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# Stability Enhancement Systems Equipped with Various Controllers using Wavelet Technique

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***Abstract***

***Additive noise is common for communication channels and outputs of sensors which deviates the outputs and adds error to the system response. Different controllers are available in literature to handle the uncertainties in system inputs. Many a times the controllers also have the limitations in handling these uncertainties. So removing of this noise at the input stage of the system is necessary. For removing of noise and mathematical analysis of the signals wavelet transform plays a key role. It is necessary to study the effect of noise on closed loop system, and study the effective de-noising capabilities of PID and fuzzy controllers. Fuzzy controller effectively reduces ripples due to predefined rules. The wavelet technique is used to de-noise the input signal. This is further extended to include the noises other than Gaussian. This provides a case study of the application of wavelet de-noising for different structures of the noise. The de-noised signal is given as input to various systems equipped with PID and Fuzzy controllers.***

***Keywords-PID Controller ,fuzzy controller, wavelet based denoising, Haar wavelet, Comparative noise effects, Disturbance***

## Introduction

There are so many types of noises added to communication channels, which are disturbances in the system. These disturbances reduces the efficiency of the system. PID controllers are usedfor reduces the steady state error and improving stability not controlling the noise or disturbances which are added to the system.The fuzzy logiccontrollers can decrease disturbanceseffectively better than simple PID controllers and improves de-noising efficiency. Different filtering techniques are available to eliminate the signal disturbances.the difference between active Kalmanfilter and wavelet filtering to tackle Gaussian noise is given in [2]. Butit has certain drawbacks such as it has estimation errors and iscomputationally inefficient [3]. Also, the method fails toeradicate baseline drift under high-frequency variationsmainly due to convergence factor of Kalman filter and itsadaptability. In recent time many noise elimination algorithmshave been proposed to produce an original signal from thenoisy signal. Some of these techniques are Filtering based onLeast Mean Squares, subspace, Line enhancer,active filters , spectral subtraction approach and muchmore [4,5].

All these algorithms have some disadvantagessuch as computational complexity, recoverability of originalsignal is reduced, less efficient in handling real-time signalsetc.pid controller nullifies error but less capabilities of removing the noise.fuzzy controller gives better performance because of its predefined rules. The desired output can be achieved by giving rules of member ship function.Fuzzy controller can effectively reduce the noise from image processing. In present days wavelets popularly used for 1D and 2D signal processing. Along with wavelet denoising fuzzy controller gives effective denoised signal. In this context we can distinguish between performance of pid controller and fuzzy controller on denoised signal which is comes from wavelet transfom.

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## DESIGN OF AN INDUSTRIAL SYSTEM

Industrial process system considered is single input single outputsecond order, the non-linear withDelay time. The open loop transferfunction T(s) of industrial process derived experimentally is

$$T(s) = \frac{e^{-0.00564\,s}}{(1 + 0.0155s)^2}$$

The fourth order

systemT(s)= $\frac{1310000\,S+1742300}{S^4+520S^3+56850\,S^2+1307000\,S+17330000}$

A simulation model of the process without PID controller is shown as and its response is shown ion below figure

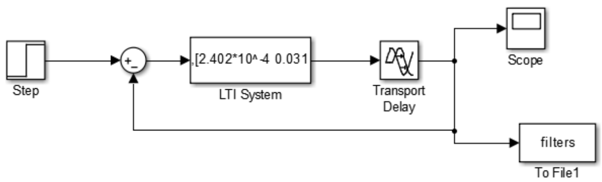


Fig1 system without PID controller

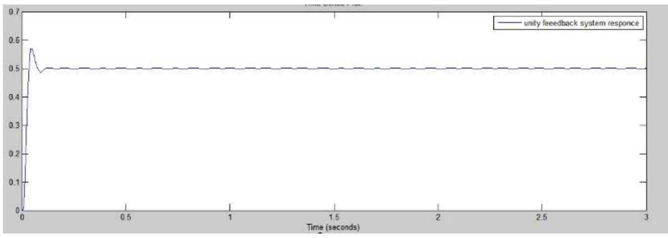


Fig2: system response without PID controller

Industrial system response without PID controller has large steady state error ie 0.5.it is notsatisfactory to minimize the steady state error we need to use pid controller. Therefore to achieve the desired response,simple PID controller with unity feedback andtheoretical tuning is added into the system as shown in fig3.

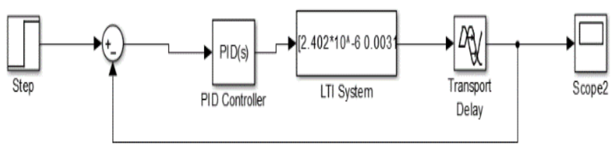


Fig.3 Modeling of industrial process with PID Controller

The output response of the system with pid controller with unity feedback is given Fig.4

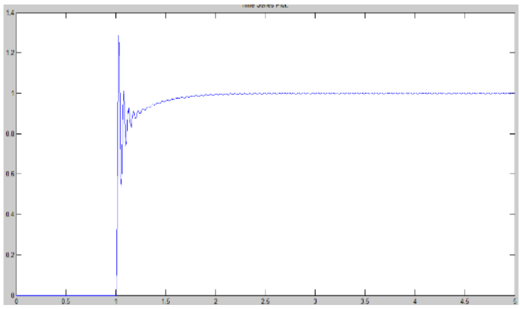

Fig.4 Closed loop response with PID unity feedback Tuning andwithout Noise.

By using PID controller we can effectively reduce steady state error to zeroand its closed loop response. The Tuning parameters for getting zero steady state error are tabulated in Tables I and II.

### TABLE I:. PID TUNED TUNING PARAMETERS FOR SOCOND ORDER SYSTEM

| Tuning type | Kp | Ki | KD |
|---|---|---|---|
| Theorical tuning | 3.4674 | 14.8148 | 0.01 |

### TABLE II:. PID TUNED PARAMETERS PARAMETERS FOR 4TH ORDER SYSTEM

| Tuning type | kp | Ki | kd |
|---|---|---|---|
| Theoretical tuning | 1 | 21 | 0.01 |

Theoretical tuning values should not be applied toHardware kit because of Kd value exceeding the limits ofhardware circuitry. Therefore, in order to improve hardwarekit range for Kd value need to be increased but at the cost ofan increase in price and complexity of hardware. Simulinkstudies have been carried out for further study because ofhardware limitations available in the laboratory.

## TYPES OF NOISES

Different noises of high and low frequencies arecontaminated with system response that may lead to

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deviationof response from desired specifications and introduce error to the system

## Gaussian Noise:

Gausian noise is a static noise and it satisfies all properties of probability density function.it is a white additive noise. Practically the noises which are aiding to communication channels are followsgausian distribution. The density function of Gaussian noise is as fallows

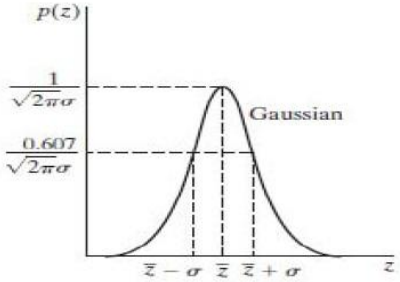


Fig.5. Distribution Function of Gaussian Noise

$$p(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

## Rayleigh Noise:

Speed signals are always curbed by the disturbance thatcan be sculptured via the Rayleigh distribution. Theprobability density function, variance and the mean ofRayleigh noise are given by

$$p(z) = \begin{cases} \frac{2}{b}(z-a)e^{\frac{-(z-a)^2}{b}} & z \geq a \\ 0 & elsewhere \end{cases}$$

$$\mu = a + \sqrt{(\frac{\pi b}{4})}$$

$$\sigma^2 = \frac{b(4-u)}{4}$$

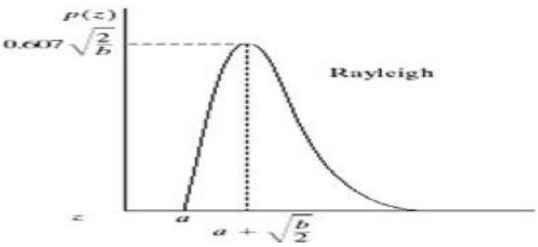


Fig.6 pdf of Rayleigh noise

where μ is an expectation of the average value of z and σ2 is the variance of z

## EFFECT OF INPUT NOISES ON CLOSED LOOP CONTROL SYSTEMS

Noise has bad effects on any system, but its type must be agree with the system i.e. electrical systems may disturbed by electromagnetic waves not by mechanical waves. but from the stability point of view and control system, i think the effect of noise on stability appear only at time varying and nonlinear dynamical systems but for time invariant linear system the system model (fixed system poles) is only responsible for the system stability and we can see the noise as superimposed signal to the system input. generally, for any inputs to stable time invariant linear system the system will still stable, but change input for nonlinear or time variant dynamical system may drift the system to unstable response.

If you add noise externally then you will get fluctuations of your state characteristics, thus you have to calculate mean and mean square of y for instance, or better find response pdf. If you add noise parametrically (multiplied by any state variable) then it may lead to instability.

Now when we tune a feedback control loop, we do it so as to keep its output stable within certain limits for a certain range of the input variables. When you add white noise, will push the input variables outside the range of permitted variation.

To test the performance of anindustrial system, various input noises are being added to thesystem input such as Gaussian, Rayleigh, Rician and Uniformnoise as shown in given figures respectively

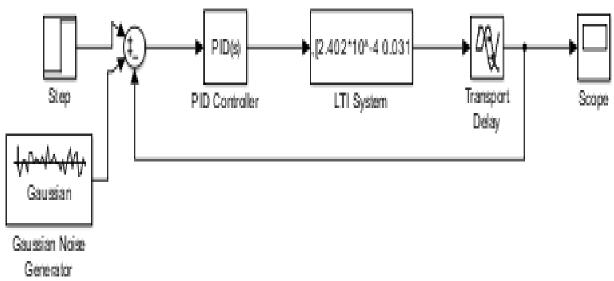


Fig7 system with Gaussian noise

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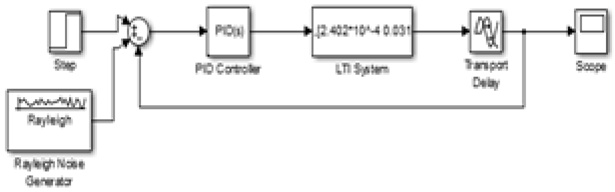


Fig 8 system with Rayleigh noise

We can generate noise from matlab code. This noise will highly effecting the system response. This noise can be removed by using wavelet transform.

## DESIGN OF FUZZY CONTROLLER

Fuzzy controller can effectively reduces noises or disturbancesCompared to pid controller due to its nonlinearity handling capabilities and predefined rules of fuzzy controller it can completely removes the noise.

## WAVELETS

Wavelet is a mathematical tool to analyse a signal.Some of exciting methods for denoising signal are Kernel estimators / Spline estimators,Fourier based signal processing. The disadvantage of above methods are

### Disadvantages of earlier methods.

1.Non-linear method .
2.The spectra can overlap.
3.The idea is to have the amplitude, rather than the location of the spectra be as different as possible for that of the noise.
4.This allows shrinking of the amplitude of the transform to separate signals or remove noise.

### Advantages of wavelets:

The Wavelet transform performs a correlation analysis. Therefore the output is expected to be maximal when the input signal most resembles the mother wavelet.

A wavelet is a wave-like oscillation with an amplitude that starts out at zero, increases, and then decreases back to zero. Unlike the sines used in Fourier transform for decomposition of a signal, wavelets are generally much more concentrated in time. They usually provide an analysis of the signal which is localized in both time and frequency, whereas Fourier transform is localized only in frequency.wavelet is zero meen function. The time function can change into number of different scaled wavelets.

In mathematics, a wavelet series is a representation ofa square-integrable (realor complex-valued) function by a certain orthonormal series generated by a wavelet. This article provides a formal, mathematical definition of an orthonormal waveletand of the integral wavelettransform.

By using wavelet transform we can denoise the signal by following steps.
Step1: generate a noisy signal by adding noise o step signal
Step2: find wavelet coefficients by decomposing given noisy signal by “wavedec”.
Step3: approximate the obtained coefficientsby ”appcoef”.
Step4:wavelet synthesis by using “detcoef”
Step5:Thresholding obtained approximated coefficients by shrinking the coefficients.
Now we can get denoised signal which is given to PID controlled system by using from the workspace and we can simulate the results.

The coefficients computed using wavelet transform(WT) indecomposition analysis. Then synthesis involves upsamplingand filtering to result in trend and detail signals using inversetransform operation. Thresholding is done by adjusting lowest scale gain to zero, this involves dumping only the fraction of the details that exceeds a certain limit to get a denoised signal.

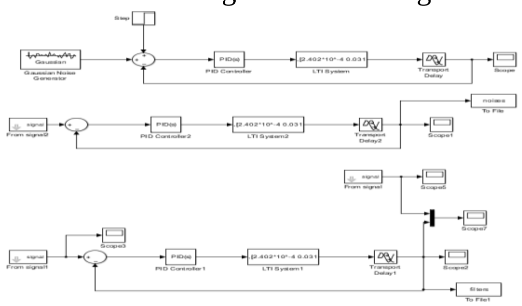

Fig:9different noise signal denoisedby wavelet transform and pid controller.

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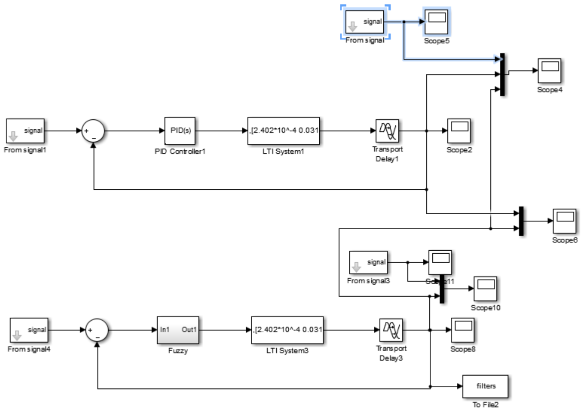

Fig:10 different noise signal denoisedf by wavelet transform and pid controller.

## SIMULATION RESULTS AND DISCUSSIONS

Closed loop response with the PID controller and withoutNoise is shown in Fig. 4. The performance of an industrialsystem is tested by adding different noises at the input and upgradation in the performance of PID controller utilizingproposeddenoising strategy in terms of sharp rejection ofdisturbance and transient response are as showfig:Noisy signal

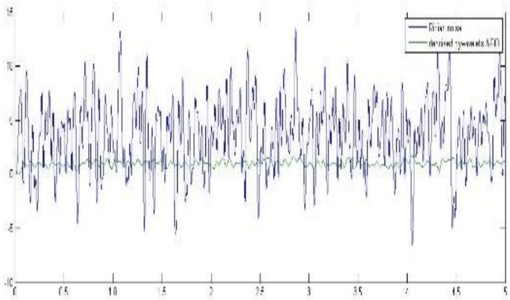

Fig:11 Noised Rayleigh signal with wavelet transform with pid

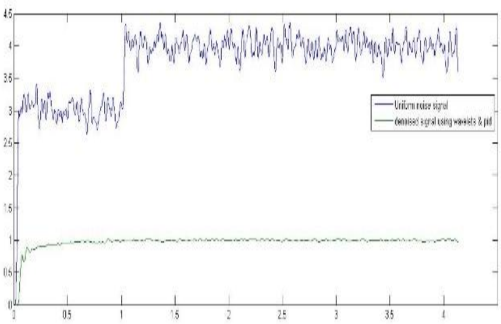

Fig:12Denoised Rayleigh signal with wavelet transform with pid

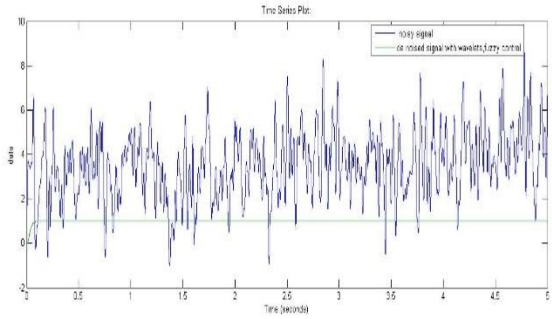

Fig14 Noised Gaussian signal with wavelet transform with fuzzy controller

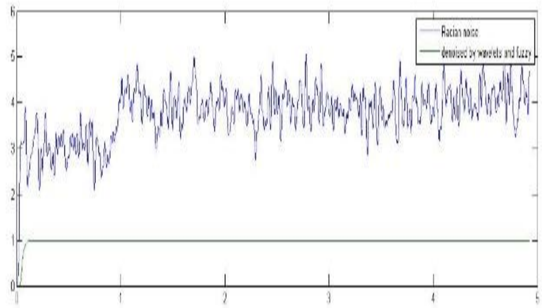

Fig15Denoised Rayleigh signal with wavelet transform with fuzzy controller

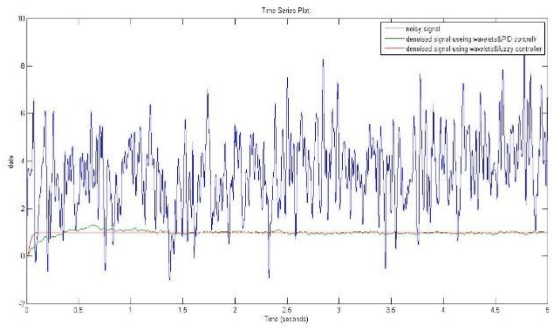

Fig16 Differences between wavelet transform denoisinggaussian noise withpid and fuzzy controller.

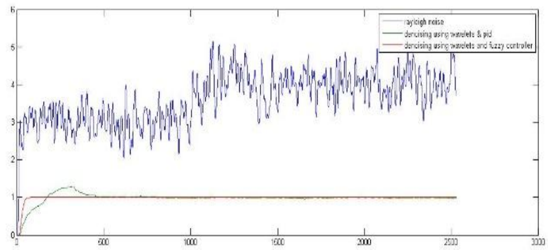

Fig17 Differences between wavelet transform denoisingrayleigh noise with pid and fuzzy controller.

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### Denoisingsingal given to higher order system

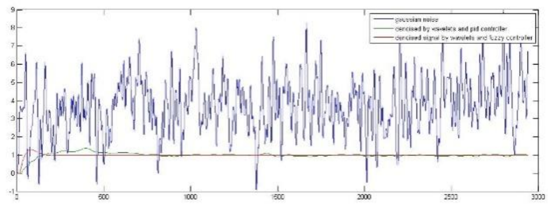

Fig18 Differences between wavelet transform denoising gaussian noise with pid and fuzzy controller for higher order system.

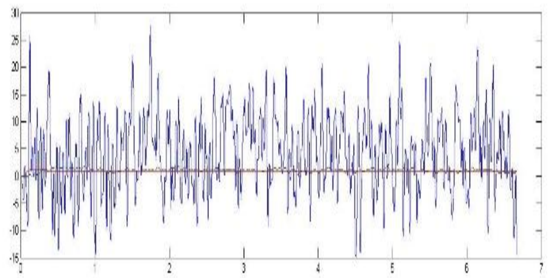

Fig19 Differences between wavelet transform denoisinggaussian noise with pid and fuzzy controller for higher order system.

### frequency response of noisy and denoised signal

We can analyze type of noise that is added to communication channel by using fast Fourier transform and can identify which frequency components present in noisy signal.

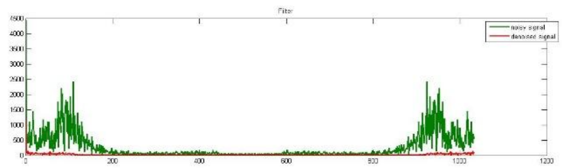

Fig20 frequency respoce of gaussion function

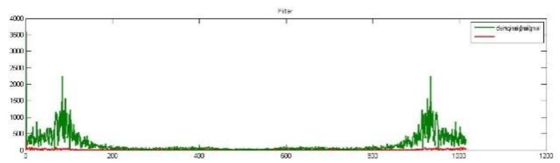

Fig21 frequencyrespoce of rayleigh function

Frequency response is useful for to find the intencityof the noise at different frequencies.Generally editing noise present at high frequencies these frequencies helps to design of wavelet transform to denoise the signal.

### CONCLUSIONS

Stability of system is decided by response of the system For a second order system Unit step response gives a steady state error, to nullify that error pid controller is used. By tuning kpkikd values error free response is achivedTo study the robustness of the system different types of noises applied to the closed loop system, but PID controller alone does not remove the noise Fuzzy controller is used for noisy signal but it is also giving the ripples.

Wavelet based denoising technique is used by observing frequency of noise by applying noisy signal to fast Fourier transform. Wavelet base denoised technic reduces the noise but some ripple content is present. Db 2 leve3 wavelet transform is used. Pid controller reduces the ripples but not effetely, fuzzy controller can effectively reduced noise due to its non linearity's handling capabilityWavelet transform and fuzzy controller combined together is effective in reducing the noise in the output of the system.

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