The PID: Hommage to a controller – with some critical remarks

Introduction

Since many decades now is the PID ***the*** standard automatic controller, the workhorse of process control. It is used in all conceivable services and for all different processes one can imagine. It is available in every control system and every control professional knows at least its principle. The PID is also the benchmark for every new approach or development: Whatever the new controller or technology that is presented is, its performance is always compared to that of the PID. Therefore let us to take a look today at what made that controller so successful and also check out if it is indeed superior in all aspects.

The PID – the most successful controller

The PID, the combination of a proportional, an integrating and a differencing controller, has made a career that is unparalleled in process control. Today we find this controller practically in every field of application, from industry to home applications, and for very type of process, from fast to slow, from simple to complex, from self-regulating to integrating and instable behavior. So what is so special about it that allows such a wide range of use?

When we take a look at the functionality and the structure of this controller then we can see that:
a) its individual elements are very simple - just as for many other extremely successful products, and
b) at least two of such simple elements had to come together in order to create a success; alone, none of the elements, neither the P-controller nor the I controller, let alone the D-controller, would have made such an impact.

These facts may be a bit unexpected but not all too surprising. But another fact is. If simple or not, the purpose of any type of controller is of course to deliver the required behavior of the variable to be controlled. In this context it is a bit strange that the rapid success of the PID after its introduction was not really so much related to the achievable performance of the controlled variable: Before the PID, most automatic control was done with on-off switches. In the hands of an expert they can deliver a truly astonishing performance – in many cases not much worse than that of the PID. But in the case of the switch there is a very high price to be paid: The controller output can only be 0 or 100 %. The effect of this behavior can be easily realized when we just think about driving a car and trying to maintain the speed constant by only fully pressing or fully releasing the gas pedal. Although the performance of our controlled variable, the speed, might be quite reasonable after some training, the resulting gasoline bill would be simply unacceptable. It is one of the big merits of the PID that it can deliver the same of even better performance with much smoother action on the process and thus less associated cost.

Many strong points – but also some surprising weaknesses

Let us now look at some more facts that made the PID a success, but also reveal some quite astonishing weak points. We already have mentioned the simple ‘design’ of the controller that makes it possible that the functionality can be relatively easily delivered – either by hardware (well, doing esp. the D-controller is a bit tricky) or in software. A consequence of the simple principle is also that the fundamental behavior and the handling of the controller is easy to learn and to understand – at least theoretically.

Another truly major advantage is that the PID is a "generic" controller: There is one standard functionality – although there are differences from vendor to vendor like the series formulation or the parallel formulation. This allows to use it in all these different scenarios, which is, on the other hand, in contradiction with the modern (but not necessarily always practical) trend to 'design' a specific controller for every single application. In the latter case the resulting controller maybe ideally tailored for the task in question but every single controller is different from the other – a nightmare as far as documentation and maintenance is concerned. The PID provides the possibility to use the same, known instrument over and over again and to adapt for an extremely wide range of situations.

Finally, it is - in principle - easy to handle: For the most widely used version, the PI-controller, only two parameters need to be adjusted, which suggests that this is a rather trivial tasks. Yet this leads us to the not so strong points of this controller.

On the negative side, the controller clearly shows several weaknesses, some of them rather being surprising: Maybe the most fundamental requirement for any controller is the capability to bring the process always right to the setpoint. Yet, in the case of the PID, two out its three elements (the P-controller and the D-controller) do not fulfill this requirement at all. Without the I-controller, the PID never would make it to the setpoint – unthinkable.

Tuning is in principle simple, typically there are just two knobs to turn, but in practice it is often problematic and sometimes quite difficult to achieve the needed performance. As a consequence, an enormous number of methods has been developed over time to assist the users in this task and still every year new, supposedly better ones are presented - a strong indication that we a far from where we want to be on this issue.

The uncomfortable tuning, especially when dealing with deadtime in the process, is also a key reason why many surveys have shown that the majority of the PID controllers in the plants are in a rather poor state and far away from their potential performance: Most studies have found that only one out of 5 controllers delivers a better performance than manual control. And this number has not significantly changed over decades, I still remember our discussions about these figures some 30 years back. These results carry two strong messages, namely
1) that in 80 % of the cases the investment in the controllers has not really yielded any ROI
2) that better equipment, e.g. a modern digital control system compared to pneumatic controllers, has not helped much because it has not made the use of the controller easier, the key issue still being the ability to find the proper settings in shortest time.

Besides, most of the tuning methods that are available are based on the knowledge of the process parameters. Although we know that the better our knowledge about the process is, the better we will be able to control it, this certainly requires extra effort, typically an open loop plant test, which means that we have to overcome the well known resistance from plant operations. The preferred approach would be to make just one setpoint test in closed loop and to get both the process parameters and the tuning from the response. This is in fact possible today, an enhanced version of the original Ziegler-Nichols method exists (which we also use in our own tools), but it is based on the use of a pure P-controller. For this test we have to disable the I-part – not a big problem but certainly an inconvenience and thus a barrier for its use. Surprisingly enough, all our attempts to interest researchers in expanding this methods for the PI-controller have totally failed so far.

As a final point on the tuning I would like to mention that there is no direct one-to-one relationship between the process parameters and the tuning parameters – which makes the automatic adaptation of the controller to changes in the process behavior somewhat cumbersome.

Closely linked to the tuning issues are the known problems concerning the troubleshooting of ill-behaved loops: The behavior does not always give strong and unmisleading information about the root cause of the trouble. It takes some experience and know how to quickly determine whether the P- or rather the I-part needs to be adjusted to stabilize a swinging loop, know-how that we find less and less in industrial plants as one consequence of the every shrinking manpower.

Conclusion

Its simplicity and adaptability are perhaps the two most important features that are responsible for the enormous success of this controller. On the other hand it is surprising that a device with such major shortcomings especially in the tuning has become such a success. Maybe one reason is that the PID has never been seriously challenged by newer developments. Although some can and do easily outperform the PID, so far all later approaches – model based control, expert systems, Fuzzy logic etc. - have not come even close in popularity.

Yet this should not stop researchers from looking for some new approaches, for a next generation controller that is as simple and as general and adaptable as the PID but easier and faster to bring to full performance, especially then when the process is more difficult to control. Until then we have to honor it as the big master of process control.

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