How Secure Power Solutions Support Critical Applications for Water/Wastewater Utilities

by Hans Luppens

Executive summary

Power availability is a key factor for operating and maintaining safe and reliable water/wastewater treatment utility plants. Dependable power architecture and intelligent power monitoring support efficient processes. This paper focuses on secure power solutions for delivering safe, cost-effective, and sustainable water/wastewater treatment services throughout the lifespan of a plant.

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Introduction

Electrical network designers and operators in water/wastewater treatment plants (WWTPs) must ensure high-quality, secure power for all critical processes along the water treatment cycle.

The risk of power interruptions may lead to public health issues or environmental damage and can create expensive contamination costs in a competitive and cost-constrained water market.

This paper focuses on power availability and reliability for a wide range of water industry applications. In a standard compliant electrical network, secure power is essential to maintaining safe, cost-effective, and sustainable water/wastewater treatment services throughout a plant's lifespan.

How a plant works

Main processes in the water distribution cycle

The water distribution cycle starts at the place where water is available (see **Figure 1**). This can be from rivers, lakes, or water sources at a specific depth. Water is pumped by means of elevation pumping stations to the surface and must be purified in specific treatment plants before being distributed.

When the water source is the sea, specific desalination plants with integrated pumping stations achieve water purification. After the water is treated, it is normally stored in specific stations and distributed by the water network to houses and cities.

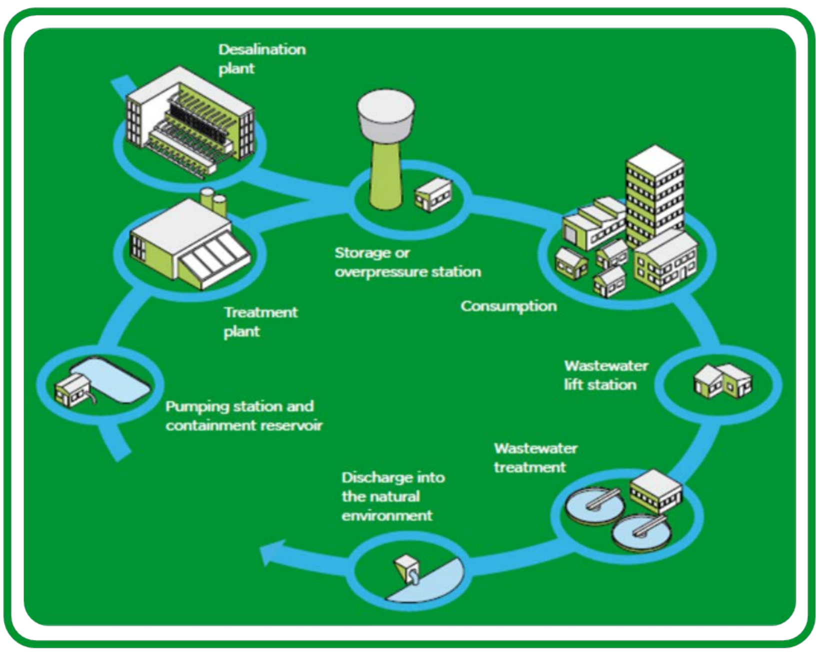

Figure 1
Water distribution cycle

In drinking water networks, constant distribution pressure is required to reach all floors in urban zones and to overcome physical barriers in rural zones. Boosting stations with considerable power needs are placed along the network, and both constant availability and real-time adaptation to the users' water demands are required. Different technologies are used, such as fixed and variable speed drives, switchboards or stand-alone devices, and medium to low voltage. In all cases, perfect integration into the electrical and automation networks is necessary.

When the water has been consumed, wastewater is delivered via water lift stations to the wastewater treatment plants.

Due to environmental laws, wastewater needs to be treated in specific treatment plants before it is discharged into the natural environment, which can be a river or the sea. Wastewater utilities use methods such as aeration and sludge processing.

Features of desalination by reverse osmosis

Reverse osmosis or membrane filtration is an emerging trend in water treatment technology, for both industrial and public use. It is the most common technique used for desalination, and it is an alternative to distillation. It may also be used in recycling to produce drinking water from wastewater. The reduced space needed for a plant and its ability to treat all types of raw water are key advantages of this technology.

Reverse osmosis uses fragile membranes that filter the salty or wastewater under high pressure (see **Figure 2**). In these plants, strict water pre-treatment is necessary because of the sensitivity to some pollutants. Power cuts may damage the membranes and create a high-cost impact. Consequently, power interruptions should be avoided as much as possible.

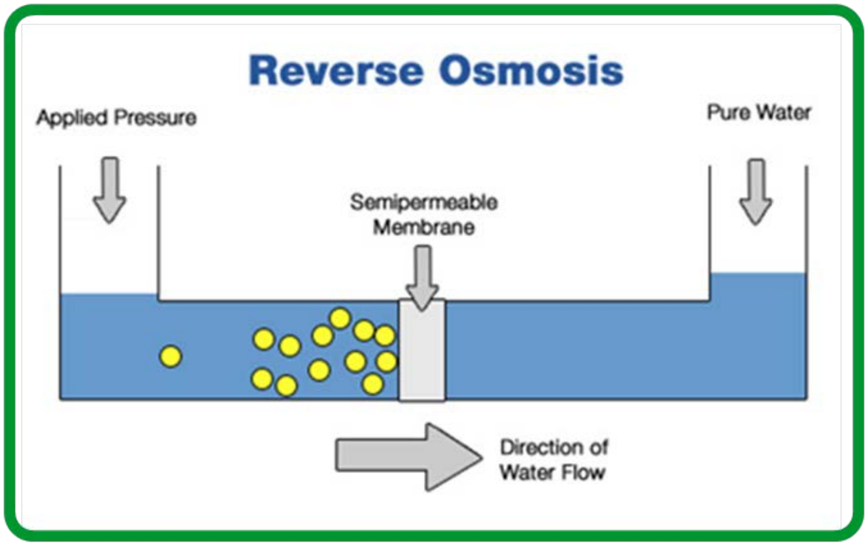

Figure 1
Principle of reverse osmosis and views of membrane tubes

High pressure has a key role in membrane filtration. This requires a large quantity of electrical energy and the use of high-power motors. Electrical distribution and motor control are a comprehensive part of the process.

Features of thermal desalination

In thermal desalination, the specific amount of heat is applied to water, so that the water starts boiling as in a distillation process (see **Figure 3**).

Although this water is cleansed of salt and impurities, it requires additional treatments depending upon the end use of the water. Purified water destined for human consumption, for instance, requires pH treatment, colour treatment, bacteria-killing treatments, and the addition of chlorine.

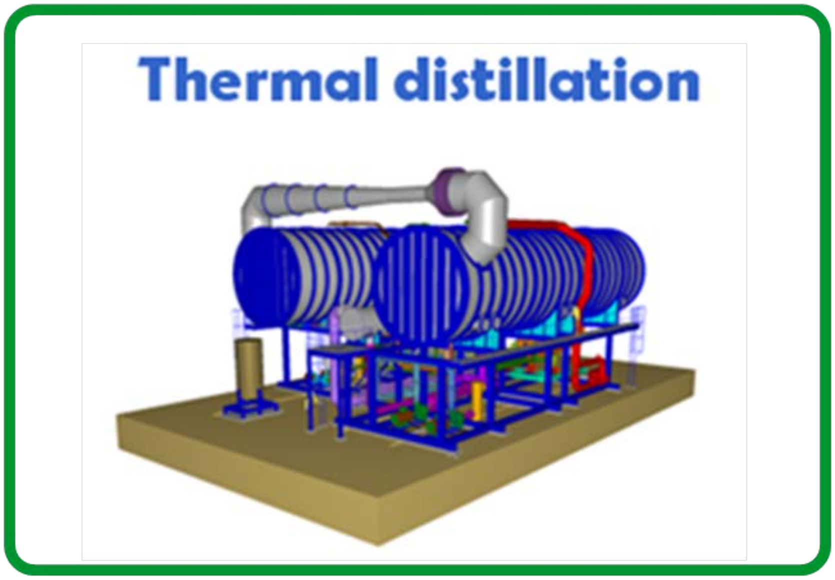

Figure 3
Scheme and view of thermal desalination unit

Features of ultraviolet disinfection treatment
During the past two decades, ultraviolet (UV) treatment has been applied in WWTPs, specifically in the U.S. market.

UV lighting emitted from bulbs damages chromosomes in bacteria so they do not reproduce. The effectiveness of this technology depends on the UV lighting dose. The bulbs need continuous power and control. This type is of treatment is driven by regulations and guidelines (UV Guidance Manual) from the U.S. Environmental Protection Agency.

Classification of water industry plants

Classification is based on destination and size of plant:

- Remote water pumping stations
- Treatment plants, including drinking water and wastewater treatment plants
- Desalination plants (reverse osmosis)

To understand plant classification, it is useful to consider the orders of magnitude of the necessary electrical energy and power in water segment. **Figure 4** presents averaged values relative to the treatment of 1 m^3 of water for the different types of water plants.

Figure 4
Electrical energy and power needs averaged for 1m^3 of treated water.

Process	Average energy for 1 m^3	Average power for 1 m^3 / day
Water supply	5 Wh / meter of elevation	0.2 W / m
Drinking water or Wastewater treatment	0.5 kWh	20 W
Desalination (reverse osmosis)	4.5 kWh	185 W

In the following tables, it is assumed that the power demand (see glossary) is approximately equal to 1.25 times the average power. Determination of the installed power of supply transformers is based on the power demand, the need for redundancy, and the potential for future plant extension.

Remote water pumping stations
Destination and size determine the three types of pumping stations:

- P1: Small lifting, pumping, and tank station
- P2: Pumping and small booster station
- P3: Booster and complex pumping station

Figure 5 presents the ranges of power demands relative to the size of the pumping station and the number of pumps.

Figure 5
Classification of pumping stations

	P1	P2	P3
Number of pumps	2	4	5 – 10
Power demand (kVA)	< 500	100 – 1000	500 – 5000

Water and wastewater treatment plants
Destination and size also determine four classes of plants for both drinking water and wastewater treatment:

- T1: Autonomous water treatment plant
- T2: Small water or wastewater treatment plant
- T3: Medium-sized water or wastewater treatment plant
- T4: Large water or wastewater treatment plant

Plant size can be expressed by the quantity of water treated per day, or by the equivalent number of inhabitants. In **Figure 6**, the approximate power demand is given for the four classes, corresponding to four different architectures for electrical distribution.

Figure 6
Classification of treatment plants

	T1	T2	T3	T4
m^3/day (drinking water or waste water)	1000 – 5000	5000 – 50 000	50 000 – 200 000	200 000 – 1 000 000
Inhabitants	1000 – 10 000	10 000 – 100 000	100 000 – 500 000	500 000 – 1 000 000
Power demand	25 – 125 kVA	125 – 1250 kVA	1.25 – 5 MVA	5 – 25 MVA

Desalination plants
The power demand for desalination by reverse osmosis technology is higher than for conventional drinking water plants (compare **Figure 6** and **Figure 7**). High power pumps are needed to generate high pressure to push water through membranes. The electricity cost can thus reach 57% of operating cost. As plant capacity is generally higher than 5000 m^3/day, only plant sizes T2 to T4 are relevant.

Figure 7
Classification for reverse osmosis treatment plants

	T2	T3	T4
m^3/day	5000 – 50 000	50 000 – 200 000	200 000 – 1 000 000
Power demand	1 – 10 MVA	10 – 50 MVA	50 – 250 MVA

Power cut consequences

In general, the main consequences of power cuts for water industries are:

- Interruption in water distribution
- Loss of water quality process
- Loss of data / loss of water quality traceability
- Increase in operating costs due to restart processes
- Increase in maintenance operations

The main concern is to avoid distributing untreated drinking water. In general, water industry regulations do not dictate limiting durations for power outages that might interrupt specific processes. In addition, water networks generally include a number of storage stations that play a buffering role. Avoiding power cuts is, to a large degree, a matter of following best practises for critical processes. Benefits of such a strategy are to ensure water quality, traceability, water flow and pressure throughout distribution, and environmentally acceptable wastewater release.

However, UV treatment presents a specific challenge, as U.S. regulations impel rigorous power continuity during treatment. Schneider Electric has designed specific power architectures – including secure power – to enable such plants to comply with specific regulatory requirements.

Main issues of power availability

Availability and reliability challenges

Among the key factors for power efficiency, W/WWTP electrical network designers have to consider availability, reliability, and ease of operations and maintenance. Water companies typically face these challenges:

- Water/wastewater processes must operate 24/7, so a plant must have continuous power.
- Producing drinking water is a critical process that requires constant control for unfailing quality.
- Leakage in the water cycle is a huge risk and requires specific systems to detect and prevent losses.
- Specific maintenance needs to be followed to keep a plant running and to optimize the life cycle of the installed base.
- Physical security is important for all plants, but is of particular concern for remote sites.
- Cost issues exist in regard to optimizing operations while reducing energy usage.

Definitions and categories

Power interruption sensitivity refers to the capacity of a function to accept a power interruption. Different categories of power interruption sensitivity can be distinguished as follows:

- Sheddable circuit: a function can be shut down at any time for an indefinite duration
- Long interruption acceptable: interruption time > 3 minutes*
- Short interruption acceptable: interruption time < 3 minutes*
- No interruption acceptable

*Indicative values according to standard EN 50160: "Characteristics of the voltage supplied by public distribution networks"

Levels of the severity of an electrical power interruption are also classified according to possible consequences:

- No notable consequence
- Interruption of process
- Production facility deterioration or severe environmental pollution
- Public health endangerment

On the electric network viewpoint, these categories result in progressive levels of criticality for supplying loads or circuits, as listed in **Table 1**.

Table 1
Criticality levels in regard to power interruption in water segment

Criticality levels	Details	Example
Non-critical	The load or the circuit can be disconnected at any time (load shedding)	HVAC for control room
Low criticality	A power interruption causes temporary interruption in the process, without any financial consequences. Prolonging of the interruption beyond the critical time can reduce or stop the water delivery.	Elevation pumping station
Medium criticality	A power interruption causes a short break in process or service. Prolonging of the interruption beyond a critical time can cause a deterioration of the water quality or a cost for starting back-up generators	Air blower for biological treatment
High criticality	Any power interruption can result in water quality deterioration and unacceptable financial losses	Quality control process, Information Technology (IT) department, Security department

Service reliability is the ability of a power system to meet its supply function under stated conditions for a specified period of time. Different categories of service reliability can be distinguished as follows:

- Minimum – implies risk of interruptions related to constraints that are geographical (separate network, area distant from power production centres), technical (overhead line, poorly meshed system), or economic (insufficient maintenance, under-dimensioned generation)

- Standard
- Enhanced – can be obtained by taking special measures to reduce the probability of interruption such as installing an underground network, strong meshing, dual MV line, etc.

Solutions for power availability and reliability

A high level of power availability is necessary for all parts of an application identified as critical, which may include redundancy. This concerns power as well as automation:

- Power architecture, stand-by generators
- UPS (Uninterruptible Power Supply)
- Motor control, PLC (Programmable Logic Controller)
- Communication and SCADA (Supervision Control and Data Acquisition)

Architecture principles
The following configurations are listed in the order of increasing energy availability:

- Radial single feeder
- Two-pole configuration (secondary selective)
- Double-ended power supply (primary selective)

There is a great benefit to configuring double-ended power supply for the most critical circuits. The duration of any power supply interruption will be limited to the operating time of the automatic transfer switch.

Backup generators
The implementation of backup generators is common in water treatment plants, where water distribution interruption cannot exceed a few minutes. No instantaneous takeover is necessary, as buffer tanks are generally present. Automatic transfer switches are naturally associated with generators for rapid takeover and smooth switchback to normal supply.

In general, a backup generator does not produce any power until it has reached its rated speed. Therefore, for critical processes, these generators are typically coupled with a UPS system to ensure a continuous power supply.

Double conversion online technology
This is recommended for the sensitive loads and harsh power conditions typical of water treatment applications. The technology provides excellent voltage conditioning (output voltage and frequency are independent of input voltage and frequency) and easy paralleling. Online operation means there is no transfer time during an AC input power failure, since the AC input charges the backup battery supplying power to the output inverter.

Redundancy for greater availability
Redundancy in water and wastewater treatment is critical. However, redundancy is a philosophy, not a set solution. Three methods of redundancy exist today: cold, warm, and hot:

- If cessation can be tolerated until the operator can intervene, then cold is best.
- When the system can handle a slight cessation, but automatic intervention is necessary, warm redundancy is the solution.
- For those operations that cannot experience even a momentary cessation, hot redundancy is the only option.

Properly understanding these levels can lead to reliable system operation, while minimizing costs.

UPS monitoring
The presence of a UPS unit is essential only if any length of power failure is unacceptable. Generally, process lines in water applications are not supplied by UPS because of the large power involved and the capacity for accepting short interruptions. On the other hand, UPSs are essential for protecting the following areas where continuous power supply is critical:

- Operator stations
- Process controllers
- Data centres
- Monitoring and control rooms

The main characteristics to be considered for implementing a UPS are:

- Sensitivity of loads to power interruptions
- Sensitivity of loads to disturbances

Figure 8 shows an example of UPS implementation to protect a critical circuit:

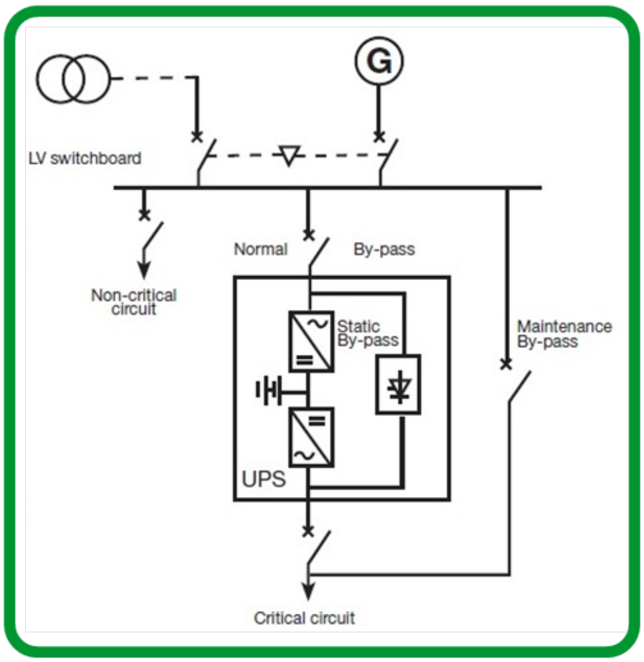

Figure 8
Example of configuration for UPS in critical circuit

Since the electrical power from a UPS is supplied by batteries, its backup time is limited from several minutes to several hours. For loads that do not accept any power failures, the UPS is combined with a backup generator. The backup time of UPS batteries must be compatible with the maximum time for the generator to start up and go online. Backup time always depends on the electrical distribution architecture.

UPS units are also used to supply loads that are sensitive to disturbances, as a UPS generates a 'clean' voltage that is independent from the network.

UPS system architecture
At a process level, UPS system architecture can be distributed or centralized, depending on a plant's size and layout:

- Distributed architecture: One or more single-phase UPS modules are installed downstream in each functional unit's electrical room, dedicated to supplying critical loads.
- Centralized architecture: Three-phase UPS modules (depending on the power load) are installed upstream in electrical rooms to supply critical loads over a large area or several functional units.

The standard design practice is to equip local process control panels with feeds from either a dedicated or a common UPS module, depending on the panel's location.
Plant managers may choose fully integrated systems with monitoring and control architecture or customized designs for specific cases. System designs can be tailored to specific electrical, mechanical, and / or environmental specifications. Customized UPS modules can also be created for precision engineering.

For critical process data, engineers can install parallel redundant or 'N+1' configurations (typically in server rooms). A parallel redundant configuration consists of paralleling several same-size UPS modules onto a common output bus. A system is N+1-redundant if the spare amount of power is at least equal to the capacity of one system module. With this configuration, the failure of a single UPS module does not prompt the transfer of the critical load to the electric utility feed. This configuration also allows the UPS capacity to increase as the load increase.

Secure power solutions

Secure power via a UPS system is essential at several levels of a W/WTP's operations.

At a process level, secure applications can prevent the loss of control over critical processes in pumping stations or in treatment units, located in an electrical room or in the plant itself:

- Automation and control circuits in pumping stations
- Communications equipment
- Process controllers and downstream remote I/O boards
- Process monitoring instruments, intelligent electronic devices, and local control stations
- Laboratories
- Security systems (fire, access control, and video)

The usual required backup time is 30 minutes, although more time may be needed in certain circumstances.

At a control room level, secure applications can prevent data loss and server shutdown. This typically comprises servers, workstations, and communications equipment, with configurations ranging from a standalone server rack to a complete server room requiring cooling services and management.

A UPS system may protect other critical loads, such as:

- UV water disinfection systems (due to sensitivity to variations in power quality)
- Desalination by reverse osmosis (for the protection of the fragile membranes)
- Inlet valves
- Remote telemetry control

Water distribution networks

Power protection is necessary to maintain the automation that monitors and controls a water distribution system. For drinking water, a plant must maintain automatism to control the pressure (4–6 bar) and the process.

In critical pumping stations for drinking water facilities, when bad power quality may disrupt water distribution, a UPS is implemented downstream to maintain the pressure and to control the automatism. **Table 2** indicates UPS sizing in such cases.

Table 2
UPS size recommended for pumping stations

	P1	P2	P3
Number of pumps	2	4	5 - 10
Power Demand (kVA)	< 500	100-1000	500-5000
UPS needs (kVA)	NO	1 -3	2 - 5

Process functional units of WWTPs

A process functional unit (FU) in a water plant is a group of devices interconnected via several communication protocols. In each unit, the information from the connected devices is received by a centralized PLC.

Both functional units and control rooms are critical processes where the UPS is integrated. The role of power protection in W/WWTP aims to:

- Protect applications that measure water quality and monitor processes
- Increase a plant's energy efficiency
- Keep a SCADA system operational during a power outage and avoid loss of data

Three types of reference architecture are used depending on the complexity of the functional unit: centralised, modular, and large process.

Depending on the size of the treatment plant, more backup power is needed to cover the critical power of the functional units, as shown in **Table 3**.

Table 3
Total UPS power versus WWTP size

	T1	T2	T3	T4
m^3/ day (drinking water or waste water)	1000 -5000	5000 - 50 000	50 000 - 200 000	200 000 - 1 000 000
Inhabitants	1000 - 10000	10 000 - 100 000	100 000 - 500 000	500 000 - 1 000 000
Power FU (kVA)	2	4	5 - 10	5
Number of UPS	1	1	3 - 5	10 - 15
Control room (kVA)	0	2	5	10 - 15
Number of UPS	-	1	1	1
Battery back up time	30 – 45 min	30 – 45 min	30 – 45 min	30 – 45 min
Total UPS power installed on site	**2 kVA**	**6 kVA**	**20 - 55 kVA**	**60 - 90 kVA**

As an example, **Figure 9** displays recommended power architecture for T2-sized WWTP, with power demand of 125 to 1250 kVA. These plants have more motors (with and without variable speed drives), resulting in greater harmonics and degrading the power factor. An optional backup generator can be implemented with fixed or mobile configuration for load shedding from the process power supply. UPSs are implemented to protect the critical loads in pre-treatment and treatment.

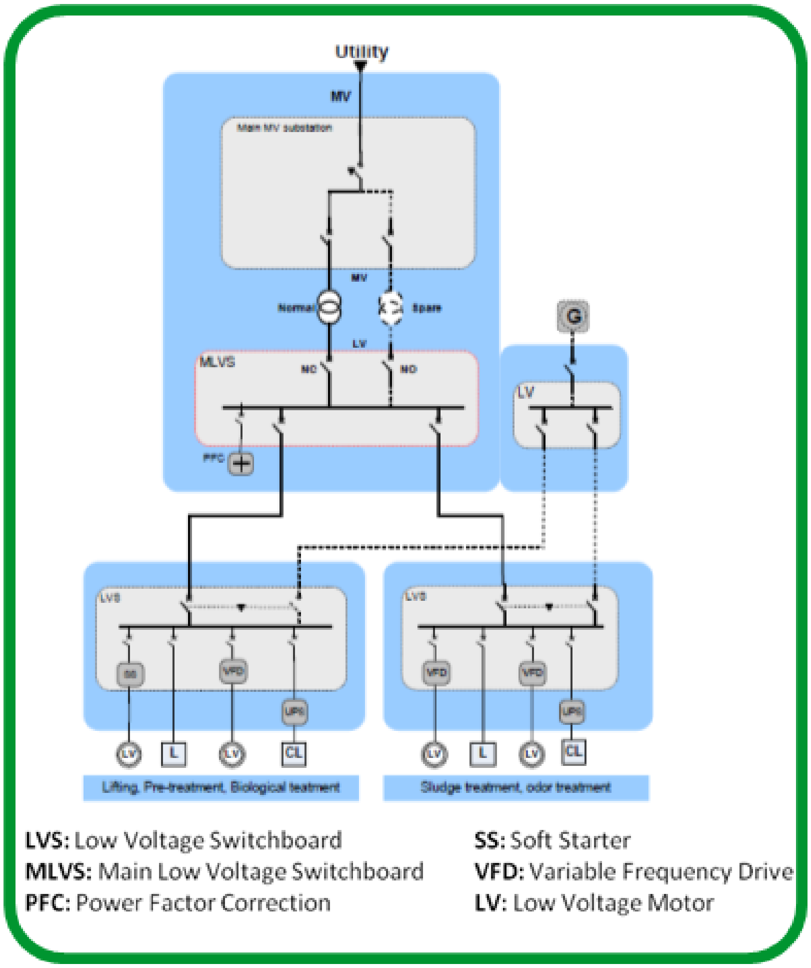

Figure 9
Example of power architecture in T2-sized plant with UPS for critical loads

Power monitoring and control room

An efficient metering architecture is crucial to both the Power Monitoring and Control System (PMCS) and the Energy Management Information System (EMIS).
Intelligent electrical devices – meters, switchboards, sensors, and others – serve as the primary data collectors. Data is sent to the PMCS, the EMIS, and the power control system. The intelligent electrical devices and a plant's communications network determine the data consistency, accuracy, and reliability. The metering architecture should be adjusted to plant size and needs. Due to visualization software packages, network and IT segments are increasing in importance to the water industry.

SCADA and DCS

Implementation of sophisticated SCADA and DCS systems in the water industry has given plant operators unprecedented capability to monitor and control all aspects of water production and distribution from a centralized control room (or control centre). The control IT room, which contains workstations for supervising a plant, visualizing energy operations, and managing assets, can be built into a data centre solution that includes UPS protection (see **Figure 10**).

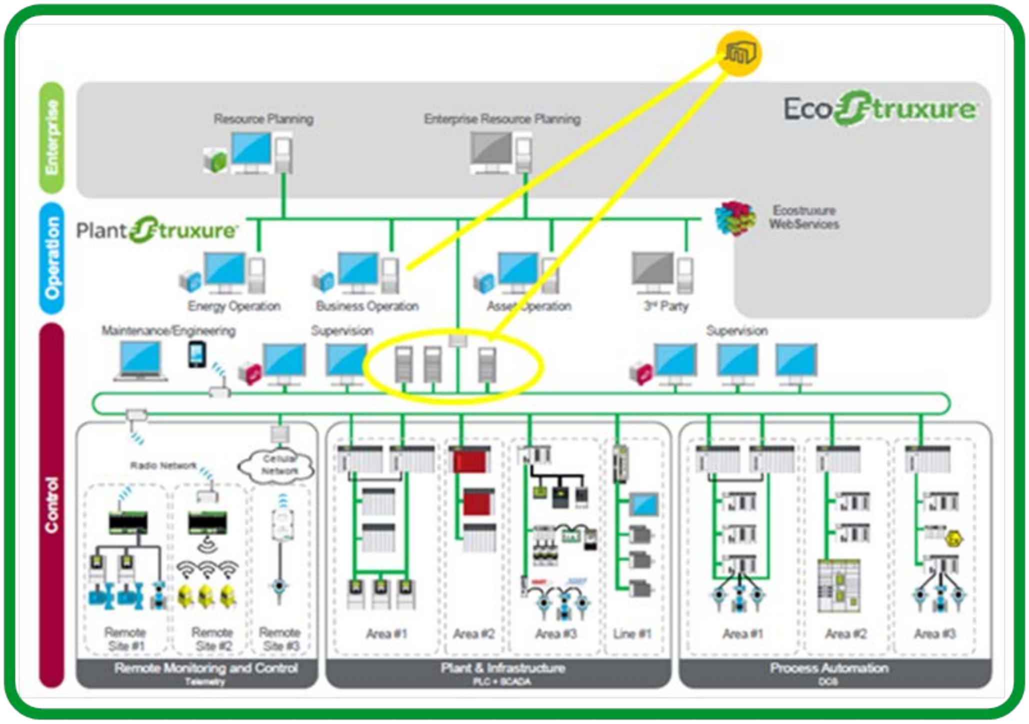

Figure 10
Example of UPS implementation in control systems

Specific treatments

Reverse osmosis treatment
In a complex process like reverse osmosis treatment, power and control are highly interconnected. Based on the size of such utilities, a large amount of process information has to be treated and exchanged between the different parts of the plant. Integrated solutions for power and control are required to reach the expected performance level.

Specific UPS solutions are prescribed to maintain system control and to keep the PLCs and radio running for reliable communications. Due to harsh environmental conditions and required voltages, many situations require a customized UPS solution.

Thermal desalination
In this type of process, a UPS solution is implemented to secure data protection and to secure the power for specific measurement instrumentation. Critical power is required for:

- Instrumentation (flow meters, CO_2 sensors, hydrocarbon analyzers)
- SCADA, DCS, process visualization software
- Emergency lighting
- Alarms

In thermal desalination plants, customised DC and AC UPS are often required due to specific requirements:

- Robust design compatible with harsh environments (IP level, salt and humidity)
- Compatibility with unstable electrical environment
- Long life expectancy
- Systems engineered according to customer needs

Ultraviolet treatment

Due to the severe regulations and guidelines that have been written by the Environmental Protection Agency (U.S.), together with the power fluctuations of the U.S. electrical network, criticality of these systems is high. Power protection with UPS is essential to fulfil the following criteria:

- Ensure water quality by preventing bulb outages
- Avoid "boil water" alert
- Increase bulb and ballast lifetime due to minimized re-strikes from power loss
- Enable power breaker maintenance without complete shutdown of the bulbs

To maintain the high quality of treatment and eliminate any risks in the process, Schneider Electric has defined a specific power architecture where the UPS is integrated. UPS range can be up to 225 kVA depending on UV lamp application and water flow.

Figure 11 shows an example designed for the U.S. market based on LV to MLV solution (480–4160 V). This configuration has one main incomer and a backup generator. In case of a power-down situation, the UPS will ensure that the UV lamps remain on. When the backup generator is on power, normally after 15-20 seconds the power of the UPS will be shifted back to the generator.

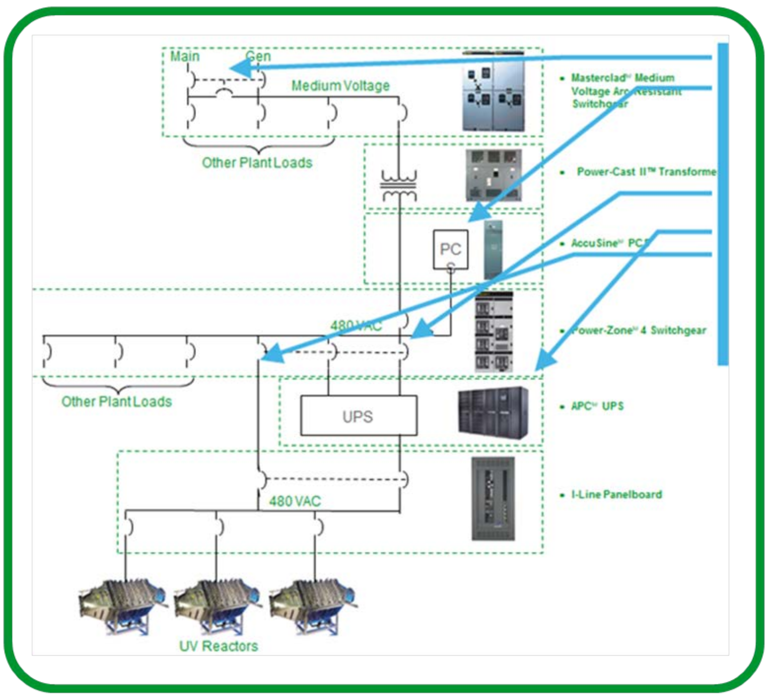

Figure 11
Example of power architecture and UPS implementation in UV treatment plant

Table 4 list the types of secure power devices and their locations in a W/WW plant.

Table 4
Secure power solutions

		Control room	Pre-treatment	Aeration	Disinfection	Sludge treatment
Products	Decentralized Single-phase UPS	☑	☑	☑	☑	☑
	Centralized Three-phase UPS	☑	☑	☑	☑	☑
	Operation and monitoring mgmt.	☑	☑	☑	☑	☑
	Physical security	☑				
Services	UPS and cooling services	☑	☑	☑	☑	☑

Preferred UPS and communication protocols for W/WW segment
Within the power and monitoring architectures of the functional units, the UPS need to be able to communicate with other devices.

To allow for easy integration of the different UPS ranges, the most common communication protocols are MOD Bus and MOD Bus TCPIP. SNMP protocol can be used for direct integration in the SCADA protocols.

Conclusion

Process risks exist in the water/wastewater industry, which may lead to expensive contamination issues. Reliable power is essential to ensure safety and continuous quality in water treatment. Specifically, critical applications throughout the various water treatment processes require power protection.

The secure power systems presented in this paper range from high power UPS for control rooms to small units for field automation devices. Backup generators associated with UPS protection – combined with dependable power architecture and intelligent power monitoring systems – enable plants to keep their equipment running, protect against data loss, and ensure data transfer among critical systems.

Since W/WTPs are permanent facilities with durations of 50 years or more, it is generally cost-effective to invest in a reliable, high-quality electrical network and high power availability.

About the author

Hans Luppens is the Global Business Development Manager for Industrial Solutions for Critical Power for Schneider Electric, specializing in the healthcare, water/wastewater, and airport segments. He has participated as an event speaker in many sessions, covering critical power infrastructures in buildings, industry and transportation, and he contributes to the Schneider Electric blog site. Hans joined Schneider Electric 15 years ago and previously worked for Phillips Medical Systems in a global capacity. He holds a B.Sc degree in telecommunication engineering from the HTS Haarlem in Holland and a master's degree in marketing and business administration from ESMA, Barcelona, Spain.

Glossary

Functional Unit: A functional unit is a group of devices interconnected via several communication protocols. The centralized device is the programmable logic controller (PLC), which receives all the information of the connected devices.

Power demand (in kVA or MVA): Represents the maximum power possibly consumed at a given time by the entire installation. It can be derived from the average power. Different factors must be taken into account, such as power factor (in the order of 0.9), and daily or yearly process fluctuations.

CAPEX	Capital Expenditures
CCS	Collaborative Control System
DCS	Distribution Control System / Data Control Systems
EMIS	Energy Management Information System
EPA	Environmental Protection Agency
EPC	Engineering Procurement Constructions
FU	(Process) Functional Unit
IMCC	Intelligent Motor Control Centres
OM	Operating margin (= operating income / revenue) in %, which does not account for the investment (capital)
O&M	Observation and measurements
OPEX	Operating Expenses (charges exploitation)
PLC	Programmable Logic Controller
PMCS	Power Monitoring and Control System
ROI	Return on investment
ROS	Return on sales
RTU	Remote Terminal Unit
SCADA	Supervision Control and Data Acquisition (type of industrial control by computers)
TCO	Total Cost of Ownership, which includes CAPEX and OPEX over a plant's lifetime