Comparitive Study of PID and Fractional Order PID Controllers for Industrial Applications

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***Abstract*— In this paper a fractional order PID (FOPID) controller is proposed for a continuous stirred tank (CSTR) problem. CSTR is used to carry out chemical reactions in industries. The characteristics of particular problem is studied using integer order controller and fractional order controller. PID controller is relatively simple structure, which can be easily understood and implemented in practice. They are thus, more acceptable than advanced controllers in practical application. But in the last two decades, fractional calculus has been rediscovered by scientists and engineers and applied in an increasing number of fields, namely in the area of control theory. The success of fractional-order controllers is unquestionable with a lot of success due to emerging of effective methods in differentiation and integration of non-integer order equations. Fractional-order proportional-integral-derivative (FOPID) controllers have received a considerable attention in the last years both from academic and industrial point of view**

Keywords: Controllers, Fractional order, PID,FOPID

I. INTRODUCTION

There is an increasing interest in dynamic systems of non-integer orders. Many real dynamic systems are better characterized using a non-integer order dynamic model based on fractional calculus or , differentiation or integration of non-integer order . Traditional calculus is based on integer order differentiation and integration. The concept of fractional calculus has tremendous potential to change the way we see, model, and control the nature around us. The number of applications where fractional calculus has been used rapidly grows. These mathematical phenomena allow to describe a real object more accurately than the classical “integer-order” methods. A typical example of a non-integer (fractional) order system is the voltage-current relation of a semi-infinite lossy transmission line [1] or diffusion of the heat through a semi-infinite solid, where heat flow is equal to the half-derivative of the temperature [2].

The main reason for using the integer-order models was the absence of solution methods for fractional differential equations. At present time there are lots of methods for approximation of fractional derivative and integral and fractional calculus can be easily used in wide areas of applications (e.g.: control theory - new fractional controllers and system models, electrical circuits theory - fractances, capacitor theory, etc.). Since (integer order) PID control dominates the industry.we believe FO-PID will gain increasing impact and wide acceptance. Furthermore, we also believe that based on some real world examples, fractional order control is ubiquitous when the dynamic system is of distributed parameter nature.

II. PID CONTROLLERS

The PID controllers have remained, by far; the most commonly used in practically all industrial feedback control applications. The main reason is its relatively simple structure, which can be easily understood and implemented in practice. They are thus, more acceptable than advanced controllers in practical applications unless evidence shows that they are insufficient to meet specifications. Many techniques have been suggested for their parameters tuning . Consider the general feedback system with a PID controller and plant transfer function G(s), which is shown in Figure 1

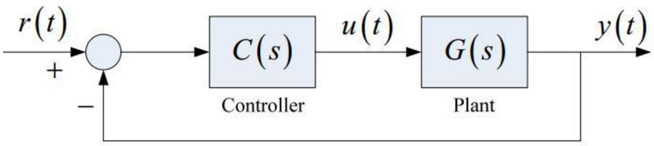

Fig. 1. A feedback system with PID controller

Where r(t)is the reference signal, (u) tis input signal, y(t)is the output, (Cs) is the controller to be designed. For the PID controller, (Cs) will be:

$$C(s) = k_p + \frac{k_i}{s} + k_d s \quad (1)$$

,Kp, Ki, Kd are the proportional, integral and the derivative gains, respectively. Those parameters should be adjusted so that acceptable performance, such as the rising time, settling time, gain margin, etc. could be obtained There are several different methods for tuning PID controllers that have been explored by researchers over the years. The tuning rules by Ziegler and Nichols, however, are the most prevalently used since its use is simple. The most widely used controller in the industry is PID due to its simple structure and auto tuning capability. Although there are many rule based methods and analytical tuning methods, it is difficult to adjust PID parameters properly to meet the requirements because many industrial systems are often burdened with problems such as structural complexity, uncertainties, large transportation lags and nonlinearities.

III.FRACTIONAL ORDER PID CONTROLLER

Fractional-order calculus is an area of mathematics that deals with derivatives and integrals from non-integer orders. In other words, it is a generalization of the traditional calculus that leads to similar concepts and tools, but with a much wider applicability. In the last two decades, fractional calculus has been rediscovered by scientists and engineers and applied in an increasing number of fields, namely in the area of control theory. The success of fractional-order controllers is unquestionable with a lot of success due to emerging of effective methods in differentiation and integration of non-integer order equations. Fractional-order proportional-integral-derivative (FOPID) controllers have received a considerable attention in the last years both from academic and industrial point of view. In fact, in principle, they provide more flexibility in the controller design, with respect to the standard PID controllers, because they have five parameters to select (instead of three)[4][5][6].

The concept of FOPID controllers was proposed by Podlubny in 1997 (Podlubny et al., 1997; Podlubny, 1999a). He also demonstrated the better response of this type of controller, in comparison with the classical PID controller, when used for the control of fractional order systems.

The differ integral operator, denoted by $a^{D_t^r}$is a combined differentiation-integration operator commonly used in fractional calculus. This operator is a notation for taking both the fractional derivative and the fractional integral in a single expression and is defined by

$$ {}_aD_t^r = \begin{cases} \mathrm{d}^r/\mathrm{d}t^r & \Re(r) > 0, \\ 1 & \Re(r) = 0, \\ \int_a^t (\mathrm{d}\tau)^{-r} & \Re(r) < 0, \end{cases} \quad (2) $$

where a and t are the limits of the operation .And r is the order of the operation, generally r ∈ R but r could also be a complex number.

The most common form of a fractional order PID (Podlubny, 1999a), involving an integrator of order λ and a differentiator of order μ .where λ and μ can be any real numbers[4].

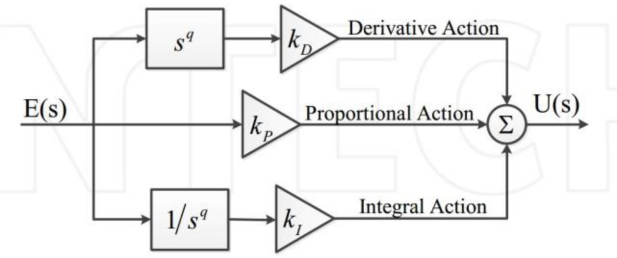

Fig. 2. Fractional order PID controller

The transfer function of such a controller has the form

$$ G_c(s) = \frac{U(s)}{E(s)} = k_P + k_I \frac{1}{s^\lambda} + k_D s^\mu, \quad (\lambda, \mu > 0) \quad (3) $$

And which can be represented as a block diagram which is shown in the fig 2

Clearly, selecting λ= 1and μ= 1, a classical PID controller can be recovered. The selections of λ= 1, μ= 0, and λ= 0, μ= 1 Respectively corresponds conventional PI & PD controllers. It can be expected that the fractional order PID controller may enhance the systems control performance. One of the most important advantages of the FOPID controller is the better control of dynamical systems, which are described by fractional order mathematical models. Another advantage lies in the fact that the FOPID controllers are less sensitive to changes of parameters of a controlled system .This is due to the two extra degrees of freedom to better adjust the dynamical properties of a fractional order control system.[6]

IV.SIMULATION STUDY AND ANALYSIS

To compare the characteristics of integer order PID and FOPID a continuously stirred tank reactor (CSTR) is used. CSTR is used to carry out chemical reactions in industries. Chemical reactors are the most important unit of chemical plants in industries.by considering different parameters as in [3]transfer function of CSTR can be written as follows

$$ g(S) = \frac{-1.117s+3.1472}{s^2+4.6429+5.3821} \quad (4) $$

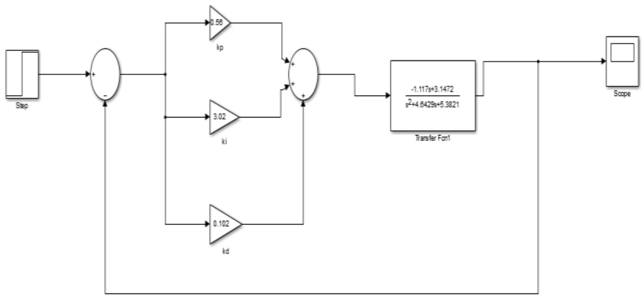

Fig.3.simulink model with PID controller

For tuning PID controller Ziegler-nichols method is used and values of Kp,Ki,Kd are obtained as Kp=0.56, Ki=3.02, Kd=0.102. and for the simulation of fractional order PID values of λ=.95 and μ=.75[3].

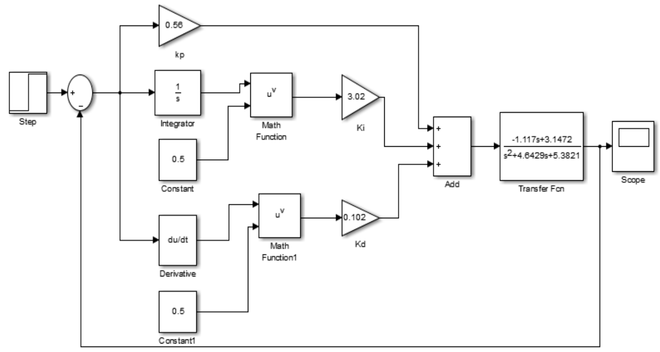

Fig.4.simulink model of FOPID controller

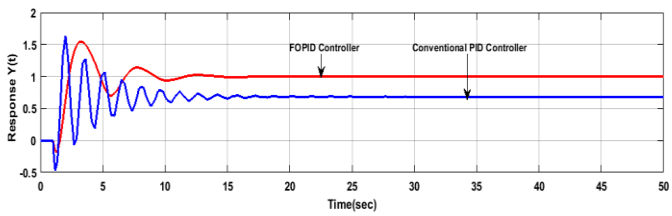

Fig.5. comparison between PID and FOPID controllers

During the tuning of controller use Kp to decrease rise time, use Kd to reduce overshoot and settling time and use Ki to eliminate steady state error. when we increase Kp, Ki, Kd values the time domain specifications can be changed as shown in table 1

TABLE 1: EFFECT OF GAINS IN PERFORMANCE

	Rise time	Over shoot	Settling time	Steady state error	stability
Kp	Decreases	increase	Small increase	Decrease	Degrade
Ki	Small decrease	increase	Increase	Large decrease	degrade
Kd	Small decrease	decrease	decrease	Minor change	improve

By comparing the responses of two controllers the following values of time domain specifications are obtained. Which is shown in table 2.

.TABLE 2: COMPARISON OF PID AND FOPID

	PID	FOPID
Rise time	.1334	.6163
Settling time	15.1202	14.5114
Overshoot	129.1948	64.7943
Peak time	2.0815	3.1801

V.CONCLUSION

Fractional-order calculus is an area of mathematics that deals with derivatives and integrals from non-integer orders. Fractional-order proportional-integral-derivative (FOPID) controllers have received a considerable attention in the last years both from academic and industrial point of view. In fact, in principle, they provide more flexibility in the controller design, with respect to the standard PID controllers, because they have five parameters to select (instead of three). To compare the characteristics of integer order PID and FOPID a continuously stirred tank reactor(CSTR) is used.CSTR is used to carry out chemical reactions in industries.

By comparing the values we can say that the error and dynamic response of the system will get improved and also the time taken for te operation is improved.

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