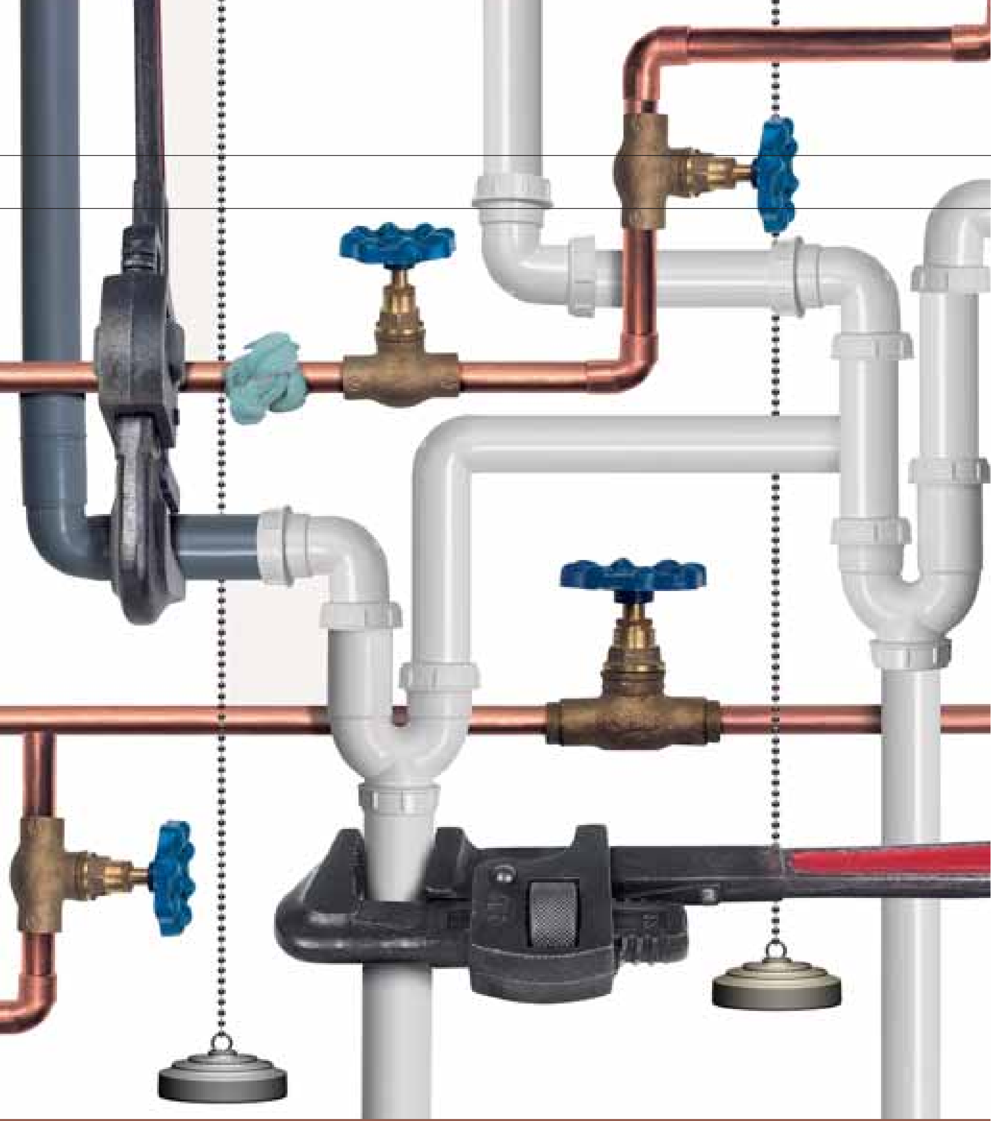


A smooth shutdown

ABB softstarters now come equipped with a new torque control algorithm to prevent hammering in water pipes

Jesper Kristensson, Sören Kling

If the motor that runs a pump is suddenly stopped, the abrupt change in the water flow that follows will cause pressure waves and water hammering in valves and pipes. Water hammering is often present in pumping systems with long pipes and in systems with a high pump head, and will, over time, cause wear and tear to the equipment. The use of softstarters generally reduces the effects of hammering by providing smooth motor deceleration. Now thanks to a successful collaboration with ITT Flygt, ABB has built on its softstarter concept by designing an innovative solution that completely eliminates hammering by controlling the optimum, time dependent motor torque.

The majority of pumps are still started with conventional electromechanical starting methods, such as direct-on-line start and star-delta start, and this means the risk of water hammering is ever present. However, various mechanical solutions, such as hydraulic valves or pressure tanks, are in place to prevent this effect. Although well-known, these solutions are costly, require high maintenance and, in the case of the pressure tanks, they need a lot of space.

Hammering in a water supply system can dramatically reduce the lifetime of pipes, valves and gaskets, cause unwanted interruptions and incur higher maintenance costs. The use of softstarters Factbox 1 generally reduces the severity of the hammering effect but cannot prevent it under all circumstances.

Because they help minimize mechanical wear and tear, softstarters are commonly used to start and stop motors in almost any AC motor application [1]. ABB, for example, developed softstarters that can control motors and pumps up to 1000 kW, and over 40 percent of ABB's softstarters are used to start and stop AC motors in pump applications. As well as their application in pumping systems, softstarters can be found in various other applications ranging from bow thrusters on ships to compressors in filling stations for natural gas to snow making machines, as well as more common industrial applications such as fans, compressors and conveyor belts. The former design, however, with its linear voltage ramps to start the motor, is not the most optimal one and needs to be improved if water hammering is to be totally eliminated.

Looking for an intelligent solution

In conventional softstarters the voltage supplied to the motor is linearly increased during a start phase (meaning the starting current is low) or decreased during a stop phase. For most applications this provides the basis for good motor acceleration and deceleration.

While water hammering is not an issue during a start phase, the situation is somewhat different during the stop phase. In a distributed water supply system with many valves and corresponding motors, the effect of closing one of these valves depends on the actual system configuration. System dynamics may differ from one start and stop to another since the water flow or number of pumps running in the system may vary. So even if the modification of parameter settings in one case prevents water hammering, it doesn't mean this is true for other system parameters.

Factbox 1 Softstarters

A softstarter uses thyristors (SCR = Silicon Controlled Rectifiers) to control the voltage supplied to the motor during start and stop. This in turn reduces the current, and less mechanical stress is put on the motor application compared to using full voltage starting, or other electro-mechanical starting methods.

Without the use of softstarters electrical, mechanical and operational problems can be expected:

- The voltage and current transients may overload the local supply network and cause voltage variations resulting in flickering lights and interference with other electrical equipment.
- Broken belts, cracked couplings, grinding gears and wear to motors can occur.
- Pressure surges in pipelines, damage to products on conveyor belts and uncomfortable escalator rides may be the result.

A more adequate solution is to take the dynamics of the water system into account when the softstarter thyristors are used to control the voltage to the motor 1. With more measurements available inside the softstarter, the water flow may be better controlled. At the same time it is possible to determine to what extent the voltage to the motor affects the water flow. By controlling the voltage it is possible to control the torque which in turn controls the motor speed and hence the water flow 2.

Hammering in a water supply system can reduce the lifetime of pipes, valves and gaskets, cause unwanted interruptions and incur higher maintenance costs.

Various measurements will allow a torque control loop algorithm to be established whose function is to control the deceleration of the water in the pipes to prevent water hammering when the pumps are stopped.

This is a typical example of control loop technology but with the added requirement that the same solution must work for all types of pumps and pipe configurations, as well as all motors between 15 kW and 1000 kW. An ideal scenario is a solution that requires no fine tuning of the settings. In order to better understand these varying requirements ABB contacted ITT Flygt **Factbox 2** in Sweden.

Cooperation with ITT Flygt

ITT Flygt and ABB had previously worked together on variable speed drives and other starting equipment. ITT Flygt's experience in water supply systems, together with its sophisticated simulation tools convinced ABB it was an ideal partner with whom the water hammering problem could be solved

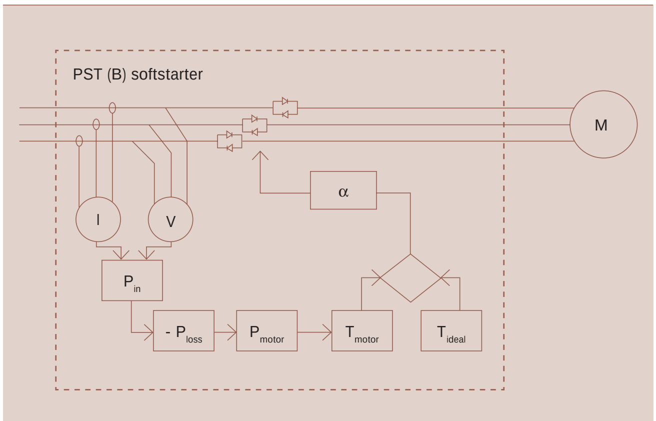
From an ABB point of view, getting to know the simulation tools gave valuable insight into the optimal way of decreasing motor torque and hence the water flow in the pump during a stop phase to prevent water hammering.

Judging whether or not hammering will occur is dependent on a number of parameters including the main pipe

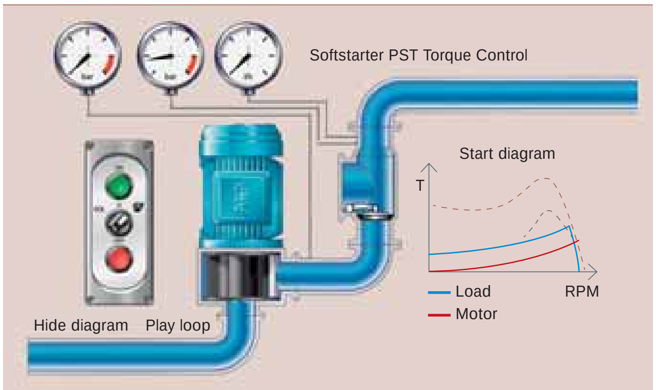
Factbox 2 ITT Flygt

ITT Flygt was founded in 1901, and with its headquarters on the outskirts of Stockholm in Sweden, ITT Flygt is the world leader in submersible pumps and mixers. ITT Flygt is involved in a broad spectrum of activities aimed at helping governments, municipalities and companies to improve sewage handling, flood control, energy conservation, land reclamation and tunnel construction. Their products are also used in mining, industrial processes, agriculture and aquaculture.

1 Motor control using feedback from a water flow system



2 Softstarters to control pumps – a demo showing the positive effects on current, torque and water flow when using ABB's PST softstarter with torque control



system and its components, and the type of pipes used, the pump head, length and the water flow. A number of other parameters must also be considered including the pipe work of the internal pump station. Slamming check valves is very common since the dynamic behaviour of the valves is too slow.

At shutdown the problem is much more acute. The most critical parameter during this phase is the change in flow speed. This, as well as the actual number of pumps on duty will affect the ramp down demands of individual pumps. To deal with these changes ITT Flygt already had a detailed analysis tool/method in place. For difficult cases this tool, which can perform a transient analysis of the system, is utilized when designing specific pipe configurations. During the project it provided ABB with valuable information concerning critical water flow parameters during pump shutdown.

With clear specifications from ITT Flygt on how a torque control solution needs to perform to prevent water hammering and increase the lifetime and up-time of their pumps, ABB's team of researchers concentrated on designing the desired solution. ITT Flygt proved to be an excellent discussion partner by taking a wider approach to the question of how the use of softstarters can increase the reliability of pumping stations, or which intelligent functions are required in the starting equipment to facilitate the softstarter's use in pump applications.

3 The new ABB softstarter for pump applications

Softstarters have to cover a wide range of applications, from home equipment to pipelines

The solution designed by ABB in collaboration with ITT Flygt to eliminate water hammering in pumps focuses on controlling the optimum, time dependent torque in the motor.

The solution designed by ABB to eliminate water hammering focuses on controlling the optimum, time dependent torque in the motor. To determine the required torque, it is necessary to carry out measurements and advanced calculations. The calculated torque is then compared to an ideal torque curve both during start and stop. If the torque is too low the voltage supply to the motor is increased using the thyristors. In the same way the voltage supply is decreased when the measured torque is too high. During the start and stop sequence both measuring and control are carried out in real time, and are fast and accurate enough for the torque to be controlled for all possible pumps and motors in all pipe configurations.

The available prototypes were first subject to ABB in-house testing followed by further testing at ITT Flygt's research facilities in Stockholm. Field tests were then carried out at several pump stations where ITT Flygt was already running tests on new pump models and prototypes. The tests in real systems helped validate both the simulation results and the torque control algorithm. The test stations were also used as demonstrators for end customers, thus enabling them to see the positive effects of torque control when stopping pumps.

The close cooperation between ABB and ITT Flygt during the initial design period enabled control algorithm modifications to be implemented at an early stage, thus reducing the product development phase significantly. Building on this successful cooperation, both companies will demonstrate a joint pump system at various fairs to show the advantages of using a submersible pump from ITT Flygt together with ABB's PST softstarter with the newly implemented torque control algorithm 3.

Towards wider applications

The selection of a leading customer as a collaboration partner to cover the general market requirements turned out to be instrumental for both parties. Among others, the open exchange of crucial design data and ideas not only led to an innovative solution to eliminate water hammering but it also provided invaluable expertise that can be used to address similar challenges in other applications where the starting currents and mechanical stresses in compressors, fans, bow thrusters or conveyor belts, for example are to be minimized.

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