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Altitude Autopilot System Comparison using PID

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Abstract

The aim of this paper designs an autopilot of aircraft on the basis of control with PID control, and is used to determine the control method. To apply control with PID control method, it has been a model for the journey with the console mode. Is derived from the transfer function is determined using a short period of time, through transfer function equation aircraft. Control with PID control with values that maintain a stable system of any change in the value of the controller. The system was designed and tested to ensure the stability of the autopilot system, using. MATLAB SIMULLINK blocks in two different scenarios to assess the stability of the system design.

Keywords: *Autopilot of aircraft, PID controller, flight system.*

1. Introduction

The overall structure of the control system in flight operations has changed dramatically over the years. Shortly after the first flight of the articulated surfaces were introduced to control the basic operation aeronautics, operated by the pilot through a system of cables and pulleys that. This technique has survived over a period of time, and now is still used in small aircraft.

Making it the largest size of the planes enter and increase the weights trip to increased effort muscular pilot, which makes pilot loses control in moments of air stops may be on the surface deflection; it was the first solution to this problem is the introduction of air balances and signs, but continue to grow in the aircraft and weights sizes in flight brought to the need for operating systems to control air articulated surfaces [1].

An autopilot is system used to control the trajectory of an aircraft without constant 'hands-on' control by a human operator being required.

An autopilot do not replace a human operator, but assist them in controlling the vehicle allowing them to focus on broader aspects of operation, such as monitoring the trajectory, weather and system[2].Autopilots are used in aircraft (known as self-steering gear) spacecraft, missiles and other. Autopilots have evolved significantly over time, from early autopilots that merely held an attitude to modern automated landing under the supervision of pilot. The autopilots system on airplanes is sometimes colloquially referred to as "George" [3].

Fight control is classical control system such as (PID controller, root locus, and feedback…..etc). Or modern control system such as (Adaptive, optimal, and Robust) .It can also be controlled using Artificial intelligence system such as (ANNs, and Robot….etc).

2. A Proportional Integral Derivative Controller

A proportional _ Integral_ derivative controller (PID controller) is a control loop feedback mechanism (controller) commonly used in industrial control system. A PID controller continuously calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error over time by adjustment of a control variable, such as the position of a control valve, a damper or the power supplied to a heating element, to a new value determined by a weighted sum:

$$\cup(t) = k_p e(t) + k_i \int_e (t) + k_d \, {}^{de}/_{dt}$$

Where k_p, k_i and k_d all non_ negative, de not the coefficients for the proportional, integral and derivative terms, respectively (sometimes denoted P, I and D).In this model [4] and [5].

CL Response	Rise time	Overshoot	Setting time	S_S error
k_p	Decrease	Increase	Small change	Decrease
k_i	Decrease	Increase	Increase	Eliminate
k_d	Small change	Decrease	Decrease	Small change

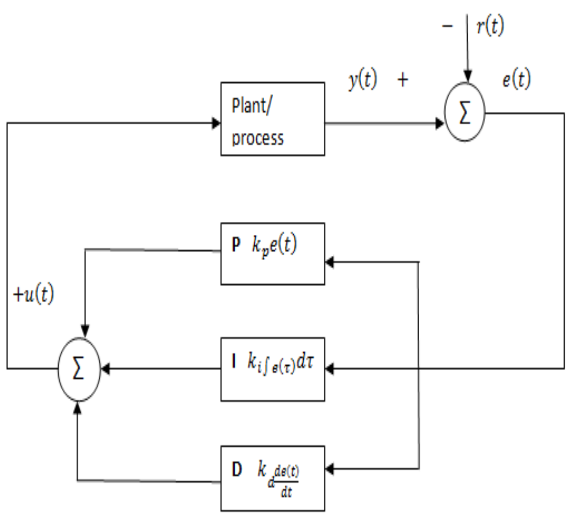

Figure 1: A block diagram of a PID controller in a feedback loop

3. Longitudinal Motion Equations and Transfer Functions

To obtain the transfer function of the aircraft it is first necessary to obtain the equations of the motion for the aircraft. The equations are derived by applying Newton's law of motion, which relate the summation of the external forces and moments to the linear angular accelerations of the system or body. To make this application, a certain assumption is needed and an axis system should be defined. This results in considering the three longitudinal motion equations 1, 2, and 3 which represent the aircraft elevator movements [6-7].

$$(13.78s + 0.088)\acute{u}(s) - 0.392\,\acute{\alpha}(s) + 0.740\,(s) = 0 \quad \ldots(1)$$

$$1.48\,\acute{u}(s) + (13.78s + 4.46)\acute{\alpha}(s) - 13.78s\theta(s) = -0.24\delta e\,(s) \ldots(2)$$

$$(0.0552s + 0.619)\acute{\alpha}(s) + (0.514s^2 + 0.192s)\theta(s) = -0.710\delta e\,(s) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where:

α: is the angle of attack
θ: is the pitch attitude angle
δe: *is the elevator deflection*

4. Derivation of the Short-Period Transfer Function of the Jet Aircraft

The short-period oscillation almost occurs at a constant forward speed, therefore $\acute{u}$ equals to zero in the equations of motion. Equation (1), which represents the motion in X direction, can be neglected, since it doesn't contribute much to the short period oscillation. Then the new equations of motion can be written as:

$$(13.78s + 4.46)\acute{\alpha}(s) - 13.78s\theta(s) = -0.24\delta e(s) \ldots\ldots(4)$$

$$(0.0552s + 0.619)\acute{\alpha}(s) + (0.514s^2 + 0.192s)\theta(s) = -0.710\delta e\,(s) \ldots\ldots\ldots\ldots(5)$$

And the transfer function could be evaluated as follows:

$$\frac{\theta(s)}{\delta e(S)} = \frac{\begin{vmatrix} 13.78s + 4.46 & -0.246 \\ 0.0552s + 0.619 & -0.710 \end{vmatrix}}{\begin{vmatrix} 13.78s + 4.46 & -13.78s \\ 0.0552s + 0.619 & 0.514s^2 + 0.192s \end{vmatrix}} \ldots(6)$$

The Expansion of the transfer business jet aircraft is:

$$\frac{\theta(s)}{\delta e(s)} = \frac{-1.39(s + 0.3.06)}{s(s^2 + 0.805s + 1.325)} \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

5. Autopilot System Modeling and Design

The basic components of a pitch attitude control system are shown in Figure 2. The system is composed of PID controller, amplifier, elevator servo and the block of the aircraft dynamics.

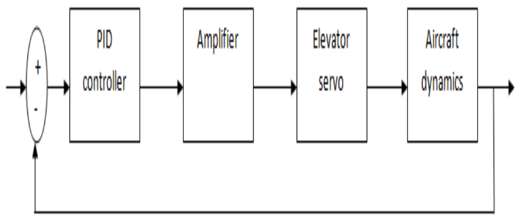

Figure 2: Pitch Displacement Autopilot General System

In this study the reference pitch angle is compared with the actual angle measured by a gyro to produce an error signal, this signal is amplified and sent to activate the elevator servo which causes the deflection of the control surface (the rudder in this case). The movement of this part forces the aircraft to achieve a new pitch orientation, which is fed back to close the loop.

To build the complete system of the aircraft the transfer function of each element in Figure2 needs to be defined. The transfer functions of the gyro and amplifier are represented by a single gain k. the elevator servo transfer function can be represented by the first-order system:

$$\frac{\delta e}{v} = \frac{Kg}{Ts+1} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (8)$$

Where:

δe is the deflection angle of elevator

V is input voltage

Kg is elevator servo gain

T is the servo time constant

In this research the value of the servo time constant is chosen to equal 0.1 seconds for the same aircraft model transfer shown by equation (7)

As for the transfer function representing the compensator must be designed, and before that bode plot for the un PID controller system is taken to determine the design requirements. Figure (3) is the bode diagram for the uncompensated control system

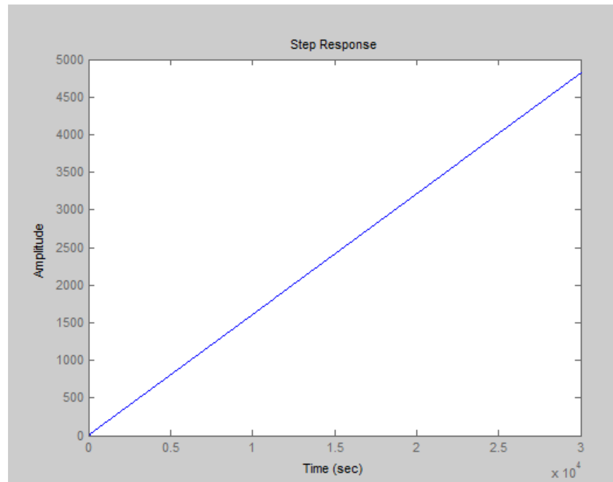

Figure 3: Step response the Uncompensated open loop control system

Found in the response of system that the system is not stable and there are very high overshoot and setting time in it, so we should choose certain values for PID as shown in table, so we should define the value of **P** and we found it equal **1.6**

$$\frac{kd\,s^2 + k_p s + k_i}{s}$$

$$\frac{1.6s^2 + s + 1}{s}$$

Substituting the transfer function of each element and with amplifier gain equal to2.3 volt has resulted in the block diagram shown in figure (4)

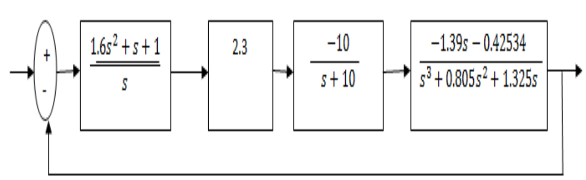

Figure 4: Aircraft Autopilot system

6. Simulation Result and Stability Discussion

To make sure that the designed system meets the target response, the system was simulated and tested using SIMULINK bocks in MATLAB.

Case1: Un PID controller

In case 1 the system has been simulated without the PID controller, as it seen from figure (5) the system is only composed of the servo and the aircraft dynamic with amplifier gain **2.3** volt. The display unit in the most top right show a negative value for step input which indicates totally instability case which is also apparently seen in figure (6).

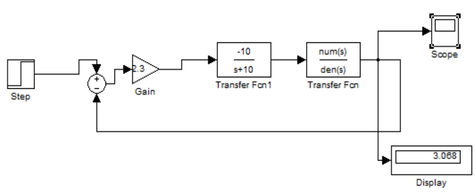

Figure 5: Simulation of the system with Un PID controller

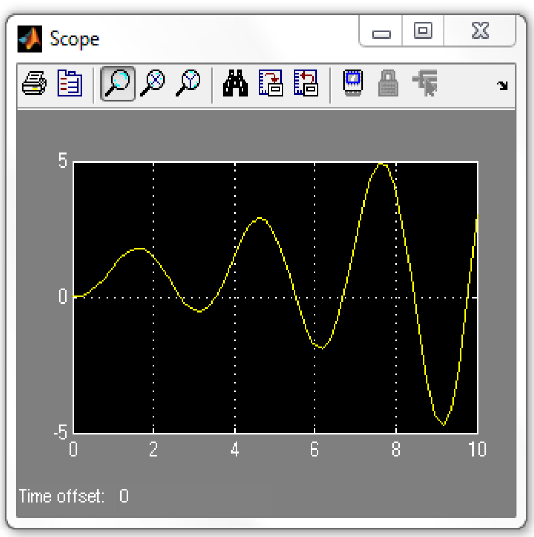

Figure 6: step response for the Un PID controller closed loop system case

Case 2: Fully system

In this case the PID controller has been used with the equation $\left(1.6s^2 + s + 1/_s\right)$ as it had been derived earlier. The system output for a given step response is shown in figure (7) with a positive value on the display unit which indicates to stability case, meanwhile the graph in figure (8) confirms the system is completely stable and the reason behind that is the PID controller that keeps the aircraft stable and in the desired trajectory against any change or perturbations that may occurs.

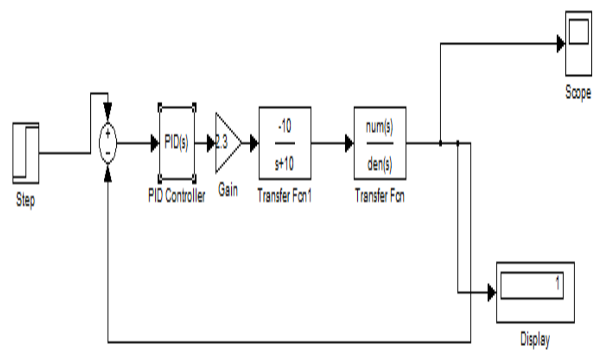

Figure 7: Simulation of system with PID controller

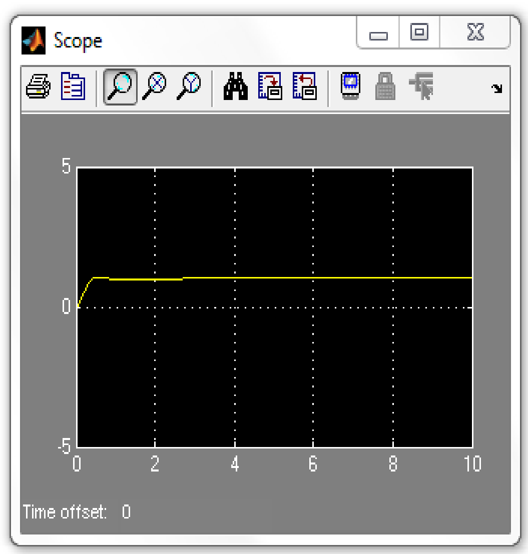

Figure 8: Step Response for PID Controller System Case

7. Conclusion

From the results above simulation and discussion shows that the aircraft system only stable when fully stable control, the status of one the system is unstable due to the lack of unity PID control, while in case2 consists of a system and fully compensate amplifier with gain equal to 2.3 volts the system damped large and the stability was sustained.
So it may apply autopilot aircraft in hardware system according case2's. The resulting response satisfactory to the dynamics of the aircraft.

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