AUTOMATIC LOGIC CONTROL FOR WELL WATER

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ABSTRACT

Many industries use ground water for their process. Ground water is the water present underground in the tiny spaces in rocks and soil. Underground areas where ground water accumulates in large amounts are called aquifers. Aquifers are layers of rock or soil that can store and supply enough water to wells and springs to be economically useful. Most ground water moves slowly, usually no more than a few feet a day. For that reason, the extraction rate is one of the more important things to take into account. If an industry has more than one well of water, an automatic control logic should be implemented on each well in order to obtain balanced extraction.

The objective of this work is to add a new well of water to the existing ones and improve the automatic control in order to perform a balanced extraction according to the services factor of each. The current configuration is based on three pumps which start and stop according to demand.

INTRODUCTION

In many industries the automatic control for ground water extraction is implemented using a discrete control (ON-OFF control). A typical application for well water supply to the process uses a single water extraction pump, a buffer tank for storing water, a level measurement in the buffer tank and a pressure measurement in the water supply line as shown in figure 1.

In this case the objective is to maintain the level within a certain range (PV = measured level). The final control element is the pump and the control signal is a discrete signal type whose possible states are two (Start and Stop). The configuration for the application of the control action is performed taking into account something called hysteresis to avoid continuous starts and stops of the pump when the level indication is near to the desired level. If the tank level drops below a minimum value the pump turns on. The pump stays on until the indication exceeds the maximum level. After reaching this value the pump shuts off and remains in the latter state until the level drops below the preset minimum value as shown in figure 2.

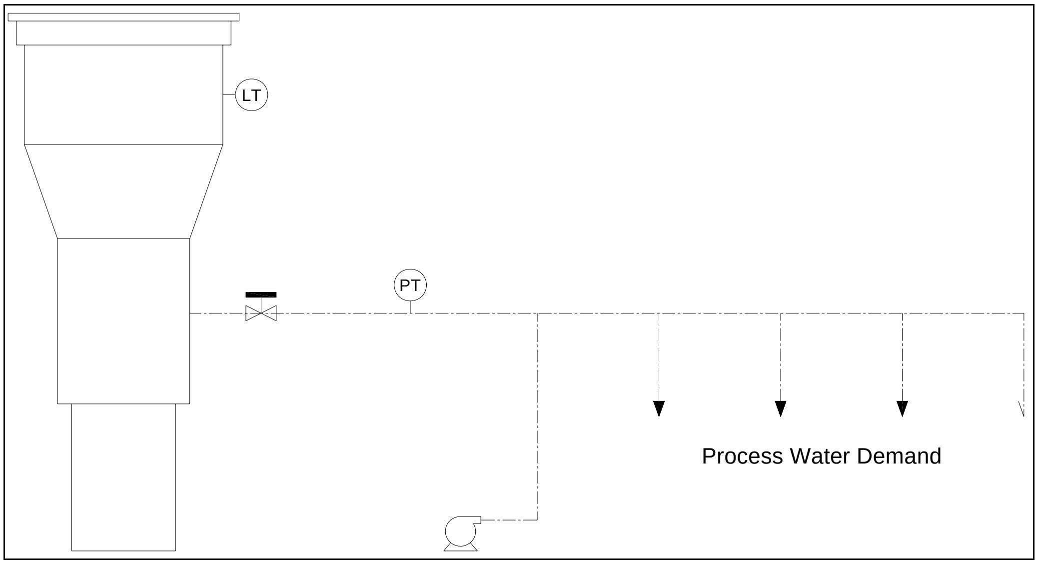

Figure 1 Simple level control

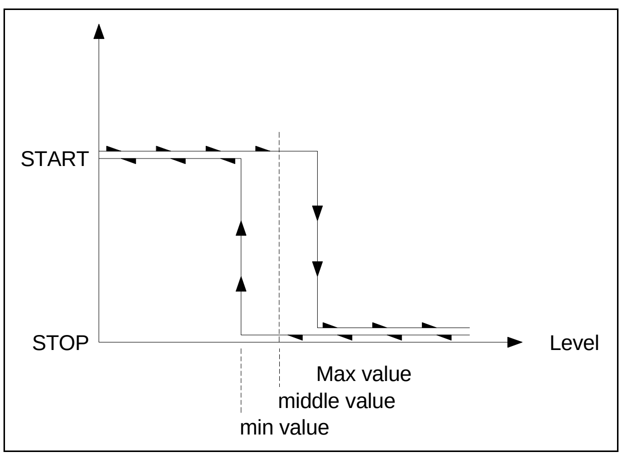

Figure 2 Hysteresis in simple level control

The PID controller provides a familiar and flexible interface for the operator. The use of on-off control eliminates the need for PID tuning that is particularly difficult for integrating processes with different cross sectional areas and variable extraction rates that complicate the computation of the window of allowable controller gains.[1] Since there is more than one extraction well water pump, a PID controller is used to implement a multiple pump control as shown in Figure 3 where the controller output, called implied valve position (IVP), is used for discrete control (On-Off control) to start or stop pumps. The number of pumps in the running state will be proportional to the intensity of the control action. The pressure fluctuations from pumps starting and stopping do not significantly upset downstream users because of the moderating effect of the large system volume.

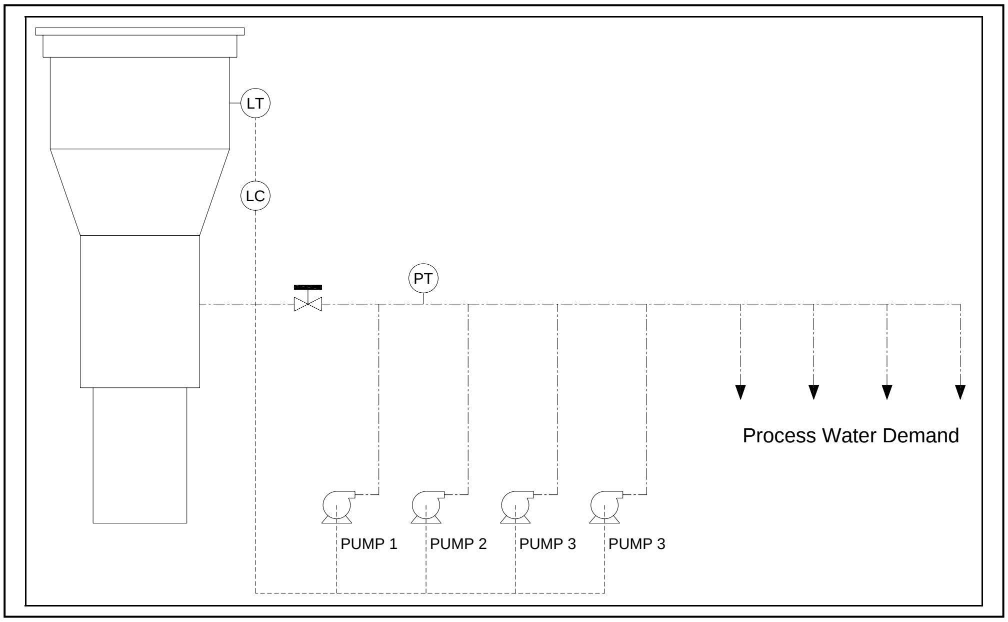

Figure 3 Level control of multiple pumps

Figure 4 is an example of how the described control system works for large changes in user demand. In this figure the buffer tank level passes through the five settings for control action that result in the level controller output (%IVP:1LC823-01) starting or stopping each of the 4 pumps. Table 1 gives an example of the impact of the hysteresis setting on the start and stop of pump 3.

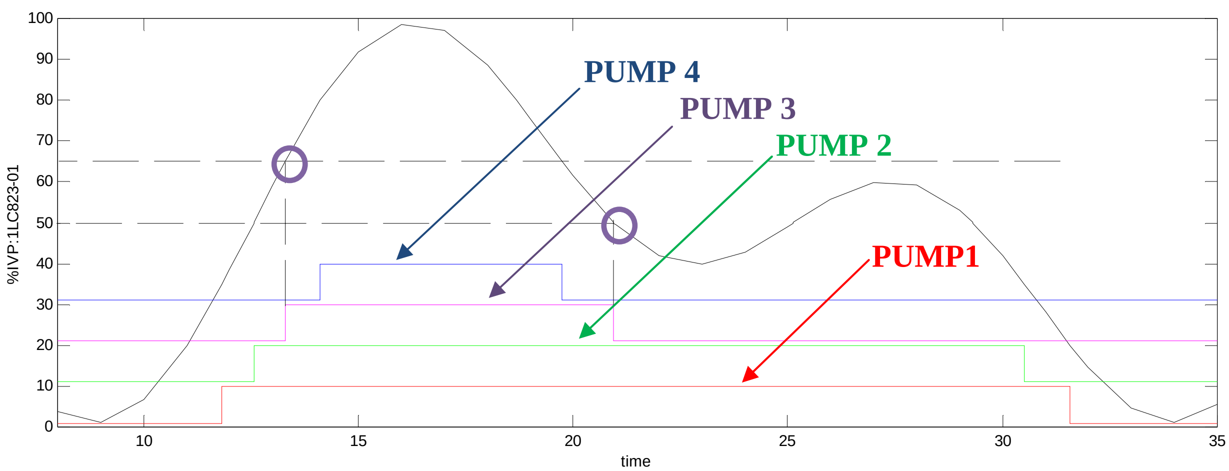

Figure 4 Hysteresis for level control with multiple pumps

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	%IVP START at [%]	STOP at [%]
PUMP 1	35	20
PUMP 2	50	35
PUMP 3	65	50
PUMP 4	80	65

Table 1

This is just an example that shows the impact of the hysteresis set to start or stop the pumps. The pump 3, for example:
_ is turned on if %IVP > 65 and
_ is turned off if %IVP < 50
As we see here, the hysteresis for each pump, represents 15% of the control action.

PROBLEM DEFINITION

In the particular case of our plant, we have three well water extraction pumps and a logic which turned on and turned off the pumps according to the control action computed by the level controller.

Recently, we added a fourth pump into the system (well water extraction system) and we found that we did not have a logic that generates a periodic rotation of pumps in order to ensure:

- First, a balanced extraction from each well water source for the system
- Second, a balanced electrical and mechanical wear for each pump

Furthermore, we found that not all wells water can provide the same flow rate. Either by environmental restrictions or by the constructive design is logical that not all well of water will provide the same flow rate. This made us think about the need, that the logic takes into account a variable related to the duty cycle of each pump.

In other words, a good control logic should not only ensure a rotation sequence of the pumps, but incorporate four new variables (the service factor of each pump) to balance out pump use.

PROJECT GOALS

This work aims to:

1. Implement a logic which ensures a periodic rotation of pumps in order to have a balanced extraction of water of each of well water subsystem and ensure at the same time a balanced wear, both electrical and mechanical, of each pump.
2. Incorporate four new variables. Those will be the service factor of each well water subsystem and calculate the hysteresis taking into account this value. In other words, the service factor

will be designed into the logic that calculates the values of start and stop of each pump. The contribution of each pump is affected by the appropriate service factor. The logic does not sacrifice well water from a source that cannot provide the same flow as other sources.

CONTROL STRATEGY

The control strategy consists of a linear control implemented using a level control loop (specifically using a PID). The control output (%IVP:1LC823-01) is compared against a set of discrete values. These depend on the service factor of each pump and the amount of available pumps. Based on this comparison each pump starts or stops as appropriate. This control strategy has been configured in a block of continuous runtime configuration called a Functional Sequence Table (FST). Figure 5 shows an example for service factors listed in Table 2. Figure 6 shows the flow chart logic used to develop the algorithm in the FST.

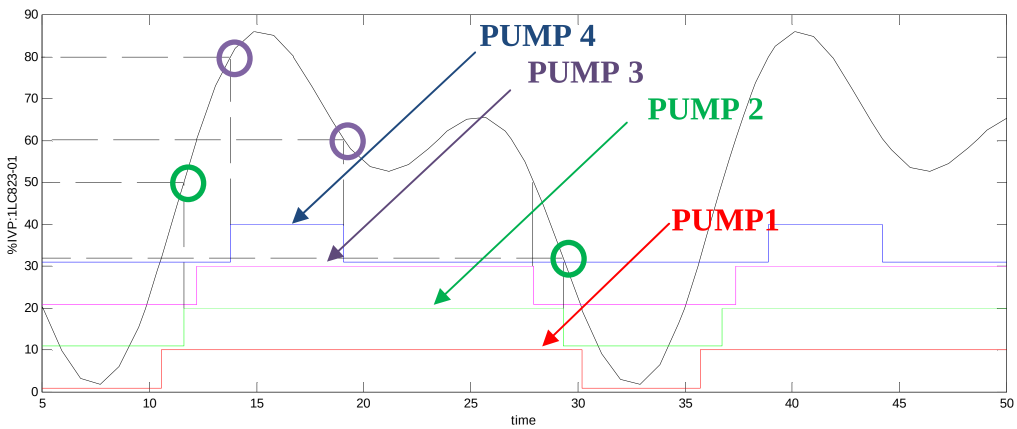

Figure 5 Hysteresis for level control with multiple pumps and different services factors

	%IVP	
	START at [%]	**STOP at [%]**
PUMP 1	32	20
PUMP 2	50	32
PUMP 3	60.5	50
PUMP 4	80	60.5

Table 2

Figure 5 shows an example in which has been assigned different service factors for each pump SF_PUMP1 = 0.8; SF_PUMP2 = 1.2; SF_PUMP3 = 0.7; SF_PUMP4 = 1.3; as a result, the hysteresis for each pump has been different.

Pump 2
_Start if %IVP > 50 y
_Stop if %IVP < 32

Pump 4
_ Start if %IVP > 80 y
_ Stop if %IVP < 60.5

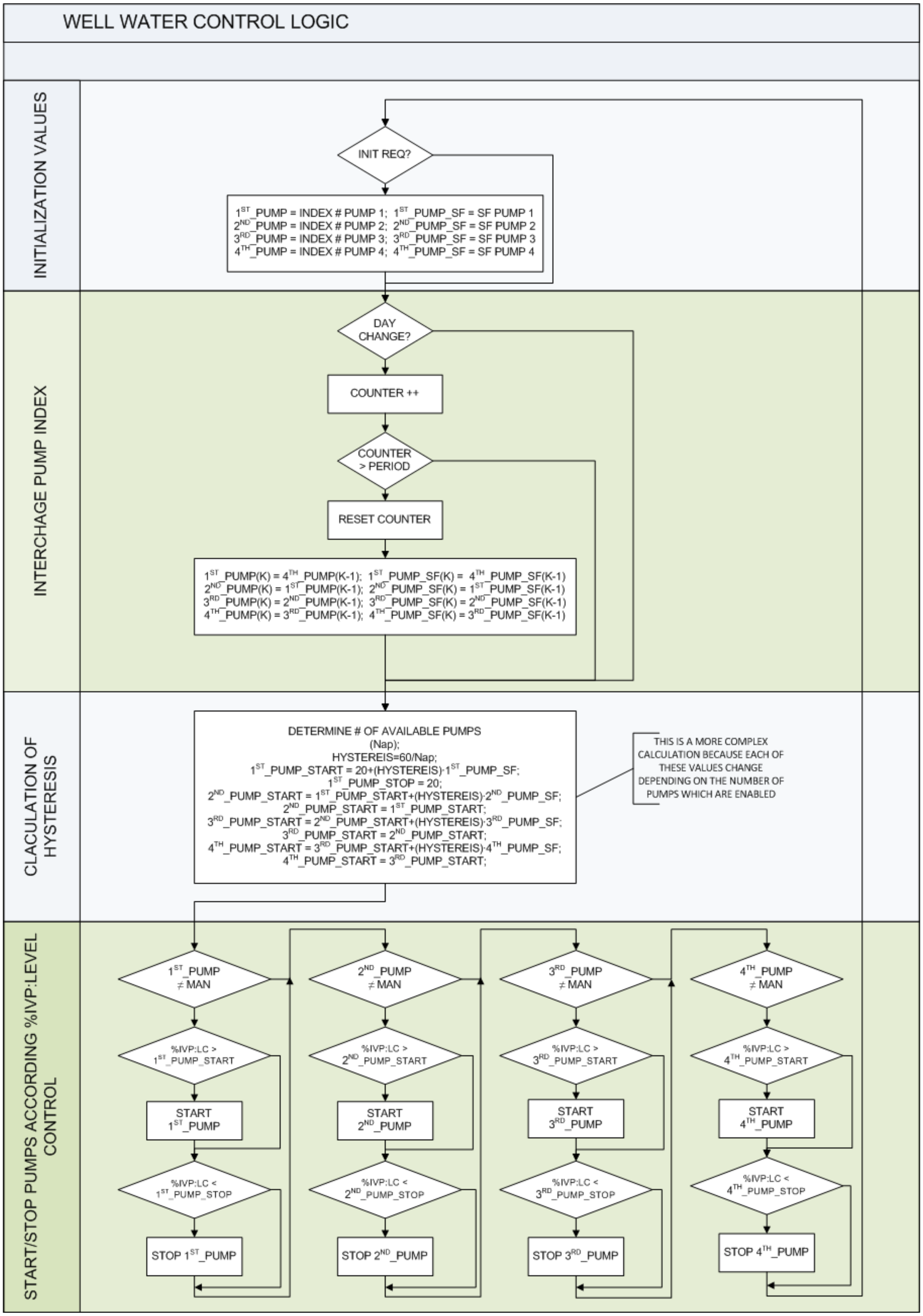

Figure 6 Well water control logic

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There are few variables to enter into the algorithm:

PERIOD = Period of time in days in which each pump contributes to the same level of demand for the control action.
SF_PUMP1 = Service factor of the pump 1
SF_PUMP2 = Service factor of the pump 2
SF_PUMP3 = Service factor of the pump 3
SF_PUMP4 = Service factor of the pump 4

RESULTS

This strategy allowed us to have reliable control by keeping the level always in bounds, reducing interruptions for pump maintenance and eliminating the inconsistencies from human intervention. The logic allowed us to make a rational exploitation of the wells with a balanced system.

CONCLUSION

Even though control using frequency inverters could be tighter by a continuous adjustment of pump speed, the simple but innovative control system keeps the process variable (level) within bounds for a much lower implementation cost and reduces maintenance costs by eliminating inverter support and reducing pump wear. This control configuration could be extended to other applications such as fan control in cooling towers.

REFERENCES

1. Greg McMillan, *GOOD TUNING: A Pocket Guide 2nd Edition*, ISA, 2005.