Getting fresh water from the sea

ABB's variable speed drives turn the wheels of desalination technology

MATTHEW WONG – "Water, water everywhere, nor any drop to drink". How the Ancient Mariner would have marveled at today's technology that can extract the cleanest of drinking water from the briniest of seawater through the wonders of desalination. Overall though, electricity is still the key cost component of desalinated water and, depending on the desalination technology used, it can represent more than 30 percent of the operational costs. As a result, energy efficiency and lifecycle cost optimization are among the most important challenges for both developers and plant owners. ABB offers a comprehensive range of advanced technology for the desalination industry which enhances plant performance, efficiency and reliability. A prominent member of this range which is very suitable for use in desalination is the variable speed drive.

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Title picture
Desalination is still an energy-hungry activity. How can variable speed drives help reduce energy usage and costs?

Although water covers over 70 percent of the earth's surface, 97.5 percent of it is sea water. Whilst much of the remaining 2.5 percent of fresh water, is unobtainable, demand for it is increasing daily, driven by a complex combination of geophysical, geopolitical and demographic factors. The logical place to look, then, for new water supplies is to our oceans and seas. Desalination technology can unlock the almost unlimited abundance of water available there by removing salts and other minerals to make the water suitable for human use.

Currently, the most popular desalination methods are thermal and membrane desalination. The former principally uses multi-stage flash (MSF) and multiple-effect distillation (MED) methods, the latter reverse osmosis (RO) → 1. The cost of transforming sea water into fresh water is one of the main factors in deciding which method to use, but these three common desalination methods are still all considered to be energy intensive.

Other technologies, too, have been commercialized for desalination. For example, forward osmosis, which is also an osmotic process using a membrane to separate the dissolved solutes from the water; and the Passarell process which uses a vacuum to enable the sea water to vaporize at a lower temperature. Other desalination methodologies such as geothermal desalination, nanotube membrane desalination, biomimetic membranes, low-temperature thermal desalination (LTTD) are in the development phase.

Electricity is still the key cost component of desalinated water. Because the pump power required varies with the cube of the speed, even a small reduction in speed can make a big difference in energy use.

Reverse osmosis

When a power station is near the desalination plant, either MSF or MED is usually used, as these methods can utilize the thermal energy produced by the power station. Occasionally, hybrid designs which combine two or more desalination methods will be adopted. In the absence of a convenient power plant, the lower-energy RO → 2 is usually the preferred choice.

In normal osmosis, the solvent naturally moves from an area of low solute concentration through a membrane to an area of high solute concentration. This natural tendency to equalize solute concentrations on each side of the mem-

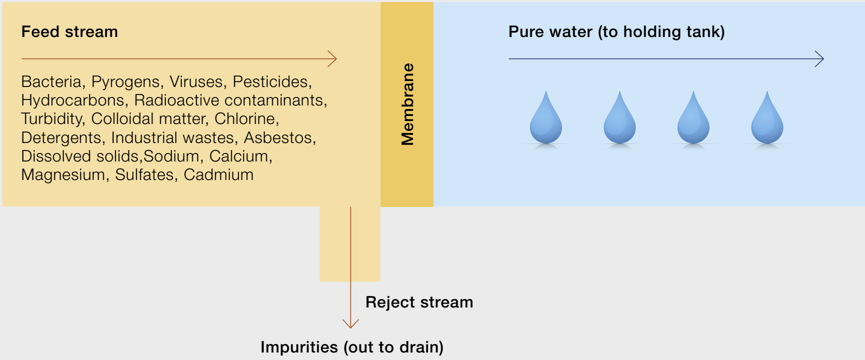
1 The three main desalination processes

Multi-stage flash (MSF).
Used in large applications, MSF is a multistage distilling method whereby the seawater is heated and the ambient pressure lowered so the water "flashes" into steam. Each stage is held at a lower pressure to the previous one.

Multiple-effect distillation (MED).
MED gets its name from the fact that more than one boiling chamber or "effect" is used to produce distilled water. Used in medium-sized applications, seawater is boiled in a sequence of effects, each held at a lower pressure than the one before. Vapor from one series is subsequently used to heat the next. Only the first vessel (at the highest pressure) requires an external heat source.

Reverse osmosis (RO):
Brackish water or seawater is pumped at high pressure through a permeable membrane in a closed vessel. Concentrated brine remains on one side of the membrane and potable water on the other side. Historically RO technology has been used in small and medium-sized plants. Because it is considered the most cost-effective desalination solution, RO methodology is used in large applications today

2 Reverse osmosis. Pressure forces water molecules through the membrane, leaving contaminants on the other side to be flushed to drain



The active front end (AFE) design of the ACS2000 eliminates the need for a special phase-shift transformer.

brane generates osmotic pressure. Applying an external pressure to reverse the natural flow of pure solvent is reverse osmosis. For drinking water, the pressure forces only the water molecules through the membrane, resulting in clean water on the other side. Different pressures are applied depending on which dissolved contaminants are present.

Membrane pressurization and VSDs

During the RO process startup, a precisely-controlled pressurization of the membrane system is essential as the membrane must be pushed gently but firmly against its support. This ensures no elements are damaged and that the ideal conditions prevail for water production at the correct flow and pressure.

Since variable pressure needs to be applied for both startup and production, a direct-on-line starter can be used to start the pumps and run the motor at full speed. Then, by throttling a valve, the required water pressure can be achieved. This method serves the purpose but it creates mechanical stress, such as vibration and hammering on the pipeline and valves, and wastes energy.

It is far better to use a variable speed drive (VSD) ➔ 3.

With a VSD, instead of using a valve to control flow or pressure the motor speed itself can simply be adjusted to achieve the desired output flow or pump pressure.

And, because the pump power required varies with the cube of the speed, even a small reduction in speed can make a big difference in energy use.

Using VSDs will not only help to save energy and enhance reliability through reduced mechanical stress, but will also improve process performance: a VSD is able to match the pump output flow or pressure directly to the process requirements, and small variations can also be corrected more rapidly by a VSD compared to other control means.

Stopping harmonics

While the VSD helps to save energy and improve reliability and control, precautions must be taken against the harmonics it can generate. Harmonics will cause distortion of the electrical waveform and, if left unmanaged, can cause problems such as overheating of cables, motors and transformers; electronic display and light flicker; and nuisance tripping of electrical protection devices. One way to solve the harmonics issue is to connect an active harmonics filter (AHF) to where the major harmonics occur. ABB's AHF solution uses the power quality filter (PQF) which monitors the line current in real time and processes the measured harmonics as digital signals in a high-speed multi-DSP (digital signal processor). The multi-DSP, in turn, drives IGBT power modules with pulse width modulated (PWM) signals, causing them to inject currents of exactly opposite phase to the harmonics into the components involved, thus eliminating that order of harmonics.

Lower cost

The motor driving the pump can be either low voltage (LV) or medium voltage (MV) depending on the pump power rating. The latest member of the MV VSD family, the ACS2000, lowers the cost of ownership as it is not necessary to use an

3 The ABB LV VFD provides simple and reliable motor control for a wide range of applications. It is designed for high reliability, easy installation and fast commissioning

expensive and specialized transformer at the input of the MV VSD to lower the harmonics generated by the VSD. The active front end (AFE) design of the ACS2000 eliminates the need for such a special phase-shift transformer.

When it comes to operation and maintenance, the ACS2000 has excellent availability and reliability due to its low parts count and, thus, extended mean time between failures (MTBF). With its modular design, it also has an impressive mean time to repair (MTTR) as its drawer design concept enables quick component replacement and thus minimizes downtime → 4.

For the low-voltage VSD → 5, the Low Harmonics Drive family offers a unique harmonics solution that is incorporated into the drive and that fulfils harmonics requirements without external filtering devices or multi-pulse transformer arrangements.

Power factor

During operation, the pump motor will generate reactive power that can cause an undesirable drop in the electrical power factor. A capacitor bank is usually used to correct for such a drop. However, a VSD already has an internal capacitor bank and this may be exploited to eliminate power factor drops or to reduce the size of the external capacitor bank that is required to do so.

Membrane maintenance

Pushing the solution through the membrane is the most energy-hungry activity in a reverse osmosis desalination plant. One of the factors which affect the pressure, and therefore the energy, required to accomplish this is the cleanliness of the membrane. When the membrane begins to foul, more pressure is required to achieve the same production rate, and the pressure is only adjustable within an allowed range. Thus, membrane maintenance is crucial.

> The VSD's internal capacitor bank may be exploited to eliminate power factor drops or to reduce the size of the external capacitor bank that is required to do so.

Cleaning is generally done by flushing, chemical cleaning or replacement, the appropriate intervals being determined by the degree of membrane fouling. This rate is affected by water temperature, concentration, flow rate, recovery rate, etc. Usually, maintenance is carried out at the fixed intervals recommended by the membrane manufacturers or when the pressure drop between feed and reject streams goes out of range. Such regimes can lead to premature cleaning, resulting in overconsumption of chemicals and excess production loss, or belated cleaning, resulting in permanent fouling which may damage the membrane.

ABB's Optimax Membrane Performance module, which won the "Water/Energy Nexus" award at the H_2O Water Awards 2010, can help to overcome the drawbacks of current approaches. One module of the Optimax, Membrane Performance Monitoring, displays the membrane performance, factoring in the hydrodynamics of membrane fouling, 4 ACS2000 – with drawer out

5 LV VSD installed at site

and provides advice for maintenance measures and recommended due dates so that the intervention can be planned and production disruption minimized. It also provides information as to how successful the cleaning was.

The other module of the Optimax is Membrane Optimization, which uses the results from the Performance Monitoring module as a basis to calculate the optimal operational conditions given the operational and physical constraints. As the fouling rate dynamics depend on the operational set-points such as feed flow and feed pressure, these are also factored in to the calculation so as to increase productivity levels as well as to optimize the fouling rate. The optimization can be run regularly and can be implemented for open-loop or closed-loop operation. By applying the optimization function, it is possible to reduce the gap between the actual and optimal set-points; productivity increases of two percent are achievable.

Increased productivity is not the only benefit: the when-needed cleaning approach reduces chemical usage and thus operation costs; lowering the risk of membrane damage minimizes unbudgeted membrane replacement; and maintenance outages can be better planned, thus increasing plant availability.

The intelligent MCC

A large proportion of the equipment in desalination plants is controlled by motor control centers (MCC). To better manage operation and maintenance, operators need more information such as how long units have been operating, what is their operating condition, etc. Traditionally, this extra data required more meters, transmitters and devices and, of course, a mass of cables leading to the control room. However, now ABB's MNS iS, the first integrated Low Voltage MCC system, will help solve this. MNS iS is a single integrated MCC system configurable for all possible customer specifications – from conventional right up to very sophisticated intelligent motor control system requirements. MNS iS makes modifications of control and protection functions possible at any time and at any stage of the complete project lifecycle. It provides much-needed flexibility for engineers, system integrators and end users. A very few standard motor starter variants are needed for a complete plant.

MNS iS is one integrated MCC system configurable for all possible customer specifications.

The MCC also provides condition monitoring such as: motor overcurrent; cable and terminal temperatures; MCC drawer reinsertion count - which may require performing some drawer maintenance; and so on. All this information facilitates predictive rather than reactive maintenance and helps reduce unplanned downtime.

Outlook

Overall, electricity is still the key cost component of desalinated water and, depending on the chosen desalination technology, can represent more than 30 percent of the operational costs. As a result, energy efficiency and lifecycle cost optimization are among the most important challenges for both developers and plant owners. ABB offers advanced technology for the desalination industry with a comprehensive range of proven products as well as the technology ownership behind these which allow ABB to play a role in enhancing the plant performance, efficiency and reliability. As a provider of instrumentation, control and electrical (ICE) solutions, ABB is able to provide complete engineered packages with the benefits of a single interface that saves time, reduces cost and manages risk.

As demand for fresh water increases, conservation and efficient usage are areas where we can maximize the utility of the water we already have. Cheaper and less energy-intense desalination is the key to unlocking the vast reserves of water in our seas and oceans and thus massively expanding the freshwater supply.

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