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Abstract

This paper describes a simple tuner for a PID algorithm. The tuner i based on a simple method for determining the critical gain and the ultimate period. The controller settings are then determined by simple rules of the Ziegler-Nichols type. The self-tuner is much simpler than algorithms proposed before.

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1. INTRODUCTION

Most control problems in industry are currently solved by simple control algorithms of the PID type. These regulators are manufactured in large quantities as standard products. When digital computers are introduced into control systems it is common practice to organize the systems so that they look like PID regulators to the user. There are well established procedures to commission and to tune standard regulators. There are also large numbers of engineers who are well educated in using, tuning and troubleshooting standard regulators. In spite of this many regulators are not well tuned. The reason for this is that the regulators should be retuned when operating conditions change. Since a large process may have hundreds of regulators it is not feasible to retune so many regulators frequently. It would thus be useful to have devices which can tune simple regulators automatically. Since there are so many persons who are familiar with the standard regulators and their tuning rules it is useful if the tuner is based on the well known ideas. One commercial device of this type is the "supertuner". See Anon (1976). The supertuner is a special hardware device which is connected to the process. When the regulators are based on microprocessors it is however possible to provide all loops with a tuner provided that the tuner can be made sufficiently simple. Such a device is described in this report. The proposed self-tuner is substantially simpler than the PID tuner described in Wittenmark et.al. (1980).

The report is organized as follows. The well known tuning rules are described in Section 2. The tuning is based upon knowledge of the critical gain and the ultimate period. The critical gain is the gain of a proportional controller which brings the closed loop system to the stability limit. The ultimate period is the period of the corresponding oscillation. A technique to obtain these parameters automatically is discussed in Section 3. In Section 4 it is described how a regulator with an automatic tuning facility can be constructed based on the ideas of Section 2 and Section 3. Some practical problems which require further attention are discussed in Section 5.

2. THE TUNING RULES

Two methods of tuning simple regulators have been proposed by Ziegler and Nichols (1943). One method is based on the determination of the open loop step response. The other method is based on an experimental determination of the quantities called the <u>critical gain</u> and the <u>ultimate period</u>. The supertuner is based on determination of the step response. This method is empirically known to give poorer results than the method based on the experimental procedure. This procedure can be described as follows. The loop is closed using a proportional regulator only. The gain of the regulator is increased until an oscillation is obtained. The gain required for this is the critical gain (K) and the period of the oscillation is called the ultimate period (T). The settings of the regulator parameters are then obtained from a table which is reproduced in Table 1.

Table 1. Regulator parameters obtained from the Ziegler-Nichols tuning rule.

Regulator	Gain	I-time	D-time
P	0.5 K		
PI	0.4 K	0.8 T	
PID	0.6 K	0.5 T	0.12 T

3. THE ESTIMATION PROBLEM

To use the Ziegler-Nichols design rules it is necessary to know the critical gain K and the ultimate period T. These parameters can be determined conveniently by using a self oscillating adaptive control loop (SOAS). See e.g. Schuck (1959). A schematic diagram of such a system is shown in Fig. 1. The adaptive control loop has the property that a limit cycle with the ultimate period will be established. The critical gain is related to the limit cycle amplitude at the relay input through

$$K=4d/(a\pi)$$

where a is the limit cycle amplitude and d is the magnitude

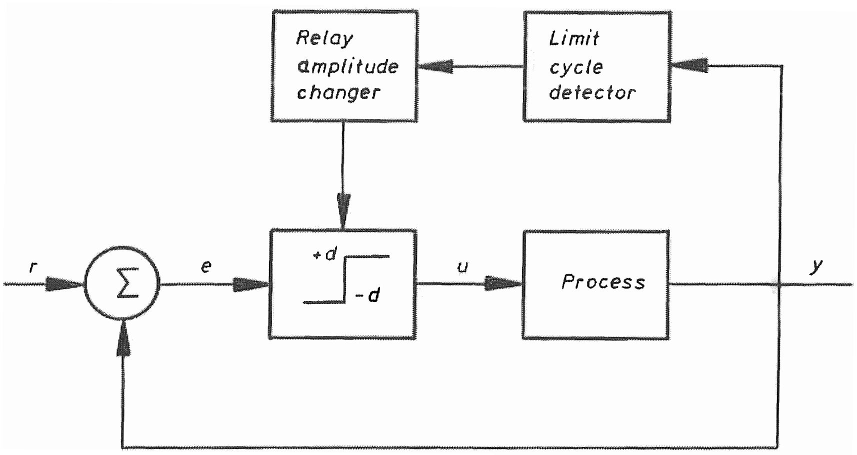

Fig. 1. Block diagram of a self-oscillating adaptive control loop.

of the relay output. The self-oscillating adaptive loop thus automatically gives the parameters required for the Ziegler-Nichols design.

4. THE SELF-TUNING REGULATOR

The ideas presented in the previous sections will now be used to obtain a self-tuning regulator. Such a regulator will have all the components of an ordinary PID-regulator. It will thus have a hand-automatic switch, buttons for increase and decrease in manual mode, displays for set point, measured value and control variable. The mode switch will however also have a position for <u>automatic tuning</u>. In this mode the SOAS system is activated. The critical gain and the ultimate period will be determined and the corresponding Ziegler-Nichols settings will be computed.

The advantage of using an SOAS to determine the critical gain and the ultimate period is that the implementation becomes very simple.

5. PRACTICAL ASPECTS

There are several practical problems that must be considered before a practical design can be obtained. A few of these issues are discussed below.

The key problem is the determination of K and T. A simple way to determine T is to measure the time between zero crossings at the relay output. A simple way to obtain the limit cycle amplitude is to measure the signal swing. More sophisticated estimation methods can also be used.

When the SOAS mode is activated during the tuning it is necessary that the mean value of the output signal has the right value. This could be achieved manually by first setting the regulator in manual mode but it can also be done automatically.

It is necessary to adjust the limit cycle amplitude during the tuning phase. This can be done by adjusting the amplitude of the relay output. Automatic adjustment to a preset amplitude is also a possibility.

The Ziegler-Nichols design is known to give a reasonable closed loop response. The response can however sometimes be too oscillative. One possibility to have additional flexibility is to use potentiometers to allow for individual adjustment of the Ziegler-Nichols settings.

Concerning the operation of the tuning it seems useful to arrange the system in such a way so that the tuning runs automatically after initiation. It should probably be useful to be able to override the tuning by switching to manual mode.

To provide a safe startup it could perhaps also be useful to give default values via potentiometers.

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