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Energy optimization in water supply system in the Sultanate of Oman

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ABSTRACT

In water supply systems, the power cost is one of the most important components in which large amounts of energy are required for production, pumping, transportation, and distribute the water in the networks. The water supply systems are the most important public utility for safe supply of potable water. Energy consumption in water supply system represents a major concern in the Sultanate of Oman. This paper discusses several studies and actions have been done in water operational assets to reduce and optimize the power consumption. The public authority for Water in Oman (Diam) has implemented many successful energy optimization methodologies and tools in desalination plants, pumping stations, wells and water distribution networks such as energy recovery devices, variable frequency drivers, pumps overhauling, rescheduling of pumping times, bypassing the pumping stations, maintenance of wells.

Keywords: Water network; Pumping stations; Energy recovery device; Variable frequency drivers; Maintenance

1. Introduction

Providing safe drinking water is a highly energy-intensive activity. Energy usage can vary based on water source, facility age, treatment type, storage capacity, topography, and system size. The growing demand for electricity has a direct impact on the environment. The intervention to increase the efficiency of water systems becomes one of the essential subjects in the Public Authority for Water in Oman (DIAM). This report highlights the main initiatives and activities in reducing the power consumption in the operational assets of water supply system in Oman such as desalination plants, pumping stations and reservoirs.

Electricity consumption by water utilities has typically accounted for about 3% of all electrical energy consumption in the United States and United Kingdom. Increasing the energy efficiency can reduce power consumption for pumping by as much as 5%–25% (Bunn 2009).

Providing safe drinking water is a highly energy-intensive activity. Drinking water and wastewater systems are typically the largest energy consumers accounting for 25%–40% of a municipality's total energy bill. Approximately 80% of municipal water processing and distribution costs are for electricity (Water, 2013).

2. Discussion

The consumption of electric energy, due to the water pumping, represents the biggest part of the energy expenses in the water industry sector. Among several practical solutions, which can enable the reduction of energy consumption, the change in the pumping operational procedures shows to be very effective, since it does not need any additional investment but it is able to induce a significant energy cost reduction in a short term (Ramos, 2013).

This increment in the energy prices has created the need for increased emphasis on efficient energy use. Therefore, energy efficiency in water distribution applications must be regarded as a priority when more efficient system operation is sought (Habibi, 2014).

The introduction of the cost reflective tariff for industrial electricity has stimulated PEW to increase its focus on energy efficiency in its installations. There project to stimulate electricity saving in all PEW facilities and to increase awareness of energy efficiency by changing consumption behavior, motivate staff to use electricity properly and to reduce losses. This campaign is planned to run to the end of 2018 (DIAM, 2017). An overview of water supply system in Oman is shown in Fig. 1.

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The main components of the system are desalination plants, wells, pumping stations, tanker filling stations, reservoirs and networks (transmission/distribution).

In 2016, the Public Authority of Water started an evaluation of energy consumption in many operational locations, Fig. 2 shows the power consumption in the assets (Diam & Seureca, 2016).

The consumption varies from site to site from less than 10,000 to 60,000 MWh/year, the types of selected locations are desalination plants, pumping stations, wells.

For desalination plants, key performance indicators are the recovery percentage and the specific consumption (Fig. 3).

For pumping stations, booster pumping stations and well fields, an average efficiency of 70% is an accepted value based on benchmark and international standard (Fig. 4; Diam & Seureca, 2016).

Efficiency of pumps (excl. Well Field)	70%
Efficiency of pumps in Well Field	65%
Pump energy indicator	4.5 kWh/1,000 m^3/m

Pumping stations are the water distribution system components that provide the greatest opportunity for cost savings due to improved operation. Optimal operation in these cases corresponds to minimizing pumping energy consumption while maintaining adequate service.

There is no single simple approach to minimizing pumping energy costs because there is no single reason that pumping systems are operated less than optimally. Some of these reasons include:

- Pumps which were incorrectly selected.
- Limited capacity in the transmission/distribution system.
- Limited storage capacity.
- Inefficient operation of pressure (hydro pneumatic) tanks.
- Inadequate or inaccurate telemetry equipment.
- Inability to automatically or remotely control pumps and valves,
- Cost reflected tariff constraints.
- Lack of understanding of demand or capacity power charges,
- Operator errors.
- Control strategies.

The efficiency percentage is lower for the wells, around 65% efficiency as shown in Fig. 5 (Diam & Seureca, 2016).

The main required actions for power optimization in the operational assets are as following:

Sr.	Required action
1	Bypassing the pumping stations to supply water directly to networks
2	Change of impeller and coating
3	Cleaning of suction line
4	Frequent maintenance/cleaning of strainer for well fields
5	Installation of new pump with motor and as a replacement of existing
6	Installation of VFD in pumping stations
7	Lighting optimization
8	Optimization of impeller diameter
9	Pump operation at valve throttled opening
10	Installation of ERD in desalination plants
11	Reduction/change in operating hours of pump and combinations
12	Refurbishment/ internal coating of pump
13	Replacement of existing belt to flat belt for high pressure pump driven
14	Voltage optimization
15	Suction lines modifications
16	Trimming impeller

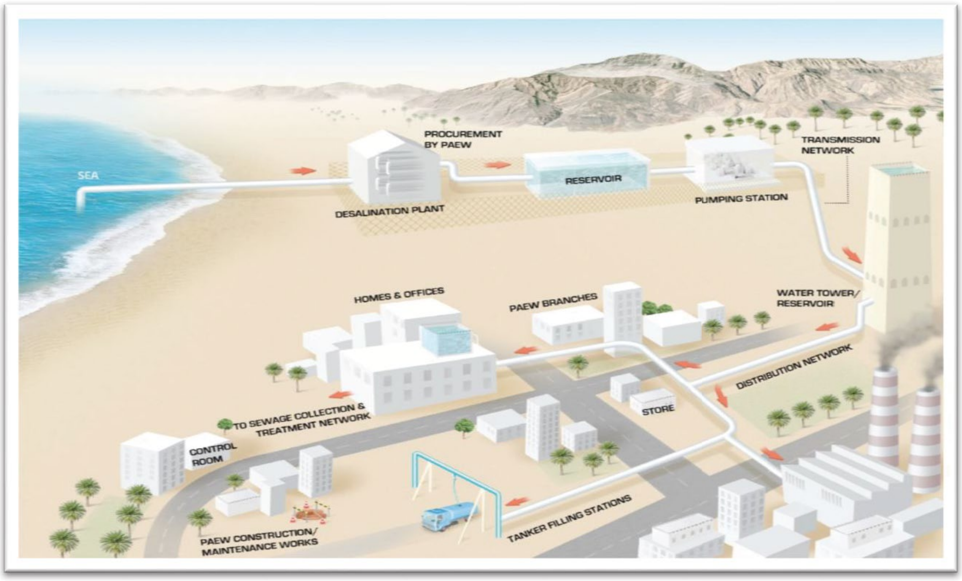

Fig. 1. Water supply system in Oman.

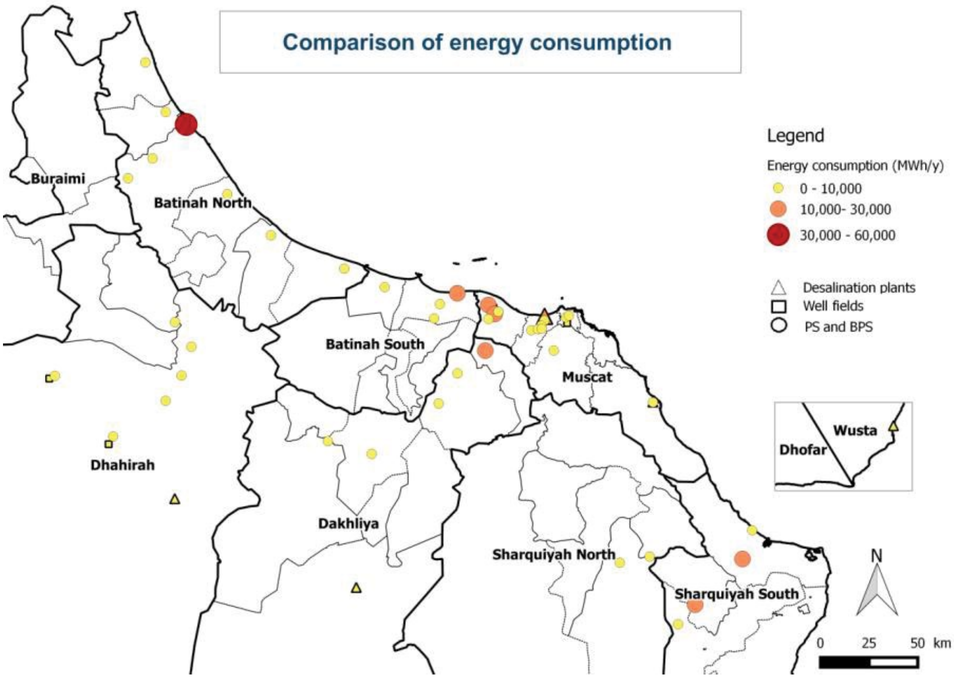

Fig. 2. Overall evaluation of the biggest energy consuming.

Name of the desalination plant	Type of raw water	TDS of raw water (ppm)	Recovery percentage	TDS of product water (ppm)	Specific Energy Consumption (kWh/m^3)
Adam DP	Brackish water	1,607	69%	386	2.37
Ghubrah DP	Sea water	40,000	36%	400	4.15
Hamra DP	Brackish water	2,910	67%	73	3.40
Lakbi DP	Sea water	27,500	34%	330	5.24
Quriyat	High brackish water	18,000	42%	480	3.97

Fig. 3. Desalination plants evaluation.

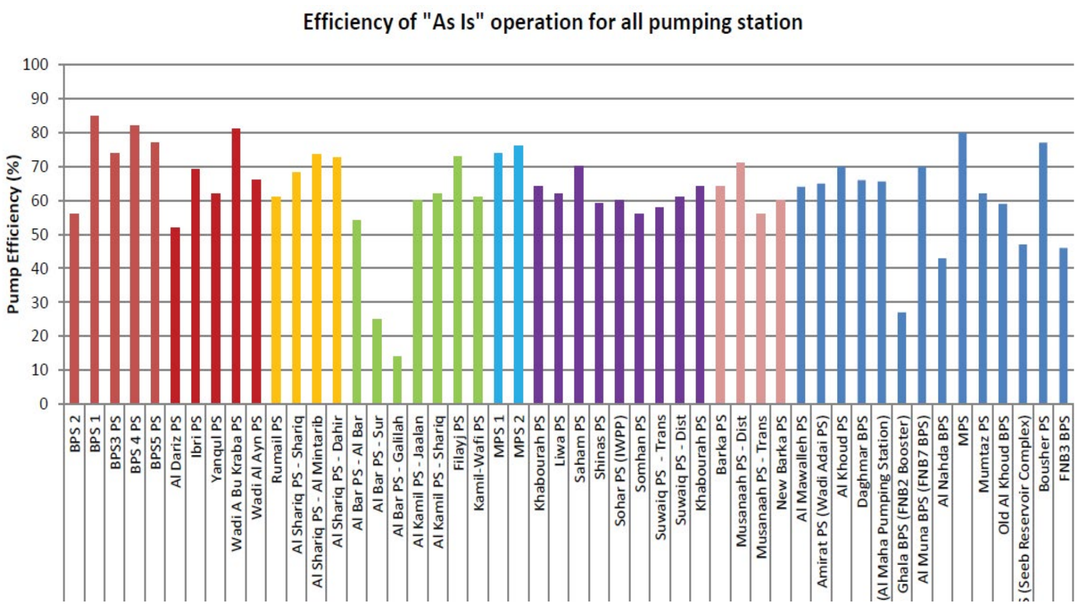

Fig. 4. Pumping stations energy evaluation.

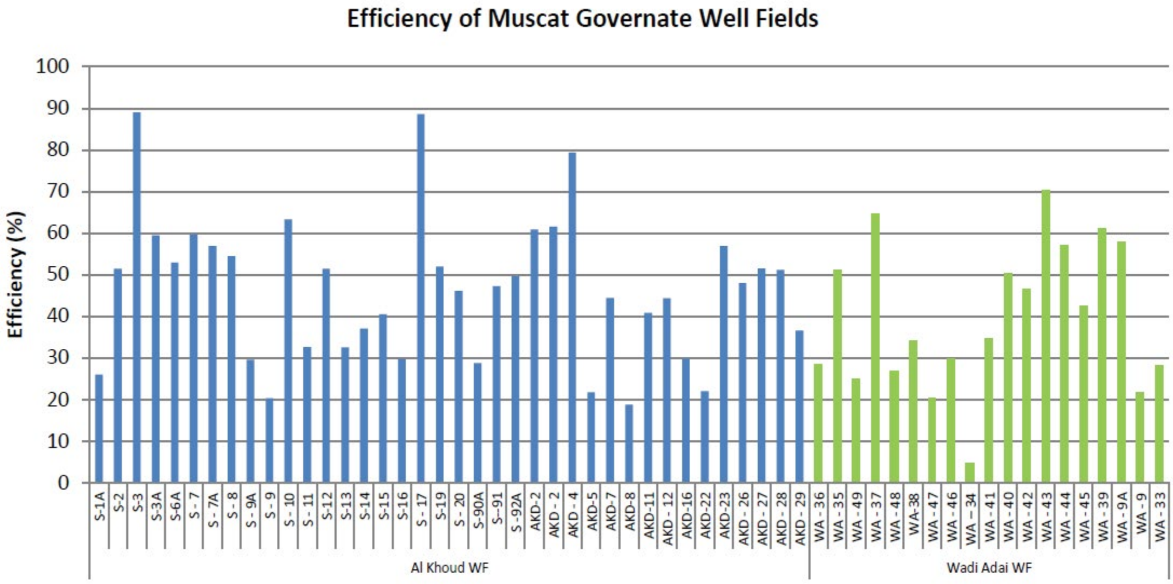

Fig. 5. Wells efficiency evaluation.

3. Case studies and initiatives

The Public Authority for Water in Oman (Diam) has implemented in 2017 and 2018 many successful solutions to optimize the energy usage. In this section, we will show few examples of the activities and initiatives done by operation teams.

Optimizing the pump-scheduling is an interesting proposal to achieve cost reductions in water distribution pumping stations. As systems grow, pump-scheduling becomes a very difficult task. In conventional water supply systems, pumping of treated water represents a major expenditure in the total energy budget. Because so much energy is required for pumping, a saving of 1% or 2% can add up to several thousand dollars over the course of a year. In many pump stations, an investment in a few small pump modifications or operational changes may result in significant savings (Christian von Lücken, n.d.).

3.1. Running the most efficient pumps in Mawalleh Pumping Station

In Mawalleh pumping station in Muscat governorate, the team selected the best scenario by using the most efficient pumps and stop the low efficiency pumps, the results are shown in Fig. 6 (Seeb Operation, 2018).

Al Mawalleh Pump Station			
Location	Month	Total Saving	
		KW	RO
Mawalleh Pump Station	Jan	603576	11,921.647
	Feb	837120	18,040.031
	Mar	158596	2,140.325
	Apr	398400	7,483.400
	May	461806	15,525.162
	Jun	252792	7,558.856
	Jul	371352	11,443.016
	Aug	527424	12,095.456
	Sep	504216	13,215.628
	Oct	237288	5,881.648
	Nov	251808	5,682.952
	Dec		
Total		4604378	110,988.121

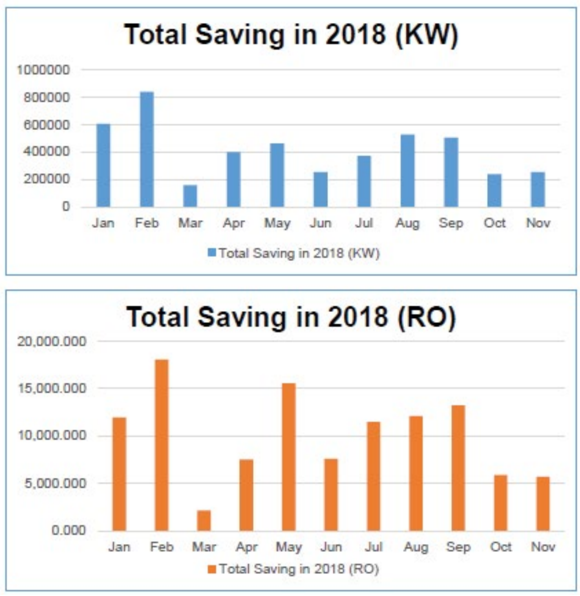

Fig. 6. Malallah pump station parameters 2018.

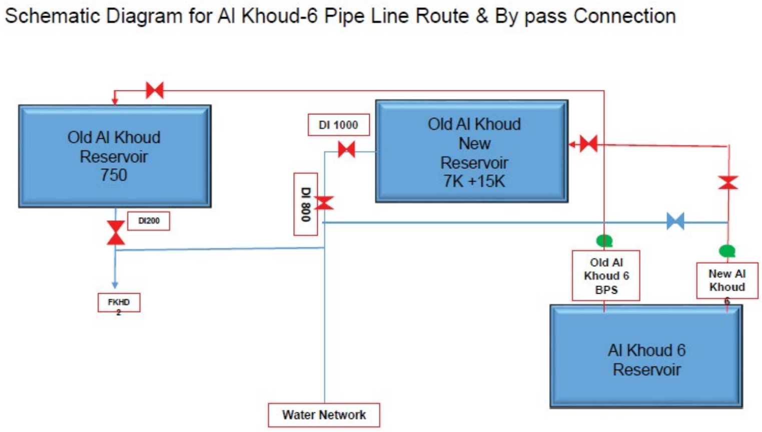

Fig. 7. Layout of Al Khoud pumping station roots.

Old Alkhoud Booster Pump			
Location	Month	Saving	
		Kw	RO
Old Al Khoud (Booster Pumps + Lighting + Guard room)	Jan	58830	1217.675
	Feb	12547	482.127
	Mar	-5036	-38.861
	Apr	67130	1466.553
	May	17225	646.299
	Jun	18639	697.042
	Jul	19661	718.168
	Aug	18693	522.737
	Sep	11131	319.042
	Oct	17367	401.809
	Nov	17463	412.502
Total		253650	6845.093

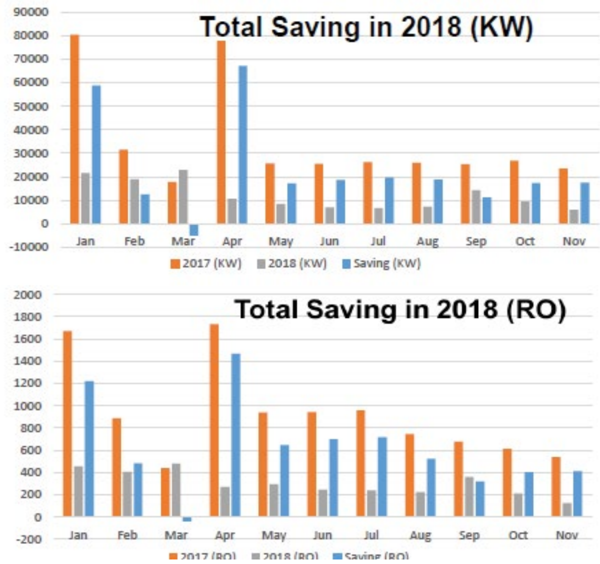

Fig. 8. Energy savings in Al Khould P.S.

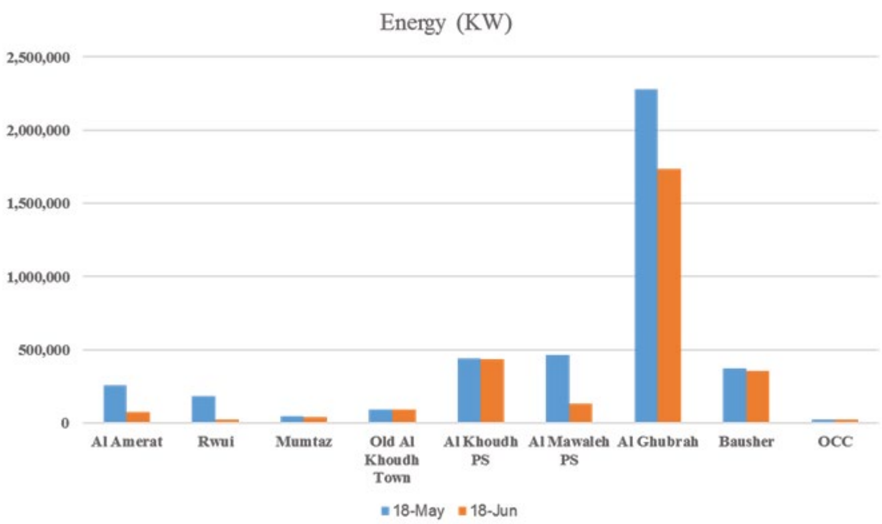

Fig. 9. Power saving in Muscat pumping stations.

3.2. Bypass the pumping station

The following figures shows the saving from stopping one pumping station (Al Khoud P.S.) and feeding the reservoir from other source, Schematic diagram for Al Khoud-6 Pipe Line Route & By pass Connection in Fig. 7 (Seeb Operation, 2018).

3.3. Energy optimization by avoiding the peak tariff time (CRT)

There was a successful activity to change the operation time in Jun-18 (Fig. 9) by rescheduling the pumping to avoid the high cost of electricity during peak time as per cost reflected tariff as shown in Fig. 10 (CCR, 2018).

3.4. Cleaning the strainers in wells

Due to the water quality of the produced water from wells, the strainers filled with dust and obstacles, which lead to low efficiency of the submersible pumps inside the wells with higher required power consumption.

3.5. Changing the old membranes in desalination plants

One of the interesting activities is changing the old membranes in the desalination plant. The following example is from Wusta area in Hima plant in Fig. 11, which indicates big saving in the consumed power.

Moreover, there are also many other activities that have been made for energy optimization in the water supply system in Oman. These include:

- Installing and utilizing variable frequency drives in pumping stations
- Installing and utilizing energy recovery devices in desalination plant
- Pumps maintenance and overhauling

TOD Register Identification	T1	T2	T3	T4
Register	Off - Peak	Weekday - Peak	Night - Peak	Weekend Day - Peak
Time Slot	02:00 – 13:00 17:00 – 22:00 16 Hrs	13:00 – 17:00 4 Hrs	22:00 - 02:00 4 Hrs	02:00 – 13:00 17:00 – 22:00 4 Hrs

	Off - Peak	Weekday - Peak	Night - Peak	Weekend Day - Peak
January - March	12	12	12	12
April	14	14	14	14
May - July	16	67	24	38
August - September	15	26	21	19
October	12	14	14	14
November - December	12	12	12	12

Note; all prices are in Biza per kw and above rates might be changed in yearly basis. The above table represents 2018 rates.

Fig. 10. CRT (cost reflected tariff in Oman) (Regulation, 2018).

Energy	Jan. to Nov. 2017	Jan. to Nov. 2018
Total consumption (KWh)	6,727,343.18	6,317,784.90
Power saving (KWh)	409,558.28	

Fig. 11. Hima desalination plant in Wusta.

4. Conclusion and recommendations

Operating water supply systems requires significant amount of energy. Thus, the discussed initiatives are implemented to optimize the power consumption that should be working to satisfy the water demand forecasting and system constraints at minimal operational cost. The results showed that the used energy optimization methods such as bypassing the pumping station, installing variable frequency drivers, overhauling pumps, changing operation scenarios, cleaning the strainers in the wells outlet, changing the old membranes in desalination plant and installing efficient energy recovery devices led into significant savings in the overall operational cost, and also led to considerable improvements in the system. All the obtained solutions are found feasible in terms of satisfying the system constraints, water demands, and hydraulic requirements. In order to measure the progress of energy savings actions, it is very important to do a close monitoring of energy consumption on PAW (Diam) operational sites by advanced tools and systems. Finally, it is recommended to continue the energy savings and optimizations actives to a next level by using a special software for power analysis to have clear data for each individual site from production to the networks.

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