New Solar Pumping Technology for RO and Desalination Plants

Dr. Labib Sultan* , Soalropia Inc.

1. Introduction

RO and Desalination plants can provide extra water source supply for the draught state of California, if their energy intensive consumption can be improved to an acceptable level to the state environmental regulation to reduce GHG emission, and to compete with imported water in cost. Considerable improvement in RO processing technologies Over the past two decades has reduced RO plants power consumption by almost 70% (from 80 KWh in 1985 to 15 KWh in 2015 per 1000 gallon of water production)[(1).] Even with these improvements, seawater desalination plants are still about 1.5-2 times more expensive than imported –transported water due to power cost. Power cost constitutes between 35%-50% of the produced water, and about 85% of plants operation cost.

Pumping constitutes 98% of the total power consumed in RO plants, so improving pumping power efficiency, or the use of alternative power (such as solar) is another venue for further RO power cost reduction- environmental improvement. A promising technology in this direction is called SPI : Solar-Pumping Inverter- VFD recently introduced by San Diego based start-up called Solaropia. The technology operates pumps directly from PV arrays with and without grid power, including high-pressure pumps from 200 psi (to treat Ground Brackish water) up to 1000 psi required for seawater desalination. SPI models are under development to operate up to 250 HP pumps , and plans to produce even up to 500KW and 1 MW are on the run for early 2016. SPI is projected to reduce RO power cost by 40% -to-60% .

This article is to familiarize readers with this technology, the power consumption metrics in RO plants , the cost estimates of water production in RO plants, and establishes the cost viability for wide deployment of solar RO plants to treat Brackish wells water, and seawater in CA- a promising direction to supply the draught state with new water sources .

2. The RO Pumping Power Metrics

RO is a proven water treatment technology widely used worldwide to produce potable water from brackish underground sources, sea water desalination, and industrial water re-use. RO technology has been evolved over the past 30 years . Their power consumption efficiency has been tremendously improved by using new filtration membranes materials requiring lower pressure (and consequently lower power consumption), and improved inter-stage pressure recovery technologies using lower pressure pump at secondary processing stage[(2)] .

The required pumping power in RO plants depends on the source salinity degree measured in TDS (Total Dissolved Solids) in (PPM Particle Per Million) units. The table below summarizes an average of required power by RO pumping for various TDS of the source water.

Estimated RO Pumping Power Requirement for Various TDS of the Source Water

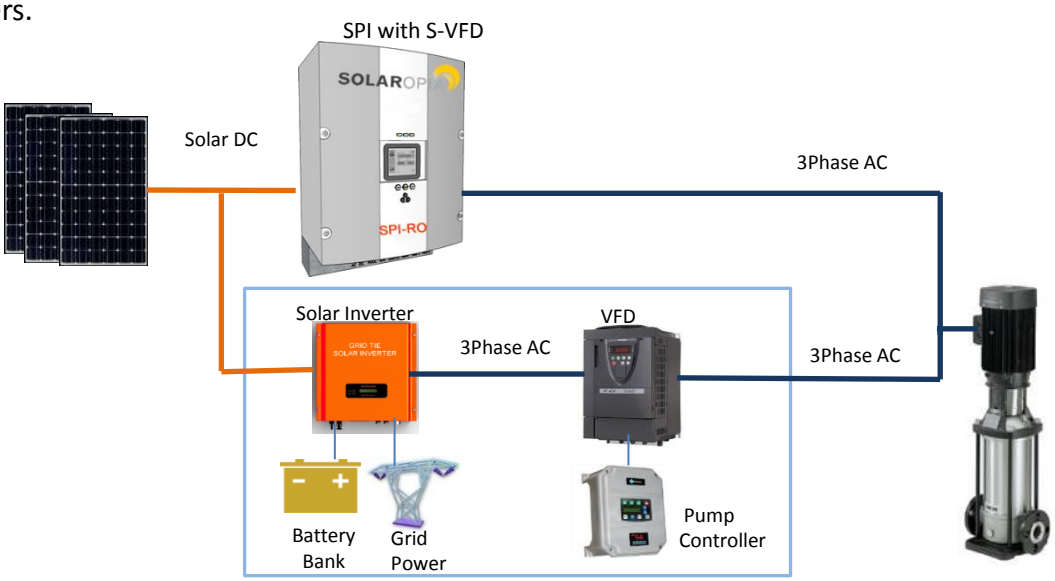
Source water TDS (ppm)	Brackish Ground Water		Sea Water	
	5000	15000	35000	45000
Required Pumping Pressure (psi)	200	350	750	900
Required Power (KWH) /1 Acre-foot (about 325,000 gallon, 1200 m^3)	1300	2000	3200	4000

3. The Solar –VFD Technology for RO Pumping

VFD (Variable Frequency Drives) are devices widely used for industrial pumping. They use AC power to operate pumps with the required water flow rate and pressure. They are energy optimizer and pump controllers. Without VFD, pumps will operate at fixed flow and will consume maximum power. They also protect Pumps from external effects such as power surge , dry run , over pressure, and they apply soft start and soft shutdown to protect pumps from structural damages .

SPI uses Solar VFD technology (in short S-VFD) to executes the same functions as conventional industrial VFDs with a unique difference –it can operate pumps with Solar instead of AC power. It combines in one three systems: solar inverter , solar VFD and pump application controller, eliminates double solar DC-to AC power transformation thus they are more energy efficient than conventional solar in pumping applications. SPI can operate pumps with and without grid in three power modes : Solar-Off-Grid (world's first Off-Grid battery-less system) , AC (ON-Grid without inject-back to the Grid), and a hybrid of Solar and AC power that use AC as complimentary to any available solar power in late-early day hours. Thus SPI can operate pumps in rural areas where the grid even does not exist as well as urban pumping plants.

An important feature of S-VFD is that it reduces solar-power cost to operate pumps by 30%-40% due to minimizing double solar power looses incurred by double transformation to AC power when using two conventional solar inverter and VFD system . Another solar system cost reduction by replacing three conventional systems to operate pumps with one- the SPI. SPI evaluation has demonstrated 50%-to-70% better solar power efficiency when compared with existing solar pumps currently produced outside the United states using traditional solar inverters.



SPI eliminates the cost of all these systems and it requires 30% less PV solar power to operate pumps

SPI systems with S-VFD high efficiency will RO power cost to about ¢7-¢9 per KWh which leads to 40%-to-60% reduction from current cost when RO is operated with solar. SPI-RO a special class designated for high-pressure pumping (up to 1000 psi) will become commercially available in late 2015 for wide pumping applications. Other SPI systems designated for large pumping stations that transports millions of gallons per day, as well as for ground pumping up to 2000' deep wells –up to 250,000 GPD (gallon-per-day) are on the way even earlier in 2015.

SPI –RO can operate all types of industrial high-pressure pumps (Positive-Displacement, Axial, Booster , and Centrifugal pumps). It is pump type and brand independent. It can maintain the required pump pressure constant , and change the flow rate if solar power is the only source to operate plants . When both Solar and AC power are used in hybrid mode , it can maintain both as set by operators. it uses any available solar power, and take the remaining power from the grid without switching power modes and source. The SPI-RO is industrial class solar pumping system - it does not inject power back to the grid –it uses grid power when it is needed. Finally SPI-RO can be remotely accessed using standard industrial communication protocols, and its pumping parameters flow arte , pressure, consumed solar and AC power and other parameters are available to SCADA systems and to plants control room operators. SPI also operates feed pumps to RO plants with Solar Power.

4. Economic Impact of Solar RO- Plants

Energy cost constitutes from 35% -up to-50% of RO water production cost [(3)] , and about 85% of plant operating cost . Accordingly, a decrease of energy cost by 40%, for example, will reduce RO water cost by 25%. To evaluate the immediate economic impact of using solar RO plants in CA, one can evaluate the cost of producing potable water from various resources (ground – brackish water, Water-reuse , seawater, transported). The table below compares the energy cost of supplying 1 acre-foot (A/F) (about 325,000 gallons -1200 m3) potable water from these various sources with conventional energy (utility or collocated plants) , and the use of SPI Solar Pumping Energy cost.

Water Source	A/F Approx. Energy Consumption (KWh)	A/F Cost with Convent. Energy (¢18 KWh)*	A/F Cost with SPI solar Energy (¢8 KWh)
Sewage-Industrial Water-re-use plants (TDS= 3000)	900	$162	$72
Brackish Ground Water treatment plants (TDS 5,000)	1200	$216	$96
Surface Water transportation for 500 miles	2500	$450	$200
Sea Water Desalination Plants (TDS= 45000) **	4000	$720	$320

* This cost is not fixed as with SPI fixed cost for 15 years. It can be lower in private contract, or higher from grid power. It is projected to be increased by 27% by 2030. With draught hardening the lower cost hydraulic power generation can be increased dramatically [(Z pacific report)]

5. Future Vision on Solar RO plants

In order to draw a wider picture for the future clean economy of the state – Solar Pumping can play a major rule in lowering water supply cost and at the same time maintain clean environment - supporting the state economy growth even in draught conditions. Water related pumping consumes about estimated at 50GW (about 20% of the state power)[4] . Solar pumping can assist in the transfer of this huge portion of power to renewable, and provides extra water sources to the state at lower cost.

The emerging S-VFD technology and on its base the SPI-RO solar pumping systems can pave the road for wide deployment of low cost clean-energy operated RO-Plants that can meet environmental regulation in States like California (the state has committed to reduce the GHG to the level of 1990 by 2020. [5] The S-VFD pumping technology will assist RO plants operators to reduce their operating cost and the state in achieving increase of renewable energy volume to 33% by 2020 [6]. Supplying renewable-low cost energy can assist in supplying durable and very valuable low cost potable water source from deep-wells brackish water, and sea-shore - sea-water can address current draught conditions, and future water needs for the State of California. Pilot projects to use SPI technology in RO small and medium plants , and training solar companies on this new solar pumping technology will be valuable for their wide deployment .

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* Dr. Sultan, Ph.D EE , is the founder and current President of San Diego based SOLAROPIA a company specializes in developing solar pumping technologies . Dr. Sultan is well known for shaping, designing and deploying the world first solar RO systems -more than 729 solar RO units were deployed since 2012 (award winning by Global Energy Organization). Dr. Sultan have also taught at several US and Canadian universities and can be reached at: labib@solaropia.com .