Desalination and Water Treatment
www.deswater.com

doi:10.5004/dwt.2018.22434

113 (2018) 1–5
May

The role of SWRO in peak load reduction and grid stability

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Received 1 January 2018; Accepted 25 March 2018

ABSTRACT

The marked development of renewable energy has been able to offer in the GCC market the possibility to pave the road for a sustainable energy development in the area. In particular recent tariffs of 2.5–3 cents/kWh achieved in recent PV tenders in the UAE and the record tariff of 1.75 cents/kWh achieved in the tender of Sakaka project in Saudi Arabia underpins a continuous development of renewable energy technology and tariff that are more competitive than conventional energy supply [1]. One of the aspects that often is at odds with installing more renewable energy and in particular PV systems in the GCC is the objective difficulty in the energy storage and in harmonizing the energy production with the energy demand pattern and stabilizing the grid operation. In the UAE where the weather conditions are stable and predictable for the great part of the time, photo voltaic power generation operates practically at base load. This poses several objective difficulties for instance during the winter months there may not be sufficient electricity generation at co-generation stations to maintain water production of the existing thermal plants. Moreover the peak energy production from PV plants does not correspond with the peak energy consumption from the grid and daily peak load remains still to be catered by peaking stations operating inefficiently and with large CO_2 emissions [3]. This paper aims at demonstrating how judicious use of SWRO technology can offer a great contribution to energy savings and peak load reduction as well as in the stability of the grid operation when a large PV capacity is installed.

Keywords: Sustainability; SWRO; Renewable energy; Energy storage

1. Daily energy demand pattern

Fig. 1 shows the daily electricity demand profile in winter and summer [5]. It shows a peak between 18.00 and 19.00 h where the power load is maximum and a period between 3.00 to 6.00 h when the power demand is substantially lower than the daily average.

The typical average daily power demand profile in the GCC countries therefore can be simplified as indicated in Fig. 2 showing the winter and summer peak profiles and the drive towards a higher peak load between 18:00 to 20:00 hours mainly driven by residential power demand.

Meeting power grid demand at peak point is always the most critical point in the overall grid management. This is often met by peaking power plants operating with a high heat rate and is therefore extremely costly both in terms of energy demand and environmental and sustainability impact.

The alternative to peaking plant is generally provided by energy storage solutions. Energy storage is a key of in the transition from fossil to renewable energy. However state of the art solutions are still relatively costly and difficult to manage (except for pumped energy storage which is very site selective).

2. State of the art energy storage and peaking devices

Fig. 3 [4] shows different state-of-the-art energy storage technologies against their storage capacity and reaction time. In the same figure the reaction time of SWRO has been indicated along with the range of power that in principle

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can be released or absorbed and the related costs. Both the costs for energy storage are still high and the response to the demand grid peaking are low.

The current way peak energy is matched in the GCC is generally through the adoption of peaking stations operating on a open cycle gas turbine mode or diesel whose operation is featured by a very high heat rate and therefore large fuel consumption and CO_2 emissions.

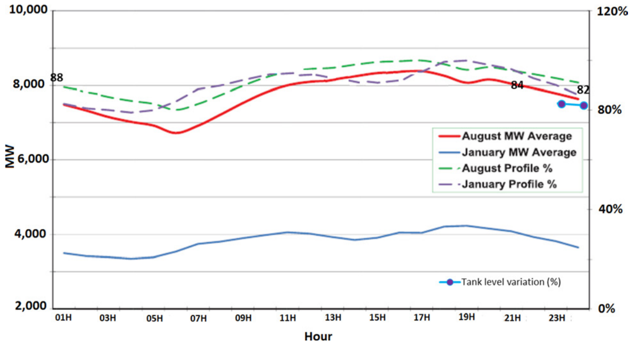


Fig. 1. Abu Dhabi 2015 system electricity profile [2].

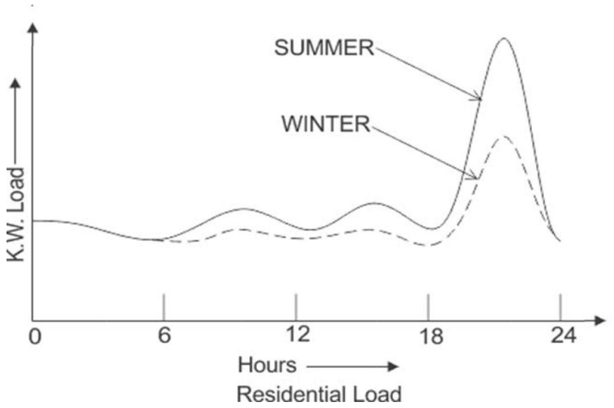


Fig. 2. Schematic typical average daily power grid demand.

3. Use of SWRO technology for peak load shave and harmonization

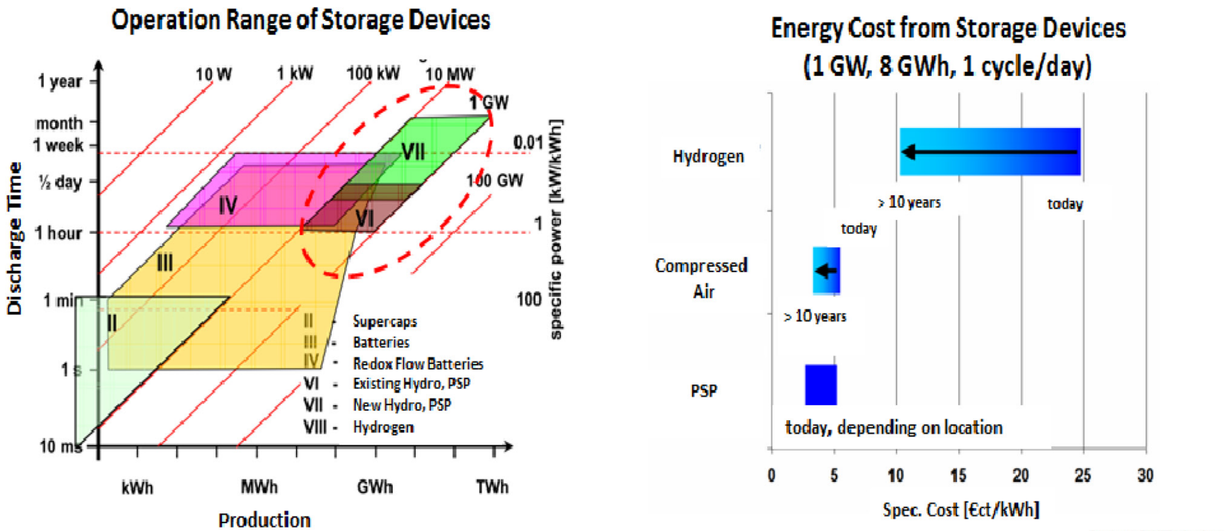
A significant contribution to improve matching of grid demand requirement with power generation can be provided by a judicious use of SWRO. In this respect it is possible to take advantage of the modularity and flexibility of the technology to produce more and consequently absorb more energy during the off peak period. In the same manner is it possible to reduce the capacity in the network demand peak period in order to contribute to shave off the peak demand, and a tariff structure could be structured that is variable on a day-by-day basis to encourage this production pattern [5].

Electricity tariffs from the grid to the SWRO plant developer or product water generator therefore could be structured to encourage this production pattern. This would bring about a lower tariff in the off peak period so that generator is encouraged to produce water at a lower cost and higher tariff in high peak so that energy absorption from the grid is reduced, and as a consequence also peak load is reduced. This would enable potential cost and energy savings arising from this concept and prevent greenhouse emissions.

Table 1 shows a typical tariff premium scheme, which would enable to take full advantage of the technology flexibility.

SWRO process parameters could be parametrized over a variability of operational fluxes which does not impose to build redundancy in the SWRO plant arrangement but enable to vary the product water generation and therefore in turn the power grid absorption by simply using the inherent flexibility of the process parameters as indicated in Table 2.

The corresponding mode of operation of the SWRO could therefore adapt to the grid demand as indicated in



Source: RWTH Aachen

Fig. 3. Energy storage solution reaction time and costs (RWTG Aachen [4]).

Table 1
Typical tariff structures to encourage water savings in IWPs

Situation	Hours	Water production	Electricity tariff
Off power peak	0.00–11.00	Peak water	Discounted
Average power load	18.00–24.00	Rated water production	Base tariff
Peak power period	11.00–18.00	Minimum load	Base tariff x multiplier

Table 2
Typical process parameters of SWRO technology in process modulation

Situation	Hours	Membrane flux	Plant recovery
		l/(m^2 h)	%
Off power peak	0.00–11.00	15	43
Average power load	18.00–24.00	10	40
Peak power period	11.00–18.00	7.5	37

Fig. 4 adapted from ADWEC 2016 statistical report [2], whereby the SWRO production could be boosted to 120% during the low electricity demand (and consequently low electricity price), and curtailed during peak load time.

In particular taking advantage of the flexibility and modularity of the SWRO configuration it would be possible to operate the SWRO plant at peak water production during the off peak power demand periods.

In this period the SWRO plant could operate at higher flux and maximum power demand.

When the power demand increases the SWRO production could be module in order to minimize the power grid absorption in off peak season and contemporarily.

This modularity in the SWRO technology could be accompanied by a dynamic storage pattern in the tank farm as indicated in Fig. 5, which would enable to maintain the water dispatch to the network constant during the grid shave period.

In particular as can be seen from Fig. 5, the tank level variation would remain in the range of 100% to 80% while the water generation is reduced. Compared to other energy storage techniques (Fig. 3), the modulation of SWRO operation is both capable of responding to grid load variations in a fast manner. Furthermore the modularity in SWRO operation is an inherent feature of “state of the art “ design and does not require a substantial dedicated investment.

Furthermore as described in Fig. 6 taking advantage of the product water storage tanks installed within the SWRO yard it is possible to modulate the electricity absorption from the grid without affecting the level of potable water dispatch.

4. Estimated energy savings in peak load shave

Eq. (1) illustrates the energy that can be shaved off from the peak load by modulating the capacity ad consequently the energy absorption of the SWRO plant

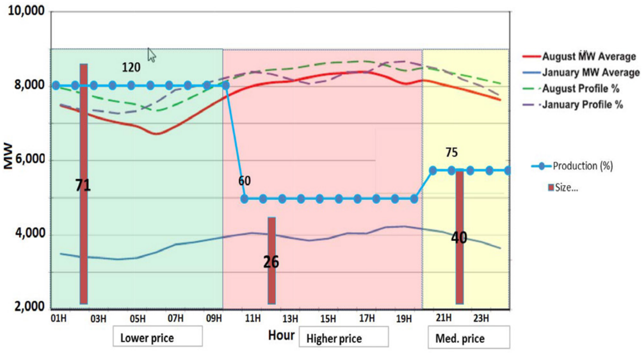


Fig 4. Abu Dhabi 2015 daily power demand profile pattern and proposed SWRO modulation (modified from ADWEC 1999–2015 statistical record [2]).

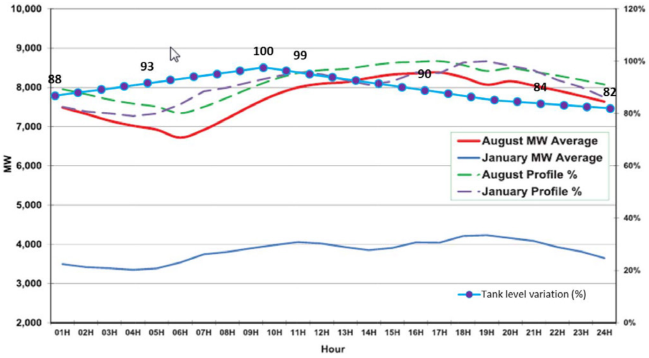


Fig. 5. Abu Dhabi daily power demand profile pattern and proposed SWRO modulation .

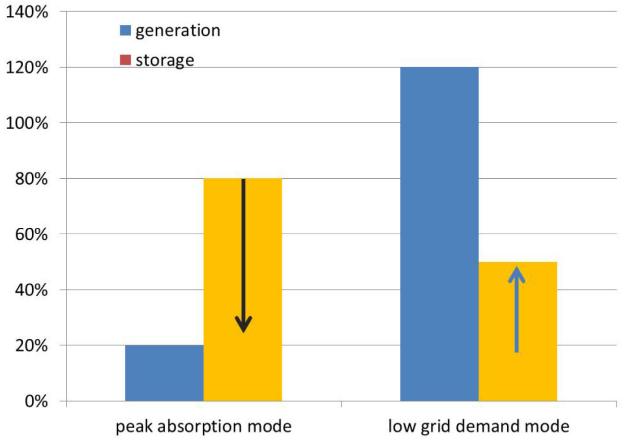


Fig. 6. Typical dynamic generation and storage mode of operation.

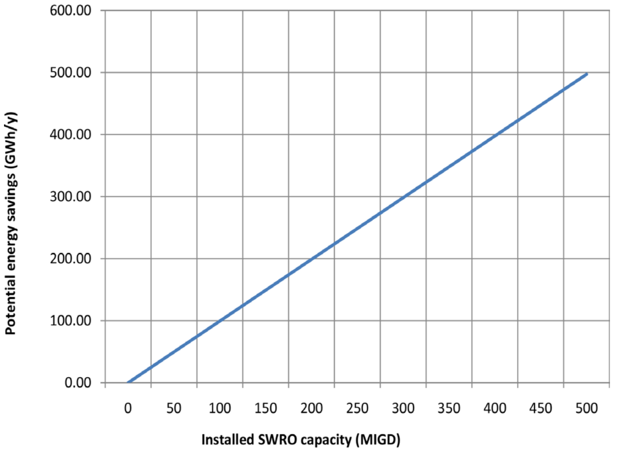


Fig. 7. Potential energy savings against installed modular SWRO capacity

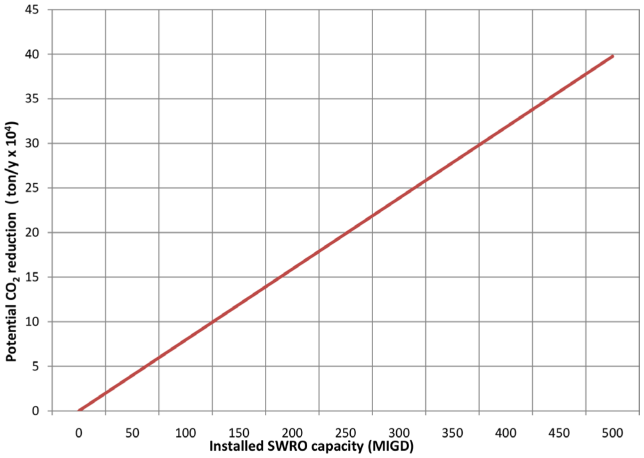


Fig 8. Potential energy and CO_2 savings against installed modular SWRO capacity.

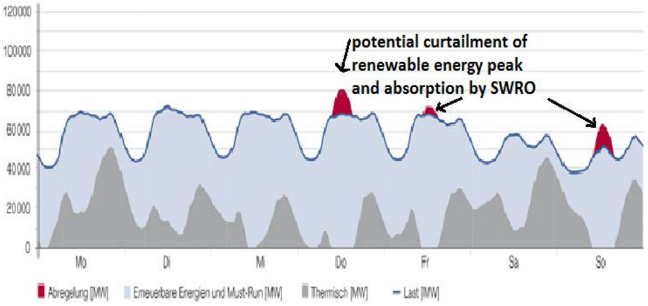


Fig. 9. Use of SWRO technology for excess capacity harmonization adapted from [4].

$$P_m = C_{SWRO} \cdot \gamma \cdot \varepsilon \tag{1}$$

where P_m is the power demand that can be withdrawn from the grid by modulating the SWRO capacity [kW]; C_{SWRO} is the installed capacity of SWRO connected to the grid [m^3/h]; γ is the average SWRO specific power consumption (kWh/m^3); ε is the average SWRO turn down capacity.

Considering an average specific power consumption for SWRO technology of 4.5 kWh/m^3 [2], the reduction for instance of one 100 MIGD SWRO desalination plant capacity to 60% of production on peak load still maintaining the dispatch unaltered would enable the reduction of about 50 MW peak load. The overall energy that can be saved in this case is given by the formula indicated in Eq. (2):

$$E_m = C_{SWRO} \cdot \gamma \cdot \varepsilon \cdot \tau \tag{2}$$

where τ represents the duration of the peak load (h/d).

Considering Eq. (2), Fig. 7 can be obtained, which shows the power savings that could be obtained by installing a modular SWRO capacity as described in this period and if the tariff in the power connection agreement is structured in a way to encourage this production pattern.

In the Middle East where power generation plants are newly constructed and operate with combined cycle, it is reasonable to consider an average grid emission factor of 0.5 tons of CO_2/MWh. On the other hand, because of the peak load, it is reasonable to consider a higher grid emission factor as a consequence of the open cycle operation that is required to deal with the peak factor.

As can be seen from Fig. 8 in comparison with state of the art energy storage, the adoption of SWRO technology can in principle react within a very short time.

5. Harmonization of renewable energy generation instabilities

When a considerable mix of renewable energy technology is installed in the grid there is often the possibility that more energy is available from the source that can be absorbed form the grid.

This is indicated in Fig. 9 [4] where the red area represents the energy peaks generated for instance by a sudden high wind energy load.

If there is no energy storage available and the energy peaks are above the grid capacity of absorbing the energy this energy would be wasted.

On the contrary the adoption of SWRO technology can allow the harvest of this energy by increasin the generation mode and pushing the flux of the SWRO membrane. This mode of operation is however curtailed by the storage capacity of the facilities.

In this case increasing the water storage is both strategic and much cheaper than state of the art energy storage. Therefore this also represents a business case in favor of SWRO technology.

6. Conclusions

With the current solar and nuclear electric base load the application of selective tariffs to SWRO technology according to the diurnal electric network power load may allow a substantial contribution to peak load optimization with a substantial savings in both fuel consumption plant capacity optimization and related greenhouse emissions. The design of SWRO should therefore be considered in order to take advantage of its inherent flexibility and modularity.

A holistic approach to water may enable to further decrease of the seawater desalination requirements contributing to a further decrease in power requirements.

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