Integration of Power Generation and Water Desalination Operations

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Introduction

In the last five years, the interest in the United States for consideration of the development of new water supply sources with seawater desalination has dramatically accelerated. Visionary leaders in water resource constrained states such as Texas, Florida, and California are examining the opportunity to utilize reverse osmosis (RO) membrane desalination to meet water supply needs, avoid, mitigate, or reverse environmental damage from over-draft rivers and aquifers at reasonable delivered water cost. This new opportunity to develop significant water supplies from seawater is not a minor change in the water resource and supply business, it represents a major inflection point, a period that demands that we re-think many of the principles and practices that have guided the water supply industry since the mid point of the last century. Seawater desalination does not yet fit into the existing tapestry of regulations, planning and design practices, installed infrastructure systems or the environmental consciousness that controls this industry. If we are not willing and open to examine the potential of the opportunity presented, then the opportunity to provide local drought proof sources of water for the benefit of our constituent populace may be lost.

Perhaps the single largest factor which weighs against the use of seawater desalination in any given situation is the relatively high delivered water cost of the desalinated water. The delivered water cost is the all-in unit cost to produce and deliver a useable volume of water such as an acre-foot. The delivered water cost includes the total project capital cost and the operating costs for the desalination facility over the life of the facility. There are many factors that are keeping the delivered cost of seawater desalination higher than it could be, some of the significant ones are: the lack of desalination planning, design and regulatory expertise; the limited size of the RO desalination industry; the lack of environmental experience with RO desalination plants; and, the energy efficiency and intensity of the RO desalination process. Each of these factors currently has an adverse impact on the delivered water cost of RO desalination. This paper has been developed to explore one small facet of one of these factors related to the high delivered water cost of desalination, the nature of the relationship between the power generator/supplier and the desalination plant. There are potential areas of improvement or change in this relationship that need to be considered as a matter of public policy and in the earliest development of the desalination project concept that could dramatically reduce the delivered cost of desalinated water.

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Electric Cost and Desalination

The cost of electricity is the single largest O&M expense at a desalination facility that uses an RO process. The electric cost can approach 70 percent of the total annual O&M expenses of a Reverse Osmosis seawater desalination plant. Consequently facility efficiency and energy conservation measures can provide significant benefits but only marginally effect desalinated water costs. The rates for electrical service, consequently, are one of the most important factors impacting desalinated seawater costs. Generally, electric rates are dependant on factors such as power plant fuel costs, electricity transmission rules and regulatory policy.

Texas Electric Marketplace

Texas Deregulation

Texas is one of a handful of states that has aggressively pursued the deregulation of wholesale and retail power markets. Retail choice is currently available to customers located within Investor Owned Utility (IOU) service territories in the Electric Reliability Council of Texas (ERCOT). ERCOT monitors and controls the delivery and reliability of power supply to the majority of electric customers in the State. Although IOU's are required to offer retail choice, to date, municipal utilities and distribution cooperatives have not opted into retail competition. However, as a practical matter, municipal utilities and distribution cooperatives regularly compete with retail choice options in order to retain and attract new loads. As a result, current market conditions are such that there are numerous power supply options available to a desalination plant outside of traditional rate options offered by a regulated utility. These options could potentially lower power costs for a Desalination plant by a substantial amount.

Since, the mid 1990's, the Public Utilities Commission of Texas (PUCT) has been aggressively deregulating the Texas wholesale and retail power markets. The Texas Public Utility Regulatory Act was amended in 1995 to deregulate the wholesale generation market. As a result, in early 1996, revised rules were issued that created an independent system operator (ISO). The PUCT also promulgated open access rules that allowed power generators within the Texas market access to the transmission system under a single postage stamp rate. These rules eliminated the monopoly power of large Texas investor-owned utilities with respect to the transmission of power to load and opened the wholesale market to all generators.

Although this new open-access market improved competition to some degree, further re-regulation of the ERCOT market was enacted, via Texas Senate Bill 7, to open the Texas electric retail market to competition as well as of January 1, 2002. Other provisions of Senate Bill 7 required utilities to unbundle services, allowed competition for metering and billing, and provided for recovery of stranded costs. In addition, investor-owned generation companies, retail electric providers (REPs), and transmission and distribution utilities were required to be separated, either by creating separate nonaffiliated companies, or separate affiliated companies with the same holding companies, or by selling off assets to a third party.

Since 2002, while there has been some degree of both wholesale and retail competition in ERCOT, the power market is still in transition to full competition. For large high load factor customers, such as a desalination plant, competition has been robust compared to other customer groups as REPs have aggressively sought to retain these load types.

Electric Pricing Options

Because of retail choice, for large high load factor end users such as a desalination plant, traditional tariffs that might be offered by regulated IOU's are not applicable. In Texas, a desalination plant located within an IOU service territory is not subject to specific rate tariffs based on class or other load characteristics. Instead, to obtain power service, a desalination plant can issue a Request for Proposals (RFP) soliciting power from qualifying REPs.

An REP functions as a load aggregator and takes the place of a traditional utility. The REP purchases power from the wholesale power market and arranges power delivery through the local wire company. Various REPs would compete for the desalination load given the requirements of the REP. Because the typical desalination load is large with typically a very high load factor, the load would be attractive to REPs and would likely compliment other customers in the REPs portfolio with lower load factors. As a result, a desalination project should generate much interest from numerous competing REPs.

This presents the desalination plant with an excellent opportunity to discover prices for a variety of product and service configurations. Through the RFP process, pricing can be obtained for on-peak, off-peak, annual, seasonal, firm and interruptible products. Additionally, the desalination plant can request pricing at different delivery voltage levels to evaluate the cost/benefit of installing its own distribution and/or sub transmission facilities. Based on the RFP response, numerous plant operating and power supply options can be evaluated to minimize power costs and ultimately the cost of treated water.

Desalination facilities then, have a variety of options under the existing Texas electric regulatory climate to secure a retail contract for power a supply. Due to their size and electric load factor, they can issue an RFP to a privately owned utility or negotiate directly with a municipal utility.

Wholesale Power Opportunity

Power rates can be categorized broadly as having four components, the wholesale power cost, the distribution costs, the retail costs and state and federal taxes. If the desalination plant is within the fence of the power plant, then it is theoretically possible to consider providing power to the desalination plant at the wholesale plus the distribution rate. If the desalination plant provided its own distribution system, the distribution system component of the rate could possibly be further discounted. Reducing the electric cost to the wholesale rate could reduce the cost of desalinated water by as much as 20 - 25 percent. An exemption from utility taxes for seawater desalination power suppliers may be required. The objective for any such exemption would be to keep drought-proof water supply affordable. Similar special rates have been considered by public utility regulators, but without legislative direction are generally rejected.

Another consideration in the cost analysis would be to drought-proof the water supply cost premium value. Rethink the environmental benefit of once-through cooling and concentrate management.

Power Generator Sensitive Desalination Plant Design

Generally, designers of water production facilities only have considered the characteristics (available voltage, kva, allowable sag) and location (nearest point of connection) of the electric supply. Their thinking stopped at the treatment facility fence line. As a rule, water plant designers tend to focus on developing the least complex answer to meeting a specific water supply need. In practice this translates into using the least amount of installed treatment equipment to reliably meet a specific facility design production capacity. Axiomatically, the most efficient use of a water plant is to run at a steady and constant optimal rate of product output. These practices generally work because they tend to assure the lowest installed capital cost for the facility being designed. But in consideration of the life-cycle economics of delivered water costs and the sensitivity of desalinated water costs to electric expense, using these widely held practices can hold the prospect for adversely impacting the cost of desalinated water.

The energy requirements for an RO seawater desalination system are significant. They can exceed 70 percent of the facility's annual operating and maintenance (O&M) costs. A 50 MGD facility operating with a seawater total dissolved solids range of 28,000 mg/l to 36,000 mg/l would require about 750 to 850 mega-watt hours per day or approximately 15 to 17 kW-hr/1000 gal. of product water (energy consumption also depends on other factors including the required product water quality, the recovery rate, the seawater temperature and the use of energy recovery devices).

Typically, O&M costs dominate the life-cycle cost analyses of a desalination plant by a 60/40 to 70/30 ratio relative to capital costs. In a retail power market, power represents 50 to 70 percent of the direct O&M expense of a desalination plant. Using a design approach that took into account time of day retail power generation rates and an adequately redundant desalination plant could reduce O&M costs by up 20 to 25 percent. This reduction in the desalinated delivered water cost would vastly benefit the customer and improve the implementability of seawater desalination.

Optimizing the design for power management would include the power supplier and the desalination plant designer cooperatively evaluating the power supplier's generation load and transmission characteristics and rate structures and then optimizing the level of installed desalination processing equipment and the capacity of product water storage. The object of the evaluation and design would be to minimize to the extent practical the use of peak period power. If the desalination facility's daily or weekly production cycle could be made to better match the off-peak operating periods of the power generator it could lead to reductions of power costs by 10 to 40 percent and overall O&M costs by 5 to 25 percent. Even with a negotiated retail rate there are any number of situations within which the mutually agreed upon and coordinated management of such a large power load has value to the power producer by reducing their generating operating expense.

An example of the above would be where the desalination plant power distribution, SCADA, control systems, the RO systems levels of redundancy (installed production capacity above the plants average design capacity), flush water system and the plant's product water storage capacity were designed to allow some or all of the RO plant's electric load to be shut down during the hours on weekdays that are the power suppliers "Peak" demand period while still meeting the water supplier's system water demand objectives. The object for the desalination plant designer would be to minimize or eliminate peak power usage and maximize off-peak power usage to the extent that provides the best financial return to the owner. This approach may require larger amounts of water storage capacity than would be normal for a typical water distribution system. The dynamic balance of this situation is the trade off between the relatively low capital cost of RO production capacity and water storage vs. the high operating cost of peak power.

Co-located RO Desalination Projects

Perhaps one of the best opportunities to reduce the capital and operating costs of a seawater desalination plant is to co-locate the desalination plant on or adjacent to a power plant. The general seawater desalination co-location concept is to utilize the post condenser cooling water from a once-through cooled power generating station as a source of seawater for the desalination plant. The major byproduct of the RO desalination plants is processed seawater that has had roughly half the fresh water removed from it so that the natural salts are twice as concentrated. This byproduct is therefore called concentrate. The concentrate from a co-located desalination plant can be returned to the outlet of the power plant's cooling water discharge to be mixed into the larger power plant cooling water flow before being discharged. Mixing the concentrate and power plant cooling water flow presents the ability to mitigate localized impact that could occur with an unmixed concentrate discharge. A collocated power plant is shown schematically below:

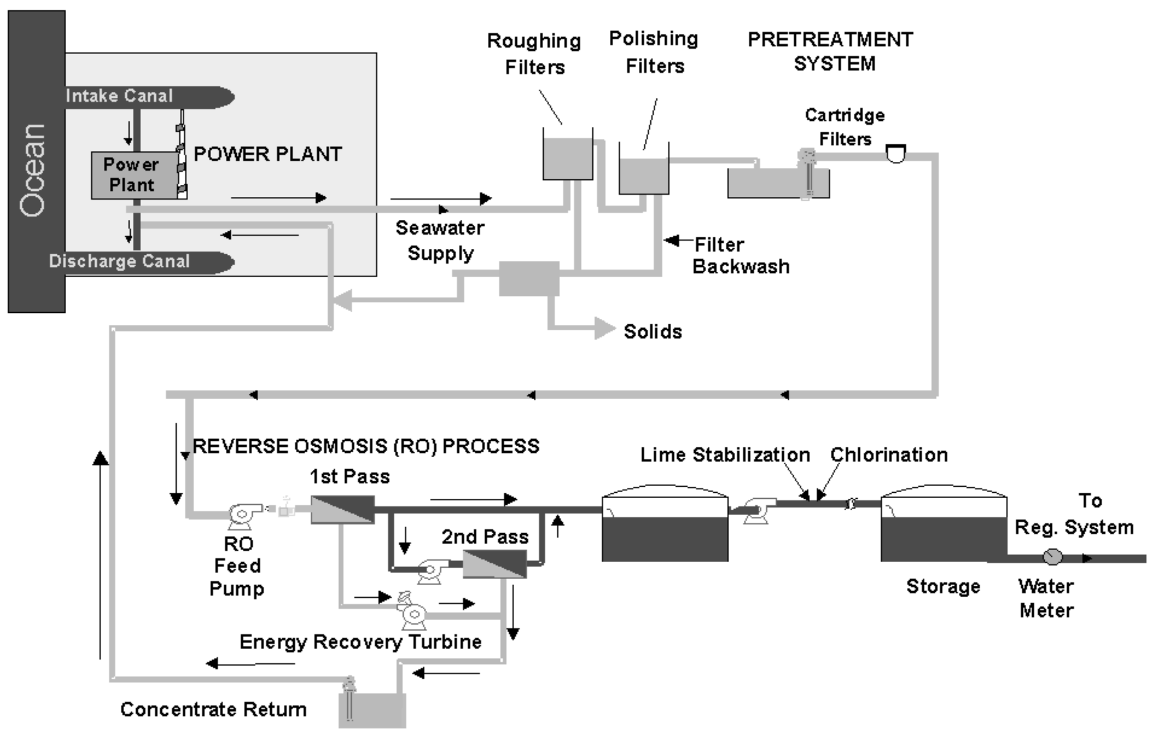

Figure 1 Co-located seawater desalination project process schematic

Once-through cooled power generating plants frequently use very large volumes of cooling water often in the range of one quarter to one and a half billion gallons per day range. To appreciate this scale, the largest RO desalination plant operating in the US produces 25 million gallons per day (MGD) of drinking water, requires 50 MGD of seawater supply and discharges 25 MGD of concentrate. The advantages of an RO desalination plant being co-located with a once-through cooled power generating station in the above configuration are as follows:

- <u>No New Intake required</u>
  Tapping a seawater supply for the desalination facility from the post condenser side of the power generating station's seawater cooling water circulation system can eliminate

the need construct a new seawater intake. Using the existing power plant intake facilities can significantly reduce desalination construction costs and avoid any intake construction related environmental disturbances. This can also avoid or lower the operating costs related to an independent desalination plant seawater supply.

- No Concentrate Discharge Diffuser Required
  Utilizing the existing power generating station's seawater cooling water circulation system's discharge eliminates the need to construct a new seawater discharge or other concentrate disposal means for the desalination facility. This can also avoid or lower the operating costs related to an independent desalination plant concentrate discharge.

- Elevated Raw Water Temperature
  Warmer water temperatures require less energy to treat by RO, but require more attention to materials corrosion and biologic fouling. Use of warmer water will reduce electric power consumption on a unit production basis.

- Limited Intake Permitting
  Using a seawater supply for the desalination facility from the post condenser side of the power generating station's seawater cooling water circulation system can eliminate the need for permitting a new seawater supply intake. As the cooling water is already used by the power plant there are no increased environmental consequences from also using the water to supply the desalination plant.

- Reduced Concentrate Discharge Permitting
  Using the power station's cooling water circulation system to mix, dilute and then discharge the concentrate can significantly reduce the extent of permitting a new seawater concentrate discharge.

- Lower Product Water Pipeline Land Costs
  Power Plants frequently have significant disturbed utility easements for the distribution lines to supply the power to customers. It may be possible to secure access to these easements for water distribution transmission lines. This can lower the capital cost of transmission mains to get the desalinated water to their customers. This can reduce the capital costs of the transmission pipelines and limit construction to previously disturbed corridors to limit adverse environmental impacts.

Joint Water and Power Supply Agencies

Extending the concept of optimizing power management up the supply chain can lead to development of more sophisticated relationships with power suppliers and opportunities for creating new joint ventures, contract relationships or tariff possibilities between the power supplier and the water supplier. In many states, joint water and power supply agencies have the statutory authority to supply power to themselves at their cost, or effectively the wholesale power cost.

It may also be possible for some agencies to significantly expand the concepts of desalination power performance optimization by considering designing and implementing a desalination project with both a power generation component and a desalination plant component. Joint water and power supply agencies or joint utility ventures already exist throughout the US. Such a joint supply responsibility provides the potential opportunity to develop lower cost desalination water supplies. It would be the objective of any such agency to utilize the power generator sensitive design concept as it would lower the power plants operating costs. Further, the prospect of improved desalination energy efficiency through a pressurized steam host-client supply relationship may be possible.

Perhaps one of the most significant aspects of such a joint water and power supply agency would be the prospect to supply energy or power at or near the wholesale cost to the seawater desalination plant. A "within the fence" relationship such as this and any such power supply transaction may be subject to regulatory review in Texas. It would require that the components of the electric rate associated with retail, tax and distribution not apply to the power purchase contract. This would require careful public consideration of the public policy implications of approval of this power supply arrangement.

Steam Supply - Direct Compression Drive Desalination Pumps

The principle process to generate power is to burn an energy source, such as coal or natural gas in a boiler to create steam. The steam is then used to turn a turbine and the turbine drives a generating unit. The generating unit produces the electricity. At each step there is a loss of energy because of various process efficiencies. One of the ways to avoid some of these efficiency losses is to use the power plant's steam directly to power pumps in the desalination plant.

In a once-trough cooled power generating station, steam can be extracted from the turbine at the correct temperature and pressure to drive steam driven pumps for the desalination plant. It is also feasible to route the post condenser desalination plant intake feedwater through a heat exchanger heated by the spent steam from the steam driven pumps to keep the intake seawater at a constant operating temperature year round. The power plant production would be reduced by only 35 to 50 % of the electricity that would otherwise have been needed to power the electric desalination plant pumps.

In a multi generator power plant with a new gas turbine power unit and a once through cooled generating unit, the waste heat from the gas turbine could be run through a Heat Recovery Steam Generator to create steam for direct drive compression pumps. The thermodynamics of direct steam drives over steam driven generators powering electric motors would improve overall efficiency. In some circumstances, it may also be possible to have the steam supply come from high quality water. This spent steam could then be injected into the desalination plant feed to dilute its concentration and further warm the feed water improving the RO efficiency.

These compression drive pumps are a proven technology and are efficient. The gain in efficiency in their use for the RO desalination high pressure pump could be significant in reducing the desalinated water production cost. In addition, during periods of low energy demand it may benefit the power generator by better utilization of the installed generating assets.