Performance of Rotary Inverted Pendulum by Different Tuning Methods in PID Controller

S. Arumuga Raj, S. Dhanush, P. Balachandran, G. Gailainathan, R. Muniraj

Abstract**:** ***Now a day's is over intelligent system is well developed to produce a complicated technique for sensible management systems .Modern world the technology is developing faster .The system has to different control techniques and various theories are updated faster. Now here control analysis of various pendulums especially cart pendulum, rotary(furuta) inverted pendulum in various techniques like Proportional Integral and Derivative controller using some different tuning techniques like Ziegler Nichols method, Direct synthesis method, pole placement method, Cohen Coon method, Internal Model Controller method. They are several tuning method are available, but we are chose to three method. The analysis of various problems from various sources and simulated it in MAT LAB. We are measure the raise time, settling time and peak over shoot. In simulation result is compare to the theoretical calculation.***

Keywords **:** ***PID, rotary inverted pendulum, NI ELVIS, Ziegler Nichols(ZN), Cohen Coon(CC), Internal Model Controller(IMC).***

I. INTRODUCTION

Rotary Inverted pendulum is the fundamental and very interesting problems in the area of control system. Proportional, integral and by-product (PID) controllers area unit the foremost wide used controller in method industries thanks to their simplicity, lustiness and in sensible applications several standardization ways area unit projected for inflammatory disease controllers. Our purpose during this study is comparison of those standardization ways victimization simulations. Integral of absolutely the price of error has been used because the criterion of comparison. The system consists of encoder pendulum arm, output pendulum gear, encoder and dc servo motor. Proportional, integral and by-product (PID) actions become commercially offered and gained widespread industrial acceptance. This succeed is also a results of the many smart options of this formula. Many alternative standardization ways area unit projected for gaining higher and a lot of acceptable system response supported our fascinating management objectives like pc of overshoot integral of definite quantity of the error, sinking time, during this study we've compared the performance of many standardization ways. The hardware systems we are going to use are QNET 2.0 Rotary inverted pendulum board for national instrument ELVIS. The national instrument educational laboratories of virtual instrumentation suite present a modular teaching platform suitable for control engineering laboratory. Initially inverted pendulum models and mechanism are used to describe the rockets at take-off. The rocket take-off is very complex. Otherwise, the inverted pendulum requires a continuous correction, because the system is unsteady and open-loop design. The rotary pendulum can be use to a mimic gantry crane. The support crane is a crane where the load hangs from a trolley.

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There are unit range of a technique be enforced for the controller style supported stability criteria of Cohen & Coon, 1953; Karl Waldemar Ziegler and Nichols, 1942, synthesis technique of Smith and Corripio, 1985, open loop transfer function perform technique (Haalman, 1965), pole placement technique (Clement & Chidambaram, 1997) and IMC controll technique(Rivera, Morari, and Skogetad, 1986; Wang, Hang, and Yang, 2001) unmoving heap of highly developed management algorithm that increase the performance of the system underneath bound constraint. Cohen and Coon style a technique with the inflammatory disease controller parameters determined supported a FOLPD model. The most style demand is that the rejection of load disturbances. The controller parameter settings area unit given. Despite a much better model, the results of the Cohen Coon technique are not much better than the Karl Waldemar Ziegler Nichols technique.

II. HARDWARE DESCRIPTION

The hardware systems we are going to use are "The Quanser QNET 2.0 Rotary Inverted Pendulum Board for NI ELVISII". The brief description about the kit is below.

The quanser QNET 2.0 Rotary Inverted Pendulum board for national instrument ELVIS II, is a flexible servo system considered to teaching and express a variety of pendulum-based experiments. The model is determined employing a dc-drive 18 V brushed direct current motor. It makes a hard aluminum structure. Two encoders are used to calculate the angular position of the direct current motor and pendulum. compacted and absolute a servo mechanism for national instrument ELVIS II (+) , 18V direct current brushed DC motor, Encoders fixed on DC motor and pendulum,

Built-in PWM amplifier, Build-in a PCI connector for NI ELVIS II (+).

A. Encoder: The encoders are used to calculate the angular position of the direct current motor and the pendulum of QNET Rotary inverted Pendulum are single ended optical shaft encoders. They output 2048 counts per revolution in qudrature mode. The encoders are use to compute the angular position of the direct current motor and QNET Rotary Pendulum. The optical shaft encoders are used in a rotary inverted pendulum.

B. DC Motor: The QNET Rotary Pendulum include a DC motor 18V brushed direct current motor house in a hard aluminum frame. QNET Rotary Pendulum incorporate an allied Motion CL40 Series ironless direct current motor model 16705.

C. Power Amplifier: The QNET Rotary Pendulum circuit card includes a pulse with modulation, voltage-controlled power amplifier. It's able to provide that 0.5A endless I and 2A end current. Rotary inverted pendulum output voltage range between ±10 V. Status LED: The QNET Rotary inverted Pendulum is fixed with a multiplicity of security actions that use the Status LED for feedback. In particular, two digitals enable lines (one high, one low) are used.

D. System Model: System model is the one of the important element .It is require to the physical data of the system. Really the system is not described for the physical data. Step signal are used in the system. Consider the FOPTD model. Step signal are used to the determination of steady state gain, td delay time maximum overshoot, settling time.

C(s)/R(s)=2.2*e-s/(40.48s+1)

III. PID CONTROLLER

The Proportional Integral Derivative controller is measured to an excessive shape of a phase lead-lag compensator. It's single pole at the origin. The model Proportional Integral Derivative controller is also known as the three important terms. The model Proportional Integral Derivative controller is parallel form is given by

$$G(s) = Kp + Ki\frac{1}{s} + Kd\,S \qquad (1)$$

The Ideal form is

$$G(s) = Kp\,(1+\frac{1}{T_i}S+Td\,S) \qquad (2)$$

K_p = Proportional gain,

K_i = Integral gain,

K_d = Derivative gain,

T_i = Integral time constant,

T_d= Derivative time constant.

The important terms of a Proportional Integral Derivative controller are,

- ✓ Proportional conditions are provided that an in general control action proportional to the tracking fault of a system. The signal through the all pass gain factor.
- ✓ Integral conditions are decreasing the SS state errors through the low frequency compensation by an integrator.
- ✓ Derivative terms are improving the transient response during the high frequency compensation by a differentiator.

IV. PID TUNING METHOD

A. Ziegler and Nichols tuning method:

ZN method are introduced to Ziegler and Nichols in 1942. This method are called in otherwise closed loop method. The (K_p) propational gain is increased and it's produces oscillations. It is marginally stable.

Ziegler Nichols Tunning Parameters

Controller type	K_c	T_i	T_d
ZN-PID	0.6Ku	0.5Pu	0.125Pu

B. Cohen and Coon tuning method:

CC method are introduced to Cohen and coon in the year 1953. Cohen Coon method makes the use of first order plus deley time model. It is open loop method and based on the first order plus deley time model.The tunning parameters of the model is shown in the given table ,

Controller type	K_c	T_i	T_d
CC PID	$\frac{t_p}{k_p\theta}[\frac{4}{3}+\frac{\theta}{4t_p}]$	$\theta[\frac{32+\frac{6\theta}{t_p}}{13+\frac{8\theta}{t_p}}]$	$\frac{4\theta}{11+\frac{2\theta}{t_p}}$

C. Internal Model Controller tuning meethod:

IMC control strategy is created by a Garcia and Morari. It's apparent structure of the control stystem and design& tuning. Propational Integral Derivative controller is the standard feedback structure.

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This controller design based upon the method of transfer fcn.Tuning parameter depend upon the time delay & time constant.

Controller	K_c	K_i	K_d
Integral model controller-PID	$\frac{1}{K_p}[\frac{t_p+\frac{\theta}{2}}{\lambda+\frac{\theta}{2}}]$	$t_p+\frac{\theta}{2}$	$\frac{t_p\theta}{2t_p+\theta}$

V. IMPLEMENTATION OF PID TUNING METHODS

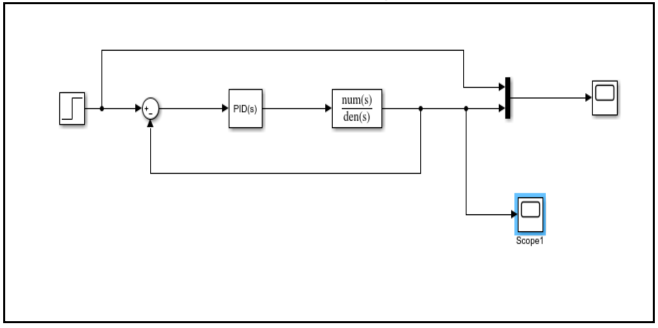
Controller parameter of each tuning method is calculated and the three methods are simulated and compared using MATLAB package. Three tables are indicating the controller parameters of each tuning method. The step response is the input of three tuning method. Figures are shows the output of the three methods.

Controller Tuning Parameter

Tuning Parameter	Kc	Ti	Td
ZN	3.458	2.873	0.719
IMC-PID	2.68	5.702	0.745
CC	2.34	4.612	0.744

Simulation diagram

Simulation diagram

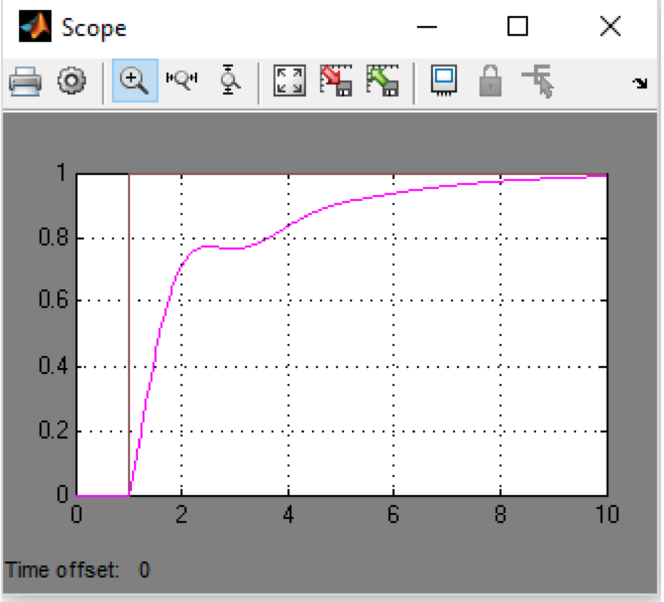


VI. RESULT AND DISCUSSION

Three tuning method are simulated and the time domain specification of settling time, raise time, peak over shoot are considering the simulated response. The tables and the graphs are representing the output of three tuning methods.

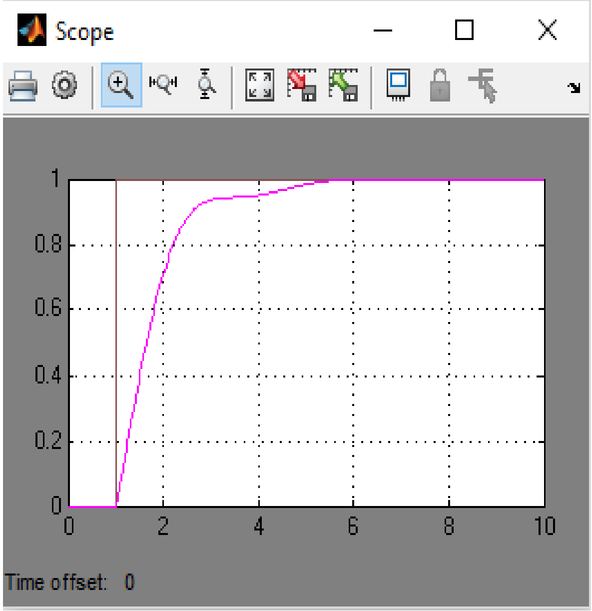
Ziegler Nichols method

Settle time (sec)	Peak Over Shoot	Peak Overshoot%	Rise time (sec)
9	2.44	52.7	0.7



Cohen Coon Method

Settle time (sec)	Overshoot	Peak Overshoot %	Raise time (s)
6	1.5	12	0.85



Internal Model Controller Method

Settle time (sec)	overshoot	Peak overshoot	Raise time (sec)
6	No	0	0.9

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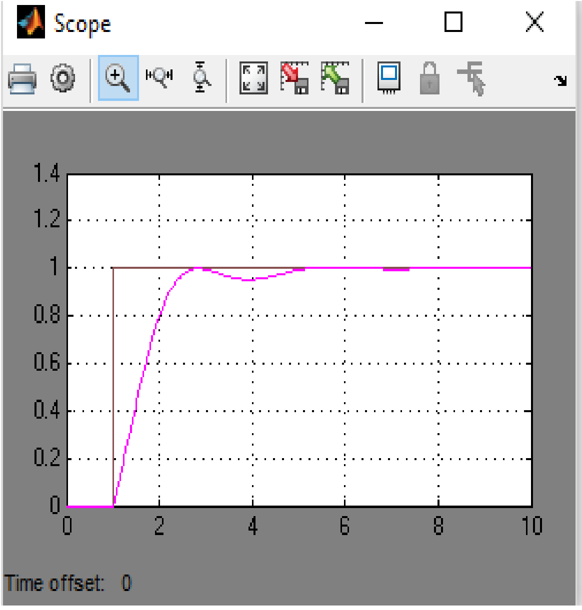

VII. CONCLUSION

There are three tuning methods are Ziegler Nichols ,Internal Model Controller and Cohen Coon method was calculated and applied. Simulation results show that the settling time for integral model controller is less than the Ziegler Nichols and Cohen Coon tuning methods. The simulation and experimental result that integral model controller -PID tuning method have no overshoot but Ziegler Nichols and Cohen Coon has 52.7% and 12% peak overshoot. The integral model controller tuning method is utilizing for proportional integral controller tuning. The real time completion of set-point tracking shows that the integral model controller tuning method is utilizing for proportional integral controller tuning perform better than Ziegler Nichols and Cohn Coon tuning methods.

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