Flow Control Valves. This must be done while considering the current capacity of the water sources, and the distribution system characteristics, and while satisfying various operating constraints in order to Supply consumers demands. Optimal schedule is achived by minimizin pumping during on-peak hours and by avoiding pump cycling.

Figure 4 Energy Management System



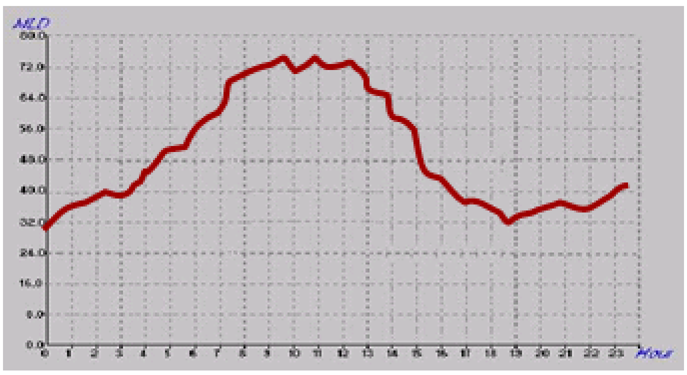
The execution of the computed schedule is enabled via the SCADA system. Control commands or set points for the facilities operation are issued to the SCADA and to the facilities at site. As this all process is based on forecast of demands and estimation of the supply facilities availability, a process control is required. Deviations in actual demand Vs. the predicted one, breaks in supply devices, problems in the control system, each of which might require adjustments in the existing schedule or call for re-schedule. This control may be carried out manually by the system operator or in a semi or fully operated system. A scheme of such automated processi introduced in Figure 4.

Optimal Schedule

Energy cost savings are primarily realzed when the water distribution system has storage capacity. The power peak period, is typicaly adjusent to the water demand peak period. This means that when the power tariffs are low, we might have extra supply capacity. This capacity is utilized by storing the excess water in the reservoirs during the off peak period, and by supplying from the reservoirs during the peak period while reducing the pumps production at this time. A typicl optimal schedule is shown in figure 6. The reservoir is filled up during the off peack period and the water is supplied from the reservoir during the Peak period.

Such strategy requires operation of the network at high capacity during the off peak time. In order to enable this increase the flow, the pressure needs to be increased. Headloss in pipe flow is function of $Q^{1.852}$. It means that the headloss is augmented more when flow is increased as opposed to its reduction when it is decreased. Consequently, the total accumulated power consumption (energy emission) is increased. However, it is typical that on Time of Day energy tariff policy, the ratio between the off peak cost to the peak cost, compensates for this increase in energy consumption. Eventually, water utilities actually optimize their energy cost rather than the energy consumption.

Figure 4 Reservoir water level profile



Water Loss & Energy

General

Minimizing water loss through an active leakage reduction program will reduce the waste of energy embedded in the lost water. Reducing leakage levels will also reduce the water flows and the headloss in the network.

Leakage reduction increases the water availability and therefore the reduction of intermittent supply and the occurrence of breaks caused by intermittent supply operation. Well balance scheduled operation, i.e minimization of pump starts and stops, may also reduce transients and pressure variations which are main causes for pipe breaks and increase of water loss and energy consumption.

Water Loss Reduction by Pressure Modulation

Pressure modulation in water supply network is probably the most efficient tool to reduce leakage. Dynamic pressure control strategies are applied to reduce the excess pressure by adjusting the network pressure to the level of water supply. This action is particularly effective during night time. In typical non controlled systems, when night flows are low due to the reduced consumption, pressure is high and leakage is increased. Pressure Reducing Valves (PRV) are installed to modulate the supply pressure and avoid the excess pressure.

Conflicting Considerations

Energy Management Operation (EMO) regime may be in conflict with Pressure Modulation controls aimed at leakage reduction. EMO increases the night pressure by shifting supply to night (off peak) hours, while pressure modulation goal is to minimize night pressure by adapting the supply curve to the low night demand.

Clearly increased night pressures will increase leakage, create new pipe bursts, and increase the overall energy consumption.

District Meters Areas

A District Metered Area (DMA) is defined as a discrete area of a distribution system usually created by the closure of valves or complete disconnection of pipe work in which the quantities of water entering and leaving the area are metered. The metering of flow into the area enables execution of water balance and analysis of the flows to quantify the level of leakage.

A DMA comprises a feeding chamber, a distribution network, and isolating valves. The feeding chamber shall include at least a water meter. Nevertheless, as pressure control is such significant tool for loss reduction, in many cases pressure control system is installed to optimize the pressure control in the DMA.

Combined Approach

A combined solution which utilizes the better of the two methods would be combination of a backbone system operated against the reservoir and pressure controlled DMAs connected to the primary lines of the backbone network. See Figure 5. Water is supplied via the backbone pipes to and from the reservoir according to the Energy Management considerations, and the supply into the DMAs is controlled by PRVs to avoid any excess pressure.

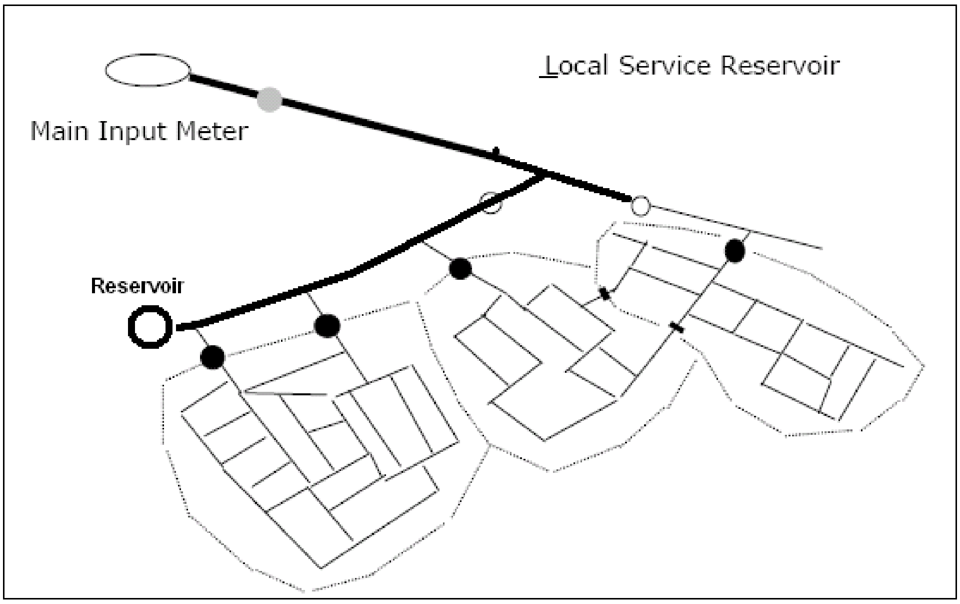


Figure 6 Network Structure which enables optimal operation

Tools for analysis and possible solution

The technical and economical aspects of the problem can be analyzed by applying:

- Hydraulic models to analyze the various networks structures and the operation strategies
- Energy Management System: A Demand Forecaster, a Scheduler and ac control module to manage the system operation
- FAVAD methodology to predict the pressure impact on water losses.

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