

WHITE PAPER

Cost effective desalination

Solving water scarcity using high efficiency motors and variable speed drives





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Introduction

Seawater is abundant, but converting it into potable water can be energy-intensive and costly. By using the latest technologies, fresh drinking water can be brought efficiently to drier regions, creating a safe, secure and high-quality water supply for future generations. Meeting the needs of a growing global population, against the backdrop of climate change, will be vital to ensure stability and prosperity around the world.

Cutting-edge water solutions are helping turn seawater into drinking water to solve this global crisis. In fact, seawater desalination is one of the most important methods of producing reliable water supplies near population centers in the driest parts of the world. Desalination plants are built to provide greater water security and reduce consumption of precious freshwater.

However, the desalination process typically involves a high energy-consumption, with electricity one of the biggest running costs. With such energy-intensive processes,

margins are typically extremely tight, so systems must be as efficient and cost-effective as possible, making energy efficiency a necessity to ensure both productivity and profitability.

Modern desalination methods are highly sophisticated. In recent decades technological advances have substantially reduced the cost of both building and running large-scale desalination plants.

With electricity accounting for some 50 percent of the operational costs of a desalination plant, energy efficiency and life cycle cost optimization are critical challenges for utilities and developers. ABB electric motors and drives lie at the heart of maximizing plant efficiency and productivity levels in creating a cleaner, more resilient water supply.



Water scarcity and the need for desalination

About 71 percent of the Earth's surface is water-covered, with the world's oceans holding about 96.5 percent of it. However, untreated, ocean water cannot be used for drinking or growing crops, while much of the remaining 3.5 percent of freshwater is locked up in ice caps and glaciers.

The world's freshwater must therefore meet all the potable drinking water and agricultural needs of a planet with a rapidly expanding population. Water scarcity can be caused by a physical shortage, the failure of institutions to ensure a regular supply, or the lack of a distribution infrastructure.

Water scarcity is affecting every continent. Water use has been rising at more than twice the rate of global population growth and many regions, particularly those with arid conditions, are reaching the limit of sustainable water supply. Even in regions which historically have had relatively stable supplies, droughts and other extreme weather events are causing rivers, reservoirs and aquifers to diminish, further exacerbating existing water shortages.

Water scarcity in context

Some 1.1 billion people worldwide lack access to water, and 4 billion experience water scarcity for at least one month of the year. Inadequate sanitation is a problem for 2.4 billion people, resulting in disease and mortality. Without a substantial reduction in current consumption rates, this problem is likely to get worse in the coming years.

There are two main types of water scarcity: physical water scarcity and economic water scarcity. Physical water scarcity results from inadequate natural resources or the

over-development of infrastructure, channelling water away from where it is most needed, and poor management of existing water resources.

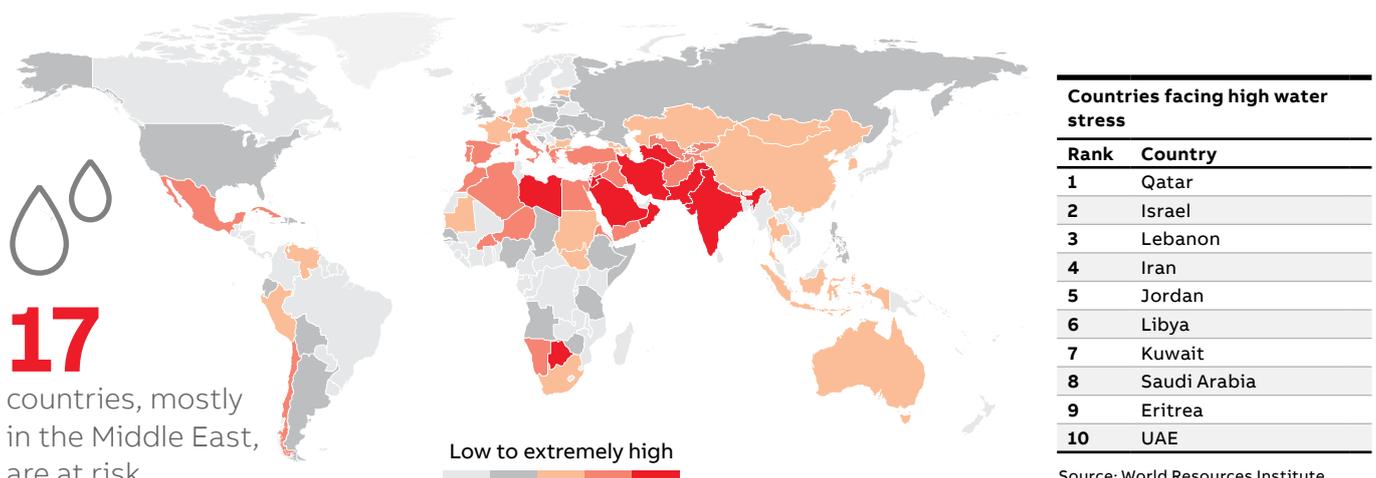
Economic water scarcity is caused by a lack of investment in infrastructure or technology to ensure reliable access to water, resulting in people having to travel large distances to clean water sources.

Water is not used only for drinking. It is also important for bathing, laundry, livestock and cleaning, as well as commercial and industrial usage. 72 percent of all fresh water is used by agriculture, while 16 percent is used by municipalities for households and services, with 12 percent used by industry.

A lack of water could have profound social consequences both locally and globally, with 700 million people potentially being displaced by intense water scarcity by 2030. Nearly half of the global population are already living in areas that are potentially water scarce for at least one month of the year, and this could increase to some 4.8-5.7 billion people by 2050.

Lack of water also disproportionately affects women and children – spending time fetching water from great distances means they cannot do other things such as improve their education or employment prospects. It has been estimated that by 2040, around 25 percent of the world's children will be living in areas suffering from extremely high water stress.

— Countries at most risk from water crisis



Factors driving water scarcity

A wide range of factors contribute to water scarcity, with certain regions affected more by some than others. The key global trends driving water shortages include the following:



Industrialization

Water is vital for industry, and usage in this sector accounts for 12 percent of all water use worldwide. Power generation can also require vast amounts of water. As the world grows more industrialized this puts a strain on available supplies, both through the increasing amount required and through harmful by-products and toxic chemicals released back into the supply through pollution. Untreated sewage discharged into rivers can be highly harmful to the environment, and severe pollution can ultimately render local water supplies unusable, sometimes on a long-term basis.



Agriculture

Agriculture uses around 72 percent of the world's accessible freshwater. However, large amounts of it are wasted due to irrigation system leaks and poor water usage and crop management. In some parts of the world, irrigation systems have been known to drain entire lakes, potentially irreversibly. Agriculture also generates large amounts of pollution through the use of fertilizers and pesticides, which can be harmful to humans and wildlife.

Urbanization

For the first time in human history, more than half of the world's population live in towns and cities. Population density in these areas is increasing, with citizens requiring not only clean water, but the infrastructure to provide it. Large scale infrastructure projects like dams are highly disruptive and can be extremely expensive, potentially taking several decades to plan and build. Ensuring that both infrastructure and supply can keep pace with the demands of an increasingly urbanized population is a major challenge for governments and municipal planners.

Population growth

Over the last 50 years, the human population has more than doubled, and this rate of growth continues to accelerate. By 2050, the UN estimates that there will be an additional 3.5 billion people on the planet, with most of this growth occurring in developing countries that already suffer from water scarcity to at least some extent. Furthermore, drinking water is only one aspect of an individual's water requirements, as the industrial and agricultural processes, and water-reliant items, required to sustain modern life also put additional pressure on supplies.

Climate change

It is widely accepted that climate change is warming the planet, affecting weather patterns and making the availability of water less predictable. Unprecedented droughts in some regions are exacerbating existing water shortages, while extreme weather events such as storms, floods and wildfires can destroy infrastructure and contaminate supplies. Continued disruption to water supplies will impact health and food security, and could prompt mass migrations away from water-scarce areas.



Desalination as a solution to water scarcity

Desalination is a process that removes salts from sea water to make it drinkable. There are currently nearly 17,000 operational desalination facilities worldwide, generating an estimated 95 million m³ per day of freshwater to approximately 300 million people across more than 150 countries.

Desalination processes

There are several methods used to desalinate water, and these can largely be divided into two categories: thermal-based and membrane-based.

Thermal-based methods typically involve the distillation of water, i.e., boiling and then recondensing it to leave salt and other impurities behind. The most commonly used type of distillation is multi-stage flash distillation. Such plants produce around 26 percent of all desalinated water in the world.

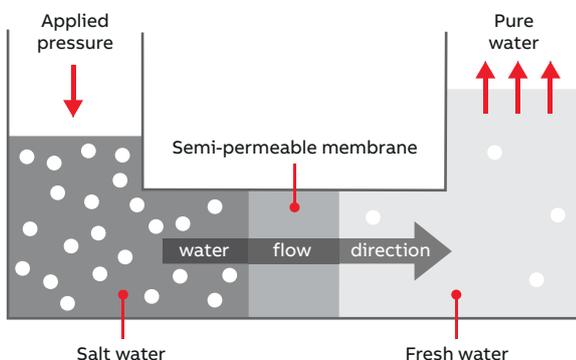
However almost all new plants use **membrane-based methods** such as **reverse osmosis (RO)** due to their markedly lower energy consumption. RO is the most prevalent type of membrane technology and involves pumping brackish water or seawater at high pressure through a fine-pored, ultra-thin, semi-permeable membrane

in a closed vessel. Concentrated brine and impurities remain on one side of the membrane, while water molecules pass through, resulting in potable water on the other side. Applying high pressure with a pump is necessary because in conventional osmosis, the water molecules would naturally flow in the other direction, creating even higher concentrations of salt and impurities.

In order to achieve optimal operation, membrane unit pumps have to operate at peak efficiency to keep productivity levels and performance at their maximum. The membrane stage is just one part of the desalination process. Pumps are vital for transporting water from stage to stage. Centrifugal pumps are used to deliver raw water from the sea into the plant, where it is first filtered to remove any inorganic suspended solids such as sand, oil, clays, bacteria and dissolved organic matter. Coagulant is added to bind colloids, which are then removed in a flocculation tank. This process is similar to that of a conventional water treatment plant.

The filtered water is then pumped under high pressure to separate the water and salt solution in the RO membrane stage before it is chlorinated to remove any remaining contaminants. Treated freshwater is then pumped into the water distribution network ready for consumption.

How reverse osmosis works



Challenges facing desalination plant operators

Maximizing productivity

A major challenge in any desalination plant is ensuring maximum productivity. Plants must supply guaranteed levels of cubic flow to meet daily treated water quotas. Failure to do so may result in penalties from utilities, municipalities, governments and regulators.

Moreover, as populations continue to grow, particularly in arid regions such as the Middle East where water is already scarce, plant operators must squeeze every drop of productivity out of existing systems, while also taking steps to increase capacity as it is needed. Operators must also contend with price caps and pressure from consumers to reduce prices, while also ensuring that water is clean and suitable for consumption. In areas such as the Red Sea where saline concentrations are especially high, this can drive up costs. The higher the salt content and turbidity of raw water, the more expensive it is to treat due to the amount of content that must be removed.

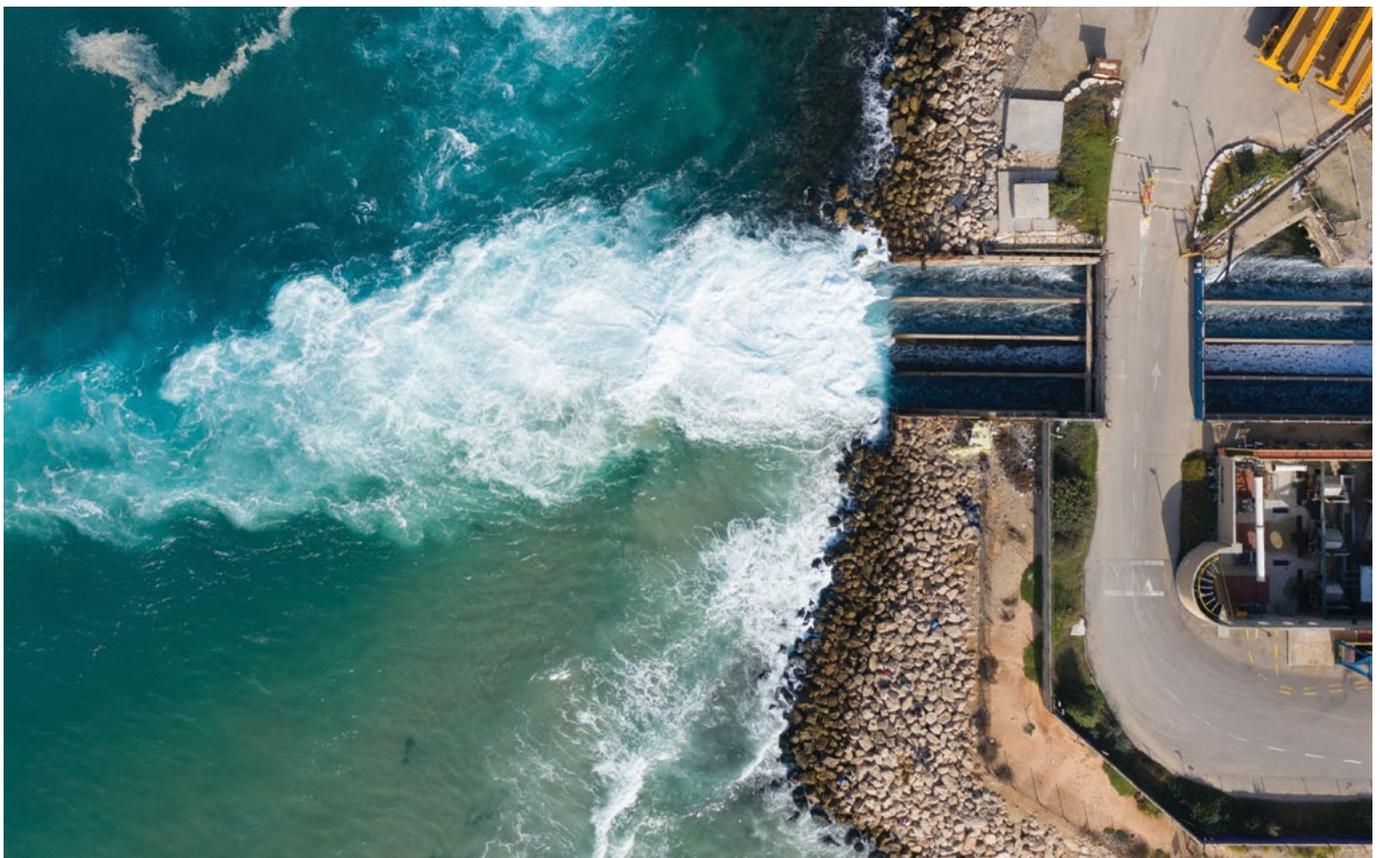
As such, the processes involved in a typical desalination plant are extremely finely tuned and require precision

control over pump motors, plus careful monitoring to ensure that quality is maintained at every process stage. For instance, during desalting, pressure levels must be carefully controlled to reduce damage to membranes, while pumping rates must be managed to ensure sufficient throughput to meet daily flow quotas while also taking care to ensure that pressure spikes do not damage equipment and infrastructure.

Ensuring reliability

Uptime is critical for desalination plants. In order to meet cubic flow quotas, critical equipment cannot afford to fail, and any unplanned downtime must be kept to a minimum. Equipment must be resilient, robust and easy to maintain, with effective visibility of maintenance requirements to predict and prevent any potential failures. This is particularly the case in high intensity processes, which can often be difficult to inspect manually.

The sheer complexity of RO processes means that specialist knowledge and techniques are typically required both to maintain equipment and to ensure that it is running



optimally. As such, it can be difficult and expensive to train and retain on-site personnel with the appropriate experience and skillsets to keep plant processes running effectively at all times.

Many desalination plants are typically built on greenfield sites, which represents an opportunity to embrace the benefits of digitalization throughout all operations. Through the use of sensors and cloud-based technology, critical assets can be monitored remotely, with any potential issues flagged up long before they develop into failures. This allows maintenance teams to isolate and rectify problems quickly without affecting productivity. Desalination plants typically have an operational life measured in decades, so plants built many years ago may be operating legacy equipment that is by now obsolete. Digital monitoring technologies can even be retrofitted onto existing assets, helping to enhance maintenance practices for older equipment and provide almost instant connectivity for such assets via the Internet of Things.

Achieving sustainability

Desalination processes, particularly the pumping of vast volumes of water, are extremely energy-intensive, and so reducing energy usage wherever possible is vital to ensuring the sustainability of processes. Climate change, industrialization and urbanization are some of the major drivers of global water scarcity, and desalination plants must be part of the solution through ensuring sustainability throughout the process.

New technological innovations are helping to drive down costs and improve the energy efficiency of desalination

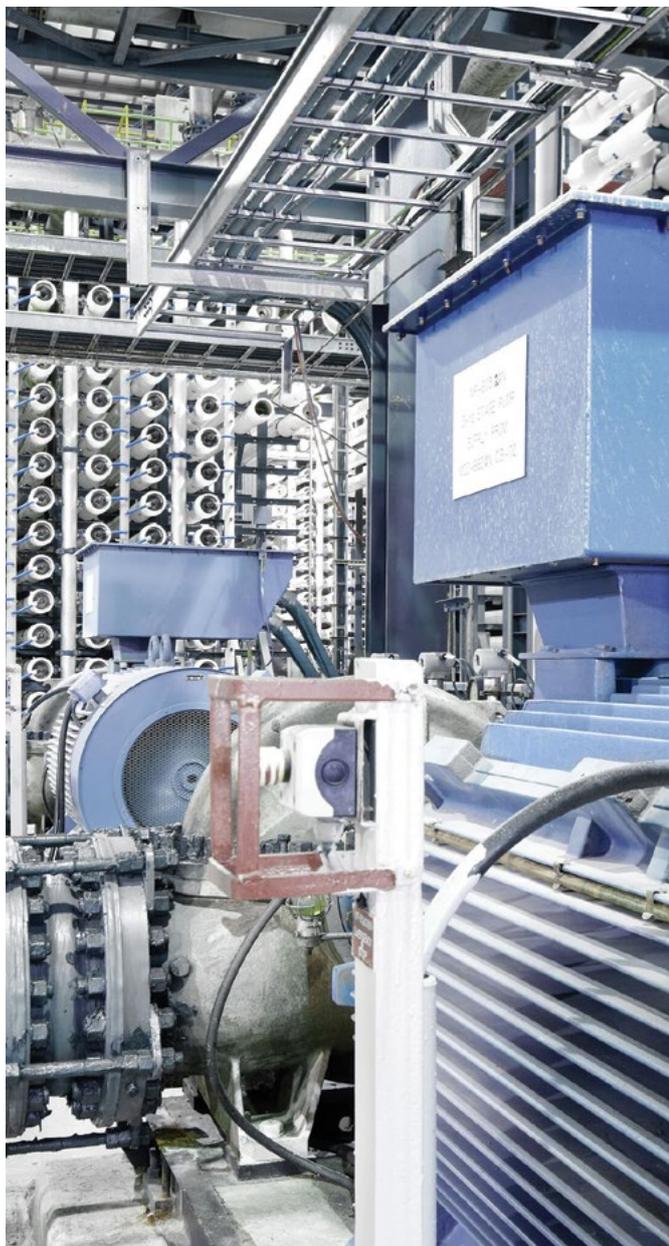
processes, for instance through energy recovery systems. However, there are many established technologies that have not been universally adopted. A variable speed drive (VSD), otherwise known as a Variable Frequency Drive (VFD), is a device that electronically controls the speed of the vast number of electric motors driving the pumps in a water treatment or desalination facility. A drive can reduce a motor's energy usage by up to 50%, particularly in centrifugal applications such as pumps and fans. Extrapolating these energy savings across an entire installed base of pumps and motors can potentially make a vast difference to overall plant efficiency, and significantly reduce energy costs. Even a small energy saving, reached for instance by optimizing existing equipment to reach its best efficiency point, can lead to substantial cost savings when applied across a whole fleet of motors. Quick and easy changes like this can quickly add up into significantly improved overall efficiency.

One of the single biggest challenges for desalination plants is their high start-up and operating costs. While advances in technology have brought these costs down in recent years, building a new desalination plant remains a vast undertaking, requiring some of the most sophisticated water treatment technologies available. Daily running costs are also high and, in an industry of fine margins, a long-term approach must be taken to ensure that equipment is profitable over its entire lifetime. This means considering not just purchase cost, but also its overall productivity, efficiency and reliability, including the cost of running and the cost of not running to determine the Total Cost of Ownership (TCO).



The SWRO desalination process

In the last few decades, desalination plant production costs have fallen fourfold thanks to the emergence of highly efficient electrical equipment. ABB motors, drives and PLCs, for instance, are used to control the flow rate of pumps with typical 30 to 60 percent savings in energy consumption. As well as improving the efficiency of the entire water cycle, drives, high efficiency motors and PLCs also reduce the mechanical and electrical stress on pumps and aeration equipment, significantly lowering maintenance costs.



Seawater intake

The first stage of the desalination process is to get seawater into the plant. The design of the intake pumps used to achieve this is highly important, as the quality of water and amount of filtration required can depend on seawater depth, salinity levels, temperature, local flora and fauna (e.g., jellyfish, phytoplankton, etc.), and the distance of the pump from the shore. The lower the quality of the intake water, the more treatment is required in order to render it potable.

Seawater pumps are typically high-volume, low-speed vertical pumps. Motors and associated equipment need to be designed to withstand harsh corrosive environments to ensure reliable performance. Efficiency is also crucial in order to provide high water output at a low cost to ensure the sustainability of operations, and ensure that flow quotas are met.

Drives allow the flow to be quickly varied by electronically controlling the speed of the intake pump motors, providing a faster response to changes in external conditions while reducing strain on pipes. Events such as storms, or particularly low seawater temperatures, or the presence of wildlife such as algae blooms, can lead to higher turbidity. This in turn increases the likelihood of membrane fouling in RO processes. As well as reducing energy consumption of pumps, having the ability to rapidly vary the flow can help to improve the resilience of the plant and equipment while maintaining flow quotas. Conversely, pumps can be ramped up to add extra capacity when conditions are appropriate.

Pre-treatment

In the pre-treatment stage, water is filtered for inorganic suspended solids, sand, oil, clays, bacteria and dissolved organic matter. This is essential to avoid fouling of the RO membranes later on in the desalination process. A coagulant is added to bind colloids, which are then removed in a flocculation tank. These processes require a combination of mixers, pumps and aerators, which can be highly energy-intensive.

Pre-treatment utilizes a lower pressure flow compared to other stages, but still requires careful control of pump motors to account for variations in turbidity and salinity. A drive provides a quicker response to changing conditions. Salt water can be harsh on pipes, pumps and valves, so a drive uses a controlled ramp up to ensure that the required motor speed is reached quickly yet carefully to avoid issues such as water hammer and cavitation. Backwash pumps can

be operated at a lower speed to achieve significant energy savings while ensuring that contaminants do not form a layer at the top of the tank.

With the latest generation of low-voltage IEC motor and drive packages, operators can achieve IE5 efficiency levels; while ABB's motors are designed for harsh environments, and offer a high degree of protection against ingress of water or solids.

Filtration

Filtration can be achieved through RO and nanofiltration (NF). Both involve passing water at high pressure through semi-permeable membranes to filter dissolved solids while allowing clean water to pass through. NF membranes, however, typically have a larger pore size than RO membranes, resulting in lower energy consumption but less effective exclusion of solids.

In order to achieve optimal operation, membrane units must operate at the highest efficiency point to keep productivity levels and performance at the maximum possible level. Multi-pump systems can be used to ensure that water is at a sufficient pressure to avoid cavitation while ensuring the efficacy of the filtration process, as insufficient pressure may not trigger the reverse osmosis effect, or do so inefficiently. One of the major challenges at the filtration stage is fouling and other types of membrane blockage. This leads to a reduction in productivity and energy efficiency, as well as requiring pumps to operate at a higher speed to compensate. Over time repeated fouling will damage the membrane, which can be extremely difficult and costly to repair and/or replace.

ABB drives can help to improve the energy efficiency of the filtration process and ensure maximum productivity. Electrical energy used in RO desalting is estimated to account for 44 percent of a desalination plant's running

costs, so even a small improvement in efficiency here can contribute significantly to improved profitability across desalination plant operations. Fitting drives to the pump motors can also protect the sensitive membrane against damage from excessive pressure, helping to enhance their operating life.

The high pressures involved in the RO process also make it a prime candidate for energy recovery, which can be achieved using pressure exchangers, turbo chargers or turbines to capture energy and feed it back into the system for use in low pressure pumping elsewhere in the plant.

Post-treatment and brine disposal

Following the filtration process, operators are left with clean water as the product, and brine as a waste by-product. Treated water is chlorinated before it enters the distribution network to remove any remaining contaminants and make the water potable. Water for irrigation purposes may not require further treatment.

Pumps are used to control chlorination dosing since excess dosing can be costly, while underdosing can compromise water quality. A drive and PLC arrangement used with pump motors can provide more precise process control and better efficiency, even at partial loads.

There are several options for the disposal or discharge of brine, and the cost and environmental impact of each depends on many factors. Local laws and guidance may vary widely from region to region, and determine whether and/or how much further treatment is required of brine before it can be disposed of. Regulations may restrict brine concentrations, total amount discharged per day, where it can be discharged and at what time of day. A drive, linked via fieldbus to a PLC, can ensure that brine is discharged at appropriate times, in appropriate quantities, to prevent the possibility of environmental incidents and fines.



ABB in desalination

ABB's motors, drives and PLCs can all play a vital role in keeping desalination processes flowing, and optimizing production to ensure low TCO and high productivity at every step of the desalination process.



Motors

ABB's motors for desalination applications are designed for harsh environments, with robust protection against external conditions, including IP55/56 protection against wet and corrosive environments. A wide range of surface treatment and corrosion protection solutions are also available.

The SynRM motor is among the most efficient available on the market, and when paired with a drive is capable of achieving efficiency levels up to IE5, with an extremely high power density. Heavy duty low- and medium-voltage motors are available with exceptionally robust construction materials, regreasable bearings, streamlined installation with horizontal or vertical mounting and flexible cabling solutions.

Variable speed drives / Variable frequency drives

Fitting a drive to a pump motor will significantly improve the motor's efficiency, and also improve overall system efficiency. Processes and flow rates can be adjusted quickly and automatically to achieve required setpoints at all times. The drive will monitor system performance, flow and

pressure rates, energy consumption and other parameters through fieldbus communication connecting the drive to plant control systems. The drive can automatically ramp up or down depending on what the process requires at a given time.

ABB's water industry drives can offer ingress protection up to IP55 for wet and corrosive environments, allowing flexibility in the siting of installations and improved reliability throughout the equipment's lifetime. Built-in functional safety ensures that pumps can be safely stopped in the event of a hazard developing, reducing risk to personnel.

Harmonics are a major issue in water applications, particularly in remote locations where reliable power quality may be an issue. ABB's drives for water include built-in harmonic mitigation, eliminating supply disturbances that could trip production with an integrated low-harmonic line filter and built-in active supply unit. ABB drives also feature built-in cavitation protection and Intelligent Pump Control to ensure adequate pressure and flow control when operating multiple pumps within the same configuration.



Programmable logic controllers (PLCs)

ABB has a comprehensive range of scalable PLCs, I/Os and robust HMI control panels that deliver performance quality and reliability. The whole PLC product range utilizes a single integrated engineering tool for programming, simulation and commissioning for PLCs, safety, drives, control panels and network. ABB's commitment to openness means that operators have a comprehensive choice of network and fieldbus protocols to integrate I/Os, drives, HMI, SCADA and third-party devices without being locked into a proprietary system.

Specific devices provide extreme protection against humid environments, high altitudes and very high or very low temperatures, vibration, hazardous gases and salt mist.



Case studies

Singapore

The United Nation's (UN) World Water Development Report recently stated that nearly 6 billion people will suffer from clean water scarcity by 2050. Singapore is using desalination as part of the solution to their water supply issue in order to provide enough clean drinking water for its ever-growing population of 5.5 million, with ABB helping to develop the nation's first dual-mode desalination plant treating both seawater and reservoir water.

Though surrounded by water, having enough drinking water has always been a challenge for this island state. Currently the demand for drinking water is up to 430 million gallons a day. The Keppel Marina East Desalination Plant (KMEDP) is the latest step of Singapore using advanced technology to help address their water challenge.



In operation since June 2021, KMEDP is one of the most advanced desalination plants in the world. Being one of the first in the world with a dual-mode facility, the plant is capable of treating either rainwater drawn from the nearby Marina Reservoir or seawater, depending on prevailing weather conditions, making it weather-resilient to provide a stable water supply to the community. The facility can produce 30 million gallons of clean water every day, enough to fill 45 Olympic-size swimming pools and 7 percent of Singapore's daily water demand.

The plant is operating with a host of cutting-edge technologies from ABB, including automation and control systems as well as instrumentation and water analyzers. With ABB's supply of energy-efficient motors, variable speed drives and switchgear, together with process optimization aimed at increasing efficiency, the gains to be realized could potentially help reduce electricity consumption by up to 40 percent. A range of smart sensors and water-monitoring equipment are also being used in the plant.

Abu Dhabi

ABB technology is being used to build the world's largest desalination plant in Taweelah, Abu Dhabi, United Arab Emirates. The USD 500 million development will have the capacity to process over 900,000 cubic meters of seawater per day, enough to meet the demands of over 350,000 households.

Approximately 45 kilometers north of Abu Dhabi city, the Taweelah project will be the first reverse osmosis independent water project in Abu Dhabi which will desalinate seawater for supply to local communities and industry in the area. It will also set new benchmarks for its size, efficiency and cost by utilizing the lowest amount of energy per cubic meter of water produced.



ABB has delivered a wide range of low and medium voltage motors and variable speed drives to ensure reliable and energy efficient pumping in the plant. The ACS580MV medium voltage drives match the speed and torque of the motors to the pumping demand for maximum energy savings.

As the world's largest desalination plant, it is estimated to supply 909,200 m³/day and is scheduled to become fully operational in the fourth quarter of 2022. The plant will play a critical role in meeting the region's peak water demand, which is projected to rise by 11% between 2017 and 2024.

Service & digitalization

Digitalization enables new smart and secured ways to prevent unexpected downtime while optimizing the operation and maintenance of electric motor driven systems. ABB can securely connect your motors, drives or your entire powertrain to our easy-to-use cloud service solutions. ABB Motion Services' digital portfolio combined with extensive industry knowledge, can help desalination plant operators to make better, more informed decisions

Delivering digital for success. Smart. Secure. Connected. Stay one step ahead with accurate status information about the health, performance, energy efficiency and CO₂ equivalent emissions of water assets for better operational decision making and cost management.

ABB's digital solutions securely collect data from applications, providing deeper status insights and a true indication of the condition of an installed base. By collecting and analysing information directly from the powertrain, cloud-based technologies are utilized to help understand and predict potential downtime events, enabling the scheduling of maintenance services at a time that suits you. While the data is always at the operator's disposal, ABB will help to analyse the data and define the steps for improving operations.

Reducing carbon emissions and waste. Driving the tomorrow

Partnering with the customer, ABB helps to maximize the value of motors, generators and drives, and improve energy

efficiency to reduce carbon emissions and waste from water operations.

ABB is a trusted partner across the entire life cycle of assets. The world is changing faster than ever. New technologies open new possibilities to gain competitive advantages. Society is realizing the need for a more sustainable world and the complexity of new regulations impose risks for compliance and business continuity. As a reliable partner, ABB offers extensive service domain expertise and help desalination plants to stay ahead of the changes to keep the world turning, while saving energy every day.

With extensive solutions and services, ABB enables plant operators to reduce CO₂ equivalent emissions and waste to meet the global, local and/or company environmental regulations while maximizing the value extracted from your motors and drives – all through flexible business models tailored to the customer's needs.

ABB's approach involves systematically working with desalination plants to:

1. Help make better decisions using ABB's industry expertise and digital solutions to identify potential energy savings and CO₂ equivalent emissions reductions as well as to track and trace rotating equipment to enable efficient operations, reduce waste and comply with regulations.
2. Implement energy efficiency solutions and services by modernizing the motors and drives at the right time based on data and advanced analytics. Together, we will determine the optimal energy savings, minimize waste through circular service models and improve financial returns for specific assets and applications.
3. Offer flexible business models ensuring savings and uptime goals are met with ABB's monitoring and multi-year support solutions, while mitigating any potential risks.

ABB offers complete range of life-cycle services, ensuring a seamless transition between old and new products. With over 130 years of experience in manufacturing and servicing motors and generators and more than 40 years for drives, ABB is recognized as a global leader for effective extension, retrofit and upgrade solutions in the field. Material circularity has been built into our offering for years, ahead of regulatory requirements. With the emergence of new technologies, ABB further pushes the boundaries reducing waste through data driven decisions, recycling and refurbishments.





Conclusion

Desalination holds considerable potential for solving the problem of regional and global water scarcity. However the challenge of ensuring that processes are cost-effective and sustainable remains a significant one. Motors, drives and PLCs all play a vital role in keeping desalination processes flowing optimally, ensuring productivity, reliability and sustainability at every stage of the treatment process. With electricity accounting for 50 percent of the operational costs of a desalination plant, energy efficiency, resilience and life cycle optimization are all crucial to the profitability of operations. ABB's range of Motion products, combined with its extensive service offering, provide real solutions for desalination plants both old and new across the world.



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your local ABB representative or visit

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