THE OPERATION PRINCIPLE OF THE HADERA SEAWATER DESALINATION PLANT AND ADVANTAGES OF THE PRESSURE CENTER DESIGN

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Abstract

The Hadera Desalination Plant located in Hadera, Israel, is the world's largest operating seawater reverse osmosis desalination plant. During the three and a half years it has been in operation, the plant has produced potable water for the State of Israel totaling 106 million cubic meters per year the first year, 127 million cubic meters per year the second year and 146 million cubic meters per year the third year.

The Hadera plant has an innovative operating regime where the pressure center design allows the water production rate to switch from 20,000 m^3/hr during the night power tariff to 7,500 m^3/hr during the day power tariffs. This change in operation regime minimizes energy costs.

IDE's proprietary pressure center design consists of a pump center, a membrane center and an energy recovery center. It has the flexibility required to change water production and power demand in a smooth and effective way, without harming the desalination equipment. This centralized pump and energy recovery system, together with small membrane banks, is an effective solution for large desalination plants.

The pressure center enables the plant operator to optimize and select the operating regime on a day-to-day basis. Operating regime selection is based on a matrix parameter analysis of actual equipment availability, monthly production required, power cost, etc.

The combination of the proprietary pressure center design and operation regime enables Hadera to achieve one of the lowest-ever costs for high-quality desalinated water.

The paper will describe the challenging operation of variable production capacities and analyze the advantages of the Pressure Center Design and its contribution to the achievement of efficient and economical operation of the plant.

I. HADERA DESALINATION PLANT

The completion of the Hadera plant was a milestone event for the desalination industry, and since starting operation in December 2009, it is the world's largest operating seawater reverse osmosis (SWRO) mega-size desalination plant, producing 127 million m^3 per year. This quantity represents approximately 8% of Israel's water needs, and approximately 15% of the total potable water consumption in the country.

The Hadera plant is a 25 year BOT project erected by a joint venture of two Israeli companies: IDE Technologies Ltd. and Housing & Construction. IDE is also a partner in the erection and operation of the desalination plant in Ashkelon (118M m^3/year), as well as the Sorek Desalination plant (150M m^3/year), which is currently under construction.

Figure 1: Hadera Plant View

II. VARIABLE ELECTRICITY TARIFF

The cost of electricity in Israel is variable, changing according to the period of the year, day of the week and the hour of the day. The year is divided into three tariff periods: summer, winter, and spring/autumn, as presented in Figure 2: Tariff Periods – Seasons.

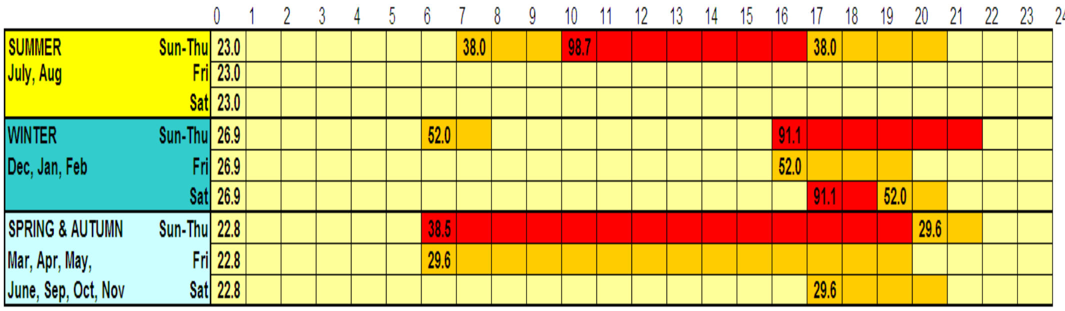

Figure 2: Tariff Periods – Seasons

The cost varies hourly from the base tariff at the lowest off-peak hour cost to shoulder and peak hours as presented in Figure 3: Base, Shoulder and Peak Tariffs, in agorot/kWh (100 agorot = 1 ILS). This cost regime is dictated by the Public Utility Authority – Electricity (PUA) and is the same for all industrial consumers. It is known as "Load and Time Variable Electricity Tariff".

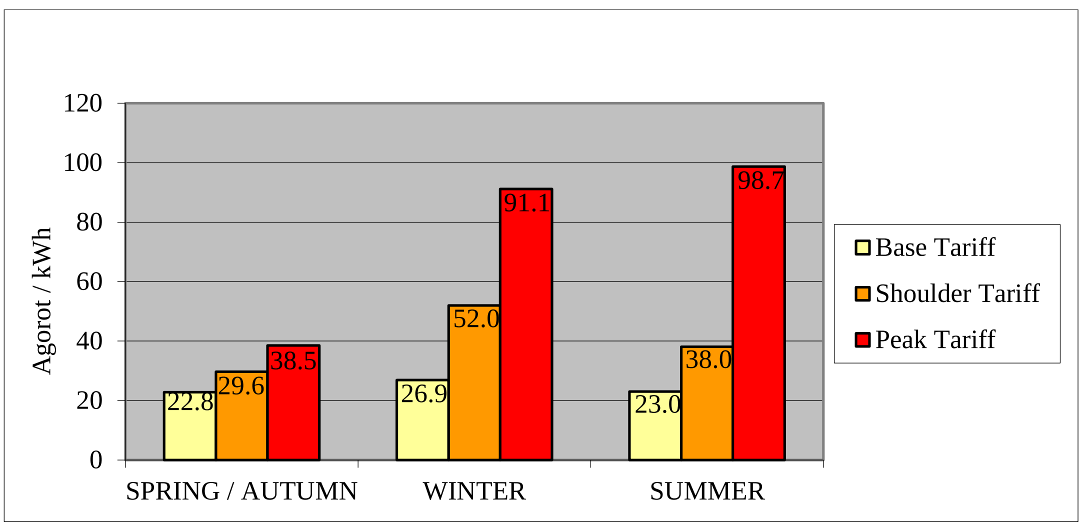

Figure 3: Base, Shoulder and Peak Tariffs

The largest component in the total cost of producing desalinated water from seawater is the energy cost per cubic meter. Desalination plants without independent power production (IPP), such as Hadera, are either obligated to purchase electricity from the PUA at its tariffs or from an in external IPP. The BOT contract for Hadera requires the developer to purchase electricity from the PUA.

Energy costs were analyzed using detailed plant models, resulting in an innovative operating model that includes two main regimes during the day. The operating model is according to the time variable electricity tariff to reduce costs and increase plant efficiency. During peak hours in the high season, just the price of electricity required to produce one cubic meter of water is higher than the price that the State pays for a cubic meter of water.

The regimes are maximal production during the base tariff and minimal production during the peak/shoulder hours. Typical production rates are 100% (20,000 m^3/hr) during the base tariff and 38% (7,500 m^3/hr) during the peak tariff. The main drawback of producing water according to the tariff is that the electricity schedule changes multiple times per day.

One of the main challenges in designing the plant was minimizing the energy cost by utilizing the different electricity tariffs over a 24 hour period, as well as a variable operation production regime. Moreover, the specific energy cost is further reduced by taking advantage of the common pressure center design during the peak electricity periods.

III. SWRO PRESSURE CENTER DESIGN

Conventional SWRO plant design contains several independent modular units, where each unit is a combination of the three main reverse osmosis components: high pressure pump, reverse osmosis membrane rack and an energy recovery system. Each of these modules runs independently, but a shutdown of one of the three components within the module forces the entire module to stop.

To enable better flexibility in operation and to overcome the above obstacle, all three of IDE's mega-sized plants in Israel (Ashkelon, Hadera and Sorek), are designed to implement IDE's unique SWRO pressure center design. The pressure center can be described as one mega-modular SWRO system with all components connected to one common piping system.

The main advantages of the pressure center design are:

- Stopping one unit, for example, one high pressure pump, does not affect the other components, which can continue to operate.
- The operator selects the most efficient combination of equipment units to run in parallel as a full SWRO system. For example, the type and number of high pressure pumps to run simultaneously, together with the most efficient number of membrane racks and ERS skids (an explanation of the 2 different HP pump types in explained in the next paragraph).
- Installing larger capacity equipment, such as larger membrane racks, multi PX energy recovery skids, and higher flow rate high pressure pumps (higher flow rate results in higher pump efficiency).
- The proprietary pressure center design enables Hadera to achieve one of the lowest-ever costs for high-quality desalinated water.

Figure 4: High Pressure Pumps

The operating model takes full advantage of the pressure center design approach, decreasing the specific energy cost per cubic meter of water produced by taking advantage of the lower production rate, keeping most of the installed equipment in operation, and producing water at lower energy consumption. The lowest production regime is achieved by special purpose high pressure pumps. As a result, during peak hours, both electricity demand and specific energy costs are reduced. Moreover, the plant availability is increased as some of the equipment is idle during the lower production rate regime.

As the seawater section has the highest energy demand, the rest of the plant production follows the governing production rate of the SWRO. Overall plant energy consumption is below the warranted figure. The key equipment components of the facility comprising the SWRO process are:

- A group of high pressure pumps working in parallel.
- Two special high pressure pumps that operate during the low-load production regime.
- 16 racks of SWRO membranes.
- Isobaric-type energy recovery system (ERI model PX-260).
- Approximately 40,000 seawater DOW Filmtec membrane elements.

Each subsystem is fully independent and can be maintained without shutting down any additional equipment. SWRO recovery is controlled by means of the variable frequency converters of the energy recovery system booster pumps and is adjusted, per regime, to optimize the energy cost of the system making use of the variable tariff electricity cost.

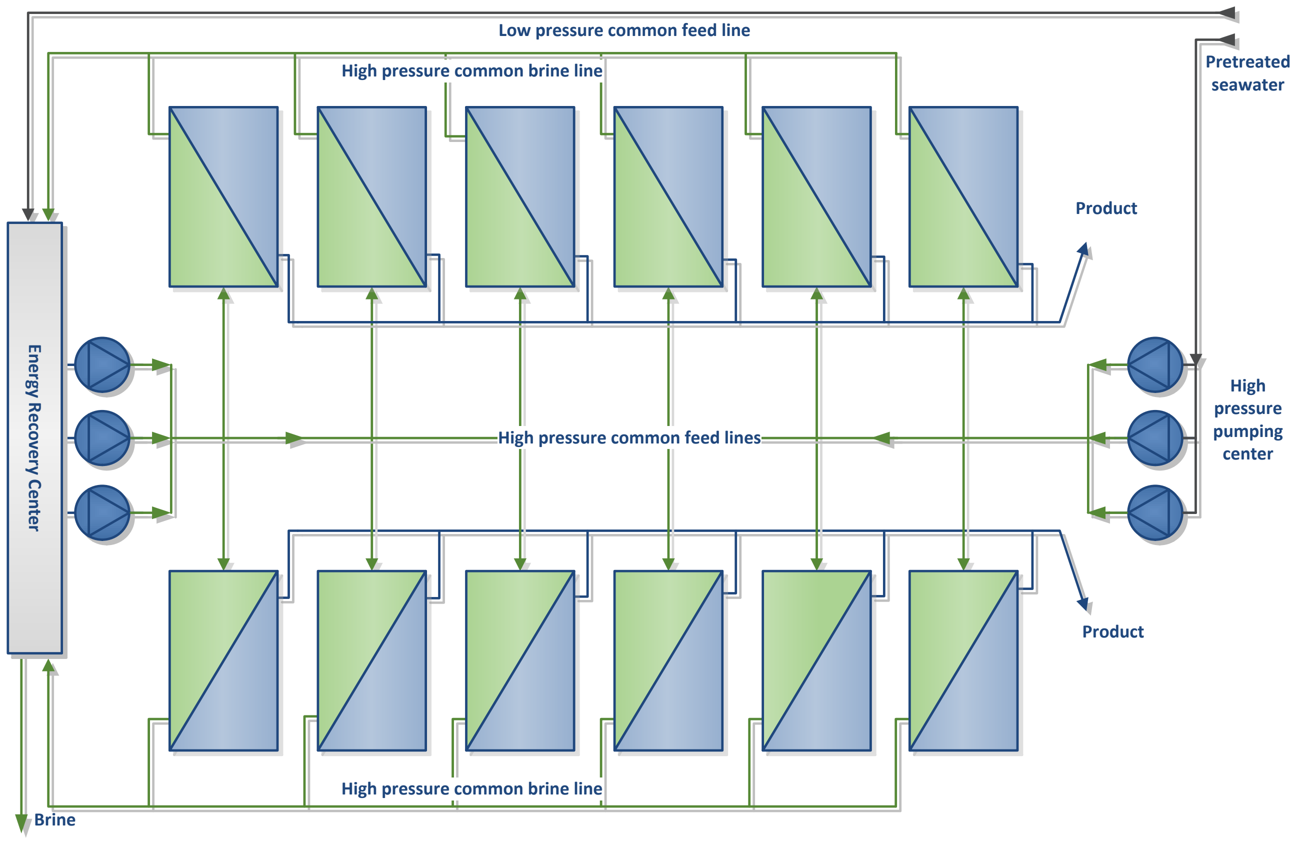

Figure 5: IDE's Pressure Center Concept

Varying capacity production presents a real and complex challenge to designers and operators. For any desalination plant, especially for a mega plant such as Hadera, dramatic changes immediately and significantly affect the equilibrium and stability of the process parameters, as well as the plant performance and the final product quality. For Hadera to be able to reduce production quantities by 60% twice a day in a matter of 15 minutes is considered a dramatic change. The pressure center design is able to manage dramatic fluctuation of production quantities with minimal complete stoppages of process modules.

Changing capacities address changing process parameters such as recovery ratio, feed flow-rate, pressure and permeate flux.

The pressure center concept reduces equipment and instrument wear, shortens startup time, minimizes array shutdowns and startups and shortens the time required to stabilize the process and quality of water after the production change.

IV. OPTIONAL PLANT EXPANSION

In 2012, the State of Israel requested to increase water production from 127 million m^3/year to 146 million m^3/year.

Due to the varying production design, the plant still does not use its full production potential all day long. The facility is able to increase production if it operates constantly at maximum production throughout the day, year round. Expansion to 160 million m^3/year is immediate and does not require additional equipment or membranes. This increase in water production would mean higher production costs as the plant would work during the peak electricity tariffs, but the State of Israel would compensate accordingly.

Figure 6: SWRO Membrane Racks

V. CONCLUSIONS

The SWRO pressure center concept is implemented in all IDE's mega plants in Israel: Ashkelon, Hadera and Sorek.

The Hadera plant recently completed three years of full operation. Its sophisticated SWRO pressure center design allows the plant to reach low energy cost, based on Israel's variable electricity tariff, combined with a variable operation production regime, while taking best advantage of the equipment installed.

The plant produces a continuous amount of desalinated potable water to the state of Israel, meeting all the required quality parameters, and allows future expansion by simple update of the operating regime.