



INDUSTRIAL WATER TREATMENT:

# OPERATION MODES FOR OPTIMIZATION AND AUTOMATION OF MEMBRANE FILTRATION SYSTEMS



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OPEX**



**PROCESS  
OPTIMIZATION**



**REDUCE COST  
PER GALLON OF  
WATER TREATED**

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## INTRODUCTION

The global water challenge is affecting a growing number of countries, forcing various industries to look into how they can reduce their water footprint. Water is widely used across industries, and Grundfos is focused on helping businesses and manufacturing facilities to reduce water consumption within a water treatment system and increase system performance and reliability by rethinking decentralized water treatment processes.

## PURPOSE

This whitepaper discusses the different operation modes available in a membrane filtration system and compares traditional fixed values, direct-parameter measurement and real-time adaptive operation. We then look at how Grundfos can use intelligent pumps and sensors, to control a membrane system. Finally, we look to the future to the potential of data analytics to further reduce maintenance, operation and cleaning costs.

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think  
innovate

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# BACKGROUND

When considering how global water challenges affect countries, the situations in the European Union and the United States provide examples.

In the EU, 11% of the population is faced with water scarcity and 20% of the population lives under constant water stress in the Mediterranean region [1]. In the United States, the Colorado River is beginning to run dry in places forcing possible restrictions to Arizona, Nevada and Mexico with water supplies in the lower basin. Researchers keep a constant watch on Lake Mead, the largest reservoir in the US, which supplies water to 22 million people.

Water is widely used across industries as a direct component of products or core processes, but also in utility applications such as wash and clean, cooling towers and boilers. This forces industries to look more deeply into how they can help reduce water consumption and mitigate water scarcity challenges.

Particle filtration and ion removal is an essential part of every water treatment process, and this is true for industry and municipal water and wastewater treatment. In this regard, the steady growth of filtration systems is one of the major trends in industrial water treatment. As a state-of-the-art technology that's widely used, membrane filtration also offers high potential for operational optimization and cost reduction.

Optimization within ultra- and microfiltration offers the best results when looking at the following areas:

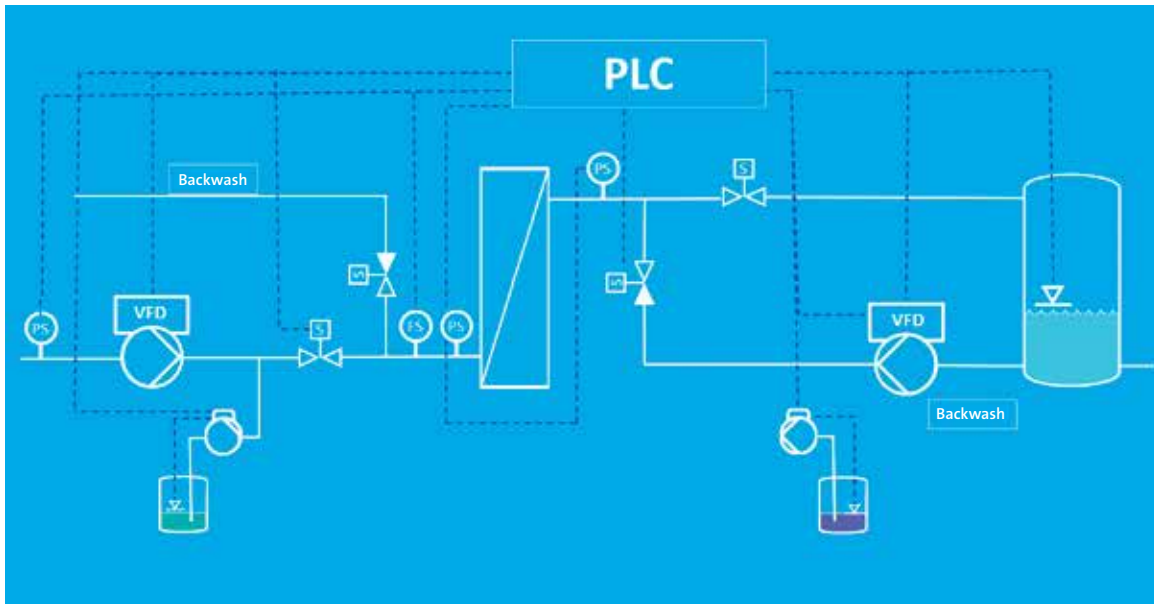
- Backwash cycle
- Backwash time
- CIP interval

For nanofiltration and reverse osmosis plants, the optimization potential lies within:

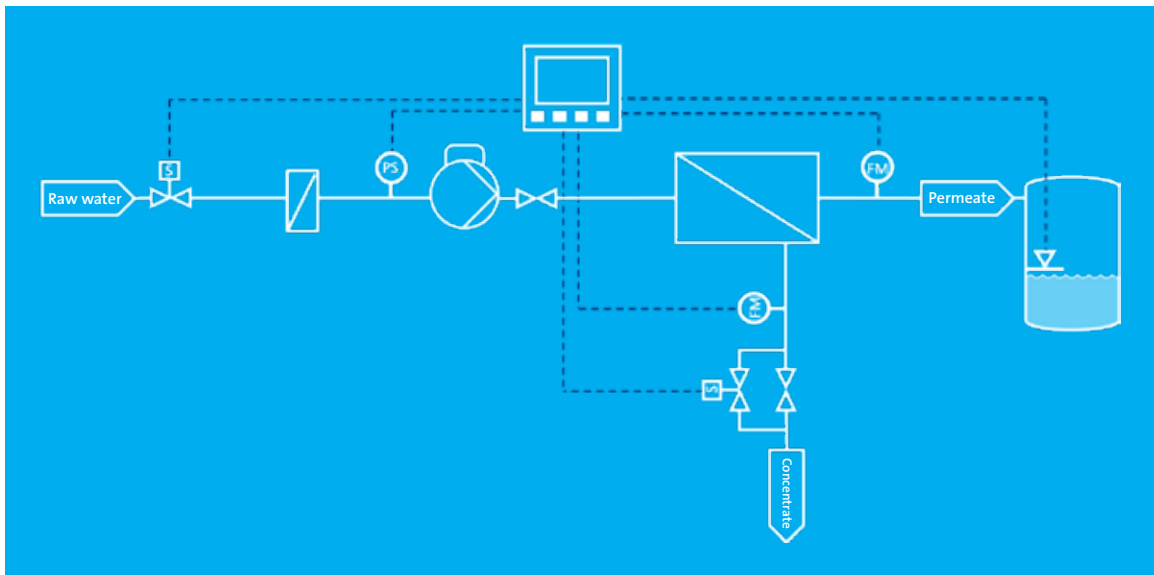
- Anti-scalant chemical feed rate
- Energy consumption
- Water consumption

## UTILIZING AVAILABLE DATA

With the increase of digitalization in the industry sector, we now have data that can be used to get a better understanding of systems and optimize the system performance compared to applying timer based operations and fixed values. The focus of the following discussion is dead-end filtration systems, specifically ultrafiltration and basic brackish water RO systems.



*Generic P&I of an ultrafiltration system*

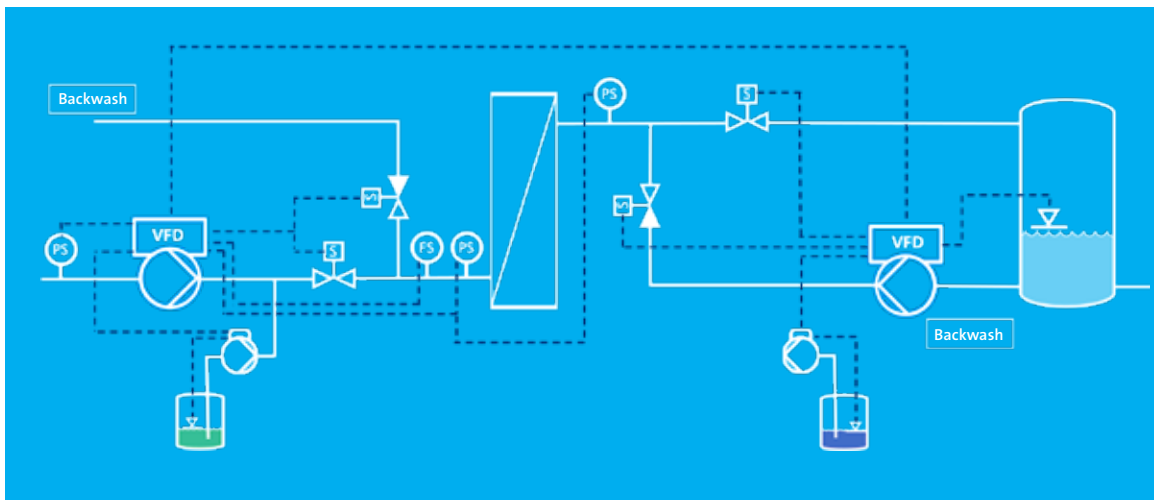


*Generic P&I of a Reverse Osmosis (RO) system*

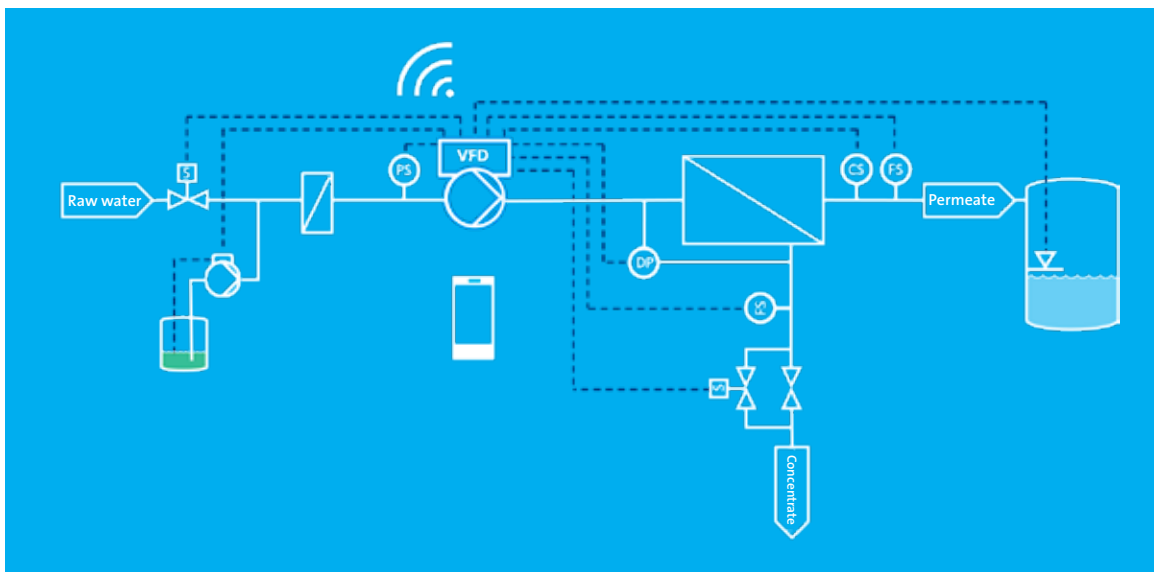
## PIPING AND INSTRUMENTS (P&I) LAYOUT

The basic P&I layout for a membrane system – whatever the type of membrane – almost always looks the same, with minor customizations or preferences, according to the membrane manufacturer specifications. This includes pumps, sensors, actuators and a central control device that coordinates the different stages of the process.

Therefore, greater improvements cannot be achieved by adding new sensors or more control. Instead, advanced and better use of the available data is what makes a difference. In every system we find pressure and flow sensors, but how we use the information from them could be smarter. A new way of approaching filtration system operation could be using a PLC-free system, where intelligence and algorithms are built into smart pumps (CRE and SMART Digital DDA FCM) instead of lying in the central control unit (PLC).



*Generic schematic of an ultrafiltration system without PLC*



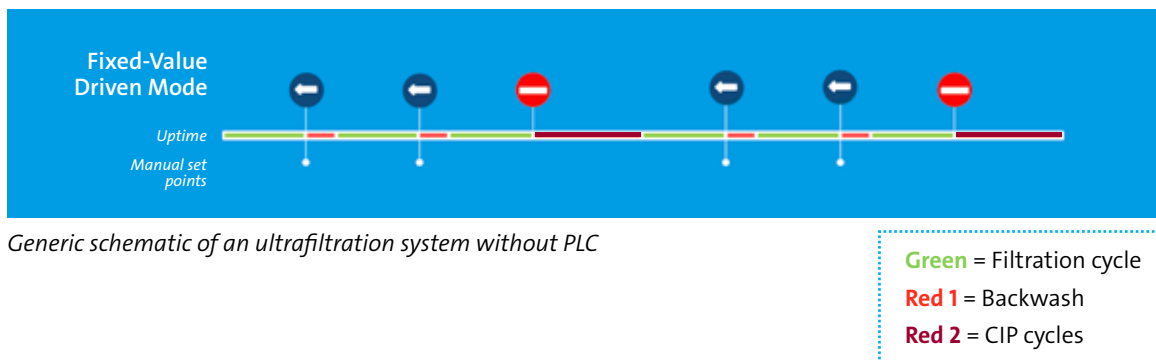
*Generic schematic of a RO system without PLC*

As we can see, the PLC is removed, and the control functions are integrated in the feed pump. All components interact directly with each other. The programming is done with pre-defined functionalities embedded in the intelligent pump.

# A LOOK BACK AT OPERATIONAL MODES OVER THE YEARS

Historically, a membrane system is built according to different design parameters such as flow, amount of water produced, and so on. When it comes to operational parameters, the water quality defines the needed backwashes with the water and the time between two CIPs. Very often this is based on historical, single sample or even theoretical parameters and is not considering fluctuations in the day to day performance or changing water qualities. Usually there is a safety margin built in, to stay in the safe operation mode.

This way of designing and running a filtration system has been more or less standard in all systems built over many years. Many of these systems are still running and also still on the payroll of many companies. We could call this operation mode: **fixed-value driven mode**. In this operation mode, every backwash is done after a certain time, whether the backwash is needed or not. Performance of the system is not considered, nor is the water quality. A typical sequence of filtration, backwash and CIP is shown below. Today, even if the water condition changes, the adaptation of the system is done manually and relies on the operator's expertise.



Technology then moved on, and fixed-speed filtration and backwash was replaced by demand-driven operation of filtration systems when variable speed pumps entered filtration. As an example, Grundfos offers integrated VFDs on the pump, combining state-of-the-art energy efficient motors with a VFD especially built and optimized to control pumps. These combined motors and drives offer the possibility to connect sensors for pressure, Delta pressure or flow measurement, as well as sensors for turbidity. Adding these sensors demonstrates a new way of controlling and operating a filtration system is possible.

We call this **controlled-value operation**. With this operation mode, the system will be able to backwash, based on the trans-membrane pressure instead of a fixed, time-based interval. The time of the interval no longer defined by hours, days or weeks. Instead, it is based on reaching a defined trans-membrane pressure, which can be based on recommendations from the membrane supplier, or on a water analysis.

In a RO system, if the feed water temperature changes, the feed pump will detect the changes with the connected temperature sensor and will adjust the flow according to the set permeate flow rate. Previously, this would have been done manually by an operator with potential delays or even missing the changes in the process.

At Grundfos, we integrate functions into the pump such as 'Limit Exceed' to operate in this way. The 'Limit Exceed' control mode is where you select a limit on an external point that influences operations. The time interval for operating is now based on reaching a defined trans-membrane pressure, as described above. With this control mode, the system starts to take surrounding factors into consideration.

Backwashes or forward flushes are done when the limit is reached and not when a timer countdown is reached. With this, we can improve uptime and reduce unwanted interruptions of the system operations. This improvement is made while still relying on historical data instead of making use of real-time analytics.



We have a customer in the United Kingdom who used the solution to reduce the overall system footprint by utilizing the functionalities in the CRE pump described above. This intelligent solution was installed in a Reverse Osmosis application, and, in addition to meeting the requirements of supplying the pure water essential for the company's operations, **it delivered 70% energy savings**. Furthermore, chemical dosing was made more reliable and safer by using the Flow Control Measurement (FCM) functionality in the DDA digital dosing pump. [2]

# A GLIMPSE INTO THE FUTURE

Today, technology and digitalization enable us to envision a new, more efficient way to run systems. This cutting-edge technology will transform the optimization of RO systems by offering a **real-time analytics driven mode** for backwashes. In this operational mode, the decision when to backwash and when to CIP is algorithm driven. Standard parameters of the system are considered, like pressure, flow, and so on, and then the algorithm analyzes the parameters in real-time and, based on the outcome, decides whether to perform a backwash or not.



*Operational backwash plan: real-time analytics driven operation*

Green = Filtration cycle  
Red 1 = Backwash  
Red 2 = CIP cycles

The time between backwashes varies; sometimes shorter sometimes longer, a bit like what we have seen in the variable-driven mode, but based on real-time data instead of predefined values. A high amount of flexibility is brought into the system, and with this, more effective effective operation. In the shown cases, the number of backwashes increased, and the algorithm also optimized the length of the backwash.

As an outcome, the uptime of the system and higher efficiency on filtrate output was achieved. Additionally, the number of CIPs could be reduced to half of that proposed by the system design.

# COST COMPARISON OF THE OPERATION MODES

The three different operational modes affect the cost structure of a filtration system. Obviously, the more uptime we can achieve, the better the system performs. This also reduces the waste of chemicals, water and of labor hours.

The operational cost of a membrane system consists of the following factors:

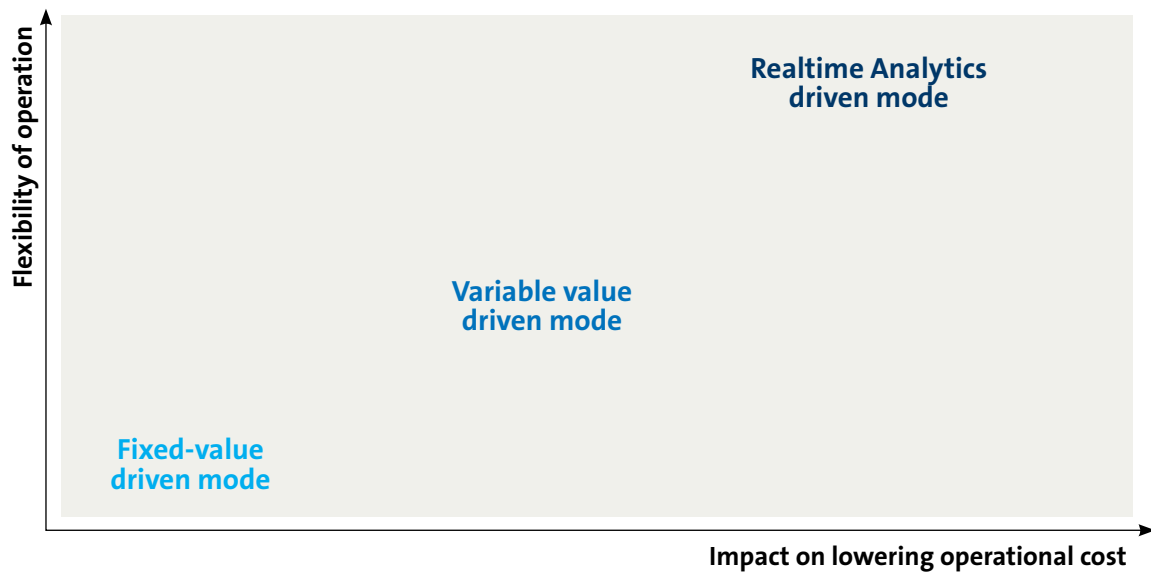
- Cost per gallon of water used for backwash/forward flush
- Cost per CIP
- Cost per hour maintenance personnel
- Cost per kWh
- Cost per gallon of water not produced

Depending where in the world the system is operated, or the type of market, the effect of the different factors on the total cost varies. For simplification, we take them as equal. The factors influencing the operation mode cost comparison are as follows:

| Operational mode | Cost per gallon of water used for backwash | Cost per CIP | Cost per hour | Cost per kWh | Cost per gallon of water not produced |
|------------------|--------------------------------------------|--------------|---------------|--------------|---------------------------------------|
| Fixed            | ●                                          |              |               |              |                                       |
| Controlled       | ●                                          |              |               | ●            | ●                                     |
| Analytics        | ●                                          | ●            | ●             | ●            | ●                                     |

*Impact on costs in relation to operational mode*

As we can see, the lowest impact on the different cost factors comes from the fixed-value approach. Only the cost per gallon can be influenced depending on how good the prediction of the fixed values is. The highest impact comes from the real-time analytics; all factors are directly connected to the performance optimization with the algorithm. Additionally, the controlled-value driven mode improves the cost factors more than the fixed mode but less than the real-time analytics.



*Cost Comparison of the Operation Modes*

| Raw Water Quality | Fixed Value operation | Variable Value operation | Real-Time Adaptive |
|-------------------|-----------------------|--------------------------|--------------------|
| Stable            | Medium                | Very Good                | Good               |
| Light variable    | Poor                  | Good                     | Very Good          |
| High Variable     | Very Poor             | Medium                   | Excellent          |

*Relation between raw water quality and technical fit of the operation mode*

## CONCLUSION

Operating a system in membrane filtration in an automated manner is not new. Sensors, PLCs and VFDs have been used in water treatment for many years. Using the functionality of the different components was the next logical step and is now common practice. The real evolution in filtration processes in water treatment comes with the usage of real-time analytics and the optimization of the process output based on algorithms fed with data from the system. To conclude, we can look to the future and see that the direction is set toward even more advanced data analytics; so, the journey doesn't end here – in fact, it has only just begun.

## SOURCES:

<sup>[1]</sup> Factsheet of the European Union based on Source: EC - Water Reuse - Background and policy context UN – Water and Jobs

<sup>[2]</sup> <https://www.grundfos.com/cases/find-case/ro-systems-gain-intelligence-and-save-70-percent-energy-per-m3-water-produced.html>

Grundfos, based in Bjerringbro, Denmark, is a global leader in water pump technology. To complement its global presence, Grundfos is committed to the American market with regional headquarters in the Houston, Texas area.

The company's purpose—pioneer solutions to the world's water and climate challenges and improve quality of life for people—inspires an operations, sales and service staff of over 1,200 across North America to deliver the world to the next generation in a better state than we inherited. For more information about the company, visit [grundfos.com/us](http://grundfos.com/us).