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A Comparison and Implementation of ZN, ISE, IMC and ITSE Tuning Methods for PID Controllers

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Abstract

Either due to uncertainty or external or internal disturbances, a system may become unstable, or if it is already unstable then to make it stable, we require to design a controller. In this paper, four methods to achieve controller tuning parameters are implemented and compared with each other and some results are achieved after implementation. Ziegler Nichols, Iterative square error, Integral mode control and *integral of Time Multiply Squared Errormethods are implemented in Matlab software and results are achieved and time domain specifications are compared. Three of the mentioned methods are minimum error criteria methods.*

Key Words: Tuning; minimum error criteria; controller; stability; ZN; ISE; IMC; ITSE

Introduction

A controller may be either analog or digital. Analog controller consist of operational amplifier as well some combination of Resistor and capacitor. Controller is basically a PID and for this we need to find its tuning parameters. After finding this tuning parameters, we are constructing a transfer function of controller, and keeping this controller in series with plant, a combined equivalent transfer function is obtained and system response is observed which must be stable and percentage of this stability depends on accuracy of method for particular type of a plant.

Controller is given by a standard equation as

$$G_c(s) = K_p(1 + \frac{1}{TiS} + T_D S)$$

K_p = Proportional gain
T_i = Integral time
T_D = Derivative time

Algorithm

ZN Tuning method

This method is most popular method among the all. In this method Gain margin, Phase margin and Gain crossover frequency is obtained from given system. And from given equations, tuning parameters are obtained as below.

$K_u =$ Gain margin;
T_u= 2*(Phase margin)/(Gain crossover frequency);

For P-controller

$$K_p = \frac{K_u}{2}$$

For PI-controller

$$K_p = \frac{K_u}{2.2}$$

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$$K_i = \frac{T_u}{1.2}$$

For PID-controller

$$K_p = \frac{K_u}{1.7}$$

$$K_i = \frac{T_u}{2}$$

$$K_d = \frac{T_u}{8}$$

ISE Method

Integral of the square value of the error (ISE)

$$ISE = \int |e^2(t)|\, dt$$

IMC Method

In this method a basic assumption for model is assumed as given from below equation. The system is modelled as

$$G(s) = m\,\frac{e^{-sL}}{1+sT}$$

A tuning parameters from this equation is obtained from below equations. A parameters obtained is used to design PID controller. When the model parameters are unknown then they can be obtained from open loop step response.

$$K = \frac{(2T + L)}{2m(Tf + L)}$$

$$T_i = T + \frac{L}{2}$$

$$T_d = \frac{TL}{(2T + L)}$$

Here T_f is considered as a design parameter which can be varied to obtain a fast and desired response.

ITSE Method

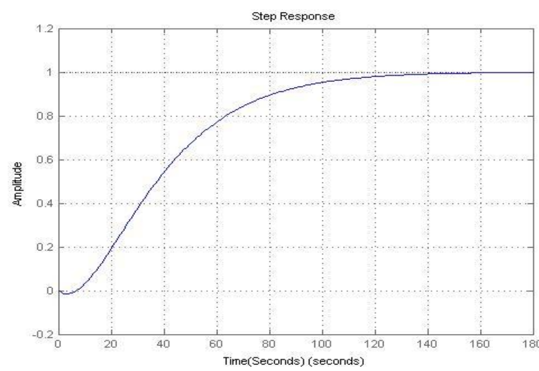
Integral of Time multiplied by the Squared Error

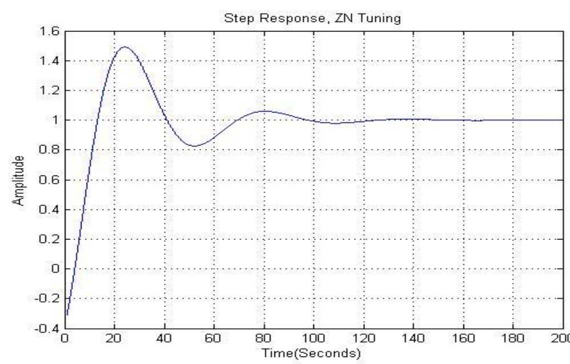
$$ITSE = \int te(t)^2\, dt$$

Here,$e(t)$ is the error signal in time domain.

Example 1 For System with negative zero

$$G1(s) = \frac{(1 - 4s)}{(18s + 1)(1 + 22s)}$$





ZN	5.8824	18.8494	4.7123
ISE	4.9365	47.8304	7.5643
IMC	2.3076	36.0678	5.8763
ITSE	7.2319	27.5363	13.689

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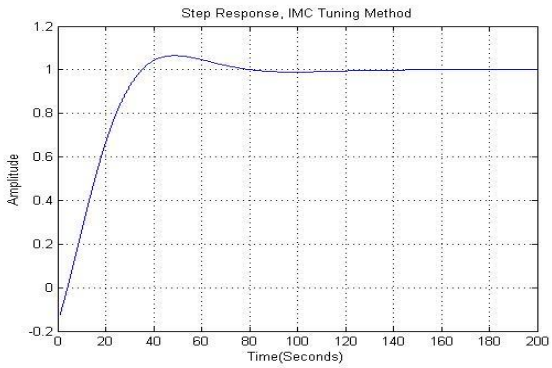
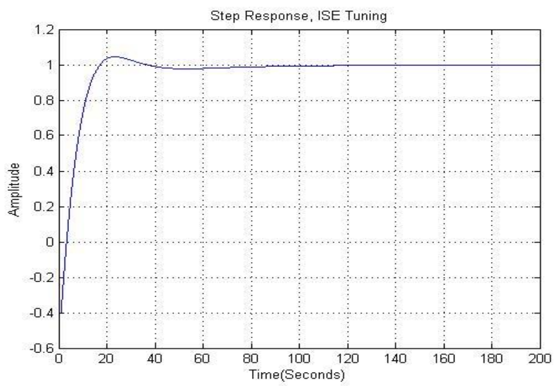
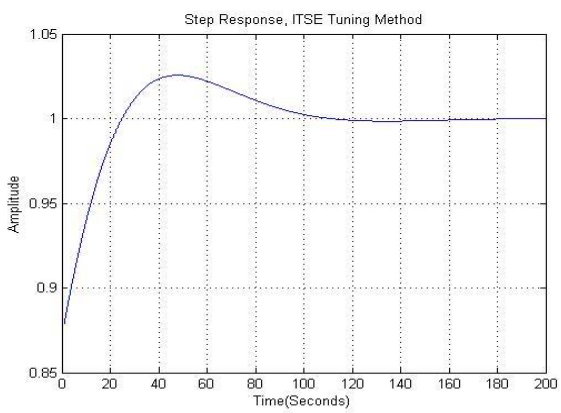
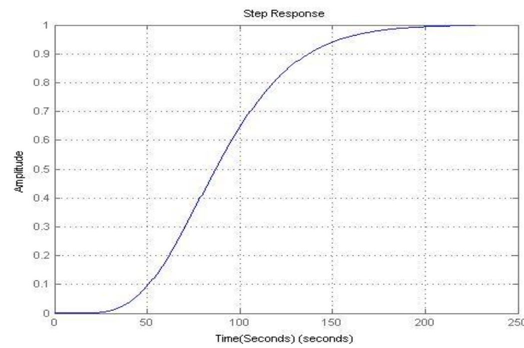
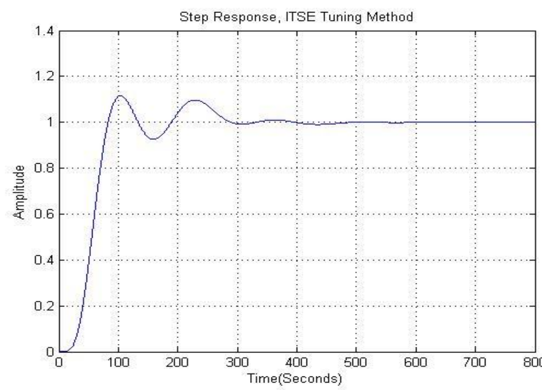
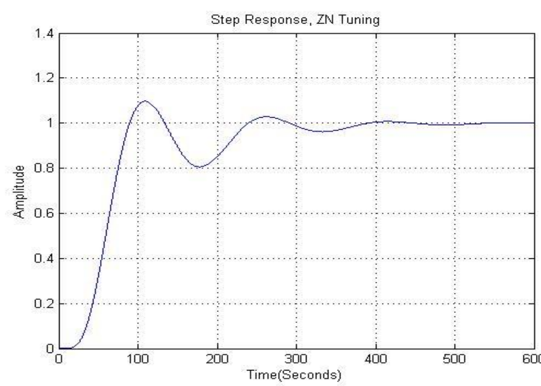








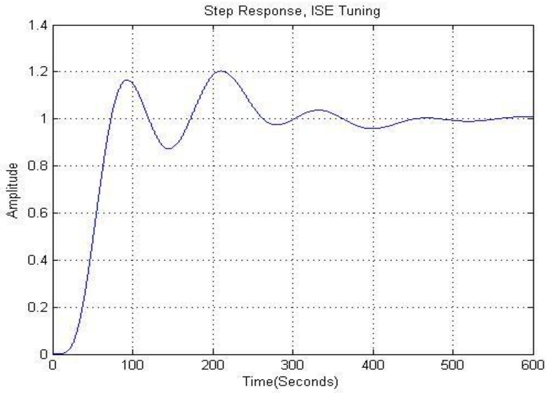


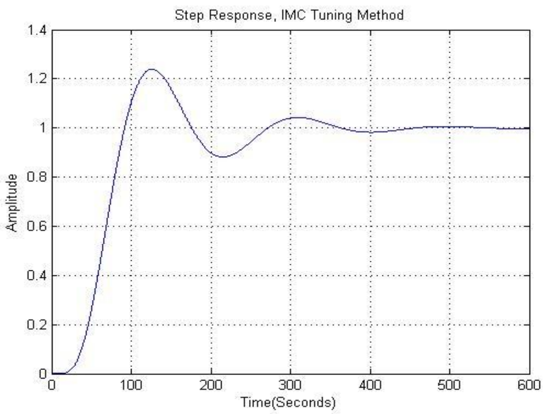


Method	Kp	Ti	Td

Example 2 For Higher order system

$$G2(s) = \frac{1}{(13s+1)^7}$$

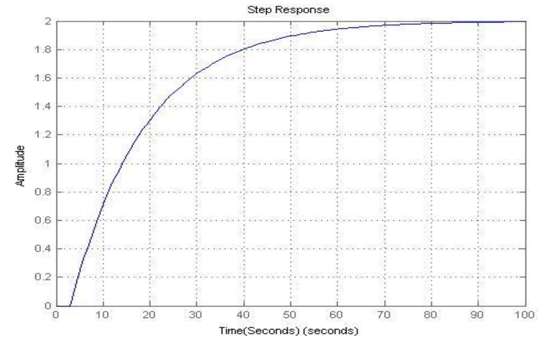


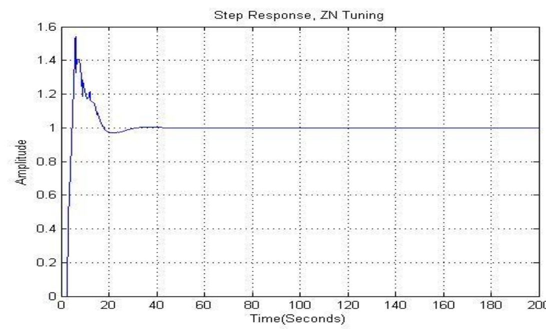


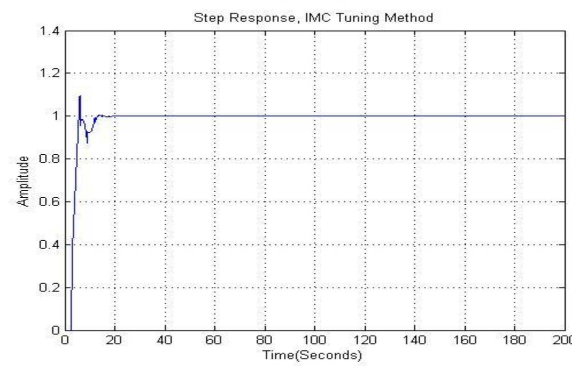
Method	Kp	Ti	Td
ZN	1.2200	84.8394	21.2099
ISE	1.0785	42.5345	45.0472
IMC	1.1563	63.6060	15.5549
ITSE	1.0854	52.4030	33.1242

Example 3 For Exponential system with some dead time

$$G3(s) = \frac{2\ exp^{-3s}}{(16s + 1)}$$







Method	Kp	Ti	Td
ZN	2.6545	5.6039	1.4010
IMC	2.1021	17.0830	1.4413

Conclusion

From the first example we can conclude that among all four mentioned methods, ISE method is best suited because it gives optimal parameters like low rise time, settling time and peak overshoot. For second example, ZN tuning method is best suited because it gives low peak overshoot and settling time as well compromise of rise time between ZN and ISE method and overall ZN tuning method is better suited. For last one example IMC method is better suited as it has low peak overshoot and low settling time.

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