Experience with Renewable Energy Source and SWRO Desalination in Gran Canaria

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Abstract

The paper describes the operational experience of a newly constructed SWRO plant in Gran Canaria – Canary Islands. The main use for the water produced, is irrigation of tomato and vegetable fields with an area of 2,300 hectares. Rainfall is very low in the Canary Islands, typically less than 250 mm as an annual average. The sources of fresh water therefore are very limited and SWRO desalination is the only option in order to meet the growing demand for water. Water demand is currently increasing at around 6% per year. By law, the population living at lower than 300 m altitude has to be supplied with desalted water.

The plant was designed and built by Gamesa (wind generators) and Tecnologia Canaria de Aguas (SWRO system), located at Las Palmas. The wind generator was commissioned in July 2002 and the complete system (RO plant included) was commissioned in October 2002. The owner, also the plant operator, is a company named Soslaires Canarias S.L., based in Las Palmas.

The plant uses state of the art technology. It constantly achieves very low specific energy consumption – less than 2.9 kWh/m^3 of produced water, over the whole process. All other desalination plants in the Canary Islands use conventional sources of energy. However, the main source of energy powering Soslaires Canarias S.L. plant is a renewable source of energy obtained from a farm of 4 wind generators. The design employs the wind generators as the main source of energy, due to the fact that although rainfall may be low, the Canary Islands have frequent and constant winds. The innovative design, coupling the renewable source of energy with SWRO, along with a proper energy recovery system, using pressure exchangers as well as motors with frequency control, is discussed and compared with a "conventional" design. This paper also discusses the environmental advantages of employing such a renewable source of energy, based on the experience gained, during the last two years of operation. The plant is a key reference for future development of SWRO plants in the Canary Islands.

The plant successfully uses Hydranautics SWC3 membranes and produces 5000 m^3 of the product water per day. Membrane performance is very satisfactory, with steady flux and salt passage and no requirement for chemical cleaning to date.

I. INTRODUCTION

Gran Canaria lies in a part of the Atlantic known as Macronesia, which includes the archipelagos of Madeira, Salvajes, Azores, Cape Verde and part of Morocco. The closest point on the African coast lies approximately 210 kilometres away, while Cadiz, the closest port on the European continent, lies 1,250 kilometres away. Within the archipelago, Gran Canaria lies between Fuerteventura and Tenerife, lying at a distance of 83 kilometres to the west of Fuerteventura and 62 kilometres to the east of Tenerife.

Being of volcanic origin, Gran Canaria´s 1,560 square kilometres of surface area and 236 kilometres of coastline encompass a great many of the varied landscapes that are found in the archipelago. It is this characteristic, as well as its diverse climatic conditions, which have earned the island its epithet of "miniature continent". The most unique geographical characteristic of the island is its round shape. The only irregularity in the roundness of the island is a small peninsula in the North-East (known as La Isleta), which is approximately 12 square kilometres in extent and which is joined to the island by a sandy isthmus. The highest point of the island is the peak of Pozo de Las Nieves (1,949 metres above sea level), which is situated right in the centre of the island. The entire island is gouged by deep ravines that radiate from the highest point in the centre right down to the coast line, these ravines being host to a completely different landscape. The annual average rainfall is just 250 mm.

The Soslaires Canarias Company was founded in 1999. The main business of the company is the production of fresh water by use of membrane desalination, using wind power as the energy source. Before the SWRO plant start up, the area was irrigated using reused water, blended with brackish well water. The salinity of the brackish wells in close proximity to the shore have increased to 4 – 5,000 mg/l. The salinity of the wells located 2 km from the sea shore have increased typically to around 2 000 mg/l. These levels of salinity, prohibit the use of blended water for irrigation.

Natural aquifers in Gran Canaria account for only 30% of the raw water supply. Unfortunately, some of the highest yielding catchments have the smallest reservoirs. There are two large companies supplying water in Gran Canaria. One is located in the north of the Island called Emalsa. Part of its supply is from Las Palmas 3 plant (71,000 m^3/day SWRO). The second company covering the south of the island is Elmasa.

Based on initial designs, the expected capital cost of the plant, including 5,000 m^3 of product water distribution system, was 4 millions € in 2001.

1.1 Choice of New Technology

Advances in membrane technology over recent years have had a significant effect on the choice of the process for the proposed plant. The plant is a single purpose plant with a low load factor, with Reverse Osmosis (RO) providing the most attractive process option in terms of flexibility of operation, space requirements and minimal visual impact in a highly exposed tourist area.

Thermal process desalination plants have the disadvantage of requiring relatively large amounts of energy. The location and capacity of the plant, which is dictated also by the seawater intake infrastructure design constraints, precludes any dual-purpose role such as combined heat and power or co-generation.

The RO process offers the following advantages compared to thermal processes:

- lower energy requirement
- short start-up and shut down time
- lower maintenance requirement
- operational flexibility
- no atmospheric pollution

II. POWER PLANT DESCRIPTION

The plant power supply is provided by four wind generators G47-660 kW. Four wind generators can produce 2.64 MW and excessive energy is supplied to the network. The main figures from operation during 2003 and 2004 are summarized in Table 1.

Table 1

Wind Generators Capacity	2,64 MW (4 x Gamesa G47 -660 kW)	
Operational Years	2003	2004
Production of Wind Generators	10,210,109 kWh	9,640,000 kWh
SWRO Power Consumption from Wind Generators	1,547,244 kWh	2,400,000 kWh
SWRO Power Consumption from Network	681,101 kWh	1,800,000 kWh
Power sold to the Network		7,240,000 kWh
Total SWRO Power consumption	2,228,345 kWh	4,200,000 kWh
Total Annual Permeate Production	768,395 m^3	1,466,480 m^3

Wind generators technical parameters:

Rated power	660 kW	
Rotor Diameter	47m	
Number of blades	3	
Length of blades	22.9 m	
Whole blade weight	1250 kg/blade	
Material of blades	Epoxy reinforced glass fiber	
Speed of wind:	Start up	4 m/s
	Shut down	25 m/s
Height of tower	40 m	
Motors	2	
Control system	The generator is a double fed machine (DFM), controlled in speed and power through IGBT' s converters and PWM (Pulse Width Modulation) electronic control.	

The wind generators are always in operation when there is wind on the island and are able to produce energy almost continuously. The SWRO consumes energy from the network, when the wind generators capacity is not sufficient. Vice versa – excessive energy is supplied to the grid when the wind generators produce more energy than the SWRO plant needs. This is possible due to an automatic control device and a two-way switch installed on site.

80% of the energy is produced between March and August, due to strong "trade winds" and the remaining 20% of energy is produced between August and March.

The average wind speed is 8.5 m/s and the preponderant direction is NE.
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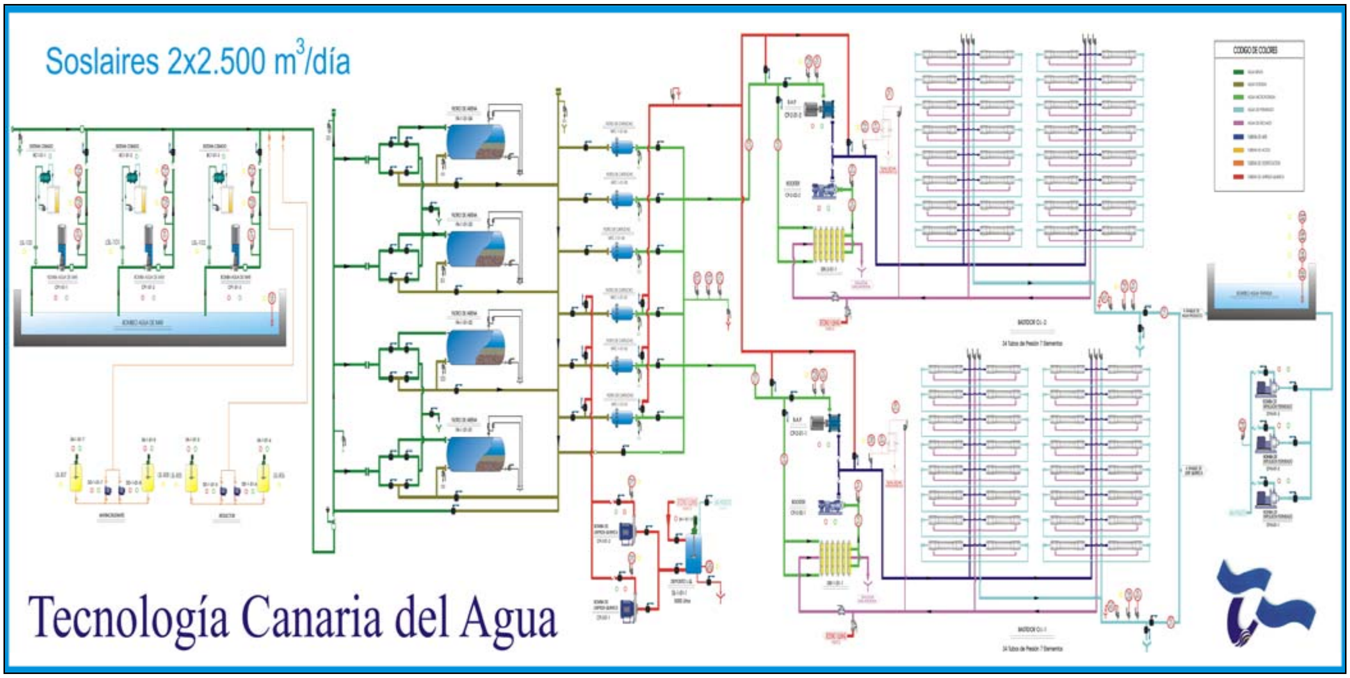
III. SWRO DESCRIPTION



Picture 1

The new sea water desalination system consists of the following main stages:

- beach wells and intake pumps
- pretreatment – sand filters with auxiliaries
- high pressure system pumps and RO trains with energy recovery
- product tank and product distribution pumps

The simplified flow diagram is presented in Picture 1. The plant is designed for a daily output of 5000 m^3/day of permeate, with a quality of less than 400 mg/l TDS, based on a feed water quality of 37,500 mg/l TDS. Full output can be maintained over the sea water temperature range of 25°C to 27°C. The seawater salinity is in reality slightly higher and TDS based on individual ion analysis is around 38,000 mg/l. Feed water conductivity fluctuates around 54.0 – 55.0 mS/cm.

3.1 Beach Wells and Intake Pumps

The sea water intake station is located on the shore line. Three beach wells are located 200 meters from the sea. The depth of the wells is 50 meters. Three vertical intake submersible pumps are installed at a depth of 20 m. Two pumps – duty/standby, pump seawater to the SWRO site through a 900 metre long pipeline with an elevation of 40 meters. The pumps are equipped with frequency controlled drives and achieve a flow of approximately 260 m^3/h.

The beach well intake achieves excellent raw water quality with a temperature within the range of 25°C to 27°C over the whole year.

3.2 Pretreatment

The role of the pre-treatment is to purify seawater to a quality acceptable by RO membranes.

The pretreatment consists of following unit operations:

- 3+1 sand filters with two sand layers: 0.5 and 0.9 mm.
- backwash pumps and backwash tank
- cartridge filters - 3 per train (6 in total)
- pretreatment chemical dosing – initially antiscalant only (dosing stopped two months ago).

The concentration of suspended solids and colloidal substances in the water from beach wells is low, and therefore, dosing of coagulant, upstream of the media filters, is not required. There are two dosing systems downstream of the intake pumps: antiscalant and SBS, but these are currently not in use.

The whole pre-treatment system can be sterilized using sodium hypochlorite. This has not yet been required..

Sand filters remove suspended solids present in the raw water. There are four closed pressurized sand filters. Filtration media consists of two layers of sand (0.5 and 0.9 mm). The sand filters normally operate using a filtration velocity of 12.0 m/h.

The sand filters are backwashed using raw well water. The calculated backwash water consumption per filter and cycle is 25 m^3.

The filtered water enters a common header, connected to six 20 micron (absolute) cartridge filters, which provide the final pre-treatment step. The cartridge filter outlet is connected to the high-pressure pump suction header.

Pre-treatment efficiency is demonstrated by continuously very low SDI values, consistently below 1.

Scale inhibitor was dosed during the first 2 years of operation but was stopped in November 2004. Since then no chemical dosing has been required on the plant.

3.3 RO Membrane System

Two 2,500 m^3/day SWRO trains are provided. Each stream consists of a high pressure pump, a battery of ERI pressure exchangers and a set of Hydranautics SWC3 membranes, each with 370 sq ft of membrane area.

Both, high-pressure and booster pumps, are equipped with frequency controlled drives to enable the plant to operate with the lowest power consumption. The RO system was designed with 34 pressure vessels per train, 7 elements per vessel, resulting in a system flux rate of 13 liters/m^2/hr. The permeate back pressure was typically 1.0 bar.

The ERI pressure exchanger utilizes the high pressure brine, rejected from the reverse osmosis membranes. The pressure exchanger transfers pressure energy in the brine reject stream to the feed stream, reducing the electrical power required during normal operation.
With 42% conversion, the projected specific energy requirement of the plant is 2.9 kWh/m^3 for full process load (intake and pre-treatment, RO part and distribution pumps with auxiliaries). The first two years of the plant operation have confirmed this figure. The average process load is 2.86 kWh/m^3 of product.

The following two charts show the projected membrane feed pressure against real feed pressure at plant start and projected product conductivity versus real conductivity. Charts 1 and 2 demonstrate the accuracy of plant design calculations and the optimised engineering design.

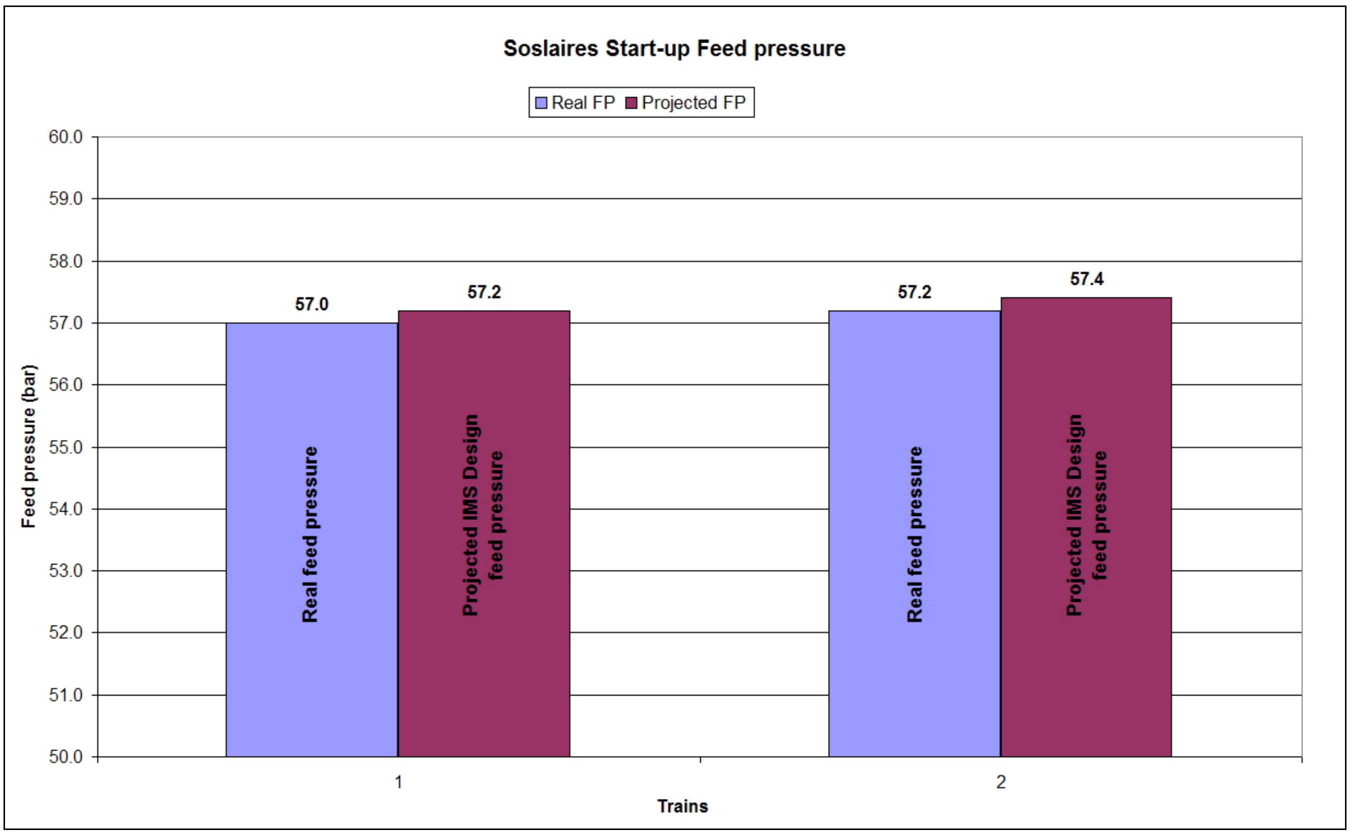


Chart 1. Projected start-up feed pressure versus actual pressure

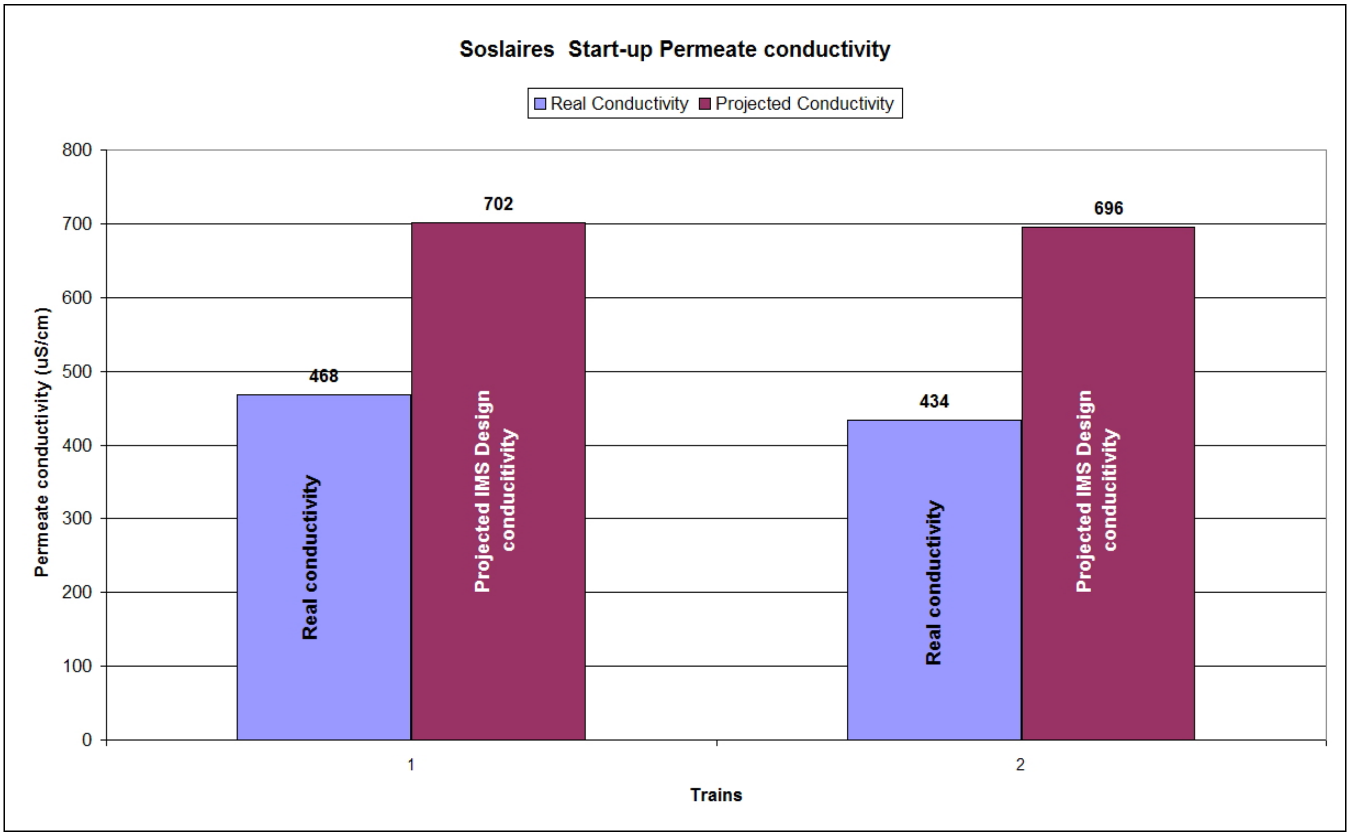


Chart 2. Projected start-up permeate conductivity versus actual conductivity

SWC3 membranes have already performed well in the Canary Islands and their excellent performance is also confirmed in the Soslaires SWRO plant. Typically, a train's performance is assessed by normalising plant performance against the first day of operation. Chart 3 demonstrates very steady normalized flow over two years of operation.

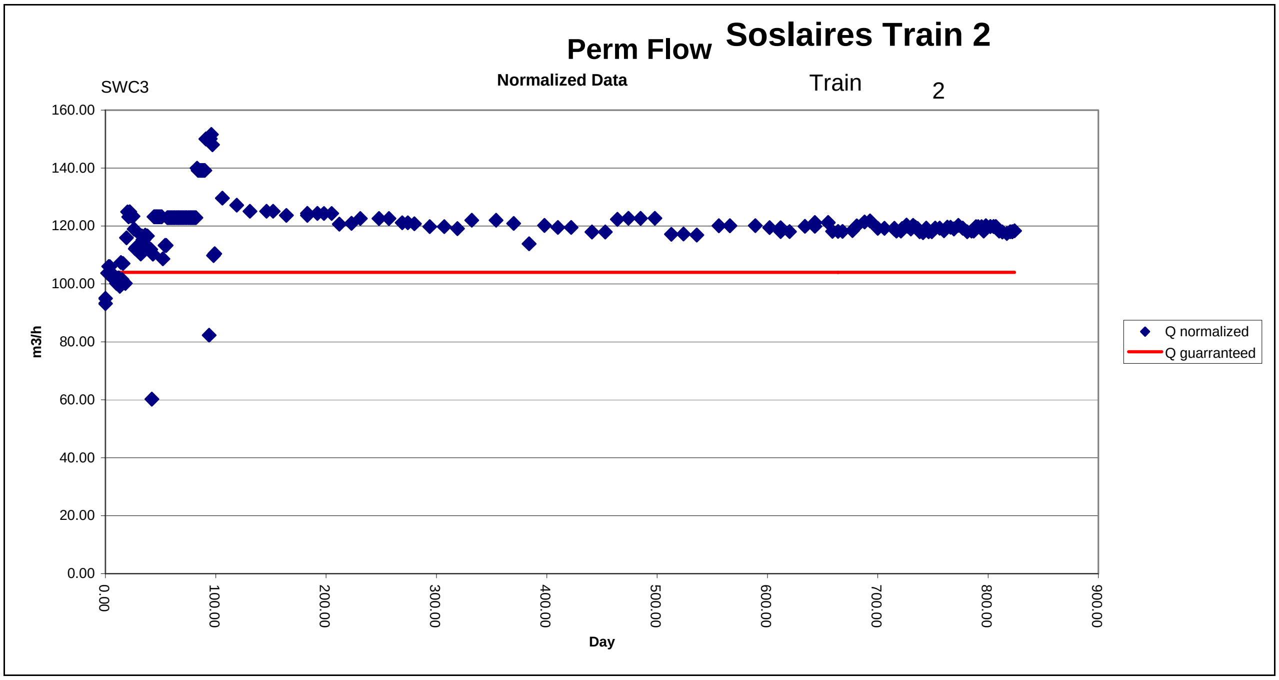


Chart 3. Normalized product flow

The salt passage of the membranes also behaves within the expected parameters. On each start up and shut down of the train, the product conductivity initially increases. This is likely to occur during initial commissioning of the train. Expected product conductivity is restored, once the train is kept in operation. However, if there are frequent shut downs and start ups of the train, the product conductivity may not be restored to its expected value. This phenomenon has been observed on other installations, with various types of membranes. Charts 4 and 5 present results of real product conductivity as well as the normalized salt passage of the system. Operational results are significantly below guaranteed conductivity value of 800 µS/cm

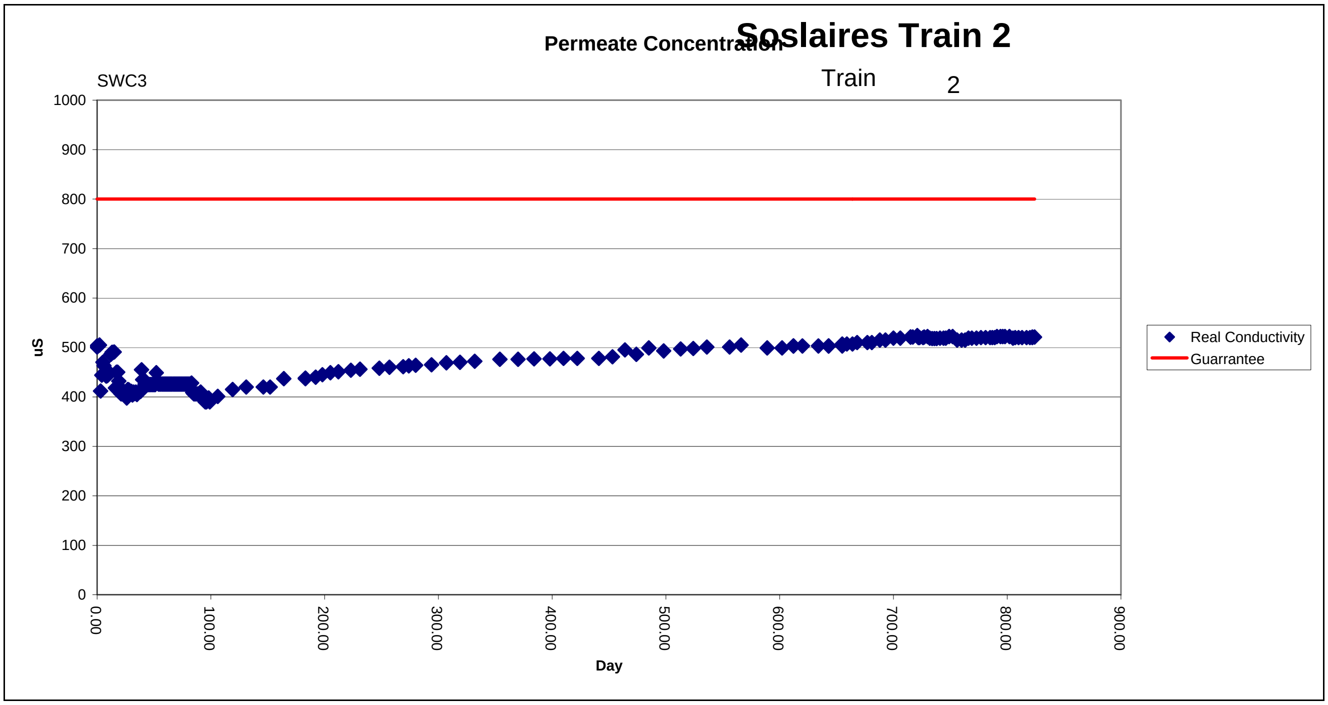


Chart 4. Product conductivity

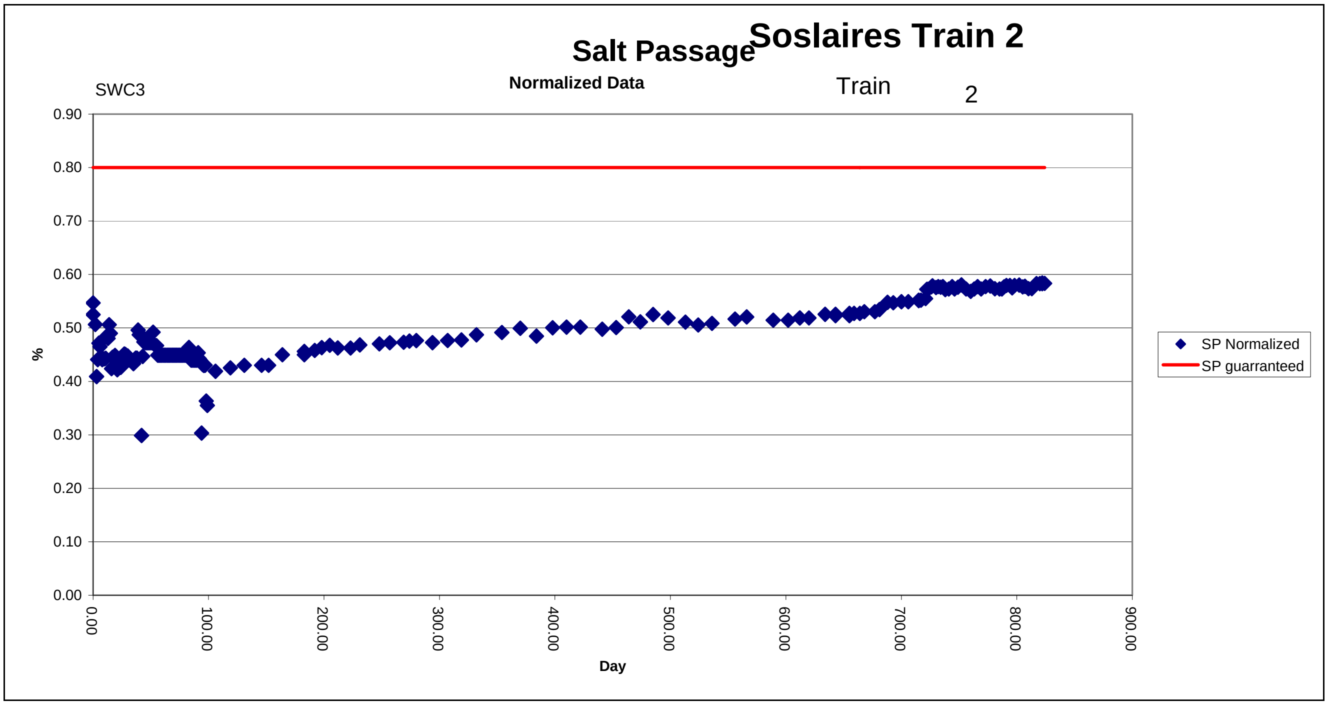


Chart 5. Normalized salt passage

Train 2 operational data are presented. The performance of train 1 was very similar, with only negligible differences. No chemical cleaning has been performed since the plant was start-up. The plant has been in operation for 828 days (displayed on the presented charts). The stable operation of the RO system is attributed to the exceptional quality of the pretreated water, absence of chemical addition, proper membrane flux rate, and careful attention to plant operation.

3.4 Control System

The system provided offers the flexibility and performance normally attributed to a distributed control system (DCS). The system is designed to provide minimum operator intervention and maintain the necessary interlocks for safe operation.

To facilitate the control of the wind generators as well as new SWRO plant, a PLC based system has been selected, with a PC based topology, incorporating a SCADA software package for ease of operation.

IV. ENERGY EFFICIENCY AND ENVIRONMENT

The figures in Table 2 below summarize the specific energy consumption. Feed consumption is the energy required for the well pumps. The process consumption is the energy required for the booster and RO high pressure pumps, while the distribution consumption is the distribution pumps. A total energy consumption value of 2.86 kWh/m^3 demonstrates that the SWRO desalination process can be very efficient, from the point of energy consumption, when the proper engineering approach is used. Comparison with energy consumption, using a typical “conventional” energy recovery design is summarized in Table 3.

Cost of electrical energy from network	**Agrícola R.1.**
Average cost 2003:	**Aprox. 6,85 cent € /kWh**
Water final price to the customer:	**60 cent € /m^3**
Average electricity price for sale (2003):	**7 cent € /kWh**
Specific electrical consumption:	**2,8 kWh/ m^3**

Table 2. Comparison of the design and real operation – power consumption

	Capacity m^3/d	Feed consumption	Process consumption	Distribution consumption	Others	TOTAL
Design	*5,000*	*0.5 kWh/m^3*	*2.5 kWh/m^3*	*0.3 kWh/m^3*	*0.1 kWh/m^3*	*3,4 kWh/m^3*
Real Op.	*5,000*	*0.3 kWh/m^3*	*2.3 kWh/m^3*	*0.2 kWh/m^3*	*0.1 kWh/m^3*	*2,9 kWh/m^3*

Table 3. Comparison with conventional ER design – power consumption

Capacity m^3/d	Feed consumption	Process consumption	Distribution consumption	Others	TOTAL
5000	*0,5 kWh/m^3*	*3,1 kWh/m^3*	*0,3 kWh/m^3*	*0.1 kWh/m^3*	*4,0 kWh/m^3*

Days of production:	**350 days/year**
Annual consumption - design:	**5,950,000 Kwh**
Annual consumption – real operation:	**5,075,000 Kwh**
Annual consumption – conventional ER:	**7,000,000 Kwh**

It is also important to point out that power produced by wind generators does not create emissions. Typically 1 kWh of energy produced by wind generators avoids emission of 0.6 kg of CO_2, 1.33 kg of SO_2 and 1.67 kg of NO_x. Compared with a similar size of small thermal desalination plant - the new RO plant avoids the burning of 34,850 liters of heavy grade oil per day and the consequent emission of 1.69 tones of SO_2. The resultant effluent disposal costs and/or resultant pollution are also avoided in the SWRO plant. This design of plant therefore, provides a significant environmental improvement.

V. SUMMARY

The SWRO Plant, constructed between 2001 and 2002 by TCA, utilizes the most energy efficient processes to produce irrigation water for crops. The design, construction, commissioning and reliability test was executed within 24 months. The plant employs the latest water treatment technologies and operating costs have been minimised.

The new SWRO plant generates no gaseous or odorous emissions and is powered by "clean energy" produced by wind generators. Environmental impact is minimal. The only significant liquid effluents consist of brine and cleaning effluents, where required.

No chemical compounds are added to the brine, during the treatment process. Shock disinfection has not yet been required on the plant, but is available if needed.

The pretreated water is of excellent quality with SDI typically less than 1. Membrane performance is very steady and meets or exceeds projected performance. Cleaning has not yet been required, after more than 2 years of successful operation.

AUTHOR REFERENCES

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