# THE EFFECT OF WASHOUT FILTER IN DERIVATIVE CONTROL

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## Abstract

This paper presents graphical analysis of washout filter in reducing electrical noise and external noise sources being observed from components of the circuit despite the fact that derivative action is the major cause of the disturbances. Using TecQuipment CE 117 process trainer along with CE2000 software for graphical detail, it shows how the derivative block reacts very quickly to the setpoint change and error produced by applying a short period large output signal to the pump in order to increase the pump speed. The effect of derivative action without the 'washout filter produces increased noise on the derivative block output (D-action output)

**Keywords**: Washout filter, external noise, derivative action, disturbances, set point change

## 1.0 Introduction

Differential (derivative) action is very useful because it responds quickly to the set point change by applying a short period large output signal to the final control element, but it amplifies electrical noise in a control circuit; this can be noise from components of the circuit and also from external noise sources. To reduce the noise amplification, a special 'washout filter' is used with derivative action.

This paper presents the use of washout filter in the derivative control in order to reduce the noise amplification effect of the controller. CE 2000 software, CE 117 process trainer and its mimic panel were used. The graphical analysis was presented with the aid of the CE 2000 software.

### 1.1 Noise effect on the Final control element

Noise is a random source of error within the Process variable (PV) signal. Noise presents a significant challenge for derivative as the additional, excited variability in the PV signal results in equally agitated, derivative-driven responses to the controlled output. Typically the end result is excessive wear and tear on the associated control loop's final control element (FCE). For most practitioners, the cost of accelerating wear and tear outpaces any improvements in control loop performance achieved through the use of derivative.

### 1.2 Derivative controller vs. Process dynamics

Since PV volatility presents practical challenges for derivative the range of industrial applications becomes quite narrow. Suitable loops include those used in temperature control, some used in pH control, as well as others that can be characterized as having a high degree of inertia. The dynamics of such loops are slow and they allow derivative to correct appropriately for error. Most other loops – flow, pressure, level, can be too dynamic such that derivative negatively affects the FCE and other process instrumentation.

### 1.3 Improve loop performance advantage of the derivative term

Whereas tuning a controller using only the proportional and integral terms is relatively simple and straightforward, the addition of derivative makes the process difficult. The addition of a third variable expands the array of possibilities exponentially. As a result, additional testing is usually required which can waste limited resources and result in lost productivity. More often than not the costs outweigh the benefit.

In spite of these challenges derivative can play a meaningful role in improved control loop performance. To assist with evaluating the pros and cons of derivative, various PID tuning software packages simulate the responsiveness of the different forms of the controller (i.e. P-Only, PI, PID, and PID with Filter) and assess the impact on the associated FCE. It's important to note, however, that most control loop tuning software products struggle to accurately model noisy process data that is particularly true of products that apply frequency-based modeling.

## 2.0 Related works

Nowadays, classical washout filters are extensively used in commercial motion simulators. Even though there are several advantages for classical washout filters, such as short processing time, simplicity and ease of adjustment, they have several shortcomings. The main disadvantage is the fixed scheme and parameters of the classical washout filter cause inflexibility of the structure and thus the resulting simulator fails to suit all circumstances. Moreover, it is a conservative approach and the platform cannot be fully exploited. The aim of this research is to present a fuzzy logic approach and take the human perception error into account in the classical motion cueing algorithm, in order to improve both the physical limits of restitution and realistic human sensations. The fuzzy compensator signal is applied to adjust the filtered signals on the longitudinal and rotational channels online, as well as the tilt coordination to minimize the vestibular sensation error below the human perception threshold. The results indicate that the proposed fuzzy logic controllers significantly minimize the drawbacks of having fixed parameters and conservativeness in the classical washout filter. In addition, the performance of motion cueing algorithm and human perception for most occasions is improved (Houshyar, etal 2015).

Many motion base simulators have been developed in the last thirty years for many different types of vehicles. In order to make a simulation more realistic, linear accelerations and angular rates are exerted on the pilot by moving the platform on which the mock-up vehicle is located. This has to be accomplished without driving the simulator out of its workspace. The software component that is in charge of this is commonly referred to as washout filter. Washout filters have been widely investigated in the past, mainly in the field of flight simulators. In this article we present a washout filter designed for a motorcycle simulator. The solution is preliminary and follows, as a reference point, techniques previously adopted for large aircraft simulators. Differences between motorcycle and aircraft simulation are analyzed and a preliminary customized solution is proposed. The washout filter, which will be used to driven a motorcycle simulator, currently being built at PERCRO, has been tested off-line showing good results and will soon be tested on real riders (Federico, etal, 2017).

Also, in a droop washout filter controller (DWC), that composed of a conventional droop controller and a washout filter controller. The droop controller is used to ensure the "plug-and-play" capability, and the droop gain is set small. The washout filter was introduced to compensate the active power dynamic performance (APDP). Compared to the droop controller, the DWC could achieve accurate active power sharing and smaller frequency difference without losing the APDP. Additionally, a novel modeling technology is proposed, using a small-signal model for an island microgrid (MG) constructed as a singular system. The system's stability is analyzed and the DWC is verified using real-time (RT-LAB) simulation with hardware in the loop (Yalong Hu and Wei Wei, 2018).

A feedback stabilizing control law for the electric power systems to delay and eliminate the appearance of the so-called "voltage collapse was examined by (Der-Cherng Liaw, Yun-Hua Huang, 2018)." The phenomenon of voltage collapse is known to be possibly attributed to the occurrence of the saddle-node bifurcation or Andronov-Hopf bifurcation. Based on a previous study (Liaw et al, 2005), in this study a washout filter aided linear stabilizing control law designed for the power systems to delay or eliminate the appearance of the bifurcation phenomena. Numerical simulations demonstrate the success of preventing the occurrence of voltage collapse by the proposed schemes (Der-Cherng Liaw, Yun-Hua Huang, 2018).

# 3.0 Method and materials

## 3.1 CE 117 process trainer and mimic panel

Process trainer is a flexible teaching and demonstration tool mainly for process technician, process engineers and student of chemical engineering control. It is also useful for student of control engineering as it demonstrates wide range of control engineering principles. The equipment allows practical investigations into a wide range of strategies for the control of:

1. Flow
2. Level
3. Temperature
4. Pressure

The access to the actuators, sensors and the process vessels of the CE117 process trainer is provided through the use of a mimic panel that is provided.

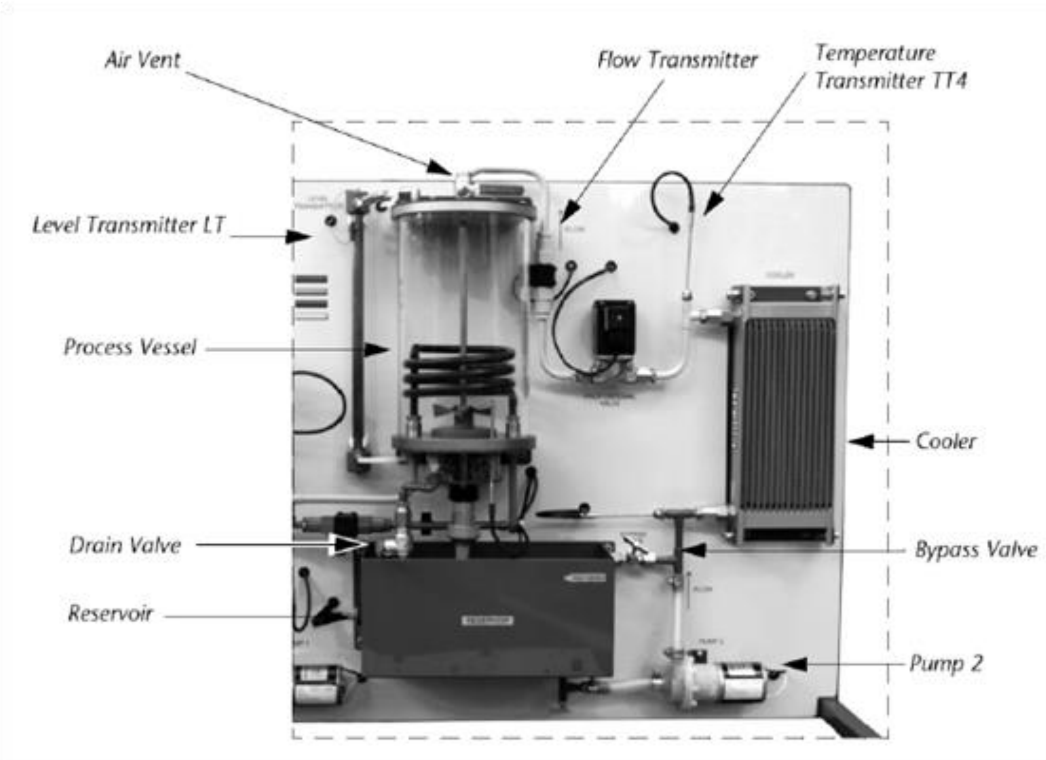


Fig. 1 Process Trainer

### 3.2 CE2000 software

The CE 117 process trainer can controlled by means of a built-in computer interface and CE2000 software by the manufacturer. The software provides all the tools needed to create, edit and run a wide range of data acquisition and control circuits. It also includes digital and graphical displays with built-in record functions.

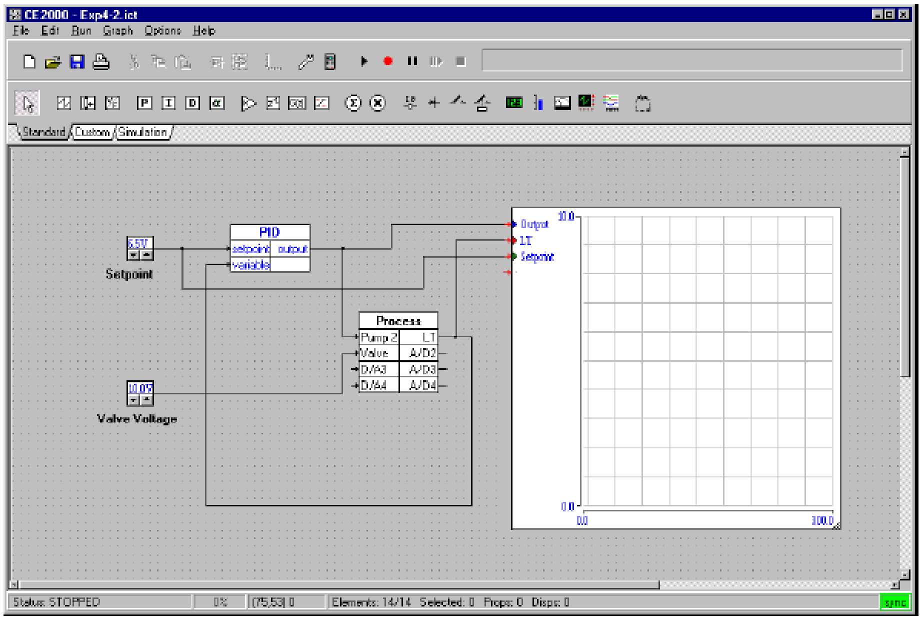


Fig. 2 CE 2000 software front Panel

## 3.3 The Procedure

The block diagram in figure 3 shows how the closed loop control of the process flow rate can be achieved using a motor as the final current element. The procedure taken to present the graphical analysis of the use of wash out filter is taken as below:

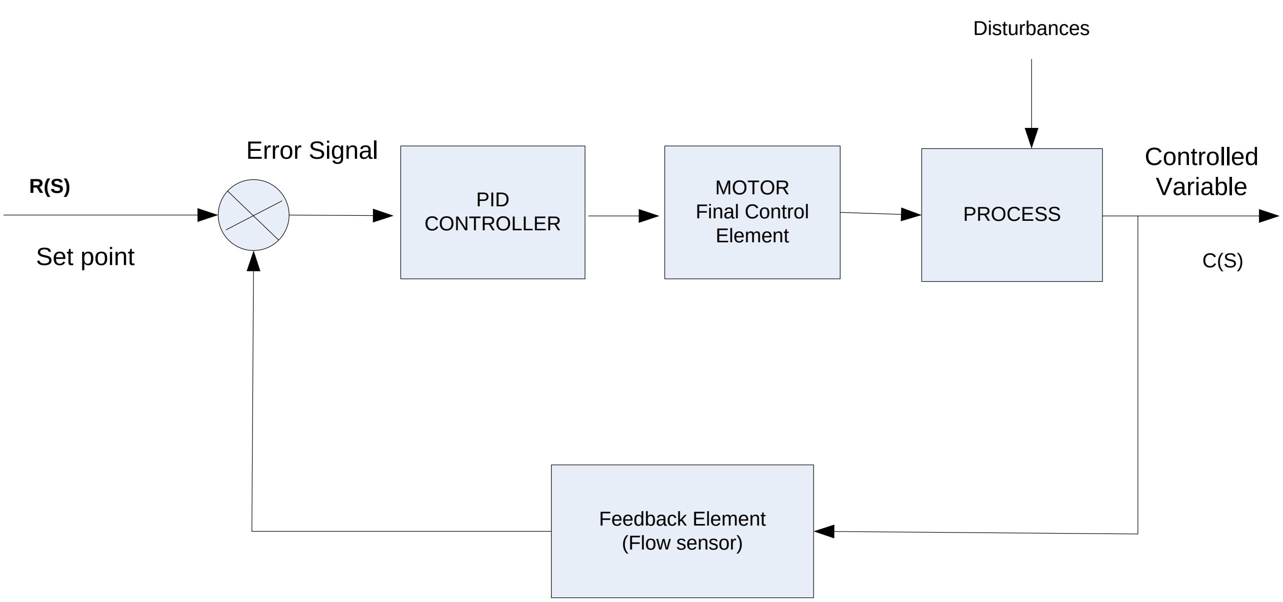


Fig. 3.0 Block diagram of the Process control

1. Connections on the mimic panel are done according to block diagram of fig. 3 and are shown in figure 4. The pump used as the final control element is switched to external to allow the use of the software controller (PID)
2. The circuit of the block diagram according to the connections on the mimic panel is loaded
3. Bypass valve on the process trainer was closed. Drain valve and the air vent are fully opened to allow the process fluid to move from the process vessel through the proportional valve, the flow transmitter (feedback element) and back to the process vessel.

**EXPERIMENT ONE**

4. The three term controller that control the pump voltage that is the P, I and D blocks are Set to: Proportional gain-2, Integral gain–0.5 and Derivative gain– 0 (zero) to investigate the effect of the no derivative controller on the process when the set point is changed from the initial 3 V to 4 V.
5. The software was run and the flow response, the error and the derivative action were recorded with the software when the flow stabilized.

**EXPERIMENT TWO**

6. To investigate how derivative controller improves the performance of the process when there is set point change (3 v to 4 v and back to 3 V), D_ block gain was set to 5 and its washout gain also to 5 with the washout check box enabled. The software was run and used to record the flow response, the error and the derivative action when the flow was allowed to stabilize.

**EXPERIMENT THREE**

7. To investigate the performance of the Derivative controller with no wash out filter, the washout enabled was unchecked and the set point was changed from the initial 3 V to 4 V. The software was run and used to record the flow response, the error and the derivative action when the flow was allowed to stabilize.

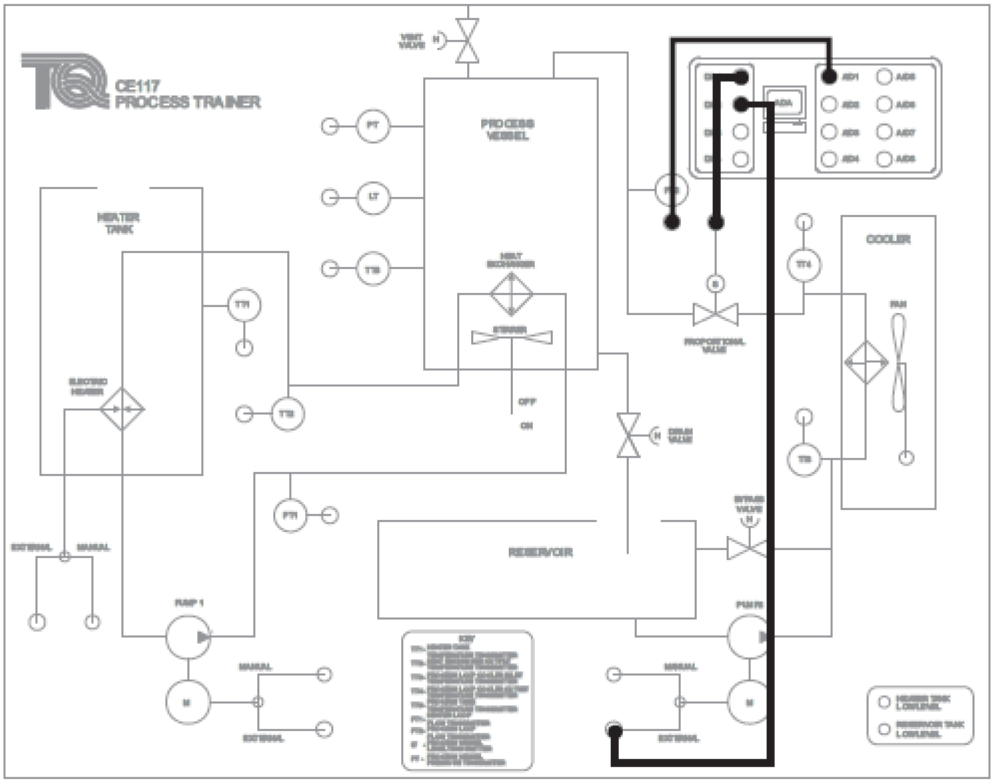


**Fig. 4 Mimic Panel connection of the experiment**

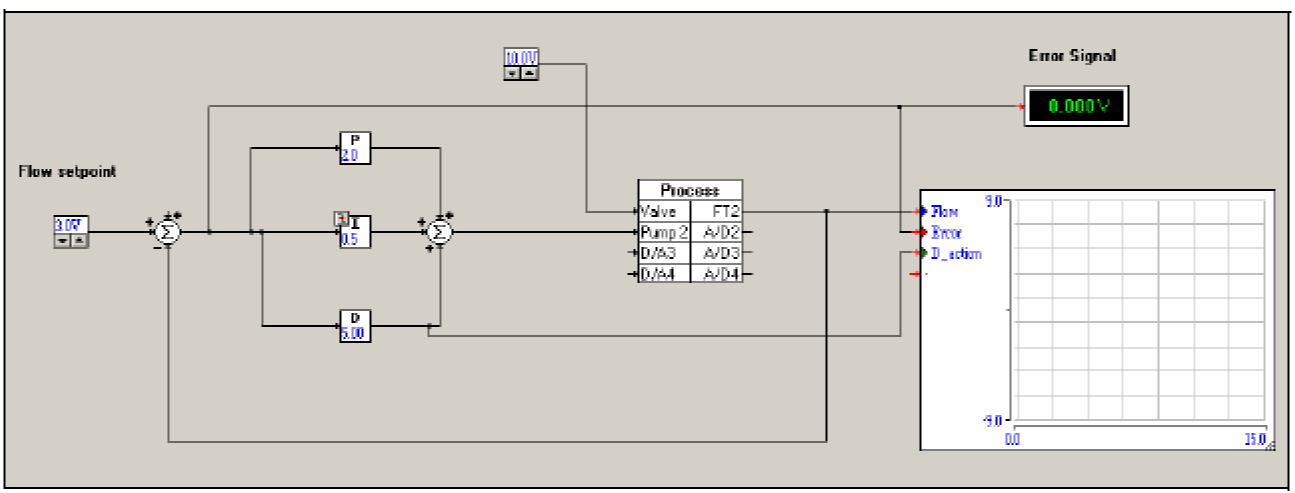


Figure 5. CE 2000 circuit connection
of the experiment

### 3.4 observations

Our observation was that noise (disturbance) was from the flow sensor and the response to a step input (change in setpoint). The response of the feedback loop to the disturbance in the flow was generated by adjusting the pump speed. However, through the aided feedback washout filter, it removed all the unwanted signals attached to the sensor.

## 4.0 Result and discussions

### 4.1 No derivative term

With no derivative action, as the setpoint changes, the controller (PID) takes a long period to respond to the change in the set point. Figure 6 shows the graphical analysis

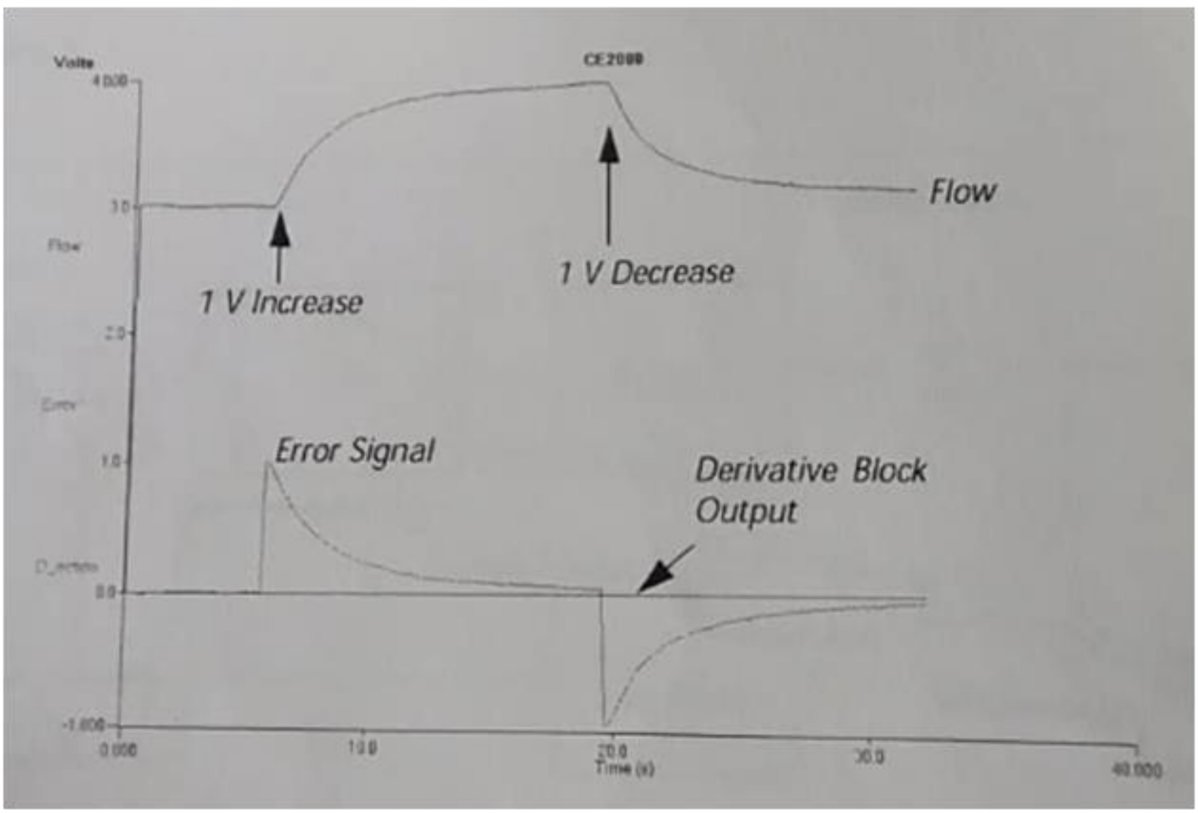


Figure 6. the graphical display from CE 2000 with no derivative term

### 4.2 With derivative term and washout filter

With derivative action and the washout filter the process reacts very quickly to the set point change (and error) by applying a short period and large output signal to the pump in order to increase pump speed. Thi is demonstrated by fig.7

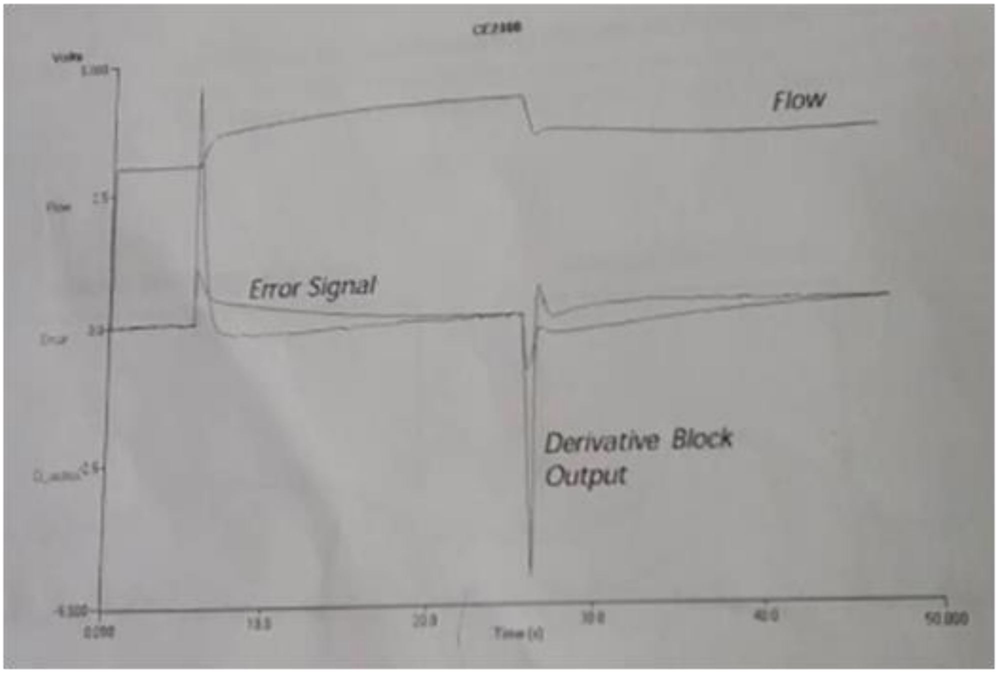


Fig. 7 Graphical display from CE 2000 with Derivative term and wash out filter

### 4.3 Derivative with no wash out filter

Figure 8 shows the effect of derivative action without the washout filter. It shows the increased noise on the derivative block output

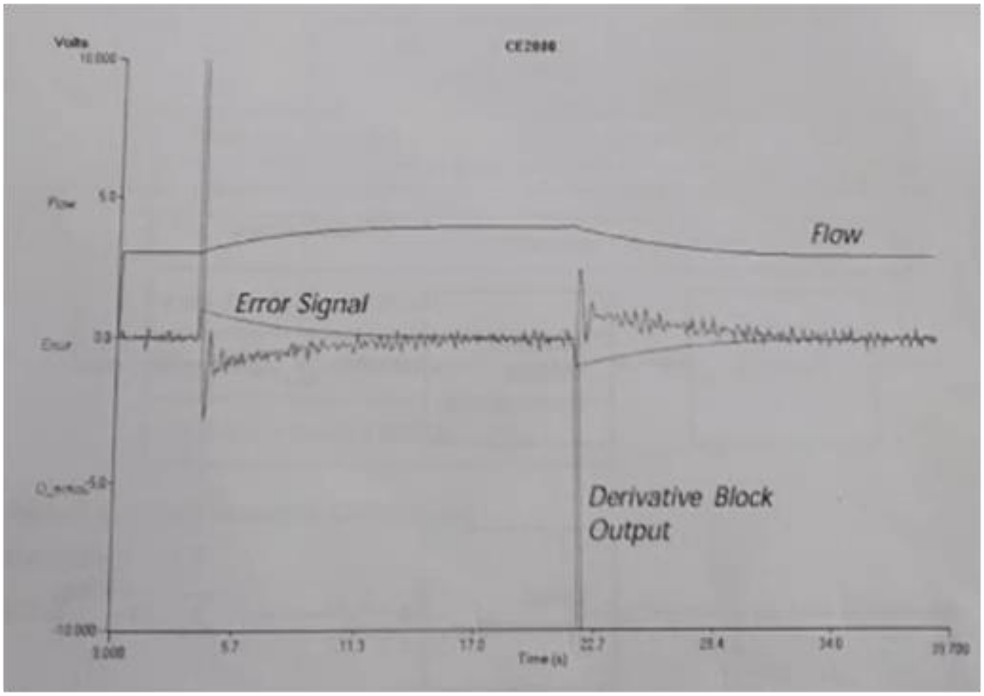


Fig. 8 Graphical display from CE2000 software of the Derivative action with no wash out filter

## 4.0 Conclusion

The dynamics and control of process systems is an important subject. However, properly configured and effectively tuned control systems have a major influence on the efficiency and safety of a process plant. Therefore, the necessities of washout filter on change in eliminating noise amplification provide desirable speed response required in process industry

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