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Simplified Universal Intelligent PID Controller

Mohamed I. Abu El- Sebah
Electronics Research Institute, Cairo , Egypt,
Arab Academy for Science, Technology, Maritime and Transport,Faculty of Engineering
Mohamedibrahi32@hotmail.com

Abstract: Many researches give a great attention to invent different techniques for process controller application. All of them tend to simplify the controller design algorithm and make it more intelligent, but the two goals seem to be an opposite goals. Although the artificial intelligent controller is proper, they need sometimes a complicated algorithm and parameter adaptation process. This paper presents a new idea to simplify the process controller, also to make it an intelligent controller. Moreover, the proposed controller is used as universal controller. The paper also contains details of the controller design and development. This Simplified Universal Intelligent PID (SUI-PID) controller is designed to yield a good command tracking for different systems. The proposed controller can be designed using a very simple logic algorithm. This algorithm adapts the controller parameters automatically, therefore no need for controller adaptation. The proposed controller is simulated using Matlab Simulation software package and applied to different systems to verify the controller properties effectiveness. The simulation results illustrate an excellent performance of the proposed controller, which used as a universal controller for any system.

Index terms-- Intelligent controller, Universal Controller, Simplified Controller

I. INTRODUCTION

The automatic control is developed begging with design of fly-ball governor for the speed control of a steam engine by James Watt (1788) followed by mathematical analysis of feedback control by Maxwell in 1868 [1] reaching to Routh's stability criterion (1877) and Nyquist's development in 1932 [2]

Since the development of the proportional integral derivative (PID) controller was described [3], More than 400 tuning rules have been developed. Open loop process step or impulse response [4], and closed loop step response [5,6] have been used. Also frequency domain closed loop Information [4]. and back-calculation from a discrete time identification method [7]. Parameter estimates graphically from a known higher order process [8]. More over System identification approach in discrete time [9] and back-calculated from a discrete time identification non-linear regression method [10].

Modern controllers such as Fuzzy and neural have been used to reduce the process parameter dependency for controller design and hence improving the controller response. Fuzzy Logic has emerged as a simple tool for the controlling of complex processes. The fuzzy controller is based on fuzzy logic. Zadeh first introduced fuzzy logic in 1965 which is followed by extension of the work [11-14], whereas the first practical fuzzy logic controller was implemented by Mamdani in 1974 [15,16]. A neural network is a general mathematical form models the operations of biological neural systems. Since the first artificial neuron was produced in 1943 [17] and perceptron [18], a significant progress is developed to brought the neural control in the front with fuzzy control. Many techniques such as genetic algorithm and neurofuzzy have been developed to improve the controller response [19,20].

During a last few decades, Adaptive control was developed and implemented to improve the PID Response by reducing the effect of the process parameter variation during control operation [21]. In the last decade, a great attention is paid to adapt the PID response by utilizing The Fuzzy and neural [22-24]. Hybrid controllers also used to improve the PID response [25].

This research proposed a novel PID controller Design and implementation. The proposed controller is superior more powerful than others because of it is a universal controller and does not need either the nature of the process or controller design process. In other word, it can be used with the unknown systems via no control background people.

II. SIMPLE PID CONTROLLER ALGORITHM

The first simple PID design formula proposed in this paper is based on the process transfer function to determine the optimum PID coefficient. Let the PID controller be implemented to control a general 2nd order system as in Fig. 1:

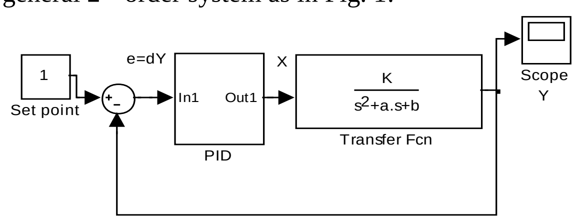


Fig.1 2nd order system block diagram

$$\frac{y}{x} = \frac{K}{s^2 + as + b}$$

$$y(s^2 + as + b) = Ku$$

$$\frac{d^2y}{dt^2} + a\frac{dy}{dt} + by = Ku$$

Substituting

$$\frac{dy}{dt} = \frac{\Delta y}{T}$$

$$\frac{d}{dt}\left(\frac{\Delta y}{T}\right) + a\frac{\Delta y}{T} + b\int \Delta y\, dt = Ku$$

$$\frac{d}{dt}\left(\frac{e}{T}\right) + a\frac{e}{T} + b\int e\, dt = Ku$$

$$u = \frac{a}{KT}e + \frac{b}{K}\int e\, dt + \frac{1}{KT}\frac{d}{dt}e \quad (1)$$

Equalingcoefficient of equation 1 with its crossponding of eq.(2)

$$u = K_p e + K_i \int e \, dt + K_d \frac{d}{dt} e \qquad (2)$$

The controller constant

$$K_p = \frac{a}{K.\Delta t}$$

$$K_i = \frac{b}{K}$$

$$K_d = \frac{1}{K.\Delta t}$$

Where ΔT is almost sampling time or multiple of sampling time. The system response based on the proposed controller illustrated in Fig. 2

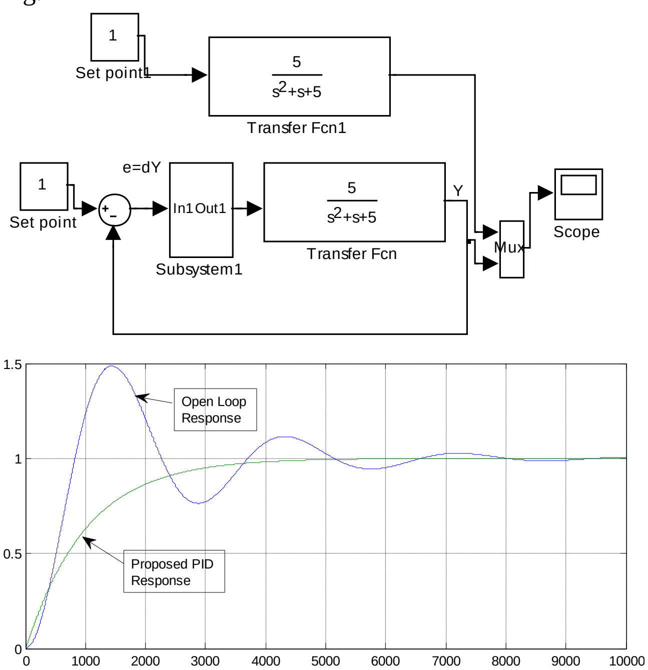
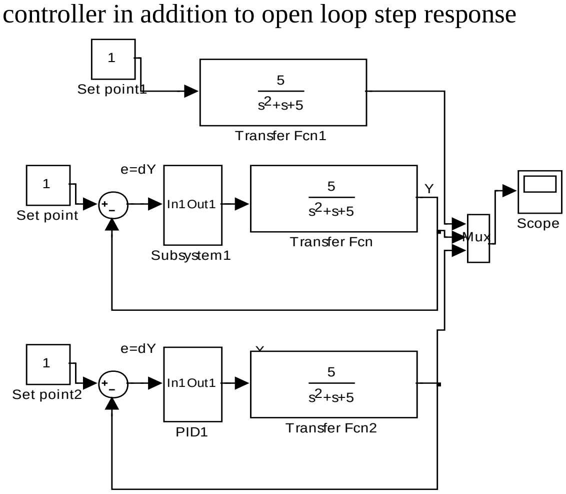


Fig. 2 System response

Applying the concept of MDOF controller to the simple PID controller by using two controllers one of themis designed for wide range of error (simple controller with higher gain), while the other is designed for fine-tuning (simple controller)[26,27]. Figure 3 shows the comparison between the simple controller with MDOF controller in addition to open loop step response



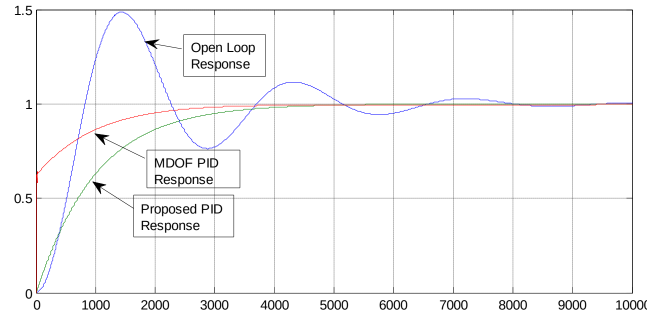


Fig. 3Multi degreeof freedom controller response

III. SIMPLIFIED PID CONTROLLER

Figure 4 illustrates the second order system step response divided into three different regions to shows the required significant action in each region. It is easy to adapt the PID Constant to improve the PID response by increasing the controller term constant in the corresponding region.

The PID controller Consists of a three Terms

The first term controller P $= K_p$ *error

The second term controller I $= K_i$ *∫ error .dt

The third term controller D $=K_d$ *d(error)/ dt

Substituting in the PID controller equation with the following values

K_p =ABS(error) , Ki =ABS(∫error.dt) , and K_d =ABS(d(error)/dt)

By selecting the Controller constant as above leads to simple design algorithm and adaptive weighting for the three terms.

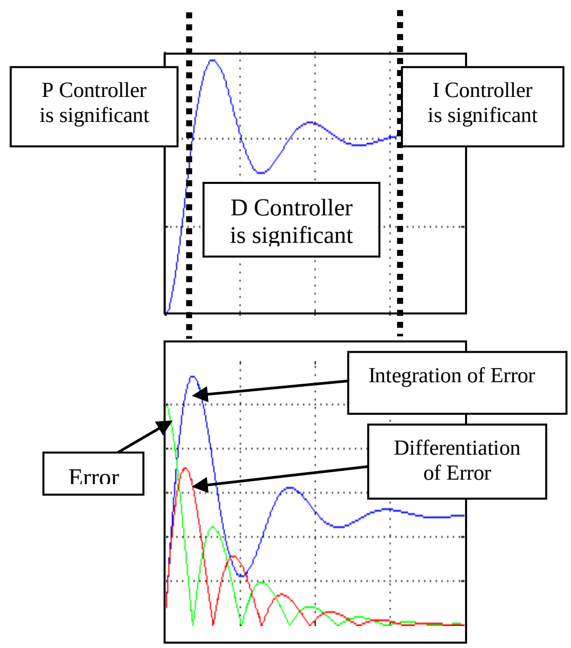


Fig. 4 The system response and the absolute values for error, integration of error and differentiation of error

IV. SIMULATION AND SIMULATION RESULTS

The simulation of a controlled second order system has been carried out using Matlab to verify the controller action. The system block diagram including its details is illustrated in Fig.4.

Figure 5 shows the system response utilizing the proposed controller.

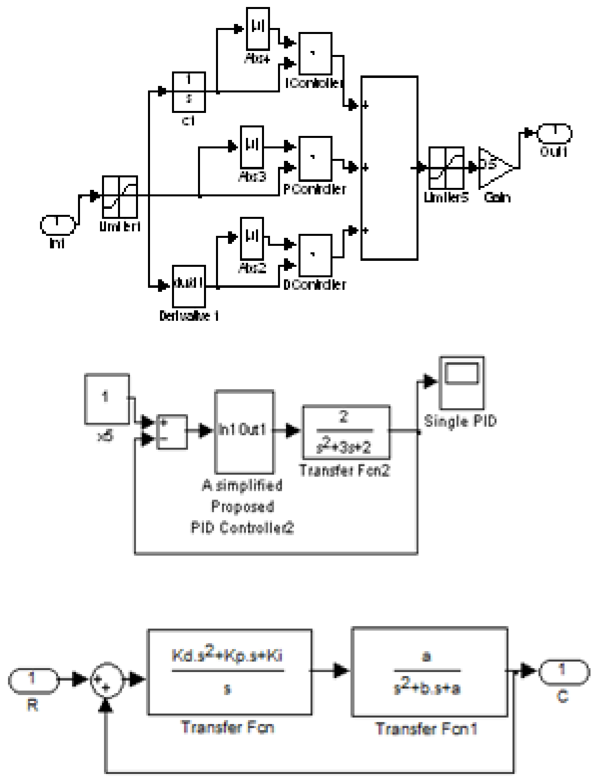


Fig.5The Proposed PID controller Block Diagram

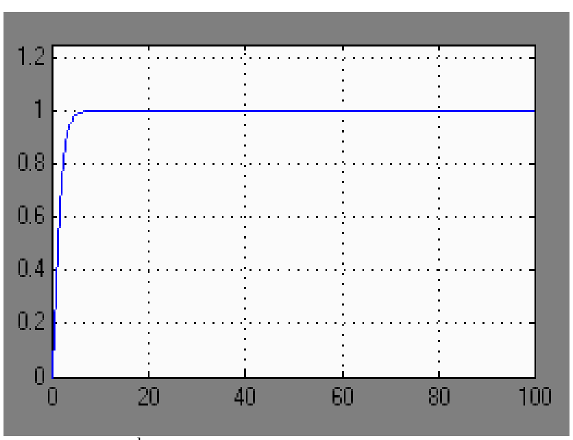


Fig. 6 The 2nd order system closed loop system

V. INTELLIGENT PID CONTROLLER

The MDOF controller depends on constructing two controllers; the first controller is designed for wide range of error, while the other is designed for fine-tuning [26,27]. The MDOF controller uses two controllers compound at each value of controller input with different weights depending on the error to produce the multi degree of freedom controller.

The MDOF controller has been designed in two steps. First step for designing the two individual controllers, one covering a wide range of large error while the other for fine tuning. In the second step the outputs of the two controllers are composed to produce the final output assuming a linear relationship between the error and the controller weights[26, 27]. The required composition formula (in per unit values) is proposed as the following:

Controller Output = O/P1*Error + O/P2*(1-Error) (2.37)

Where

O/P1: Controller o/p of the wide range controller

O/P2: Controller o/p of the fine tuning controller

As shown in the previous equation the two controller have been added with 2 adaptive weights (error) and (1-error) which leads to the response illustrated in Fig. 7.

The proposed intelligent PID controller constructed using Multi Degree of Freedom Controller concept as shown in Fig. 7. Figure 8 shows the response of a process at open loop step change, the step change using the proposed PID controller, and the step change using multi degree of freedom controller. It is clear that the intelligent PID controller eliminates the need to know the system steady state gain as shown in Fig.9.

$$Cm = C * K * error + C * \frac{1}{K} * (1 - error)$$

$$Cm = C * error * (K - \frac{1}{K}) + \frac{C}{K}$$

For K >>1

$$C_m = C * error * K$$

Where

K : the modified Controller Gain

C : the controller output

Cm : the modified controller output

VI. MULTI INPUT MULTI OUTPUT SYSTE

In practical control there are a number of process contain multi input which control multi output variables. The PID design process may be complicated compared with single input single output. SUI PID can be applied without any special arrangement as illustrated in Figure 10 and produce the same expected output as shown in Figure 11.

VII. CONCLUSION

Powerful controller must be match specific requirements in design, implementation and performance. The simple controller design preferred which means easy process modeling (classical control) or input output test (modern control), simple design and adaptation techniques. The design must be achieved by simple algorithm implementation and fast algorithm execution. The controller is preferred depends on its performance to achieve system Stability and good system response.

A proposed intelligent controller has been developed in a simplified manner. The SUI PID controller is a simplified in design and implementation beside an excellent performance. The Results of the proposed controller shows that the excellent response can be achieved via a universal PID Controller.

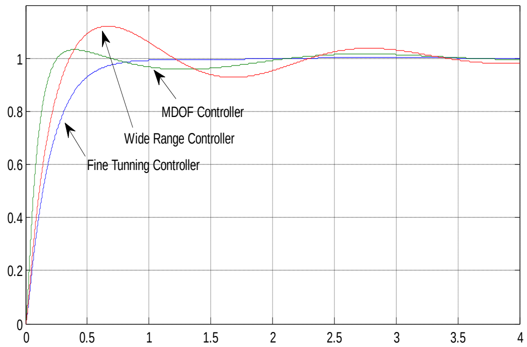


Figure 7 represents the different controller response.

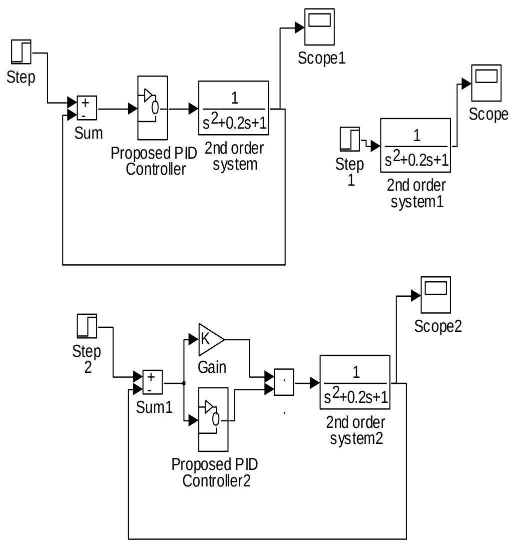
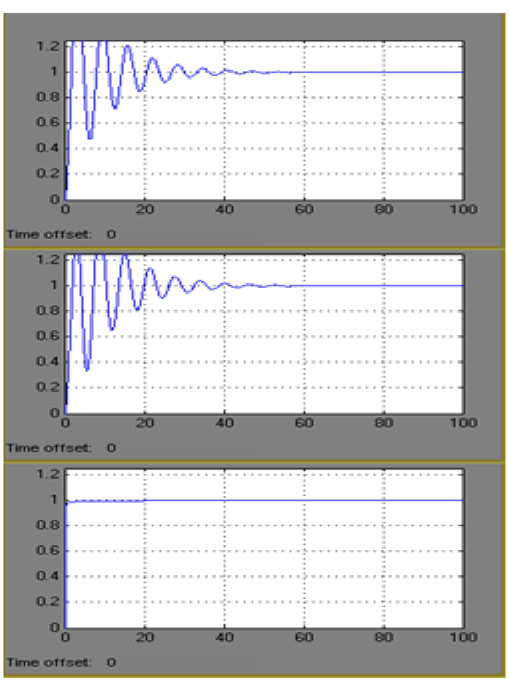
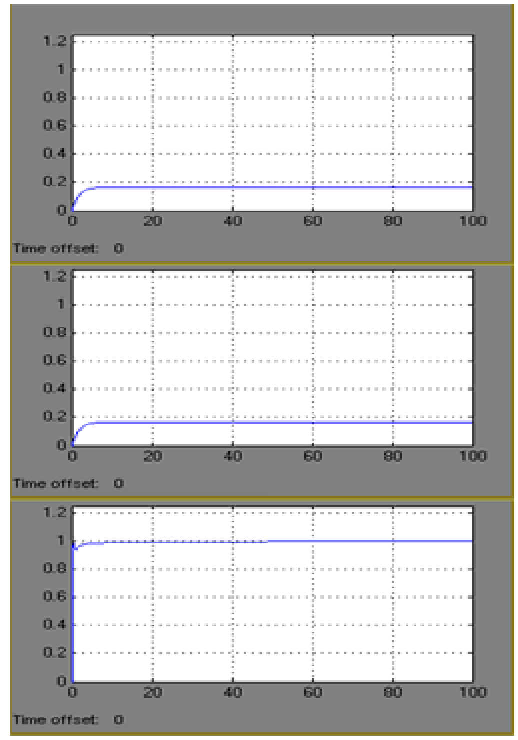


Fig.8 The 2nd order system, universal controller and the intelligent PID controller



(a)



(b)

Fig.9 The System Response under open loop,Proposed universalPID, and SUI PID Controller under different dc gain

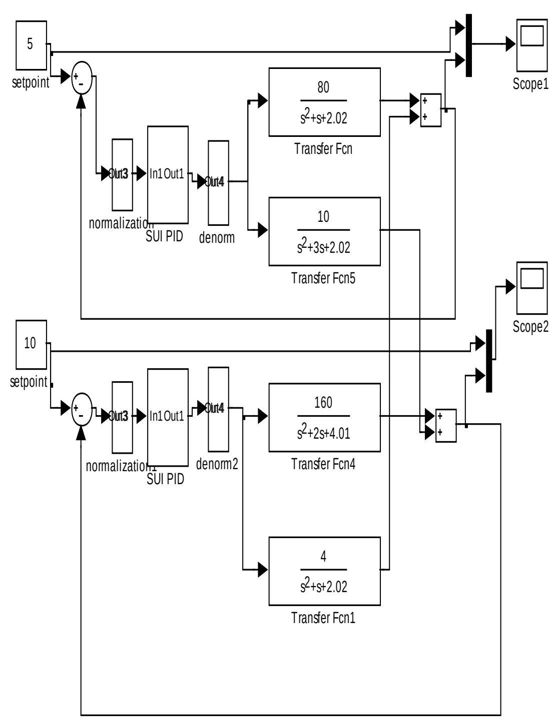


Fig.10 The 2nd order Multi input multi output system with SUI PID controller

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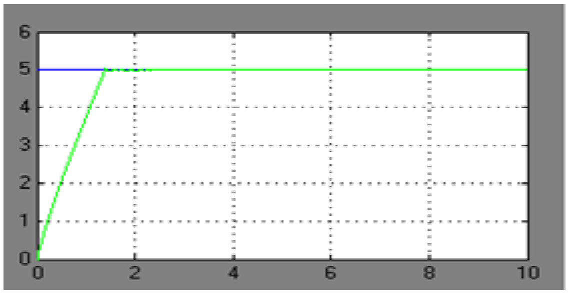

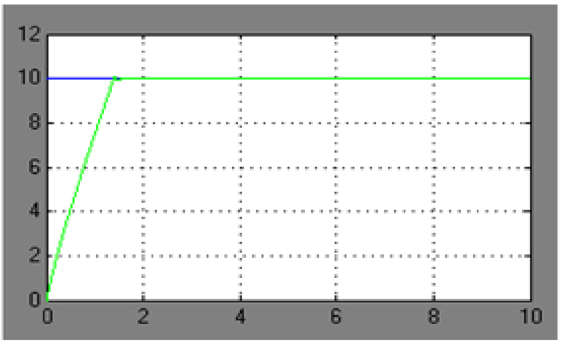

Fig.11 The multi input multi output System Response

The Proposed design method applied without needing to drive the plant transfer function. The design procedure and analysis have been developedto prove the powerful of the SUI-PID Controller. The controller has been applied practically to PMSM position control [28, 29

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