A SELF - TUNING OF THE PID CONTROL LOOPS BASED ON THE ZIEGLER NICHOLS FREQUENCY RESPONSE METHOD

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The Ziegler Nichols frequency response method is widely used for optimal tuning of the PID control systems. There are some difficulties in the method application in the industrial plants. Looking for the limit of stability, there is a danger to make the control system unstable, which may result an industrial accident. To find a limit of stability of the industrial control systems is a serious time consuming task. Using an automated tuning solves particularly these disadvantages, but it requires a highly qualified specialist to lead the process. In order to facilitate the using and to improve the safety, a Process Oriented Language program unit is developed for self – tuning of the PID control loops for Distributed Control Systems.

Keywords: Self - Tuning of the Control Systems, Process Control.

1. INTRODUCTION

The most well known and widely referenced tuning method is developed by Ziegler and Nichols [1], called frequency response method. The authors have had a major influence on the practice of PID control optimal tuning for more than half a century. The method is simple, easy to realize and it gives closed loop systems PID coefficients with relatively good attenuation and quality of control. The Ziegler Nichols tuning method can be used in the automatic regime, during the normal working of the technological installation, used also in [2].

There are some difficulties in application of the Ziegler Nichols tuning method, from the practical point of view. The method requires to increase the gain of the proportional controller and to bring the control system to the limit of stability - sustained periodic oscillation of the Process Value (PV). Looking for the limit of stability, there is a danger to make the control system unstable, which may result an industrial accident.

The application of the Ziegler Nichols frequency response method in the industrial plants is a serious time consuming task, because the period of the PV oscillations can be 10 or even 20 minutes. To estimate, if the amplitude of the oscillation is decreasing, at least two or even three periods should be measured.

The automated Ziegler Nichols tuning method [3] increases the safety, save a lot of time and helps to the users to obtain good results. The industrial applications of the automated Ziegler Nichols tuning method shows, that highly qualified specialist should lead the whole process of measurement and make decisions. Even a highly qualified person can make a mistake.

The aim of this study is to develop a self - tuning method and software, on the base of the automated Ziegler Nichols frequency tuning method.

2. DESCRIPTION OF THE METHOD

The Ziegler – Nichols tuning method requires to turn the PID controller Proportional (P), by setting the integral and differential coefficients to zero. Defining the value of the gain, some disturbance should be made and the transition process of the control system should be investigated. On this base, the stability of the control system should be established. Increasing the gain of the proportional controller, the control system should be brought to the limit of stability - the periodic oscillation of the Process Value (PV) becomes sustained. This value of the gain Kpcr is called critical or also ultimate gain, and the period of the PV oscillations Tcr is called critical or ultimate period. Ziegler and Nichols suggest calculating the optimal coefficients Kp, Ti, and Td of the PID controller:

$$Kp = 0{,}588 * Kpcr, \quad Ti = 0{,}5\ Tcr / Kp, \quad Td = 0{,}125 * Tcr * Kp \qquad (1),$$

Another advantage of the Ziegler – Nichols tuning method is that can be used in the automatic regime, during the normal operation of the technological installation. In this case, the amplitude of the PV oscillation must be kept in the technologically permitted limits.

Using the Ziegler Nichols formula (1), the transition process of the closed loop is too oscillatory. Some times, the amplitude of the oscillation is limited by the technological process and it seems like the limit of stability. That is why, it is better to use an ultimate gain, when the system is stable, near to the limit of stability, with damping less then 5 %.

3. DESCRIPTION OF THE PROGRAM UNIT

To solve the difficulties discussed in the introduction, a program unit for self optimal tuning of PID control loops was developed, using the advantages of the Process Oriented Language (POL), included in all Distributed Control Systems (DSC). The POL programs have access to all technological parameters and work in real time. Up to four emergency program sequences with different priority can be activated under defined conditions. The program unit is developed, debugged and tested on the Process Control Training System (PCTS) [4].

There are tree limits of the oscillation amplitudes. The values of Low and High Alarms (Lo / Hi Al) are given by the technologically permitted limits of the PV oscillation for safety operation of the industrial plants. The values of Low and High Technological Limits (Lo / Hi Tech Lim) are defined by the technologically acceptable PV oscillation during the production. For the precise measurement, the amplitude of the oscillations should be at least three times higher then the level of the noise, which defines the Minimal Amplitude (Min Ampl), discussed also in [5].

The start values of the gain and of the Set Point (SP) should be defined.

The experimental estimation of stability requires causing oscillations by disturbance in the control loop. The authors recommend [3] changing manually the set point to the High Alarm value and waiting until the PV increases the half value and then to turn back the SP. In this study, the programme automatically increases the set point to the Hi Tech Lim and waits the PV to reach a value of half of HI Tech Lim. Then the programme turn back the SP to the start value again. This procedure is called in the beginning of the program and also when the amplitude becomes lower then Min Ampl.

The program measures the PV every second and looks for maximum and minimum of the PV oscillations. Using a timer variable, the program measures the time between two adjacent maximums – period of oscillations. The amplitude of the oscillations is calculated as a difference between the PV values of the maximum and minimum and is displayed. The difference between two adjacent amplitudes defines the damping of the oscillations.

$$Dump = (Max_{i+1} - Min_{i+1} - Max_i + Min_i) / 2 \quad (2)$$

The relation between two adjacent amplitudes defines the value:

$$D\ rel = (Max_i - Min_i) / (Max_{i+1} - Min_{i+1}) \quad (3)$$

The idea of the Ziegler and Nichols frequency response method is, that multiplying the gain Kp by D rel, the closed control system will reach the limit of stability. In every iteration the gain Kp is multiplied by measured and calculated D rel. For safety, the calculated value of D rel is limited to 3. The experiments show that this is the fastest way of reaching the limit of stability.

Every period, the measured amplitude, period and dumping of the oscillation are displayed on the unit window. Using the possibilities of the PCTS [4], the transition process of the control system can be observed on the analog trends, group displays and alarm groups.

The damping can be positive, near to zero or negative.

When the damping is positive, the amplitude of oscillations decrease, control system is stable (Fig. 1, curve 1.) and D rel is greater then 1. The gain is multiply by D rel and the gain is increased in the next iteration.

When the damping is near to zero, the control system is near to the limit of stability (Fig. 1, curve 2.) and D rel is near to one. The iteration procedure finishes when the value of D rel is in the chosen range. We recommend from 1,02 to 1,04. The optimal PID coefficients can be calculated using the last value of the gain (called critical or ultimate gain) and the period of the PV oscillations (called critical or ultimate period) by the equations (1).

When the damping is negative, the amplitude of the oscillations is increasing and control system is unstable (Fig. 1, curve 3.). The value of D rel < 1 and the gain Kp is decreased in the next iteration.

The program unit scans the PV every second and keeps the PV oscillation under control, which is very important for the safety of the method application. If the unstable control system causes the amplitude of the oscillations to become greater then Low or High Technological Limits, an additional emergency program sequence with "Shut Down" priority is automatically activated. This program decreases twice the increment of the gain Kp from the last iteration (soft intervention).

If the soft intervention does not help enough and amplitude of the oscillations becomes greater then Low or High Alarm limits, an additional emergency program sequence with "Emergency Shut Down" priority is automatically activated. This program decreases the gain twice, every time when high or low alarms appear and brings back the control system in the field of stability (strong intervention).

The number of iterations depends on the start value of the gain Kp.

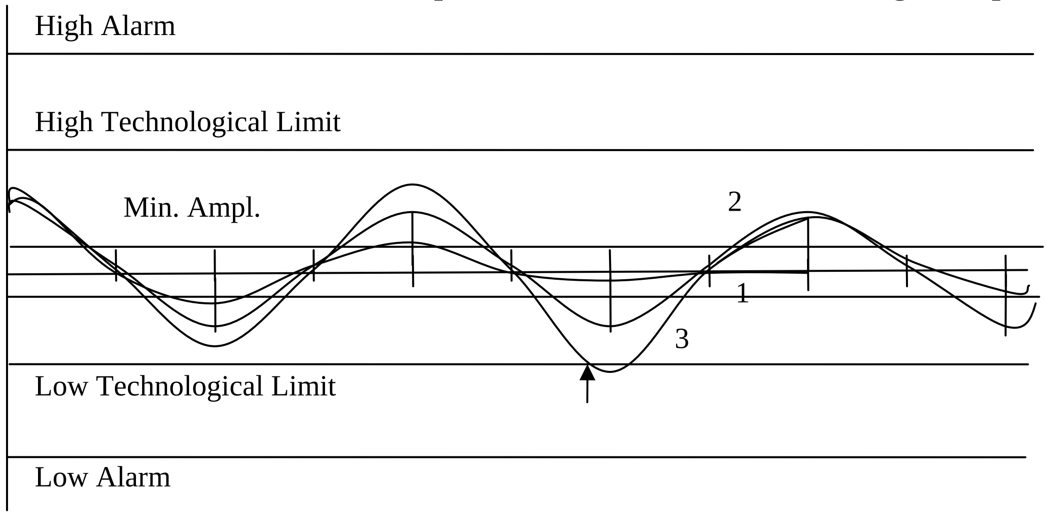

Fig. 1. Transition processes of the control systems: 1. Stable, 2. On the limit of stability, 3. Unstable.

4. CONCLUSION

A self - tuning method and software, on the base of the automated Ziegler Nichols frequency response tuning method are developed. A new approach increases the safety of the method application. Using the relation between two adjacent amplitudes D rel., decreases the number of iterations ant time. The self - tuning method helps to the users to obtain good results, using ordinary software without a need of a highly qualified specialist.

5. REFERENCES:

[1] J. G. Ziegler, N. B. Nichols, *Optimum Setting for Automatic Controllers,* Trans. ASME, 64, 1942, p. 759 – 768.

[2] E. I. Stoyanov, S. R. Stoyanov, P. I. Iakimov, A. N. Iovev, *The Development of the Quality of Control, using Cascade Control System in Boilers for Local Central Heating,* IX – th International scientific and applied science conference "ELECRTONICS 2000", Sozopol, Bulgaria, September 2000.

[3] E. I. Stoyanov, A. N. Iovev, *An Automated Tuning of the PID PID Control Loops, based on the Ziegler Nichols Frequency Response Method, Using POL Program Sequences for MIK 4000 C,* XIV – th International Scientific and Applied Science Conference "ELECRTONICS 2005", Sozopol, Bulgaria, September 2005.

[4] E. I. Stoyanov, A. N. Iovev, *Process Control Training System, Based on the MIK 4000 C,* XIV – th International Scientific and Applied Science Conference "ELECRTONICS 2005", Sozopol, Bulgaria, September 2005.

[5] N. Nedelchev, E. Stoyanov, *Manual of the Laboratory Classes of Automation,* University "Asen Zlatarov", Burgas, Bulgaria, 2002, p. 196 – 200, (in Bulgarian).