Desalination and Water Treatment
www.deswater.com

1944-3994/1944-3986
doi: 10/5004/dwt.2012.2830

Taylor & Francis
Taylor & Francis Group

42 (2012) 231–234
April

Retrofitting and enlargement of the Palmahim SWRO desalination plant (150,000 m^3 d^{-1})

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Received 12 June 2011; Accepted 1 November 2011

ABSTRACT

The Palmahim Sea Water Desalination plant supplies to the Israeli water net potable water in accordance with all contractual requirements of water quality and quantity. The plant was commissioned on 2007 and produced 110,000 m^3 d^{-1} (30 million m^3 per year). Recently, the plant production capacity was enlarged to 150,000 m^3 d^{-1} (45 million m^3 per year). Plant enlargement was performed without interrupting the potable water supply while minimizing capital cost investments. The plant original relatively small footprint (3.2 Hectare) and the high degree of operation flexibility remained the same. The enlargement involved the addition of energy recovery devices, membranes and pressure vessels and the modification of the filtration media. As a result of the enlargement, the specific energy consumption of the plant was reduced by 0.2 kWh m^{-3}.

Keywords: Seawater desalination plant; Retrofit; Reverse osmosis; Membrane; Water treatment; Energy recovery device

1. Introduction

Palmahim Sea Water Desalination Plant is located in the central part of Israel, north of the port city of Ashdod. The construction of the Plant was started in May 2005 and completed in May 2007. Since then, the Palmahim Desalination Plant produces annually 30 million cubic meter of water in accordance with all contractual requirements of water quantity and quality.

The Palmahim project agreement with the government is of the Build, Own and Operate structure type for 25 y and will remain in the ownership of the seller at the end of the term of agreement. Palmahim desalination plant is operated by GES Ltd. (Global Environmental Solutions Ltd.) which is part of Azrieli Group unit, Granite Hacarmel Investments Ltd. that today, holds a 100% of the Plant (Fig. 1).

In April 2010, the production capacity of Palmahim Desalination Plant was enlarged to 45 million cubic meter of water per year. This expansion was completed within 10 mo, without any interruption of potable water supply.

2. Unique original design of the plant

A major consideration in the original design of the Palmahim Desalination Plant was the demand for vast operation flexibility, enabling plant operation at variable production rates during the day according to the time of use (TOU) electricity tariff. The TOU electricity tariff, existing in Israel, varies significantly during the day and

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2011 Qingdao International Desalination Conference Symposium on Desalination and Water Treatment Global Platform for Water Solutions, June 20–23, 2011 Qingdao, China

Fig. 1. Palmahim desalination plant general view.

could be six times higher at "peak" hours comparing to "off peak" hours. Thus a vast operation flexibility can significantly reduce the energy cost.

In order to reduce the electricity cost, the plant was designed and constructed according to the "separate skids" design concept, allowing 25% over capacity. Smooth start-up and shut-down procedures were implemented. The proposed design allows the operation of the plant at full production capacity during the "off peak" hours and shut down up to 85% of the plant during the "peak" hours.

The Palmahim Desalination Plant consists of the following treatment stages:

- Coarse screen filtration
- Coagulation and flocculation
- Gravity media filtration
- Cartridge micron filtration
- Seawater reverse osmosis (SWRO) with partial split
- Ion exchange softeners
- Brackish water reverse osmosis
- Product stabilization (Rehardening, pH adjustment and chlorination)

This paper focuses mostly on the SWRO stage as the main constructing modifications during the expansion of the plant were performed primarily in this stage (Fig. 2).

The SWRO stage was designed to operate with six separate skids, each of which is equipped with a dedicated booster pump, a high-pressure pump, an energy recovery device and a membrane array. The energy stored in the brine was recovered by implementation of two wheels Pelton turbine mounted on the high-pressure pump shaft. According to this configuration, the entire feed stream goes through the high pressure pump while the entire concentrate stream, rejected by the reverse osmosis membrane array, goes through the Pelton turbine that recovers up to 88% of the stream energy (Fig. 3).

The flow rate of the high pressure pumps at their best efficiency point is 1540 $m^3\ h^{-1}$ but a flow of up to 1750 $m^3\ h^{-1}$ can be delivered. The two wheels of the Pelton turbine can be operated independently while each wheel can handle 375–475 $m^3\ h^{-1}$ of concentrate stream.

Fig. 2. Sea water reverse osmosis stage—original design.

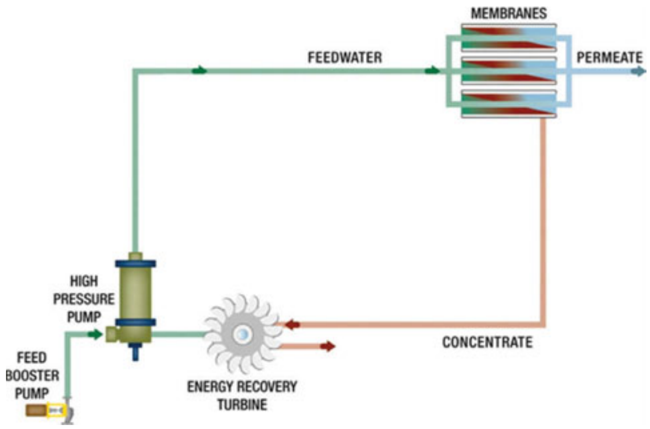

Fig. 3. Seawater reverse osmosis original design scheme. (Courtesy of ERI Inc.)

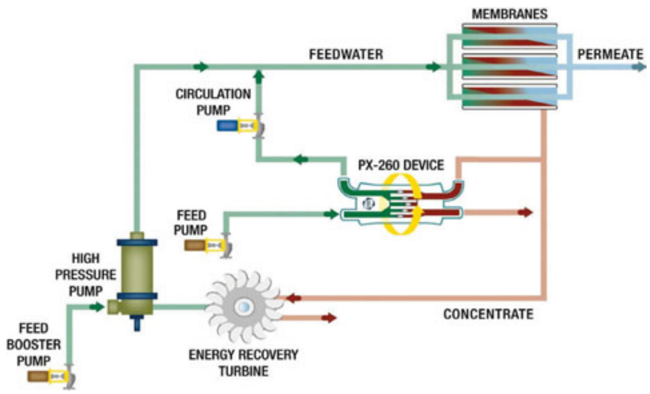

Fig. 4. Seawater reverse osmosis hybrid design scheme. (Courtesy of ERI Inc.)

3. Plant enlargement

The increasing demand for potable water in Israel led the government to request the plant production enlargement. GES targeted to achieve this enlargement without interrupting the potable water supply.

The plant enlargement was performed with emphasis on the following goals—keeping the same operation flexibility, maintaining the same footprint and minimizing capital cost investment. The plant was enlarged from 30 million cubic meter per year to 45 million cubic meter per year.

One of the unique features of the enlargement was to keep the footprint of the current pretreatment stage unchanged. This task was accomplished by a replacement of the current upper media layer by a coarser (1.5–2.5 mm) porous media. This change enabled the operation of the gravity media filters at higher filtration rates (≈10 m h^{-1}).

The main modifications were performed in the sea water reverse osmosis stage. An energy recovery hybrid design—operating the Pelton turbine together with isobaric energy recovery device (IERD, an ERI PX) [1] – was implemented (Fig. 4).

The hybrid design utilizes the existing pumps, motors and Pelton turbines. Additional reverse osmosis membranes, IERDs, circulation and feed pumps that service the IERD, were integrated. According to the hybrid design, the high pressure pump continues to operate at its best efficiency point while the excessive feed water amount is pressurized by the IERD. The concentrate stream that is rejected by the reverse osmosis membranes is divided into two streams, one goes through the one wheel of the Pelton turbine and the second stream flows through the IERD. In this way, the production capacity of each SWRO skid was increased from less than 800 m^3 h^{-1} to 1100 m^3 h^{-1}. The IERD, PX-260 of ERI, was selected. 14 PX-260 units were installed for each skid on a platform, above the existing HP aggregate as shown in the Fig. 5. The required modifications in the construction of each skid were undertaken separately. Each skid was shut down for not more than 7 d thus product water supply wasn't significantly diminished.

The retrofit of the whole plant was completed within 10 mo.

The operation flexibility of the plant after the enlargement was expanded; the plant over capacity slightly reduces from 25% to 18% while keeping the smooth start-up and shut-down procedures. The plant continues to operate according to the TOU electricity tariff.

Start up of the hybrid retrofit process begins as planned in the original design:

1. Start up of the booster pump using a VFD.
2. Deliver all flow to the Pelton turbine and starting to rotate the Pelton turbine.

Fig. 5. Seawater reverse osmosis hybrid design.

3. Complete “turbo—charger” mode and increasing the pressure up to 40 bar.
4. Starting the high pressure pump and simultaneously decreasing the booster pump speed.

Only after the high pressure pump was activated and plant starts to produce the desalinated water, the IERD system is started up as follows:

1. Supply low pressure sea water to IERD.
2. Start up of the circulation pump and simultaneously throttling the flow of the turbine (by shutting down two turbine nozzles).
3. Control the flow through the IERD by the VFD of the circulation pump and SWRO brine low pressure control valve.

The above procedure provides a smooth start up as was also achieved with the original design. The membrane recovery can be adjusted by changing the feed booster pump speed or by changing the speed of the IERD circulation pump.

The hybrid design has created an additional flexibility to the plant by providing the ability to operate each skid in two operation modes, a full Pelton turbine mode (original design) and a partial Pelton turbine and IERD mode (hybrid design). The above flexibility allows to switch the skid operation from one mode to another when required. Thus, in case of any failure in IERD, the skid can return back to the original design thus continues producing water.

Thus, by the implementation of IERD, the production capacity of the plant was increased and due to the higher efficiency of IERD in comparison with Pelton turbine, the specific energy consumption for water production reduced by 0.2 kWh m^{-3}.

4. Summary

The Palmahim Sea Water Desalination Plant was recently enlarged and its production capacity was increased from 30 to 45 million cubic meter per year. The plant enlargement was performed within 10 mo, without interrupting the potable water supply, with minimum capital investment and while keeping the same footprint and the same high operation flexibility.

The major modifications were made in the SWRO stage. The SWRO design was changed to a hybrid design by the addition of IERD, IERD service pumps and additional reverse osmosis membranes.

As a result of the enlargement, the specific energy consumption of the plant was reduced by 0.2 kWh m^{-3}.

Reference

[1] R.L. Stover, Seawater reverse osmosis with isobaric energy recovery devices, Desalination, 203 (2007) 168–175.