SEQUENCE OF OPERATIONS IN COMMERCIAL BUILDINGS

Cut-in/cut-out sequences in multi-pump operations using a Grundfos MPC unit

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CONTENTS

INTRODUCTION

For more than 60 years, Grundfos engineers have been studying pumps. This vast application knowledge has been analysed and applied to design algorithms that result in pump systems with world class efficiency.

In this white paper, we will provide a deeper understanding of how a sequence of operation algorithm works with the Grundfos multi-pump controller (MPC) systems in commercial buildings, for example in cooling applications. This involves pump cut-in/cut-out operation, and also how the MPC controller optimises energy consumption by always making sure that the most efficient number of pumps are in operation.

The Grundfos range of multi-pump controllers for up to six pumps includes:

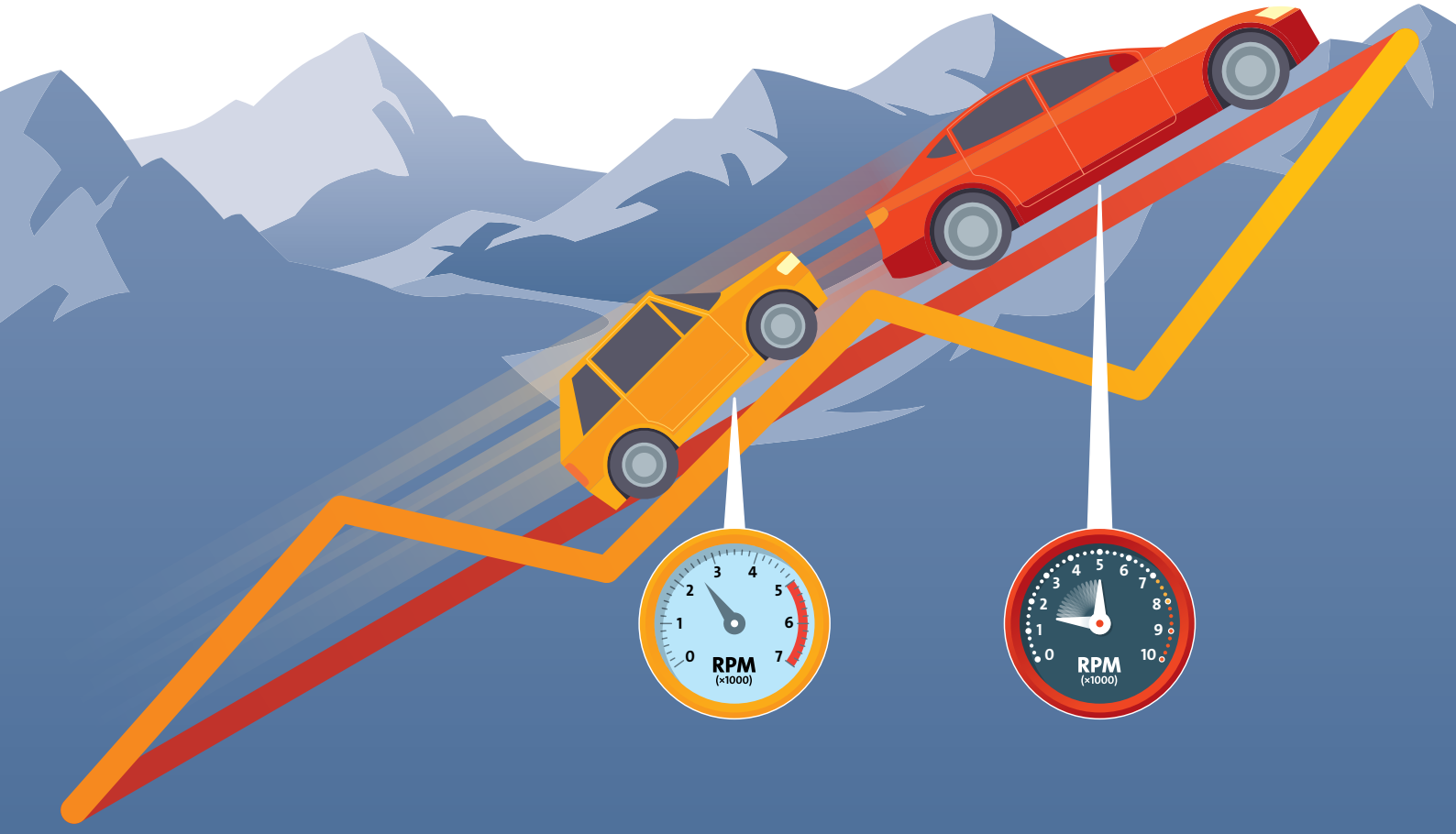
- Control MPC, a control panel with the CU 352 controller for custom-built solutions and variable speed control, for all pump types, and
- Hydro MPC, a complete plug and-pump system, ideal for pressure-boosting applications.

UNDERSTANDING SYSTEM DESIGN AND DIMENSIONING OF PUMP SYSTEMS

To understand the importance of proper and optimal pump control, we have to look at the overall system design or, even more importantly, the lack of design. Here is the reason why: In an optimal system design, where the selected duty-point (head/flow demand) is right at the pumps optimal efficiency point and the inlet pressure is stable, the pumps have optimal working conditions. Setting the cut-in/cut-out operation is relatively easy, and this ensures efficient operation. However, in reality, this is just not the case. Pumps are often oversized, either from a bad design phase, or simply from not having the correct data when designing the system and selecting the pumps.

The inlet pressure also fluctuates a lot depending on load conditions, making it very difficult and time-consuming to manually determine the optimal cut-in/cut-out point.

Proper pump control is therefore essential to overcome these challenges.



Running your pumps at constant speed is like driving a car with manual gears and changing gear according to a constant RPM after a specific time, independent of engine size and terrain. Grundfos MPC is like a sports car that automatically maintains the most efficient and smoothest operating point.

CUT-IN/CUT-OUT SEQUENCES

Before looking in-depth at the MPC's advanced control options. Let us review the traditional way of controlling pumps on/off, as this will help explain why the approach used with the MPC is far superior.

The traditional approach is to set a fixed speed for cut-in/cut-out, so that when pump 1 reaches, for example, 90 % for a period of time of about 3 to 10 minutes, pump 2 will then cut-in and ramp up in speed. Once both pumps are at the same speed, they will be regulated until the desired setpoint is reached. The same goes for pump 3 and so on.

Cut-out is done by the same philosophy, normally when the pumps are at, say, 30 % for a period of 3 to 10 minutes. One pump will be cut-out, and the speed of the remaining pumps will be regulated to reach the desired setpoint.

This can be compared to driving a car with manual gears and constantly changing gear (up and down) according to RPM after a specific time, independent of engine size and terrain (going up or down a hill). This is neither an efficient nor comfortable way to drive a car.

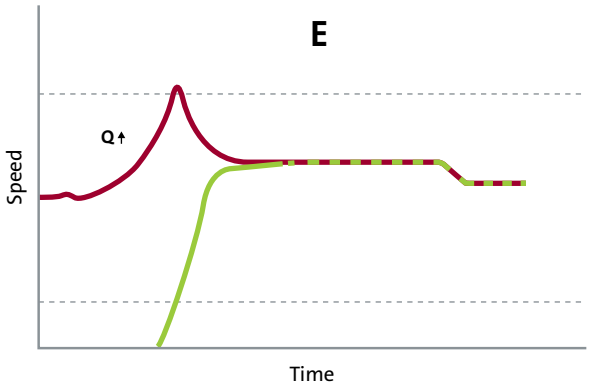
Grundfos MPC takes you from driving with a manual gear box and changing gear at the same RPM to driving a sports car with a fully automatic gearbox, where gears (engine speed) change to always maintain the most efficient and smoothest operating point.

The first step is to look at the advanced cut-in/cut-out functionality which is a part of Grundfos MPC.

A CLOSER LOOK AT ADVANCED CUT-IN/CUT-OUT FUNCTIONALITY

CUT-IN FUNCTIONALITY

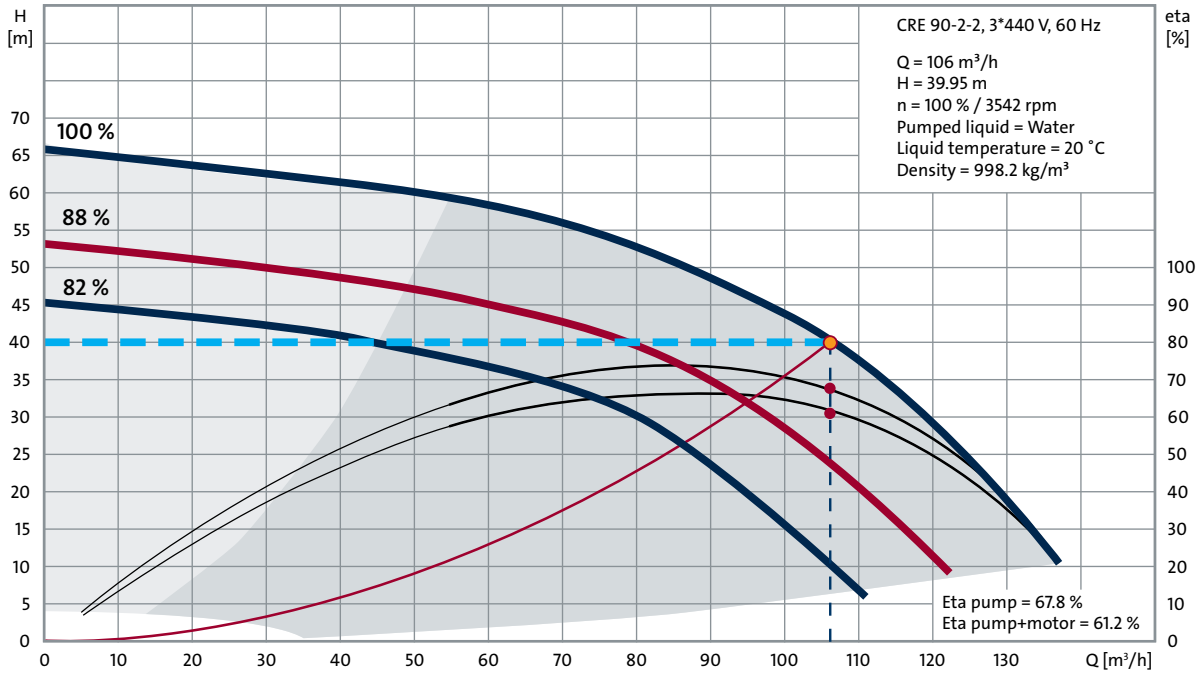
The MPC can start and stop pumps based on the speed of the pumps in the system. The speed of the pumps is controlled from a PI regulator that normally is based on the feedback from a pressure transmitter. If the feedback from the pressure transmitter drops below the set point, the controller will speed up the pump(s) running. When the pump in operation exceeds a set speed (cut-in speed, 98 % as standard), the second pump starts.



In an MPC-E system, the second pump (– green line) that starts will ramp up according to the ramp times set in the pump. When it reaches a certain speed, it will be controlled by the reverse MPC PI-controller. That means that the speed of the new pump and the speed of the pump that was already in operation (– red line) will over time be the same.

Running both pumps at equal speed allows for a better overall efficiency of the pump set, since the load will be distributed equally between the pumps.

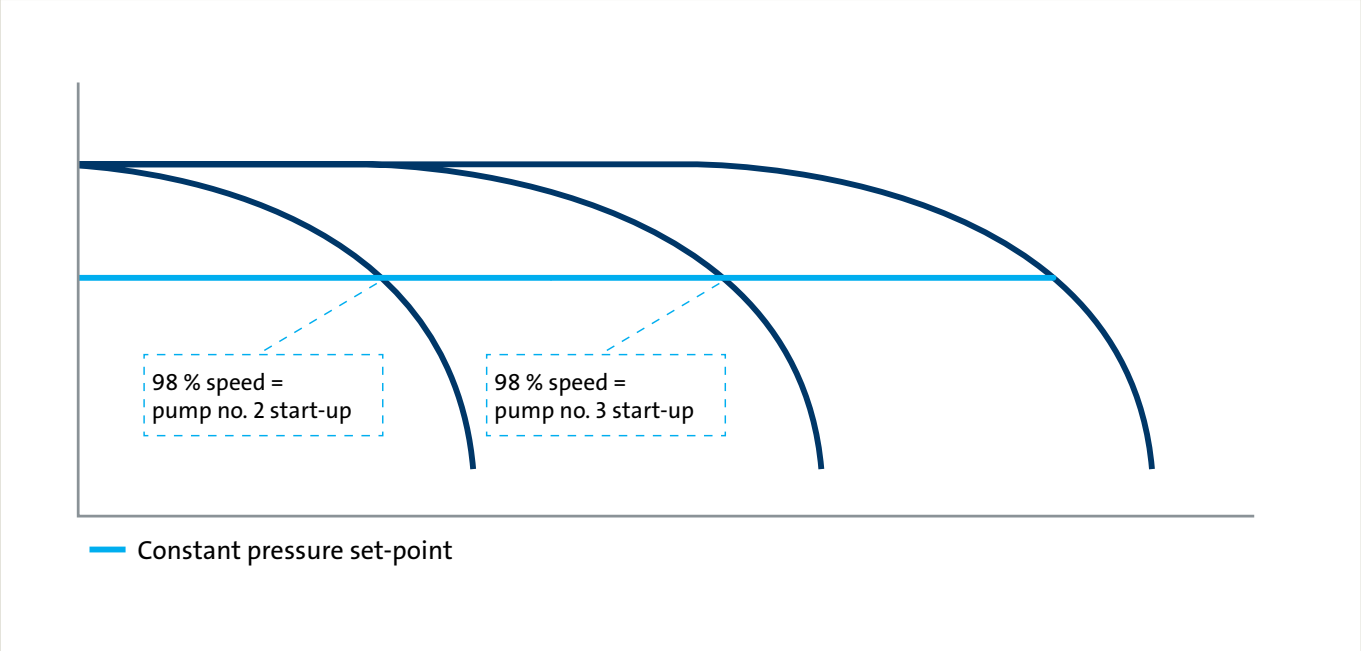
The graph below shows a case where savings are 10 % by running both pumps at the same speed.



Efficiency vs different speed, where: *Q = 150 m³ H=40 m*
Scenario 1 (– blue line): *1 pump @100 % + 1 pump @82 %*
Power consumption: *18.6 kW + 8.5 kW= 27.1 kW*
Scenario 2 (– red line): *1 pump @88 % + 1 pump @88 %*
Power consumption: *12.2 kW + 12.2 kW= 24.4 kW*

Starting the second pump in this way ensures that the pressure deviation is kept at an absolute minimum, thus delivering the smoothest operation possible and eliminating noise in the system due to pressure changes. This also helps in saving maintenance costs on pipe bursts, as a result of eliminating destructive pressure surges.

This control methodology for starting a new pump in the system is applicable for all pump start-ups in the pump set, because the equalisation of the speed of all active pumps is applied on all start-ups.



An example of pump start-up speed

CUT-OUT FUNCTIONALITY

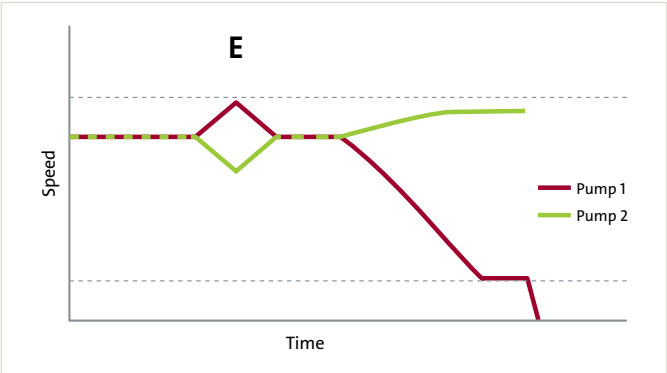
Grundfos MPC can optimise the number of pumps by repeating stop attempts instead of running the system at low speed for a fixed period of time, which is very inefficient, or completely stop a pump if the pump speed is below a predefined cut-out speed (default 40 %).

This means that when more than one pump is running, and the speed of the pumps running is below 85 %, the system will force one of the pumps running down in speed. To keep the pressure constant, the remaining pumps running will have to increase their speed. If the speed of the remaining pumps gets higher than the set cut-in speed, the stop attempt is called off. After a defined interval (default value 120 seconds), the system will make another stop attempt. If the speed of the remaining pumps does not exceed the set cut-in speed, and the speed of the pump that the system attempts to stop reaches the cut-out speed, the pump is stopped.

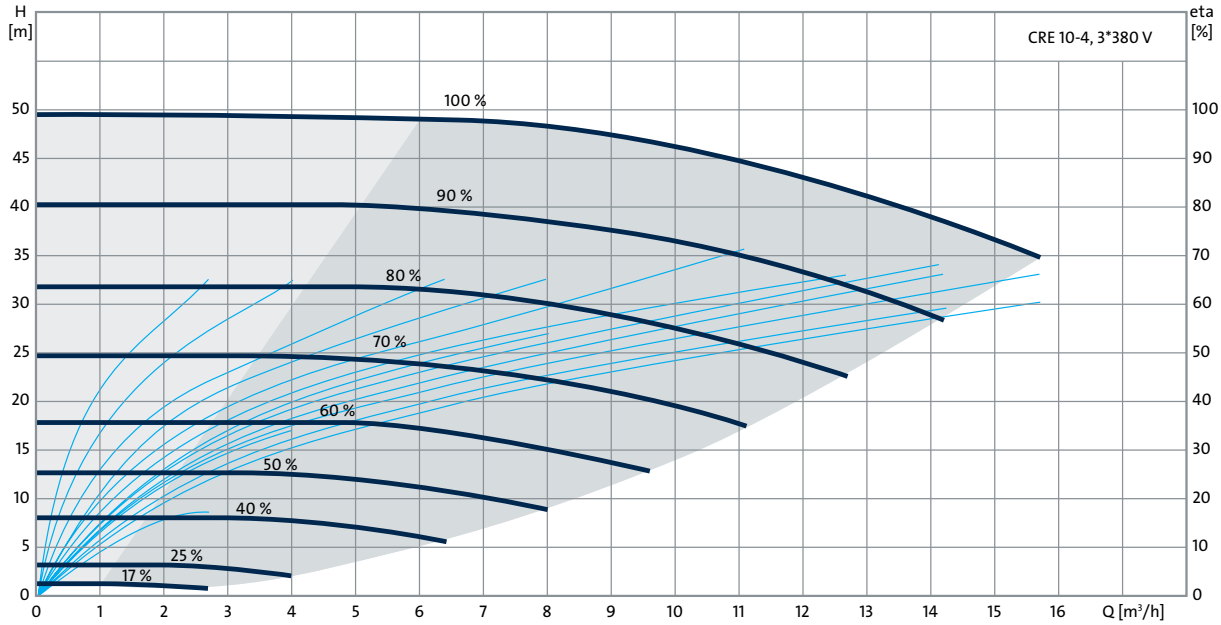
The time interval can also be 'self-learning'. This means that the time between the stop attempts will increase every time there is an unsuccessful stop attempt, to ensure even higher comfort compared to a fixed interval.

This operation ensures that only the optimal number of pumps is running and thereby contributes to lowering the energy consumption of the system.

The advanced cut-in/cut-out is just one part of the MPC sequence of operation and can be compared to your normal automatic gearbox. This is better than manual, but it can be taken to the next level.



ENERGY-BASED
CUT-IN/CUT-OUT SEQUENCES



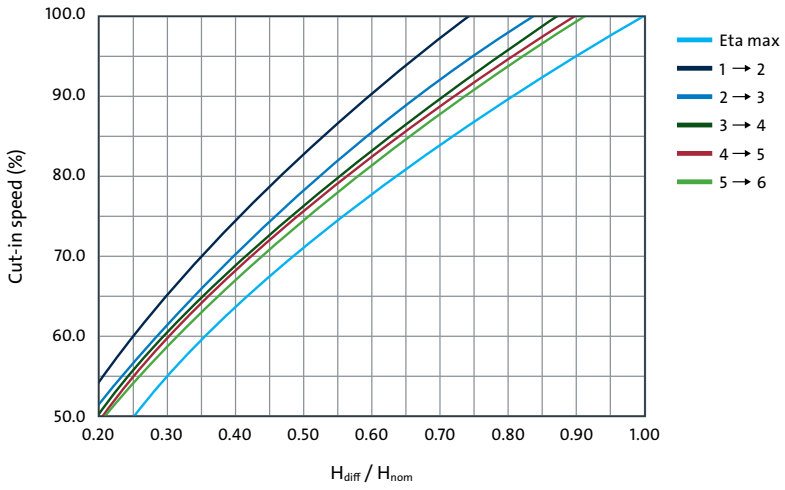
Pump efficiency curve for a CRE pump

As mentioned above, the MPC can take cut-in/cut-out pump operation to the next level. Instead of doing it as a purely speed dependent cut-in/cut-out routine, it can be done based on energy calculations using pump data.

From the factory, every Control MPC has Grundfos pump curves loaded into the controller, this along with motor speed and differential pressure is what allows the energy-based cut-in/cut-out.

Let us look at how this is done:

When comparing the exact speed of the motor, which is read in the motor via GENIbus, to the differential pressure, which is measured over the pump, the controller always knows where on the pump curve the pumps are operating and the efficiency at the given duty point.



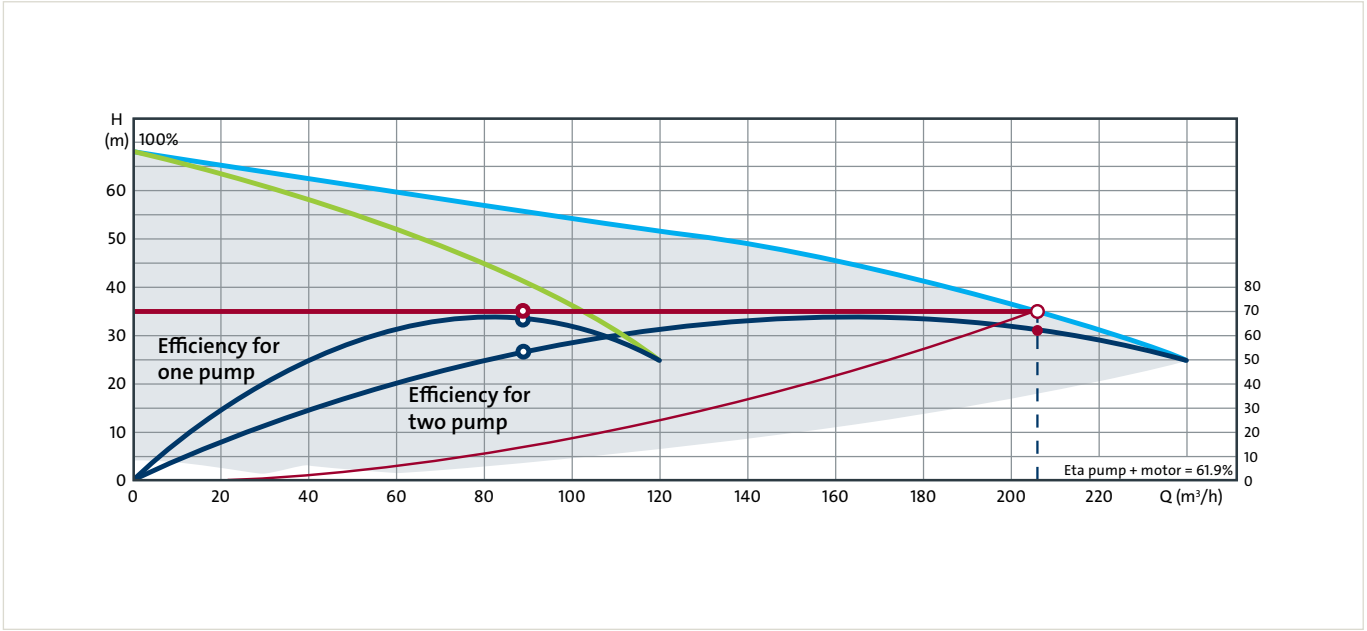
An example of a CR pump relation between duty point and optimal speed for pump cut-in

To determine the most energy-efficient cut-in point, the controller looks at the relation between H_{diff} and H_{nom}, and based on the pump curve it will calculate the speeds, where it is most efficient to cut-in the next pump. This speed will depend on number of pumps already in operation and the relation between H_{diff} and H_{nom}.

- H_{nom} is the pump's nominel pressure, known from the pump data and is static.
- H_{diff} is the differential pressure over the pump and will change depending on the system design and/or changes in inlet/outlet pressure. This has to be measured either by differential pressure at the pump or by having inlet and outlet pressure measured.

The example on page 8 of a CR pump curve shows that the most efficient cut-in speed depends on the duty point (H_{diff}/H_{nom}) and the number of pumps. If the pumps' duty point is below their H_{nom}, it is beneficial to use a cut-in speed lower than 100 %. As shown on the graph, the further away from H_{nom} the duty point gets, the lower the speed for cut-in of the next pump; and the closer the pump's duty point gets to the H_{nom}, the higher the cut-in speed.

The optimal cut-in speed will also change depending on the number of pumps in operation. This is to ensure that the change from, for example, one to two pumps does not use more energy than running with one pump. Since the change from one to two pumps will result in a flow change of 50 % on the running pump, and if that changeover is made too close to the energy-optimal running point for the pump, it would result in a higher power consumption with two pumps running compared to one pump running. Therefore, the changeover speed from one to two pumps has to be higher than the most energy-optimal point, but the change from five to six pumps can be made closer to the energy-optimal point, since the flow per pump does not change more than one-sixth (16 %).



This shows a two-pump system where the selected duty point can be covered by both one or two pumps, but there is over 10 % difference in efficient, in this case advantage for the one pump.

Cut-In: Every second, the controller calculates the required head based on the actual inlet pressure and setpoint, and this is set in relation to the pumps H_{nom}. Using the above calculations, the controller will calculate when to cut-in the next pump.

Cut-out: Is done following the same formula as cut-in, but since there will be one less pump in operation, the limit for when to cut-out a pump will have to be based on one less pump in operation.

The controller analyses the duty point and pump speed, and compares this to the energy-based pump start curve to decide when to cut-in and cut-out pumps. So, in other words, in cases where a given flow can be covered by both e.g. one or two pumps, the controller will analyse and select the most efficient number of pumps in operation based on the running pump(s) speed and the pressure.

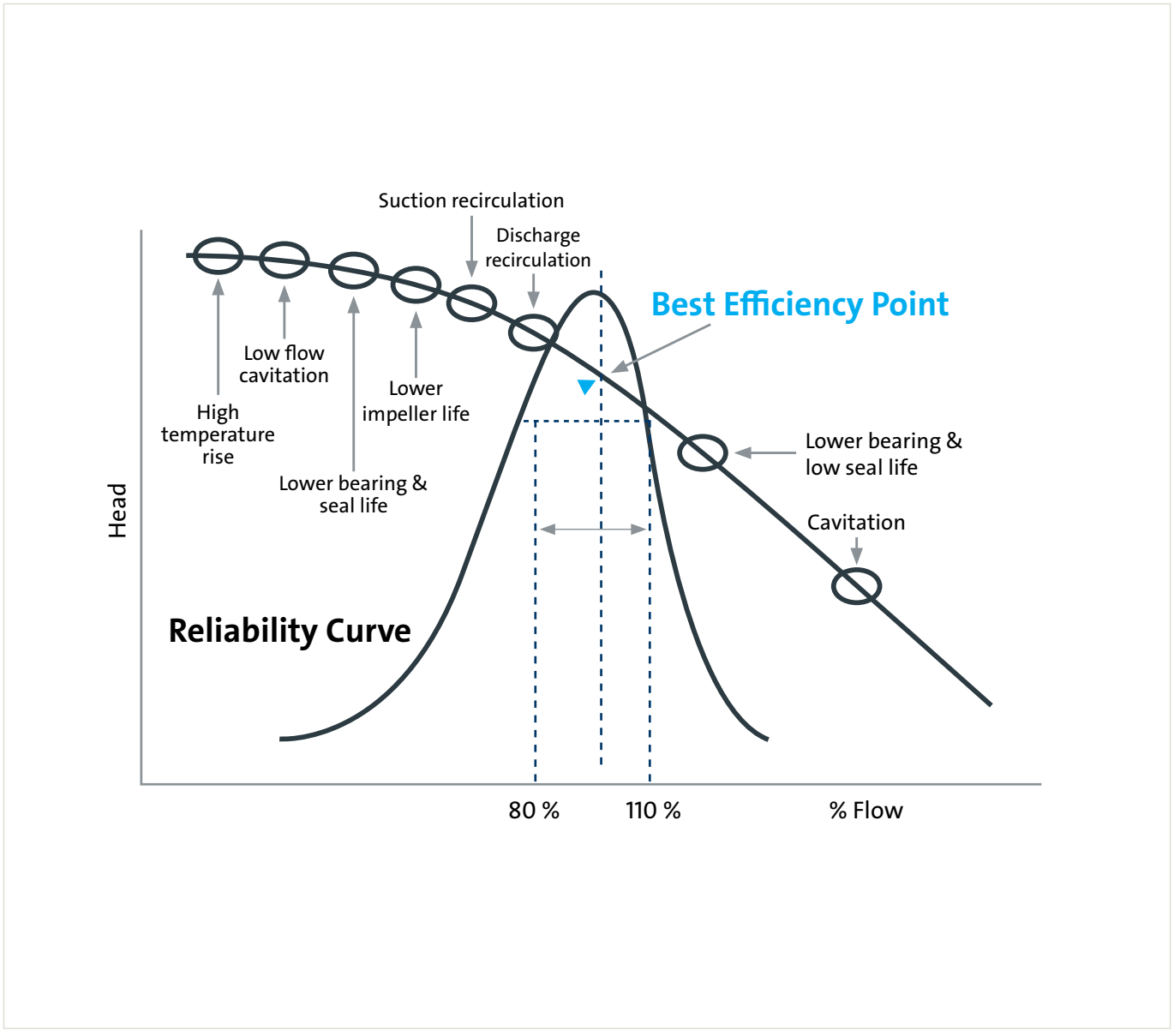
CONCLUSION – GRUNDFOS MPC IS CRUCIAL FOR PROPER PUMP CONTROL

The advanced cascade/staging of pumps offered by MPC is crucial to ensure proper pump control, which results in a more efficient system and better comfort. The technology behind is based on more than 60 years of studying pumps and constantly looking for ways to improve operation and efficiency. It is not only an incorrectly sized system that will benefit from the energy-based cut-in/cut-out; all systems will benefit from the advanced cascade function and from using an energy-based cut-in/cut-out.

Even commissioning will become a breeze, as it will no longer require time-consuming onsite programming and trial and error before, maybe, getting a decent result. With the MPC, this takes just minutes, and all guess work is removed, to ensure the best efficiency and comfort every time.

The first and most noticeable benefit will be a lower power consumption, but also better comfort is a benefit. This is due to the smoother operation, which leads to less noise in the system as well as reducing the stress on pipes.

The second and maybe even more important benefit is that by ensuring the pumps always operate within the optimal efficiency point, we also ensure that the pump does not move outside its designed work area. This would otherwise lower the lifetime of the pump, potentially causing cavitation which could destroy shaft seals and bearings.



An illustration of operation point vs reliability, and where to find the Best Efficiency Point (BEP)

ABOUT MULTI-PUMP CONTROL FROM GRUNDFOS

Grundfos multi-pump control solutions are a part of Grundfos iSOLUTIONS, which is our approach to adapt intelligent technology with precision to deliver optimal performance, total energy efficiency, and ultimate reliability in your system.

With dedicated communication modules and controls, you get trouble-free operation with application-specific features, energy optimisation and a wide selection of communication protocols. The dedicated functionality and start-up wizards make commissioning easy, ensuring you experience the full benefit of Grundfos iSOLUTIONS with fingertip control of your system on a computer, tablet or smartphone.

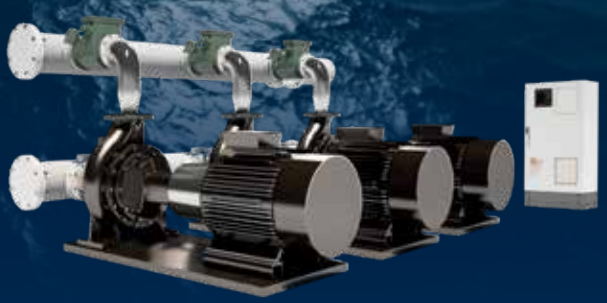
Grundfos supplies a premium range of multi-pump controllers that are designed to maximise efficiency. Grundfos Control MPC (multi-pump controller) is a control cabinet with a CU 352 controller that permits monitoring and control of up to six identical pumps connected in parallel.

HYDRO MPC BOOSTER

A complete plug-and-pump system, which is tested and ready to run with all the intelligence from CU 352 controller.

CONTROL MPC

A control panel with the CU 352 controller for custom-built solutions and variable-speed control, for all pump types.



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