Proportional Motorized Valve Control Without Real Position Feedback

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***Abstract* – In this paper a physical model and implementation device to control of proportional motorized valve is considered. Driving circuit consist of two digital outputs for opening and closing. The control circuitry is performed with PID loop and without the real valve position feedback.**

***Keywords* – PID Control, Programmable Logic Controller.**

I. Introduction to PID control

The PID controller is the most common form of feedback. It was an essential element of early governors and it became the standard tool when process control emerged in the 1940s. In process control today, more than 95% of the control loops are of PID type, most loops are actually PI control. PID controllers are today found in all areas where control is used. The controllers come in many different forms. There are standalone systems in boxes for one or a few loops, which are manufactured by the hundred thousands yearly. PID control is an important ingredient of a distributed control system. The controllers are also embedded in many special purpose control systems. PID control is often combined with logic [1] [2], sequential functions, selectors, and simple function blocks to build the complicated automation systems used for energy production, transportation, and manufacturing. Many sophisticated control strategies, such as model predictive control, are also organized hierarchically. PID control is used at the lowest level; the multivariable controller gives the set points to the controllers at the lower level. The PID controller is an important component in every control engineer's tool box.

PID controllers have survived many changes in technology, from mechanics and pneumatics to microcontrollers and programmable logic controllers. The programmable logic controller has had a dramatic influence on the PID controller. This has given opportunities to provide additional features like automatic tuning [3], gain scheduling, and continuous adaptation.

We will start by summarizing the key features of the PID controller. The "textbook" version of the PID algorithm is described by the next expression:

$$u(t) = K\left(e(t) + \frac{1}{T_i}\int_0^t e(\tau)\,d\tau + T_d\frac{de(t)}{dt}\right) \quad (1.1)$$

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Where u is the control signal and e is the control error.

The reference variable is often called the set point. The control signal is thus a sum of three terms: the P-term which is proportional to the error e, the I-term which is proportional to the integral of the error e, and the D-term which is proportional to the derivative of the error e. The controller parameters are proportional gain K, integral time Ti, and derivative time Td. The integral, proportional and derivative part can be interpreted as control actions based on the past, the present and the future. The derivative part can also be interpreted as prediction by linear extrapolation.

In the case of proportional control where integral and derivative parts are equal to zero, a steady state error appeared. The error will decrease with increasing gain, but the tendency towards oscillation will also increase. The steady state error disappears when integral action is used and the strength of integral action increases with decreasing integral time T_i.

The parameters K and T_i are chosen so that the closed loop system is oscillatory. Damping increases with increasing derivative time, but decreases again when derivative time becomes too large. Recall that derivative action can be interpreted as providing prediction by linear extrapolation over the time T_d. Using this interpretation it is easy to understand that derivative action does not help if the prediction time Td is too large. Also notice that the period of oscillation increases when derivative time is increased.

To obtain a good PID controller it is also necessary to consider

- Noise filtering
- Set point weighting
- Windup
- Tuning
- Computer implementation

In the case of the PID controller these issues emerged organically as the technology developed but they are actually important in the implementation of all controllers. Many of these questions are closely related to fundamental properties of feedback.

The control system presented in this paper is based on implementation of PID control with programmable logic controller for governing of motorized valve but without feedback of real valve position.

The paper is organized in XX section. Section II describe the controlled system. Control circuitry is depicted in section III. Next two section consider the control algorithm and hardware implementation of the control system.

II. CONTROLLED SYSTEM DESCRIPTION

At the following picture the controlled system configuration is depicted.

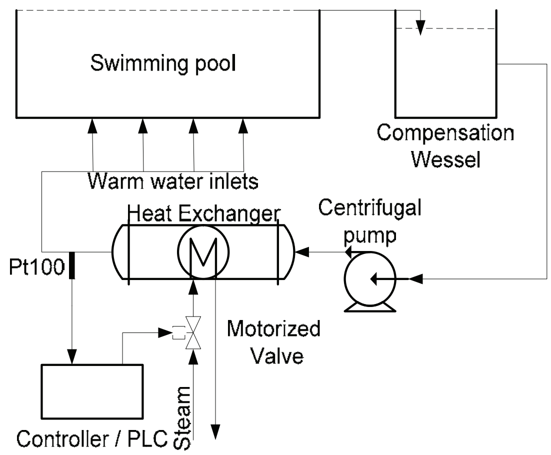

Fig. 1. Controlled system configuration

The control object is the temperature of the water in the swimming pool.

The water temperature has to be controlled around 29 Celsius degrees, with tolerance of 1 degree. This means that the minimum temperature is 28 degrees and maximum temperature should not exceed 30 degrees. The volume of the swimming pool is $60m^3$.

Compensation Wessel is intended to collect the amount of water which exceeds the pool volume. Therefore the filling of swimming pool is performed through this Wessel. Water temperature inside is around the temperature of the pool.

Water is transported from the compensation Wessel by the centrifugal pump through heat exchanger and returned back in the swimming pool through inlets located at the bottom floor. Filtration system is not showed doe to its unimportance for our investigation. The pump flow capacity is dimensioned according to pool volume, to exchange complete volume for period of one hour.

To control of water heating a motorized valve is applied to the system. As mentioned at the title this motorized valve is not equipped with position sensor, and control system has no information of its real position. Feedback is performed by the Pt 100 based transducer.

Control system is based on the programmable logic controller to improve process control flexibility.

III. CONTROL SYSTEM CONFIGURATION

Programmable logic controller equipped with the PID loop control hardware, combined with the logic function are suitable device for building efficient and flexible control hardware.

The principal schematic diagram of control system based on programmable logic controller is presented on Fig. 2.

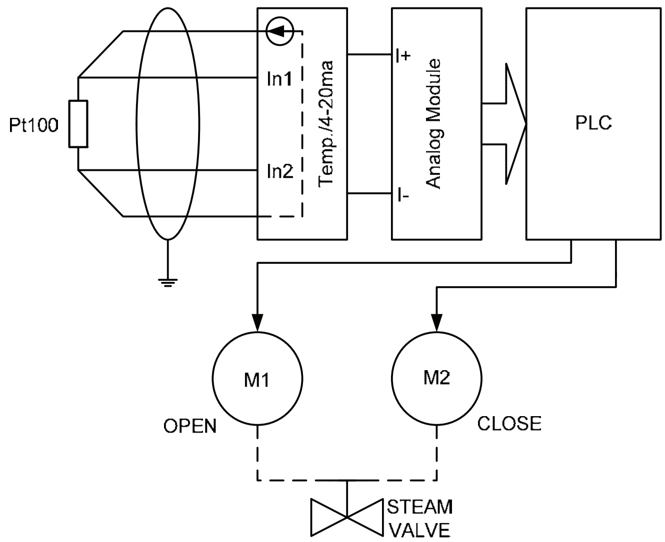

Fig. 2. Control circuitry

Measured temperature by the Pt 100 transducer is converted to analog current standard signal 4-20mA, which allows signal transmission to longer distance. Analog signal is converted in analog module in 12 bit word and sent to controller. Programmable logic controller govern the valve by the two single phase synchronous motor, one for opening and one for valve closing.

It is obvious in fig. 2 that there is not a position feedback between the motorized valve and PLC.

IV. CONTROL ALGORITHM

Programmable logic controller applied here can handle up to 14 PID loops, but in this case only one is required. Standard PID loop utilize three variables:

- PV – Process value
- SP – Set Point
- CV – Control value, the PID output

Because no position feedback between controlled motorized valve and controller, additional variable is involved so-called VVP – Virtual valve position. This variable is purposed to keep the estimation of valve position which is calculated during each valve movement. VVP variable increase there value in the case of valve opening and decrease otherwise. In the inaction case the value is not changed. The amount of VVP changes depend of the control pulse width generated by the PLC to opening/closing valve.

Next figure present the block diagram of implemented control algorithm.

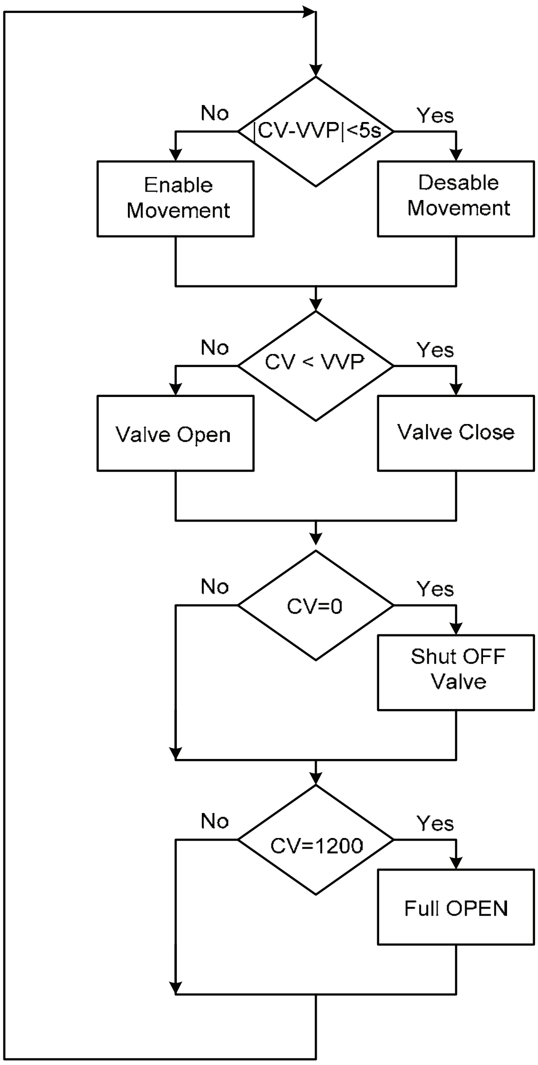

Fig. 3. Control algorithm block diagram

The elapsed time from closed to full open valve is 120 seconds. Sampling period is chosen to be 100 ms. which lead to boundary of the control value in the interval of $[0,1200]$.

VVP, virtual valve position is set to zero during PLC initialization procedure keeping the valve completely closed for the time interval a few seconds longer then interval sufficient to shut off the valve from full opened position.

To avoid oscillation around the control value point, a small hysteresis is involved, which disable movement shorter than 5 seconds.

Control value, CV, is calculated by the PID function loop defined in the PLC structure according to process value, PV and set point, SP, as input parameters, and PID loop parameters, Kp, proportional action constant, Ti, integral time and Td, differential time, defined during PLC programming phase. Programmable logic controller offers a very suitable manner of PID loop parameters adjustments, showed at the next figure:

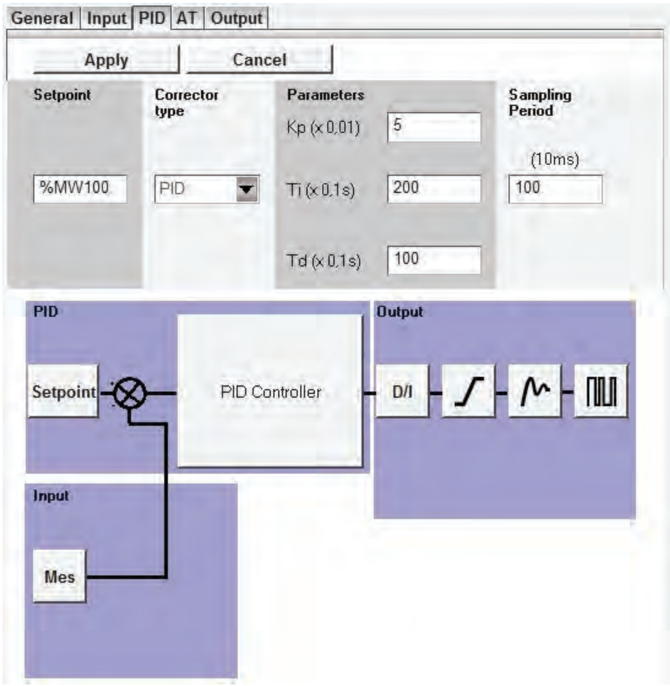

Fig. 4. PID loop configuration windows

The movement action as the output commands are defined in the ladder diagram. Control value obtained as the output result of the PID loop is compared with the VVP, virtual valve position, whish represents the estimation of real valve position. During valve movement, opening or closing VVP is increased, or decreased by 1 every 0.1 seconds. In the initialization phase or in the case of CV=0 the valve is completely closed and VVP set to zero. In the case of CV=1200, which means fool open valve, the valve will be completely opened and VVP is set to 1200.

V. Hardware implementation

Implementation hardware for realization of the control system described above consists of one PLC; model TWIDO TWDLMDA20DRT, one analog module with 12 bit resolution TM2AMI2HT and signal converter Pt100 to 4-20mA. All modules are produces by Schneider Electric, Telemecanique.

TWIDO PLC is equipped wit 20 inputs/output, which are 12 digital inputs and 8 digital outputs, 6 relay outputs and 2 transistors fast outputs. To realize PID function of analog signals an analog module is connected. Analog module consists of two analog inputs configured as 4-20mA range current inputs. Analog signal corresponding to temperature is obtained by the Pt100 transducer and resistance value is converted to current by another converter.

The valve power supply is 230V alternating current and the governing is realized by the first two PLC’s digital relay outputs. Valve is controlled by the two synchronous low power electric motors and high ratio gearbox.

Control module is presented at the fig.5.

Fig.5. Temperature control module

To control of opening and closing valve a two relay outputs are used. PWM, pulse width modulated control applied is not with the constant period. This period depend on difference between control value, CV, and virtual valve position, VVP, defined in the algorithm below.

VI. CONCLUSION

In this paper an algorithm and implementation hardware for temperature control of the swimming pool is presented. The absence of physical feedback of motorized valve position to control system is overrun introducing additional variable VVP – virtual valve position which is estimation of real valve position and is updated during every valve movement.

Applying the programmable logic controller in the control system hardware contribute to its additional flexibility.

PLC controller TWIDO is equipped with the possibilities for auto tuning of PID loop parameters which application is expected in the future implementations.

REFERENCES

[1] Dinko Vukadinović, Mateo Bašić, "Temperature Control in a Closed Space Environment by using a PLC", INFOTEH-JAHORINA Vol. 8, Ref. A-4, p. 15-19, March 2009

[2] Mohammad A.K.Alia, "Using PLC for Custom-design of a PID/PWM Program to Control a Heater Temperature", American Journal of Applied Sciences 4 (5): 307-316, 2007.

[3] Twido Suite V2.0, Programming software, 09/2007.

[4] Twido programmable controllers, Software Reference Guide, TWD USE 10AE eng Version 3.2, 2006.