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DESIGN OF AUTOMATIC PID GAIN SCHEDULING FOR FIXED WING UNMANNED AERIAL VEHICLE

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ABSTRACT

This research paper presents automatic gain scheduling for fixed wing unmanned aerial vehicle using Zeiher Nicholas approach. Presently there is a rapid development in unmanned aerial vehicle because of its various applications. The critical factor in the autonomous is Tuning of the PID loop. Improper tuning of loop gain may crash UAV platform, Here, the Proposed tuning method to estimate its required PID gain by means of dynamic response from the system. So, it is adapted to all kind of platforms, and it not required for making the complete mathematical model to calculate the required gain. An unmanned aerial vehicle does not require an external operator for tuning the gain. An experienced and skilled person is needed for tuning an autopilot in manual. In normal PID tuning, the autopilot gains are tuned by trial and error method or by means of making complete dynamics of the system. It consumes more time to make the complete dynamics of the system and its gain value. Aircraft Control Algorithm for the three axis system is designed by using relay test and Ziegler Nichols tuning technique. For continuous increase in the proportional gain of a closed loop system becomes oscillate. At particular proportional gain value the system oscillate with constant amplitude and time period. While substituting ultimate gain value and corresponding time period for the Ziegler Nichols formula system will be stabilized. Here due to the more oscillation in the tuning value system will be more unstable. To avoid that relay test was introduced for the system loop. It will reduce the unstable condition for the system.

Keywords: Autopilot Systems, Gain Scheduling, Unmanned Aerial Vehicle (UAV)

I. INTRODUCTION

The gain-scheduling approach is perhaps one of the most popular nonlinear control design approaches which has been widely and successfully applied in fields ranging from aerospace to process control. Despite the wide application of gain-scheduling controllers and a diverse academic literature relating to gain-scheduling extending back nearly thirty years, there is a notable lack of a formal review of the literature. Moreover, whilst much of the classical gain-scheduling theory originates from the 1960s, there has recently been a considerable increase in interest in gain-scheduling in the literature with many new results obtained. An extended review of the gain-scheduling literature therefore seems both timely and appropriate. The scope of this paper includes design procedures relating to automatic gain-scheduling for an unmanned aerial vehicle. Gain scheduling has over the years been widely used for aircraft flight control for two reasons: (1) It allows the designer to use a suite of linear control design tools that are powerful and well understood, and (2) Flight control clearance and certification procedures are usually based on linear methods. However, gain scheduling has had its share of problems as well, mainly due to its ad hoc nature.

II. UNMANNED AERIAL VEHICLE

The term UAV is an abbreviation of Unmanned Aerial vehicle, meaning aerial vehicles which operate without a human pilot. UAVs are commonly used in both the military and police forces in situations where the risk of sending a human piloted aircraft is unacceptable, or the situation makes using a manned aircraft impractical.Currently, UAVs are most often used for the following tasks:

Aerial Reconnaissance – UAVs are often used to get aerial video of a remote location, especially where there would be unacceptable risk to the pilot of a manned aircraft. UAVs can be equipped with high resolution still, video, and even infrared cameras. The information obtained by the UAV can be streamed back to the control center in real time.

Scientific Research – In many cases, scientific research necessitates obtaining data from hazardous or remote locations. A good example is hurricane research, which often involves sending a large manned aircraft into the center of the storm to obtain meteorological data. A UAV can be used to obtain this data, with no risk to a human pilot.

Logistics and Transportation – UAVs can be used to carry and deliver a variety of payloads. Helicopter type UAVs are well suited to this purpose, because payloads can be suspended from the bottom of the airframe, with little aerodynamic penalty.

III. AUTOPILOT

In order to fly an unmanned aerial vehicle autonomously, all the 3-axis of an unmanned aerial vehicle need to be leveled and trimmed. In general an autopilot is an electrical, mechanical or hydraulic system which will guide the unmanned aerial vehicle to fly without intervention from human being. The autopilot may consist of 3-axis accelerometer and 3-axis gyroscope to measure its linear acceleration and angular rotation about its axis. These data's helps to stabilize the unmanned aerial vehicle during engage of its autonomous mode. The autopilot may also able to control additional parameters like heading hold, altitude hold, mach hold and GPS hold. The autopilot accepts guiding and input commands from the RC pilot and moves its control surfaces according through its control law. The desired performance of an unmanned aerial vehicle has been changed by varying its closed loop gain values. To achieve this goal, one needs to use a nested structure for the basic PID controller.

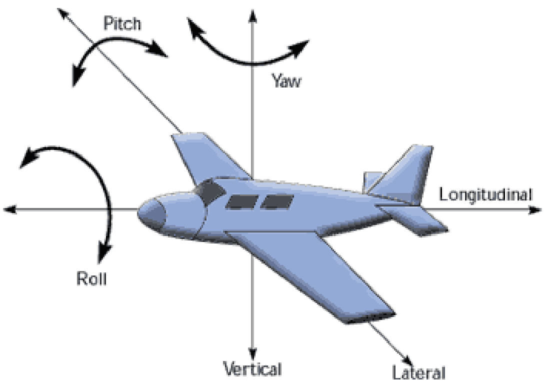

Figure 1 Configuration of Fixed Wing Unmanned Aerial Vehicle

Figure 1 shows the configuration of fixed wing unmanned aerial vehicle. An unmanned aerial vehicle has 6 degrees of freedom in free space. The attitude of unmanned aerial vehicle has been controlled by its control surfaces like elevator, rudder and ailerons. Combinations of these three controls surface deflection enable an airplane to maneuver at any desired orientation in space. The pitch refers to the movement of the unmanned aerial vehicle nose up or down about its longitudinal axis. The roll refers to the moment of the unmanned aerial vehicle wing either in right or left about its lateral axis. The yaw refers to the moment of the unmanned aerial vehicle wing either in right or left about its Directional axis.

IV. CONTROL LAW AND ITS TUNING TECHNIQUES

Figure 2 shows the block diagram of closed loop aircraft control system
The aim of the controller tuning is system should behave fast response and good stability. Unfortunately, for most practical processes being controlled with a PID controller, these two wishes can not be achieved simultaneously. In other words: 1) The faster response, the worse stability, and 2) The better stability, slower responses. For control system it is important that it has good stability than being fast so it should be Acceptable stability. Here three important tuning techniques are discussed. Such as Ziegler Nichols technique, Ultimate gain technique and relay test.

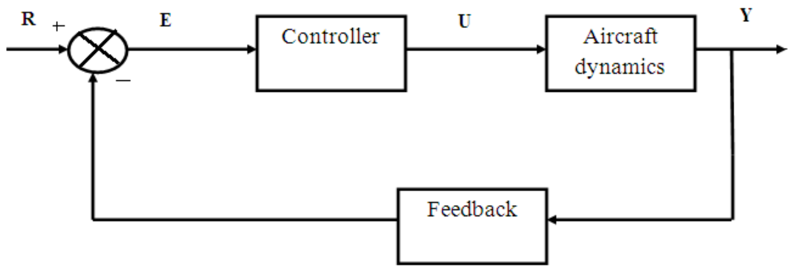

Figure 2 Block Diagram of a closed loop aircraft control system

V. ZIEGLER NICHOLS TECHNIQUE

Ziegler-Nichols tuning rule would serve as the basis for a coming new generation of PID technology. The time-honored Ziegler-Nichols tuning rule as introduced in the 1940s had a large impact in making PID feedback controls acceptable to control engineers. PID was known, but applied only reluctantly because of stability concerns. With the Ziegler-Nichols rule, engineers finally had a practical and systematic way of tuning PID loops for improved performance. Never mind that the rule was based on science fiction. After taking just a few basic measurements of actual system response, the tuning rule confidently recommends the PID gains to use. The Ziegler-Nichols rule is a heuristic PID tuning rule that attempts to produce good values for the three PID gain parameters:

1. Kp - the controller path gain
2. Ti - the controller's integrator time constant
3. Td - the controller's derivative time constant

Given two measured feedback loop parameters derived from measurements:

1. The period Tu of the oscillation frequency at the stability limit
2. The gain margin Ku for loop stability

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VI. ULTIMATE GAIN

Ziegler and Nichols also described a "closed loop" tuning technique that is conducted with the controller in automatic mode (i.e., with feedback), but with the integral and derivative actions shut off. The controller gain is increased until any disturbance causes a sustained oscillation in the process variable. The smallest controller gain that can cause such an oscillation is called the ultimate gain (ku). The period of those oscillations is called the ultimate period (tu). The appropriate tuning parameters can be computed from these two values.

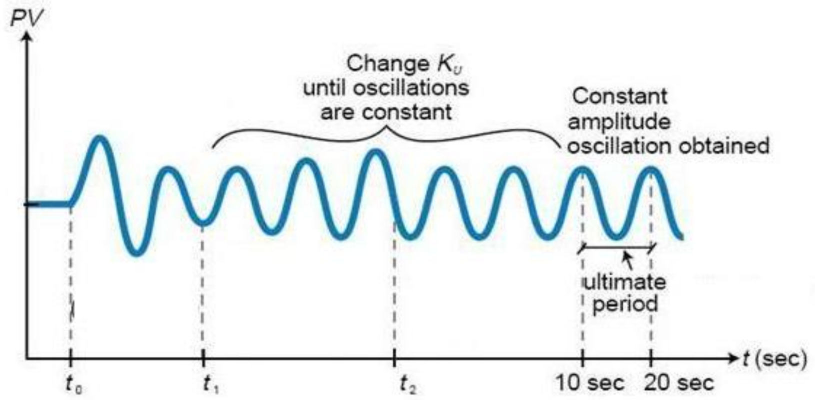

Figure 3 System oscillation responses

From the ultimate gain value and time period the controller predicts its gain value from the below table.

Ziegler – Nichols method			
Control type	Kp	Ki	Kd
P only	0.5Ku	-	-
PI	0.45Ku	1.2Kp/Tu	-
PID	0.6Ku	2Kp/Tu	KpTu/8

Table:1 Formula Ziegler – Nichols method

VII.RELAY TEST

Ziegler-Nichols methods are not a straight forward approach to implement control algorithm in practice. Different type of PID controller's uses different versions of formula. Each must be tuned according to a different set of tuning rules. The rules also change when:

- The controller is not equipped with integral or derivative terms
- The process itself is inherently oscillatory
- The process behaves as if it contains its own integral term
- The process dead time is very small or significantly larger than the process time constant.

For many years, the Ziegler-Nichols methods were strictly manual operations executed. If a new control loop was commissioned an engineer would run a test and tune the loop gain according to the simulated results. It was tedious and repetitive work to commission every loop in the plant and the results weren't always satisfactory for all type of applications and environment. Several iterations has been needed to tune the system as to make stable.

VIII. AUTOMATING THE TUNING PROCESS

The relay method generates a sustained oscillation of the process variable but with the amplitude of those oscillations restricted to a safe range. With all three PID terms temporarily disabled, the controller uses an on/off relay to apply a step-like control effort to the process. It then holds the control effort constant and waits for the process variable to exceed the set point. At that point, it applies a negative step and waits for the process variable to drop back below the set point. Repeating this procedure each time the process variable passes the set point in either direction forces the process variable to oscillate out of sync with the control effort but at the same frequency. Although the process variable's oscillations aren't strictly sinusoidal, their period turns out to be a close approximation of the ultimate period that Ziegler and Nichols used for their tuning rules. And the amplitude of the process variable's oscillations relative to the amplitude of the control effort's oscillations approximates the process's ultimate gain when multiplied by $4/\pi$. So once the ultimate period and ultimate gain have been determined, tuning the loop becomes a simple matter of plugging those two values into the Ziegler-Nichols tuning rules. To identify the ultimate period TU and ultimate gain PU of the process, the control engineer running the test temporarily disables the PID block and replaces it with an on/off relay that forces the process variable to oscillate. Where a denotes the amplitude of the controller's square wave and b denotes the amplitude of the process variable's resulting oscillations. By fixing a relatively small value, the engineer can also limit the value of b and thereby prevent the wild swings that sometimes plague the original Ziegler-Nichols open-loop test.

The critical gain measured from the relay test is

$$\text{Critical gain} = \frac{4a}{\pi b}$$

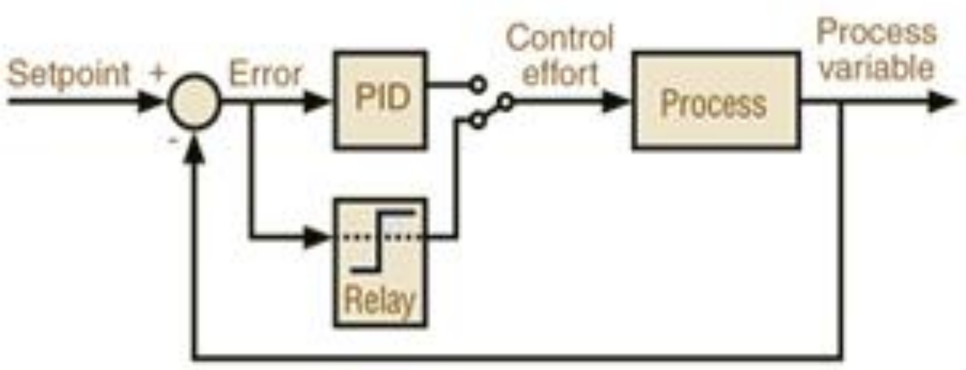

Figure 4 Block Diagram of Relay test

But unlike the original Ziegler-Nichols closed-loop test, the relay test can be configured to limit the amplitude of process variable's oscillations by fixing amplitude of control effort's oscillations at a user-defined value. This allows the controller to force process variable to oscillate just enough to distinguish process's behavior from its measurement noise. The process variable needs not swing so wildly as to endanger the process.

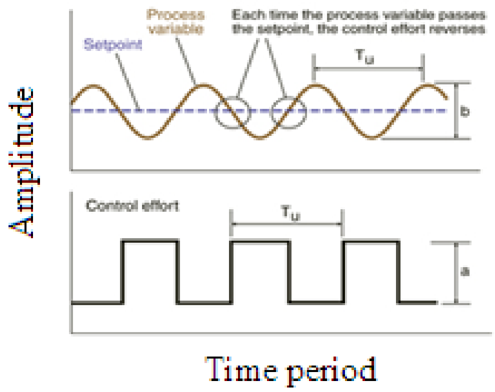

Figure 5 Relay feedback test response

Better still, the controller can be configured to conduct the relay test and tune its loop by autonomously. Theoretically, even an external operator unfamiliar with the fundamentals of tuning theory can press a button and let the controller conduct its own relay test and select its own tuning parameters accordingly. If the resulting closed-loop behavior proves unacceptable, the operator can simply push the tune button again. Forcing the closed loop system into sustained oscillations with a proportional-only controller reveals the process's ultimate gain Ku and ultimate period Tu. Unfortunately, doing so can also cause dramatic and sometimes dangerous swings in the control effort and the process variable.

IX. X-PLANE

X-Plane is an engineering tool that has been used to predict the flying qualities of fixed-and rotary-wing aircraft with incredible accuracy. X-Plane predicts the performance and handling of almost any aircraft and unmanned aerial vehicle. It is a great tool for pilots and students to keep up their currency in a simulator that flies like the real plane, for engineers to predict how a new airplane will fly, and for aviation enthusiasts to explore the world of aircraft flight dynamics. X-Plane is used by world-leading defense contractors, air forces, aircraft manufacturers, and even space agencies for applications ranging from flight training to concept design and flight testing.

X. SIMULATION MODEL

The proposed relay f test has been simulated by using MATLAB SIMULINK and X-plane software. Figure 6 shows the closed loop implementation of relay test using Ziegler Nichols PID approach.

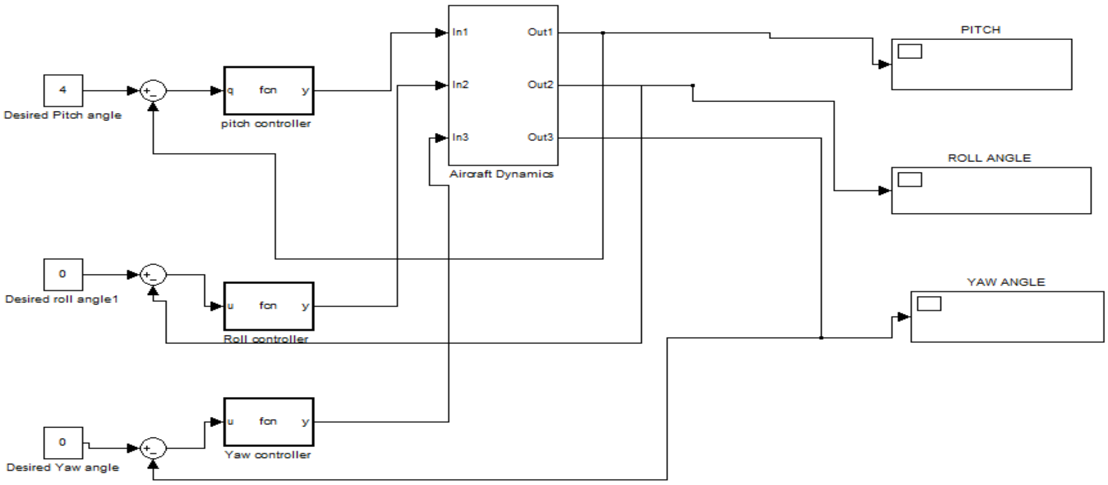

Figure 6 Block diagram representation in X-Plane

While implementing Ziegler Nichols technique for pitch controlled autopilot it may leads to harmful effect to the aircraft structure and actuator. The abrupt oscillations produced by this approach may leads to struck or jam the aircraft actuator. So, precautions have been needed to estimate the systems gain value. In order to Setting the integral and derivative gain values as zero and increasing the proportional gain value (kp) from zero to until it reaches the ultimate gain (ku). Here the following diagram shows that system response for the different proportional gain values.

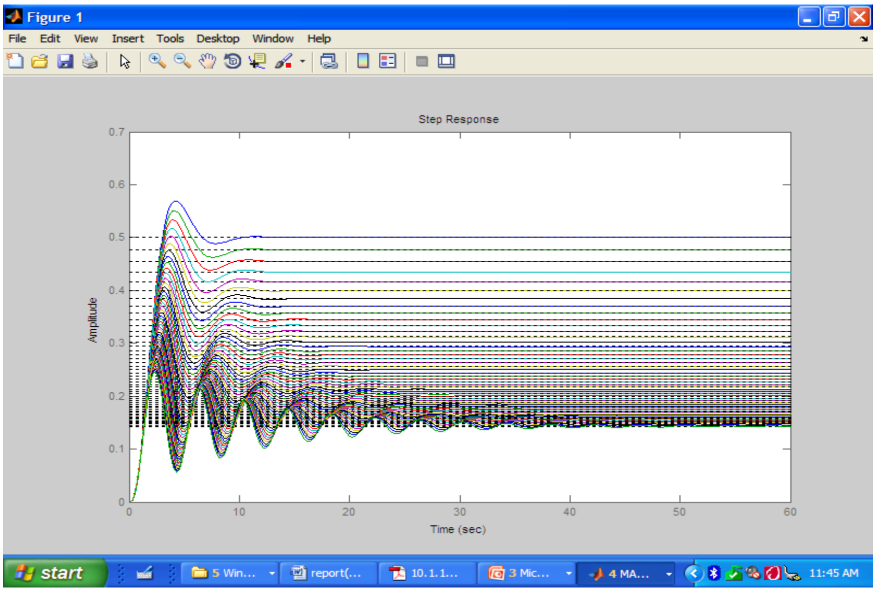

Figure 7 System Response for Different Proportional Gain Value

At particular value the output of the control loop oscillates with constant amplitude.

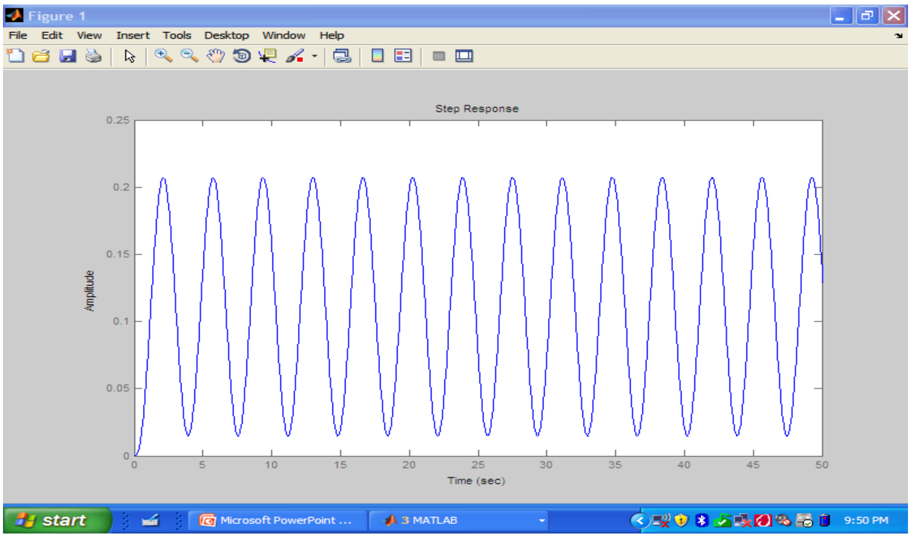

Figure 8 System Oscillates with Constant Amplitude

Calculated ultimate gain value is substituted in Ziegler Nichols formula. Then the system response stabilized output.

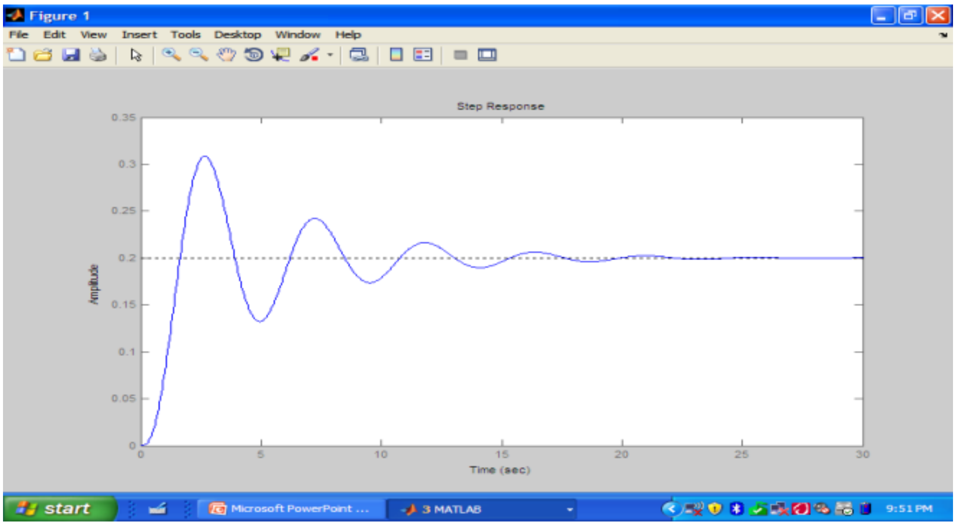

Figure 9 Stabilized system responses for Ziegler Nichols method

It is a simple method to measure critical gain of a closed loop system from its feedback sensors using a relay. Here the set point is directly fed to the system dynamics through its control algorithm. A manual switch in the closed loop system bypasses the input and passes it through a relay. Due to the minimum and maximum set point of the relay, the system will changes its states (on/off) with low time period and subjected to an oscillation. The measuring oscillation time period and amplitude gives a key idea to measure the critical amplitude and critical time period of a closed loop systems.

$$\text{Critical gain} = \frac{4a}{\pi b}$$

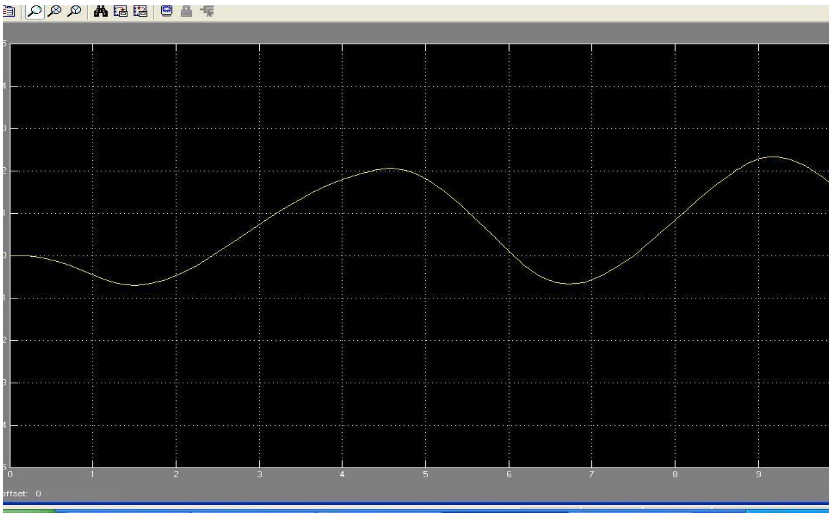

Figure 10 Process variable outputs

From the process variable response amplitude of the process value (b) can be calculated. And relay system gives the control effort amplitude (a) value. The a,b values are submitted to the Ultimate gain equation we get the desired value. Time period (Tu) also calculated from the relay test.

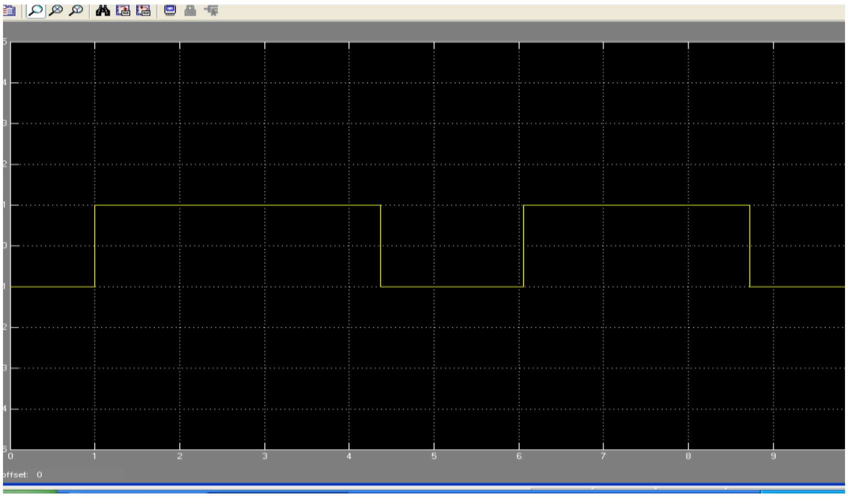

Figure 11 Control effort output

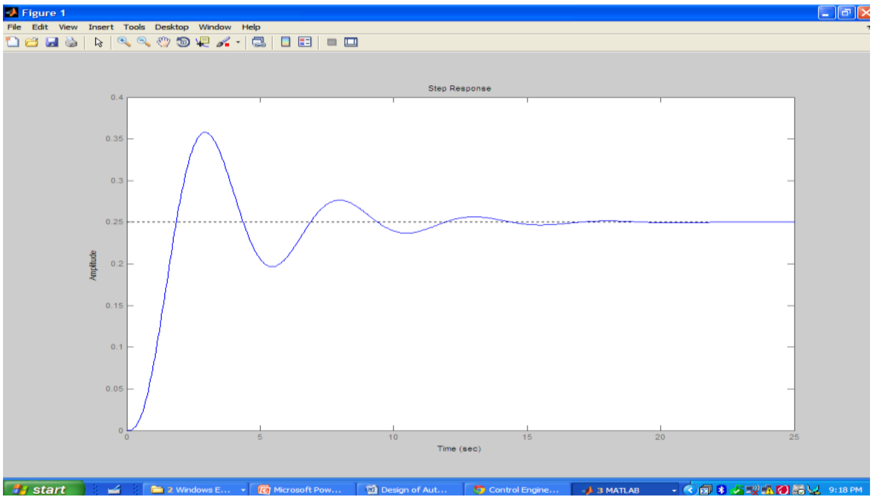

Figure 12 Improved stabilized output after the relay test

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