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INFLUENCE OF ADDITIONAL P_a CONTROLLER TO THE SYSTEM RESPONSE WHEN THE SET POINT IS CHANGING

Saša Prodanović[1], Ljubiša Dubonjić[2], Novak Nedić[3]

Abstract: One of the numerous approaches for disturbance rejection is occasionally introducing additional P_a term in parallel to the existing controller. It is strongly important to check effects of its operation to the system's transient processes caused by instant changes of set point, because it is well known that too high values of P term can lead system into unstable state. Therefore, this paper deal with researching of maximum proportional gain that can be used for disturbance rejection if it appear in the transient process (dynamical area of system response). Investigation has been carried out using numeric simulations, on the some characteristic process examples, that were considered in the previous survey of mentioned additional P_a controller.

Key words: additional P_a controller, maximum proportional gain, set point changes

1 INTRODUCTION

Various machines and processes to be controlled always attract a lot of researche's attention. All stages of system functioning are very important and have their own specifics. Transient response is specific due to dynamic changes in response and steady state can be affected by disturbance that can appear anytime. This leads to various demands for intensity of control effort (manipulated variable), that must be achieved by controller. PID controller and its variants are the most common controllers in industry. Therefore, it is naturally that they are in the focus of the numerous investigations. Comprehansive overview of their basic postulates, design and tuning has been given in [1-3]. Pretty large number of papers deal with tuning of PID controllers. Some of them done by authors are given in [4-6]. Researches directed to the iterative method [7,8] are of most significance for this survey. Namely, this research is extension of the one in the [8], where additional P_a (proportional) controller had been used for the disturbance rejection during its influencing. It was tuned iteratively based

[1] PhD Saša Prodanović, assistant professor, University of East Sarajevo, Faculty of Mechanical Engineering, East Sarajevo, B&H, sasa.prodanovic@ues.rs.ba (CA)
[2] PhD Ljubiša Dubonjić, assistant professor, University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Kraljevo, Serbia, dubonjic.lj@mfkv.kg.ac.rs
[3] PhD Novak Nedić, full professor, University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Kraljevo, Serbia, nedic.n@mfkv.kg.ac.rs

on responses characteristic (overshoot). Great attention is pay to the quality of transient response [9-11]. Present research has goal to check effect of additional controller on system transient response during its starting and instantly set point change. Examination of its effort for disturbance rejection and in the transient process is separately performed in order to point out its differences. Introduction chapter is followed by the second one that is consisted of controller examination for two cases disturbance action and set point change. Conclusions are given in the third chapter.

2 CONTROLLER EXAMINATION

According [8], additional P_a controller operates only in the periods when disturbance causes overshoot in the system response. Then it increases control effort in order to reject disturbance as soon as posible. It is adjusted step by step through the iterations based on current value of overshoot. It can also be tuned based on any other quality indicator of the response. After disappearing of overshoot, P_a term is turn off, as it will be shown later on the particular example. Taking into account previous stated, entire PID controller in the general case, in the particular periods, is described by (1) [1-3] and (2):

without additional P_a controller:

$$G_c(\mathrm{s}) = \frac{U(s)}{E(s)} = K_p\left(1 + \frac{1}{T_i \mathrm{s}} + T_d s\right) = K_p + \frac{K_i}{s} + K_d s \tag{1}$$

with additional P_a controller:

$$G_c(s) = \frac{U(s)}{E(s)} = K_p\left(1 + \frac{1}{T_i s} + T_d s\right) + K_{pa} = K_p + \frac{K_i}{s} + K_d s + K_{pa} \tag{2}$$

where: $U(s)$ is manipulated variable and $E(s)$ is error of controlled variable. K_p, K_i and K_d are proportional, integral and derivative controller gains, respectively. T_i and T_d are integral and derivative time constant, also respectively. Influence of additional P_a term to the transient response and instantly set point change have not been considered in [8]. It is well known that, high values of proportional gain can significantly deteriorate response in its dynamical stage or even cause system instability. Having in mind this fact, it is very useful to determine how much can be value of the additional proportional gain K_{pa} in mentioned stages of system functioning. Two controlled objects (first and second order) have been considered in the [8]. The same objects are examined here but regarding transient response quality.

2.1 Disturbance rejection

Additional self-tuning P_a controller for disturbance rejection has been developed in the [8]. Algorithm for its self-tuning was shown there. In this subchapter only example 1 is shown to explain starting idea.

Example 1.

In this example object is described with first order transfer function (3) [8].

$$G_{ex.1}(s) = \frac{1}{63s + 1} \tag{3}$$

Basic PI controller is tuned using Matlab toolbox for controller tuning and its parameters are: K_p=10.248; K_i=0.163. After performed simulations too high proportional gain has been obtained K_{pa}=2400. That is expected because the intensity of introduced disturbance array is high too in regard to set point r = 1, as it can be seen in figure 1 [12]. Shurely, feasibility of additional proportional gain K_{pa} depends on technical characteristic of the system components (amplifiers, actuators, etc). So, it would be good if this investigation can be completed with an experimental test in the lab to determine real feasible values of gain K_{pa} for certain system. Figure 1. also shows control effort (manipulated variable intensity) for the example 1 with and without additional proportional controller, where significant differences are noticeable.

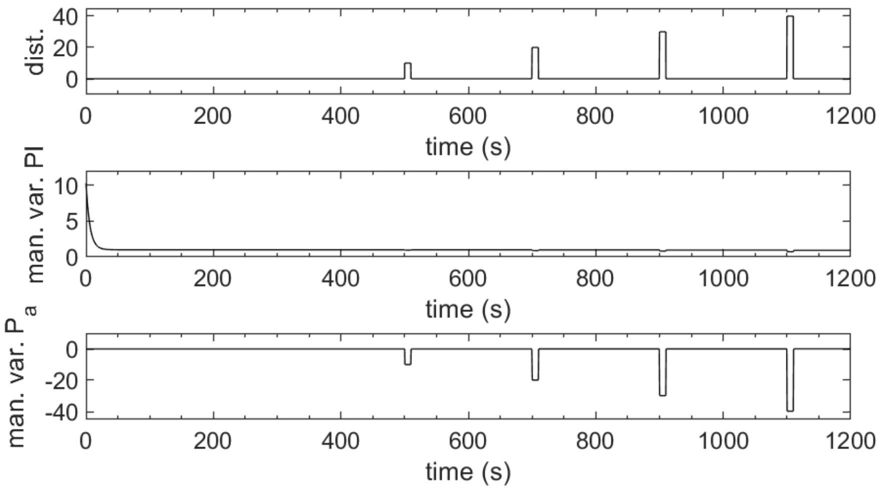

Figure 1. *Disturbance and manipulated variable (control effort) (example 1) [8]*

Simulations of entire system functioning gives response in the figure 2. Here is obvious that additional P_a controller very efficiently rejects disturbance. Therefore, it is highly important to determine appropriate value of K_{pa} in the period of transient response caused by system starting or instantly change of set point.

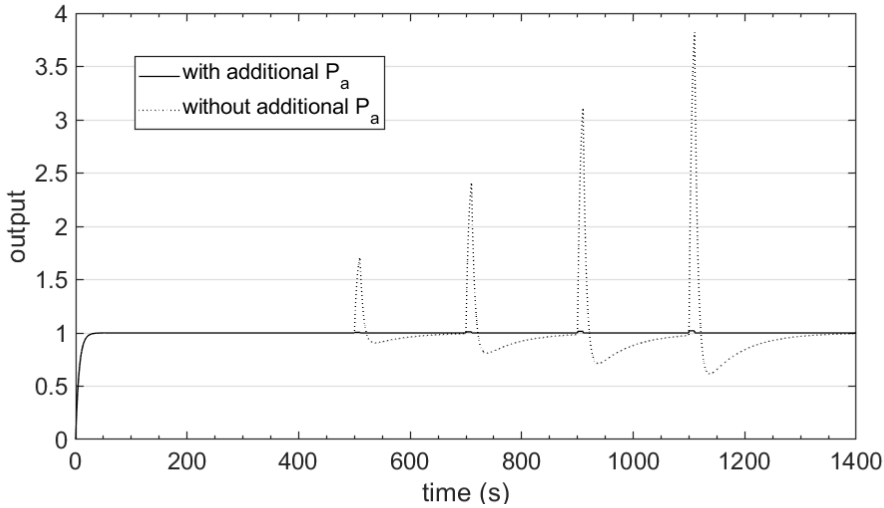

Figure 2. *Disturbance rejection with and without additional self-tuning P_a controller (example 1) [8]*

2.2 Instant set point change

As it above stated, influence of the additional P_a controller to the transient response has been examined here. Figure 3. shows system transient responses for three instant changes of the set point and for four different values of additional proportional gain K_{pa}. Values of K_{pa} were manually increasing, for the controlled object (3) in example 1, and they were giving better and better transient response, up to value K_{pa}=500. It can be clearly seen in the figure 4. Higher values start to deteriorate it, but it isn't shown in the figure 3 and 4. Disturbance was not introduced here to prevent plenty of details in the diagram and therefore its unclearnesses.

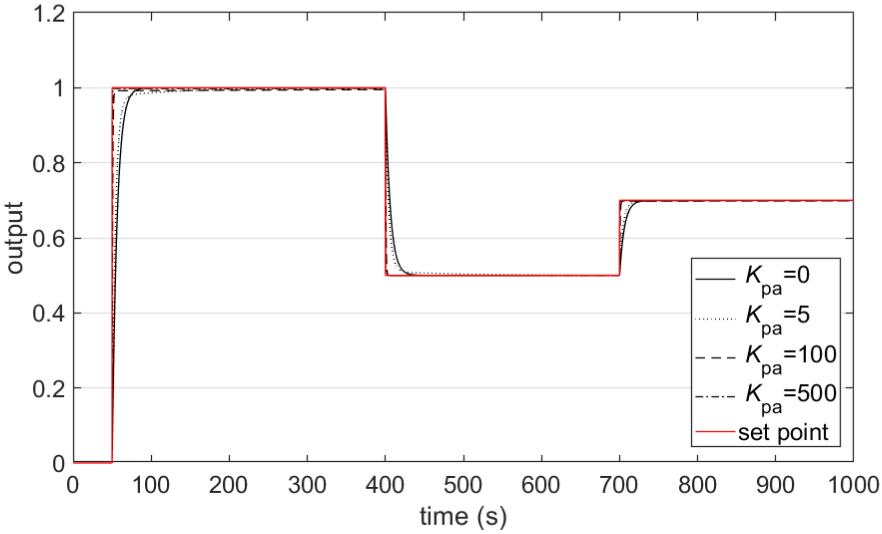

Figure 3. *System responses (example 1) for different proportional gain K_{pa} of the additional P_a controller*

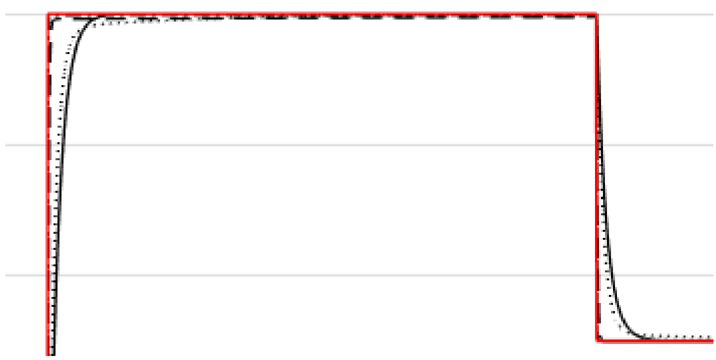

Figure 4. *Partial zoom of the fig. 3*

<u>*Example 2.*</u>

This example deals with second order object described with (4) [8].

$$G_{ex.2}(s) = \frac{9}{s^2 + 14.6s + 1} \tag{4}$$

Parameters of PI controller, that controls it, is tuned and they amount: K_p=0.442; K_i=0.028. As it is proved in [8], here also high value of K_{pa}=3400 enables good disturbance rejection (isn't shown in this paper), but its maximum value for the transient response is K_{pa}=8. Figures 5 and 6 show simulated responses of the object (4) with set points changes.

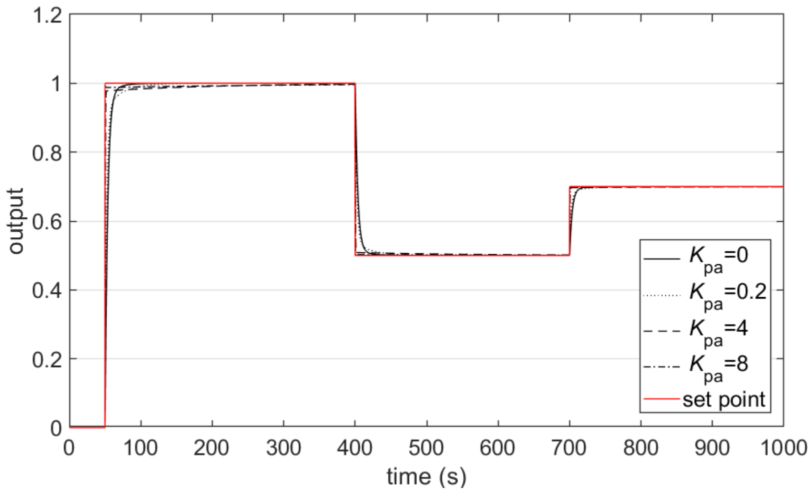

Figure 5. *System responses (example 2) for different proportional gain* K_{pa} *of the additional* P_a *controller*

Figure 6. *Partial zoom of the fig. 5*

Based on these two examples, the main thing here is to determine how much proportional term can be intensified (increased) in the particular periods of system functioning.

3 CONCLUSION

This investigation emphasize importance of appropriate applying of additional periodical proportional controller action, in order to intensify controllers effort when it is necessary. Here is concluded that this additional proportional action must has significantly less intensity in the periods of changes of set points than in the periods of disturbance influence. This is also important to know in the cases when disturbance acts during transient period of response. Therefore, qualitative determination of additional proportional gain in the relation to one within basic PI controller has been enabled by performed research, here. More precise tuning of additional P_a controller can be carried out using iterative method under constraints of time response characteristics, when set point has instant changes. That can be an idea for future work within this topic.

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