

Integrated intelligence A breakthrough in wastewater pumping

Introduction

Today's customers can have higher pump system reliability, more and smarter functions, lower operating costs and data connectivity when pumping wastewater using an intelligent pumping system. This feat can be met by integrating sophisticated power electronics and intelligent software in submersible wastewater pumping systems, resulting in unprecedented operational flexibility, cutting-edge system efficiency and increased system reliability. This will deliver substantial customer OpEx and CapEx reductions.

Intelligent pumping systems can be made to meet the requirements of all wastewater pumping applications and duty conditions as well as system requirements

that change over time. Customer pain points, such as improved system reliability, reduced energy consumption, operational flexibility, reduced footprint, connectivity and a significantly lower pump system lifecycle cost can be achieved with integrated intelligent wastewater pumping systems, the ultimate solution for trouble-free pumping.

This white paper describes the revolutionary technological advances, functionality, reduced asset management and the total reduction in operational lifecycle costs. The results will show the significant benefits that owners and operators of wastewater pumping systems will experience and appreciate.

A new level of thinking

Tomorrow's wastewater pump stations will require more functionality, higher reliability and advanced data communication. Owners and operators ask for this and flexibility, lower costs and better performance. To meet such demands new thinking and new engineering must be used to create products and an offer that is higher on the value scale, yet that will prove to be the more economical solution over time.

An answer to these challenges is the creation of integrated intelligence in wastewater pumping. This is made possible by innovation and adaptation of components in a submersible wastewater pump. By integrating power electronics, a processor, software, sensors, a synchronous electric motor and a state-of-the-art self-cleaning hydraulics inside a submersible shell, intelligent wastewater pumping with integrated intelligence has been made possible.

Integrating intelligence

The word 'intelligent' in wastewater pumping is a result of factors that together contribute to a new level of operational autonomy and efficiency, a pumping system designed to automatically deliver the desired performance at minimum energy consumption while reducing the total cost of ownership.

Intelligence refers to a pump system that can sense the environment it is working in as well as the load it



Fig 1: Intelligence integrated into a submersible wastewater pump

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is subjected to and adjust its behavior to meet the end-user optimization targets. By collecting and analyzing relevant data the pump system can make smart decisions about how it operates and what feedback it will provide the user, resulting in precise process control, a reduced risk of clogging, clean and odor free pump sumps, substantial reductions in energy consumption, reduced asset management, comprehensive data reporting and lots more. In short, it delivers peace of mind to the end user.

The word pumping is used to describe that the affected operational area has been expanded from the pump itself to include hardware, functionality and customer values that today reside both in a wastewater pump, pump controls and external communications.

Understanding the pain points in pumping wastewater

Customers are looking for lower costs, increased reliability and data connectivity. Environmental concerns are getting increasingly more important, such as carbon footprint size and neighbors' complaints about odors at their local sewage pump station.

While the pump system's upfront cost is still a major consideration the fact is that the operational costs over the life of the pump station will vastly overshadow any price difference between competing pump system designs at the time of purchase. Increases in pump system efficiency alone may not always convince a buyer to switch to a better performing system, but a single unscheduled call to clean a clogged pump will easily tip the scales in favor of a system that has proven to be consistently clog-free.

Clean and odor free pump stations are always desirable, yet many pumping systems frequently require expensive pump outs - for example vacuum cleaning call-outs, to remove bottom sediment, floatables and fat build-up that creates odor problems.

Connecting and communicating

Connectivity is the ability to connect, monitor and control a pumping system within a network of pump stations, treatment plants and other facilities. While connectivity is nothing new, the need today is to integrate even the smallest pump stations into the end user's monitoring system in a simple and cost effective way. Users are increasingly logging large amounts of

operational data, and with sophisticated data analysis schemes, pumping systems can be operated more efficiently and at a lower cost by better maintenance planning and not having to send staff for routine check-ups.

Lastly, overall reliability of the entire pump station and pumping system is high on operator's agenda. Systems that can deliver true operational peace of mind will always be in demand. This leads to the desire to build 'future proof' stations that are flexible and resilient, meaning that they can easily adapt to changing conditions and can handle extreme flow conditions without failures.

Traditional pumping solution

A typical wastewater pumping station consists of two pumps and a control panel that operates a sewage lift station based on varying liquid levels and an on/off controller. Duplex sewage pumping stations are frequently found in municipal lift stations serving municipal and private wastewater collection systems.

The pumps consist of a submersible enclosure containing an induction motor with a close-coupled hydraulic end and a seal unit. This pump type was originally developed in the 1950's and is now considered a mature product that is globally available from a multitude of manufacturers. Many pump designs have been on the market for some 10-20 years with little or no innovation added.

Today's typical small pump station control panel is often fitted with simple relay logic or basic 'black-box controllers' that operate standard contactors in an on/off pumping mode. Pump station monitoring and protection is often limited to thermal overload and pump leakage. Universal pump station design codes lead to significant pump oversizing which in turn results in excessive energy usage and unnecessarily high equipment wear and thus operational costs. On top of this many pump designs suffer from frequent clogging making the operation unreliable, unpredictable and overly energy intensive.

Recent attempts to improve pump efficiency, other than using self-cleaning hydraulics, has been realized by replacing standard induction motors with premium efficiency motors, a very minor improvement that results in only a few percentage points better pump system efficiency.

The value of integration

In the history of wastewater pumping the first integration step was conceivably the advent of a close coupled pump unit. This integration eliminated several components such as the baseplate and a separate bearing housing and lowered both the weight and cost of a pump. It also eliminated the need for on-site shaft alignment work. Additional benefits included fewer vibration problems due to shorter shafts and a stiffer design.

The next significant integration step was the invention of a fully submersible pump; here the close coupled pump was integrated into a watertight and fully submersible enclosure. The derived benefits included the ability to operate submerged as well as elimination of the suction line and associated limitations in suction lift, air leaks and the customary pump priming. With the invention of the submersible pump the need for expensive dry-pits was eliminated.

Delivering more

A wastewater pumping system with integrated intelligence can deliver much lower operating costs and breakthrough pump system efficiency improvements via increases in pump hydraulic efficiency, motor efficiency and pump system efficiency. It can add unparalleled flexibility, increased reliability and a smaller footprint. Integrated electronics and software can yield energy savings alone of up to 70% in many sewage lift stations.

Add all of this together with lower pumps station cleaning costs, additional functionality, longer equipment life and increased pump system reliability and it's clear a breakthrough technology has arrived.

A natural expectation would be to pay more for achieving savings, new functionality, flexibility and reliability but the pump system's initial purchase price may be lower. However in all cases the added up-front cost is paid back many times over due to a lower life cycle cost.

End users that have trialed this new technology during the last few years have been impressed by the savings, increased reliability and the many other positive benefits discovered with their wastewater pumping operation.

Integration of multiple components and functions into a single compact unit will drive down the cost and size of a system that utilizes separate components. Additional integration benefits are often additional integration benefits are often discovered during the development

process, further enhancing value. Integration increases the product's reliability by increasing the mean time between failures (MTBF) due to a reduction of components and connections.

Integration of electronics

When power electronics and a processor with control software are integrated into a submersible pump, costs are driven down and new functionality added. The challenge is the 'packaging' and integration of new components, i.e. the size, shape and performance within the submersible envelope.

In order to achieve efficient component integration some components need to be re-designed to fit the environment of a submersible pump and adapted to function as a system. The power and control electronics which in a conventional pump control panel are mounted on a back plate must be adapted and fitted into the head of a wastewater pump.

Placing power electronics inside a submerged wastewater pump is beneficial since they are protected from the exposure to heat, dust, dirt and extreme temperature variations. The cooling is reliable, compact and stable and not dependent on fans or A/C units.

The motor leads are as short as they can be removing any issues with wave reflections and voltage spikes. The entire system is pre-engineered and the equipment start-up and commissioning time is drastically reduced as there is an absolute minimum of configuration via simple set-up wizards. When power electronics are placed between the grid and the motor the system becomes frequency independent and voltage tolerant. Typically a single unit can operate with input frequencies anywhere from 50 to 60 Hz in the voltage range 380V to 480V.

The intelligence

The in-pump processor controls the power electronics to achieve variable pump performance, always meeting the demand at hand. A single impeller size per volute size minimizes the need for multiple spare impellers and yields maximum hydraulic efficiency as the impeller is optimized for the volute. Instead of having to remove the pump to trim or change an impeller, a different duty point can simply be met by the touch of a button.

Instead of discrete pump performance curves the new system offers an unlimited choice of performance curves within a large field. The specified duty point can always be met, yet easily changed to actual site conditions, if needed.

The intelligent wastewater pump system in total uses very few unique parts which drastically reduces the need to stock spare parts or spare pumps whether at the end user level or at a supplier's warehouse.

A new, simpler and more compact high performance synchronous motor further improves pumping system efficiency allowing operation at reduced pump capacity with maintained high motor efficiency. The concentrated winding synchronous motor does this and meets the proposed future super-premium motor efficiency standards (IE4).



Fig 2: From a complex selection

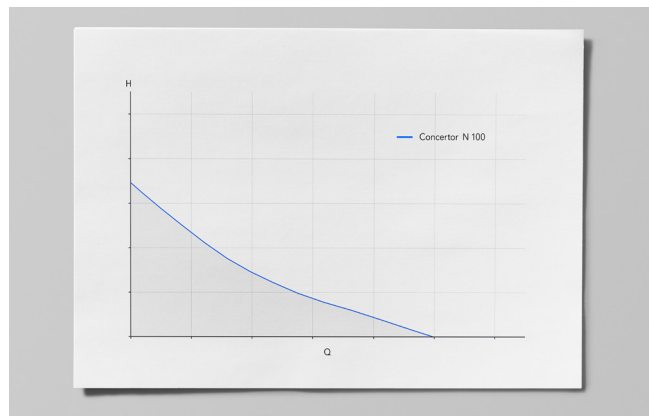


Fig 3: To one flexible solution

Advanced drive unit

The pump's drive unit is an assembly consisting of monitoring and control circuitry, software, power electronics and a synchronous motor in a single package. By utilizing a new motor design, the concentrated winding design, benefits such as increased motor efficiency, controllability, dramatically improved low speed efficiency and reduced size is derived.

The stator consists of multiple identical stator lamination packages with individual coils that are placed side-by-side inside the stator housing. The concentrated winding stator can be produced efficiently and at a shorter height than an induction motor of corresponding rating.

The rotor is equipped with permanent magnets that create and maintain the rotor's magnetic field, yielding very low rotor losses and operation at synchronous speed. The low losses means that virtually no heat is generated in the rotor and thus no heat is flowing to the bearings via the shaft. This results in a cooler running rotor and a motor with longer

bearing life due to less thermal stress on the bearings. Due to the high motor efficiency the winding temperature is lower than normal, add to this the advanced temperature protection system where motor power is reduced, should circumstances warrant it, and the result of the design is a longer motor life.

The concentrated winding synchronous motor requires power electronics to start and run the motor. The power electronics offers full control of the pump shaft speed and torque; therefore the wastewater pumping system can operate within a large flow/head field. The embedded software serves to control the motor's speed and torque as well as to read the momentary load requirements.

Data communication

The pump station controller allows for data communication and measurement/analysis, providing communication to the world via standard communication protocols. The pumping station can easily be connected to remote station monitoring systems including Supervisory Control and Data Acquisition (SCADA) systems.

Peace of mind

The integrated intelligent system offers functionality such as soft-start, pump clog detection, pump cleaning, advanced motor protection and 'always correct' impeller rotation. These are features that increase pump system life, reducing downtime and gives users peace of mind. The pump station controller can handle up to four pumps and provides pump system management functions including:

- Pump clogging detection
- Pump cleaning
- Pump energy minimizer
- Sump cleaning function
- Pipe cleaning function
- Constant power operation
- Soft start
- Soft stop
- Pump alternation

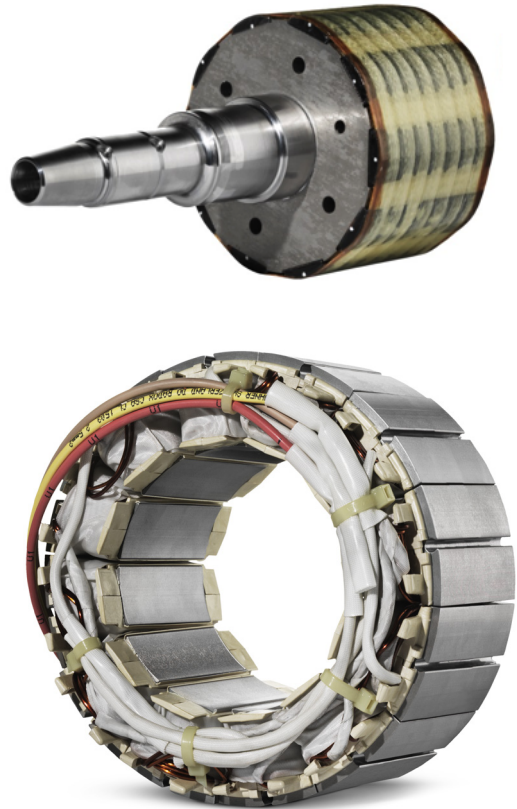


Fig 4: Concentrated synchronous motor (rotor and stator)

Smarter and smaller

Integrated intelligence creates opportunities for reduced control panel footprint, both physically, environmentally and in your wallet. Substantial reduction of CO₂ emissions will result from installations with intelligent pumps and a pump station controller. The reduced physical footprint is due to relocation of major components from the control panel to within the submersible pump as well as the compactness of new components, a result of innovation, adaptation and integration of technology.

The pump and control cabinet have a much smaller physical size and the reduced environmental footprint is due to the systems very high operating efficiency and the new pump station control algorithms.

Compact cabinets

The reduction in cabinet size depends on which pump system the comparison is made with as well as the environment that the cabinet will be operating in. When comparing a cabinet with a variable frequency drive (VFD) pump system in a duplex sewage pump station with



Fig 5: Size comparison between the traditional and new Flygt Concertor™ pump control cabinet

two intelligent wastewater pumps having integrated intelligence it becomes obvious that the cabinet size has shrunk dramatically, as did the cabinet cost. The reason for this is the absence of two variable frequency drives, two motor protection devices, two pump monitoring devices and associated wiring and wire terminations. The surface area of the cabinet's back-panel can be reduced to half or less of the original size.

For control panels located in outdoor environments in warm or hot climate zones the size reduction will be even more drastic because all heat generating power electronics are placed inside the submersible pump rather than inside the cabinet and there is no need for VFD oversizing, ventilation fans or control panel air-conditioning. This advantage will drastically reduce the upfront purchase cost, increase the system reliability and lower the pump station energy usage.

Lean asset management

An integrated intelligent wastewater pump system consists of fewer individual components than a typical pump system. This simplification means that only a few different components such as pump volutes with different discharge sizes, an impeller per volute and a couple of motor sizes are needed to cover a large performance field.

As an example, one intelligent wastewater pump can cover the hydraulic performance of multiple different conventional pumps where different impellers, volutes and motors would have been required. This means that customers who keep their own stock of spare parts or spare pumps can benefit greatly as their inventory cost will be drastically cut. This flexibility also makes it possible to do a final pump configuration close to where the pump is needed, by just assembling a few key components.

The benefit of having just a few spare pumps in stock and being able to use them for many different operating conditions at multiple pump stations can provide considerable capital savings for the pumping systems operator or owner.

Flexible functionality

The powerful and patented energy minimizing software algorithm assures the lift station is always operated at the minimum specific energy level (kWh/m³), given the prevailing head and flow requirements. The pumps are soft started and soft stopped; the integrated pump clog detection function will protect the pumps from clogging by triggering a pump cleaning cycle, preventing unnecessary service calls. The sump and pipe cleaning functions will work to keep the pump sump free. Power and motor protection functions will protect the motor from supply grid issues and thermal overloads.

Additionally the system will assure complete knowledge of what's going on with the pumps and the system. Local and remote operational data such as pump and station status information, warnings and alarms are readily available and user configurable to suit different system requirements.

Pumping functions available with integrated intelligence

Additional pumping functions add value to the pump station operations including:

Clog detection

This is a pump function that detects when a pump is about to clog. The control software senses shaft torque, motor current and rotational speed allowing it to determine if the pump is about to clog. If this is detected the pump cleaning function will be activated to remove all soft clogs.

Pump cleaning

This function works to unclog a partially or fully clogged impeller by stopping the pump and running it in reverse and in special sequences to free the pump from debris thus avoiding emergency field calls to unclog a pump. The pump acceleration and deceleration cycles are designed to limit the maximum torque so that the pump life will not be compromised. The pump cleaning cycle will often free a clog within minutes but may operate for up 30 minutes virtually guaranteeing the removal of all clogs by soft materials in the toughest wastewater. This is substantially faster and less costly than having to send out a service crew to remove a clog.

Energy minimizer

Intelligent wastewater pumps and the wastewater pump station controller allows pump stations with up to four pumps to be automatically operated in the most energy efficient way while also keeping the wet well clean and increasing the system reliability. Energy savings of up to 70% is possible as compared to conventional wastewater pumps in a typical on/off operated pump station.

The energy minimizer function assures the operator that all pumps are continuously monitored for lowest possible specific energy usage. For each pump cycle the energy minimizer adjusts the pump performance in order to run the pump station at the minimum required specific energy. It has been field proven in thousands of installations; reducing pump energy usage anywhere from 30% to 70% compared to regular on/off operated pumps under otherwise identical conditions.

The pump station controller is pre-programmed and pre-configured, thus requiring minimal technician time on site. It self-adjusts to changing pump station conditions and is in constant communication with the outside world via local and remote communication.

Motor protection

The motor protection function relies on sensors and software function built into the electronics; it constantly monitors key electrical parameters as well as the motor and circuit board temperatures. If for example the thermal environment would change it would not result in an overheated motor because the power would be reduced to a safe operating level, given the conditions at hand. This is one example of how pump system reliability has increased.

Soft start and stop

The intelligent wastewater pump is soft-started and soft-stopped by gradually increasing and decreasing the pump speed. Soft starting a pump lowers the stress on all rotating components such as shaft, couplings, seals and impeller during startup. It provides a gentle acceleration of the water column which lowers pipe system stress and noise.

A soft stopped pump results in lower forces in the discharge pipe system because of reduced pressure transients. When the pump stop cycle is long (slow pump deceleration) the liquid will decelerate slowly in the force main. By lowering the velocity slowly in the discharge line water hammer problems such as noise and slamming valves can be prevented. The soft-stop also lowers stress on rotating components during shutdown.

Constant power

The intelligent wastewater pump is programmed to operate at constant motor power. It is therefore impossible to overload an intelligent wastewater pump and all performance curves are non-overloading. A consequence of the constant power function is that both the shut-off head and the run-out flow is higher than for a standard constant speed pump.

Always correct rotation

The intelligent wastewater pump is protected from incorrect impeller rotation at start-up because the motor's software makes sure the pump impeller always rotates in the right direction. This feature will save time for pump technicians at start-up and it will eliminate unneeded service calls to troubleshoot and correct this common start-up problem.

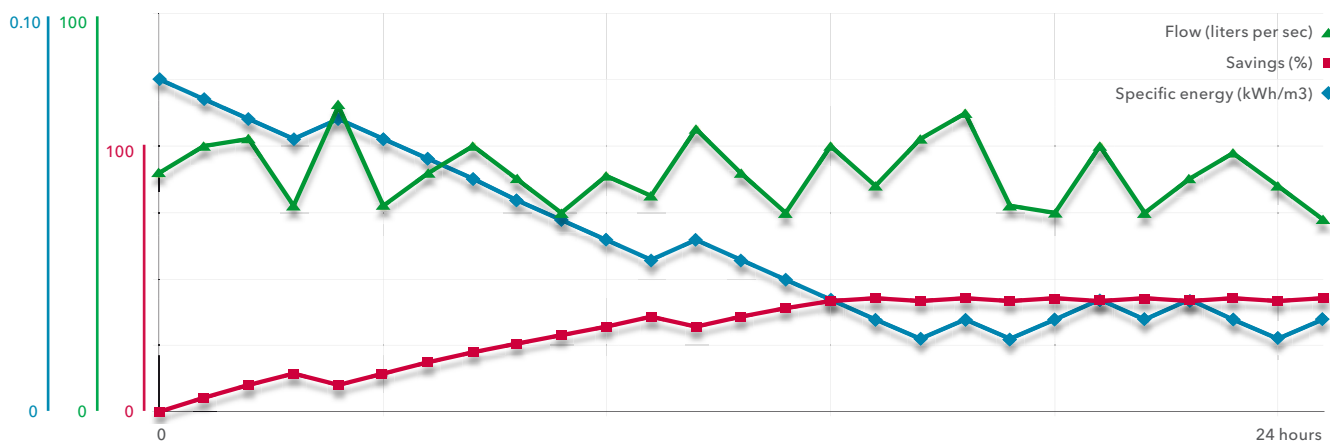


Fig 6: Patented Energy minimizer function continuously works to keep the pump system running at the lowest possible specific energy. Energy usage reductions of 25%-45% are commonly realized in wastewater applications. Each dot represents a complete pump cycle.

Operational flexibility

The intelligent wastewater pump can operate on 50Hz, 60 Hz or anything in-between, at voltages from 380V to 480V. Each pump size covers an infinite range of performance curves, often equaling the coverage of 6–8 standard wastewater pumps. These features along with the reduced number of pump components offers a high level of operational flexibility, especially for large municipalities and water boards, because inventories of spare pumps or parts can be drastically reduced.

By adding a gateway in the control cabinet the performance of an intelligent wastewater pump can be controlled in real time to meet the application needs. A master pump station controller or PLC will direct the gateway to adjust the pump output as directed.

Input and output data

Operational data can be accessed as instantaneous values and key operational parameters are also stored as logged data. Selected parameters can be set as alarms or warnings to trigger when customer set and pre-selected trigger levels are reached. Examples of available data are number of avoided clogging instances, pump run-time, number of starts, motor power, motor current, power factor, temperature, pump leakage etc...

Pump sump cleaning

This function helps clean the pump sump by intermittently drawing down the wet well level to pump snore, thus sucking out any remaining bottom sediment. The locally increased wet well velocities will efficiently break up floatables and fat deposits and mix it up before pumping out the wastewater. The result is a much cleaner pump sump with less sediment, less floatables and less odor, with up to 80% lower vacuum cleaning costs.

The sump cleaning function is fully automatic and no manual intervention is required. There is often no longer the need to use vacuum truck and sump cleaning services to remove bottom sediments, surface grease and floating debris in most pump stations.

Discharge pipe cleaning

The discharge pipe cleaning function minimizes the risk of sedimentation in the force main (the pump station's discharge line). Periodically multiple pumps are operated at maximum capacity to create higher discharge line velocities serving to re-suspend and transport sediment in the force main. The pipe cleaning function is fully automatic and uses the pump's maximum constant power function and, as applicable, multiple pumps to assure maximum sediment transport.

Control interfaces

When adding a gateway and a Human Machine Interface (HMI) pump and pump system data can be accessed and used. The HMI is required to display and adjust (if needed) system settings to suit user needs. HMI's ranging from basic monochrome displays to full-color touch screen units and smartphone/tablet applications are possible. This allows operators to view and control pumps and the entire pump system on location as well as remotely.



Fig 7: Wet pit surface before
(Customer test installation)



Fig 8: Wet pit surface after

Conclusion

An intelligent wastewater pumping system offers unprecedented flexibility in meeting varying wastewater pumping applications and duty conditions as well as changing pump system requirements. It offers a vast array of features and meets the needs of many different end users worldwide.

Desired wastewater pumping features, such as improved system reliability, operational flexibility, better asset management, reduced footprint, connectivity and significantly lower lifecycle costs are all met by combining different elements of the intelligent wastewater pump platform to meet a specific application challenge, the ultimate solution for maximum peace of mind.