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# SIMULINK AND COMPARISON OF PID CONTROLLER IN POWER SYSTEM

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## ABSTRACT

**The main objective of Load Frequency Control (LFC) is to regulate the power output of the electric generator within an area in response to changes in system frequency and tie-line loading. Most LFCs are primarily composed of an integral controller. The integrator gain is set to a level that compromises between fast transient recovery and low overshoot in the dynamic response of the overall system. This type of controller is slow and does not allow the controller designer to take into account possible changes in operating conditions and non-linearity in the generator unit.**
**There are a number of ways through which nonlinearity can be present in the system. First-Order plus Delay Time (FOPDT) systems are very common. In this report comparison of various controllers is done for the system having first order plus time delay with the help of Error and Trial method using MATLAB SIMULINK & MATLAB CODING, Zeigler-Nichols method, Cohen-Coon method, Tyreus-Luyben method, Approximated M-Constrained Integral Gain Optimization (AMIGO) method, and Fuzzy logic controller with their respective plots are presented. Plots are shown to validate the schemes.**

**Various factors such as rise time, settling time, maximum overshoot have been calculated manually. The comparisons of various controlling techniques have been done for obtaining best parameters of PID controller for power system. Therefore, the article presents advanced techniques for Load Frequency Control.**

*Index Terms* : **PID controller, Zeigler-Nichols method, Cohen-Coon method, Tuning, Delay time.**

## 1. INTRODUCTION

Frequency is an explanation of stability criterion in power systems. To provide the stability, active power balance and steady frequency are required. Frequency depends on active power balance. If any change occurs in active power demand/ generation in power systems, frequency cannot be hold in its rated value. So oscillations increase in both power and frequency.Thus, system subjects to a serious instability problem. In electric power generating system, disturbances caused by load fluctuations results in variation in its value to the desired frequency value.The principle aspect of Automatic Load Frequency Control is to maintain the generator power output and frequency within the prescribed limits.[1]. In order to keep the power system in normal operating state, a number of controllers are used in practice. The PID controller will be used for the stabilization of the frequency in the load frequency control problems. Area load changes and abnormal conditions leads to mismatches in frequency and tie line power interchanges which are to be maintained in the permissible limits, for the robust operation of the power system. For simplicity, the effects of governor dead band are neglected in the Load Frequency Control studies.

Many studies have been carried out in the past on this important issue in power systems, which is the load frequency control. As stated in some literature (RamaSudha, et al., 2010; Bevrani, 2009; Ismail, 2006), its objective is to minimize the transient deviations in these variables (area frequency and tie-line power interchange) and to ensure their steady state errors to be zeros[1]. This report is to analyze the First-Order plus delay time (FOPDT) model using various controlling techniques with the help of MATLAB SIMULINK. The report mainly concerned about P, P-I and P-I-D controllers, their unit step response in time domain and their characteristics including effects of various parameters such as rise time, overshoot and settling time. As far as load frequency control systems [2] are concerned PID controllers are found in abundance in all sectors of power system. Even most complex power system networks are there whose main control building block is PID. It provides an effective means for capturing the approximate, inexact nature of the real world.

In the integral controller, if the integral gain is very high, undesirable and unacceptable large overshoots will be occurred. However, adjusting the maximum and minimum values of proportional (Kp), integral (Ki) and derivative

(Kd) gains respectively, the outputs of the system (voltage, frequency) could be improved. The main objectives of LFC, is to regulate the power output of the electric generator within a prescribed area in response to changes in system frequency, tie line loading so as to maintain the scheduled system frequency and interchange with the other areas within the prescribed limits.

## 2. CONTROLLERS

An industrial control system comprises of an automatic controller, an actuator, a plant, and a sensor. "Automatic control systems" [2] are found in abundance in all sectors of industry, such as quality control of manufactured products where delay plays a critical role.
Classification of Industrial controllers:-

Industrial controllers [4] may be classified according to their control action as:

- Proportional controllers
- Proportional Integral controllers
- Proportional Derivative controllers
- Proportional Integral Derivative controllers

Proportional Control-:
A proportional control system [5] is a type of linear feedback control system.
This can be mathematically expressed as

$$\mathrm{Pout} = \mathrm{Kp.\,e(t)}$$

With increase in Kp :

- Response speed of the system increases.
- Overshoot of the closed-loop system increases.
- Steady-state error decreases. But with high value, closed-loop system becomes unstable.

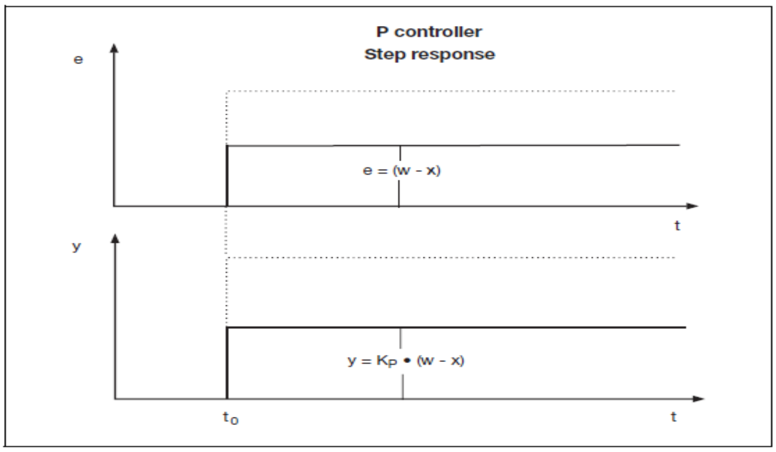


**Fig 1: Step response of P controller**

- Proportional Integral controllers:-

PI Controller (proportional + integral control) [8] is a feedback controller which drives the plant to be controlled by a weighted sum of the error (difference between the output and desired set-point) and the integral of that value.
The PI controller is mathematically denoted as:

$$\mathrm{G} = \mathrm{Kp} + \frac{\mathrm{Ki}}{\mathrm{s}}$$

As the value of Ti is increased

- Overshoot tends to be smaller and
- Speed of the response tends to be slower.

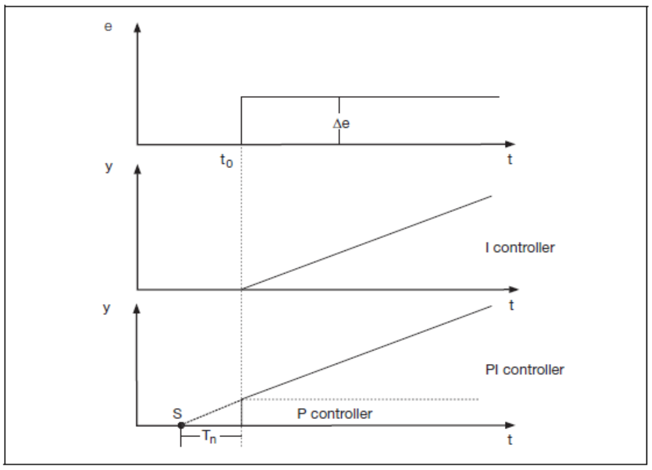


**Fig. 2: Step response of PI controller**

- Proportional Derivative controllers:-

Proportional Derivative or (PD control [9]) combines proportional control and derivative control in parallel. Derivative action acts on the derivative or rate of change of the control error.
In order to use derivative control the transfer functions must be proper. This often requires a pole to be added to the controller.

$$\mathrm{Gpd} = \mathrm{Kp} + \mathrm{Kds} \quad \text{or}$$
$$= \mathrm{Kp}(1 + \mathrm{Tds})$$

With the increase of Td

- Overshoot tends to be smaller
- Slower rise time but similar settling time.

- Proportional Integral Derivative controllers:-

"PID control [10]" is the method of feedback control that uses the PID controllers as the main tool. When used in this manner, the three element of PID produces outputs with the following nature:

- P element: proportional to the error at the instant t, this is the "present" error.
- I element: proportional to the integral of the error up to the instant t, which can be interpreted as the accumulation of the "past" error.
- D element: proportional to the derivative of the error at the instant t, which can be interpreted as the prediction of the "future" error.

The transfer function G(s) of the PID controller is

$$\mathrm{G(s)} = \mathrm{Kp}\left(1 + \frac{\mathrm{Ti}}{\mathrm{s}} + \mathrm{Tds}\right)$$
$$= \mathrm{Kp} + \frac{\mathrm{Ki}}{\mathrm{s}} + \mathrm{Kds}$$

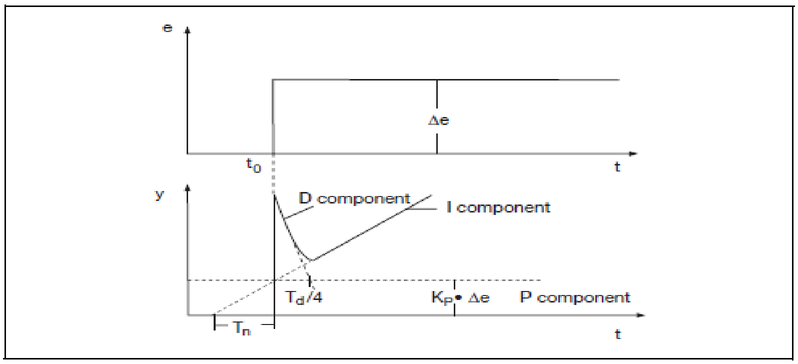


**Fig 3: Step response of PID controller**

PID controllers arefound in large numbers in all industries.

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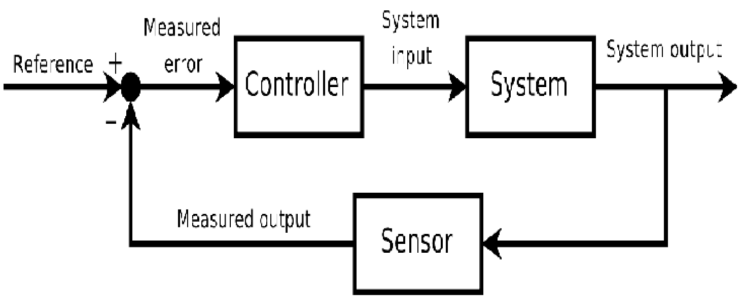


**Figure 4: Block diagram of close loop control system**

**Delay Time or Dead Time Response**

Anyone who has ever tried to stay comfortable while showering in a crowded building with old plumbing understands how delays [13] in a system can make the control problem much more difficult.

**Modeling Delays:**

The Laplace transform for a pure delay is just

$$f(t-\tau) \leftrightarrow e^{-s\tau}F(s)$$

Thus, it's easy to derive transfer functions for systems containing delays. Dead time appear in many processes in industry, power ayatem and in other fields, it is common in industrial process control. They are caused by some of the following phenomena: (a) The time needed to transport mass, energy or information; (b) the accumulation of time lags in a great number of low-order systems connected in series; and (c) the required processing time for sensors, such as analyzers; controllers that need some time to implement a complicated control algorithm or process.

Dead times introduce an additional lag in the system phase, thereby decreasing the phase and gain margin of the transfer function making the control of these systems more difficult. For a small time delay, a PID controller is commonly used. Dead time is the delay from when a controller output signal is issued until when the measured process variable first begins to respond.

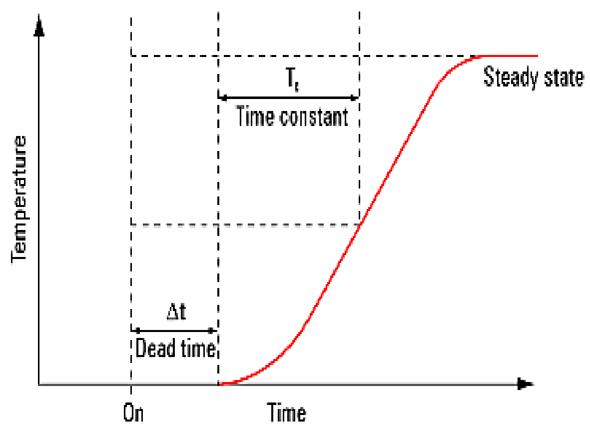


Figure3.6: dead time response of first order transfer function

**IV. Simulink Model And Simulation Result**

The temperature process [14] of an electric furnace is a common controlled object in temperature control system. This is given by the equation

$$G(s) = \frac{K}{(Ts+1)}e^{-Ls}$$

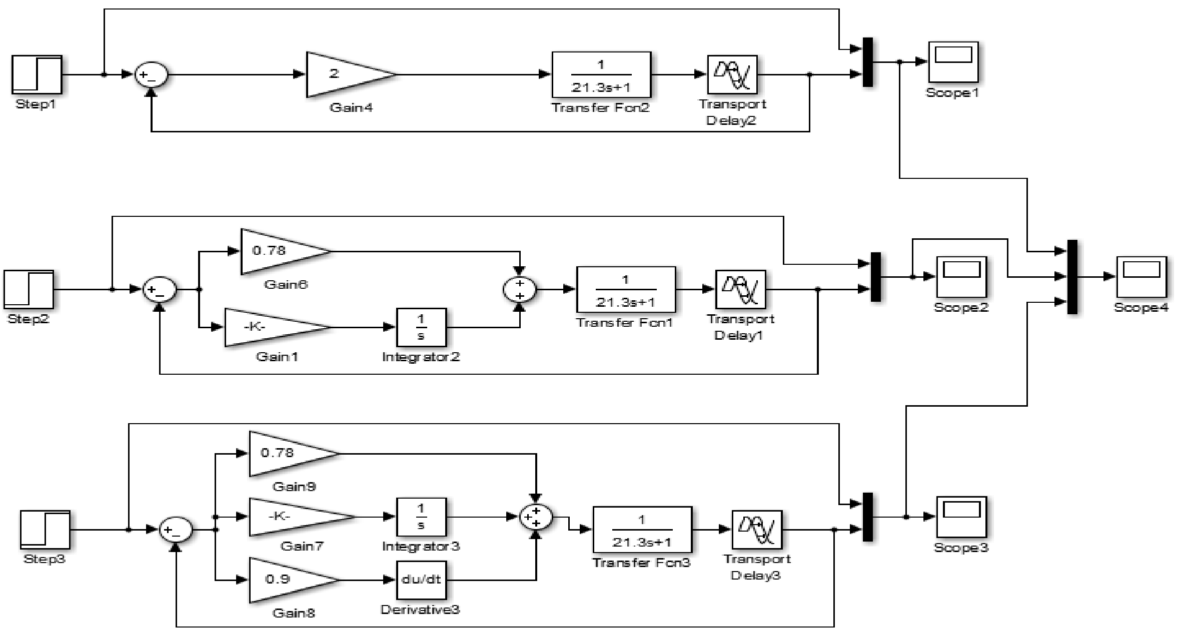


**Figure 5: Simulink model for trial and error method**

Hence, the transfer function for the given electric arc furnace system is given by the equation.

$$G(s) = \frac{1}{(21.3s + 1)} e^{-14.7s}$$

Where,
Delay time (L) = 14.7 sec    Time constant (T) = 21.3 sec    Static gain (K) = 1

## SIMULATION RESULTS

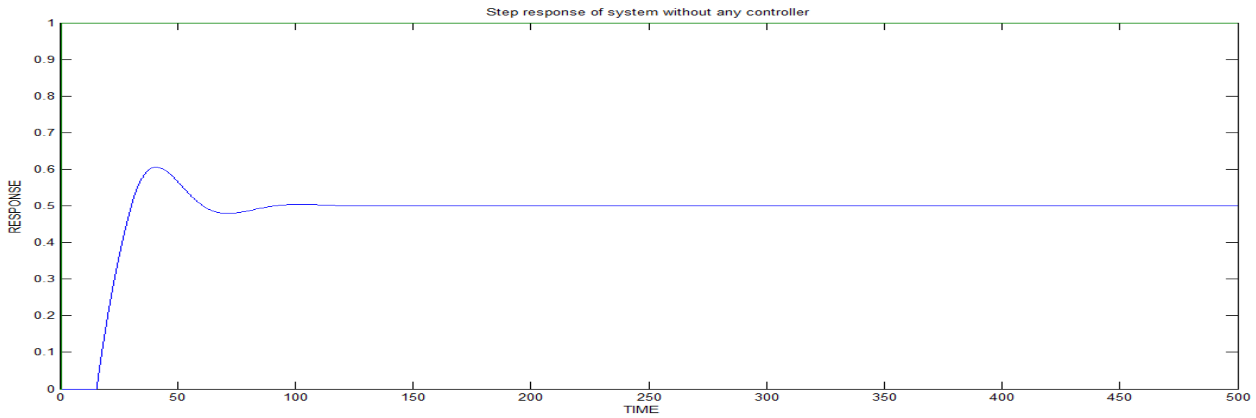


**Figure 6- Response without using any controller**

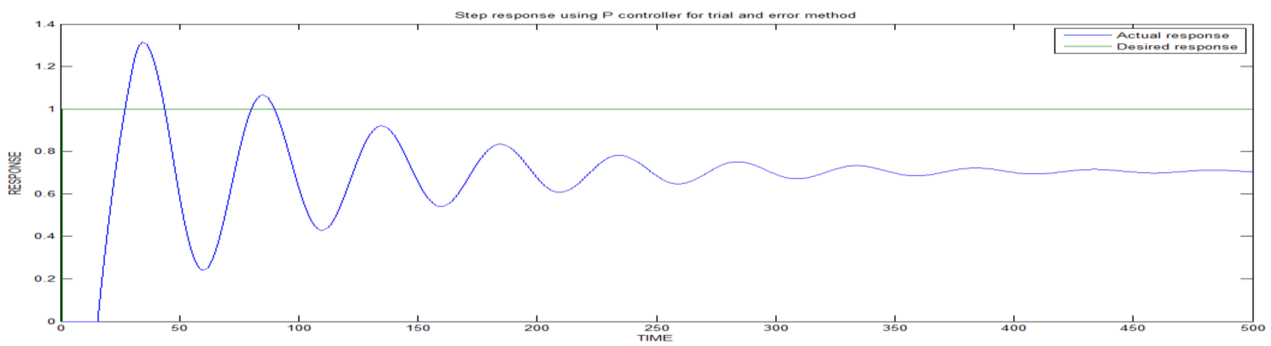


**Figure 7: Response with only proportional controller**

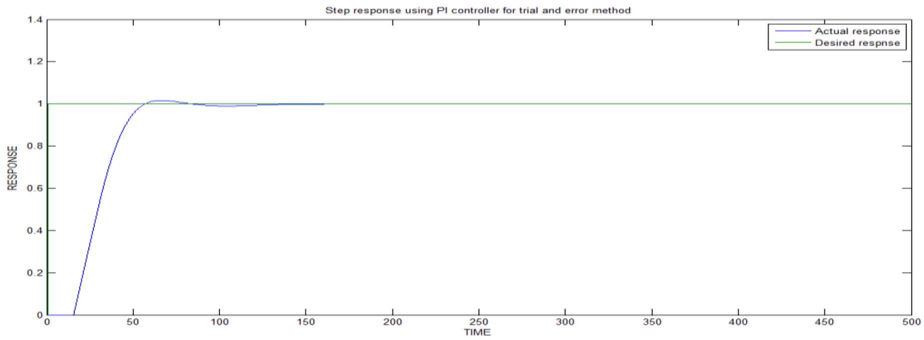


**Figure 8: Response with PI controller**

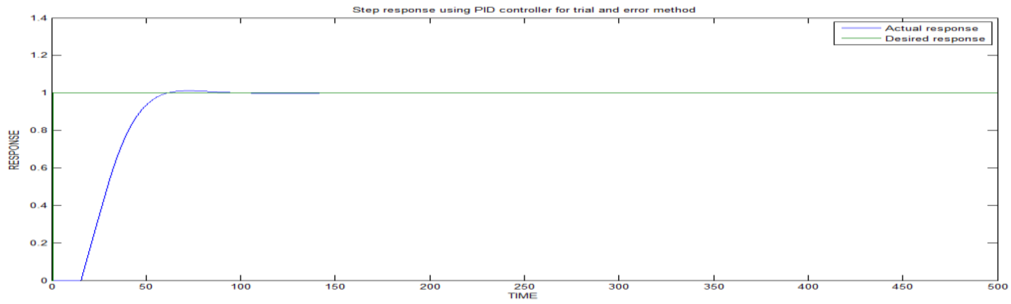


**Figure 9: Response with PID controller**

## A. SIMULINK MODEL FOR ZIGLER-NICHOLS OPEN- LOOP METHOD

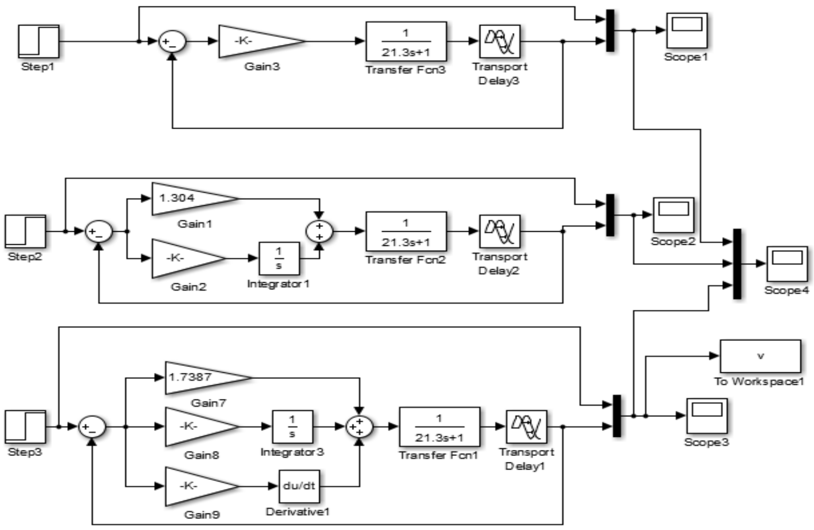


**Figure 10: Simulink model for Ziegler-Nichols open loop method**

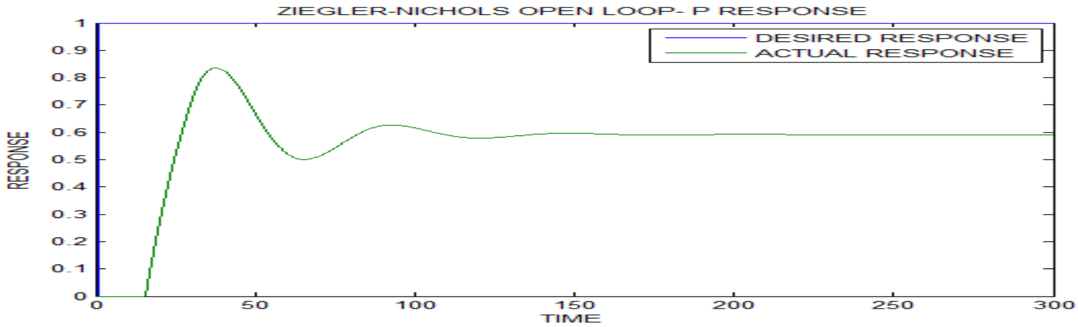


**Figure 11: Ziegler-Nichols open loop P control response.**

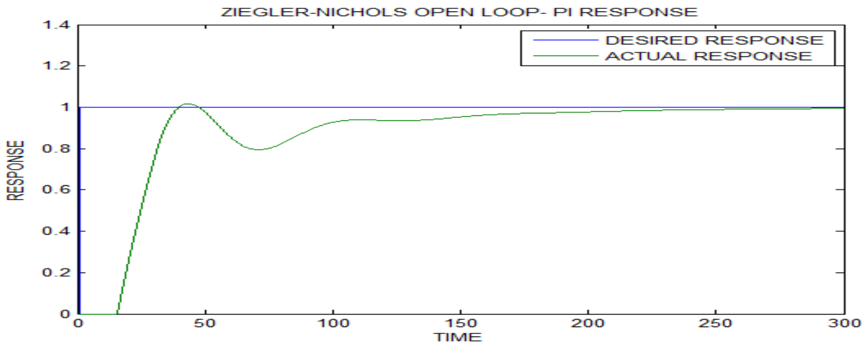


Figure 12: Ziegler-Nichols open loop PI control response

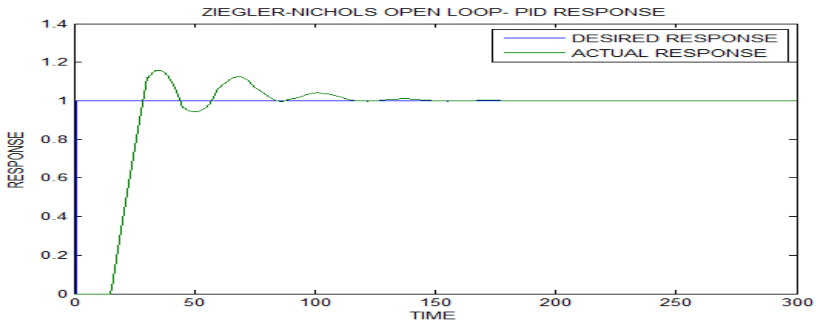


Figure 13: Ziegler-Nichols open loop PID control response

## B. ZEIGLER-NICHOLS (METHOD II)

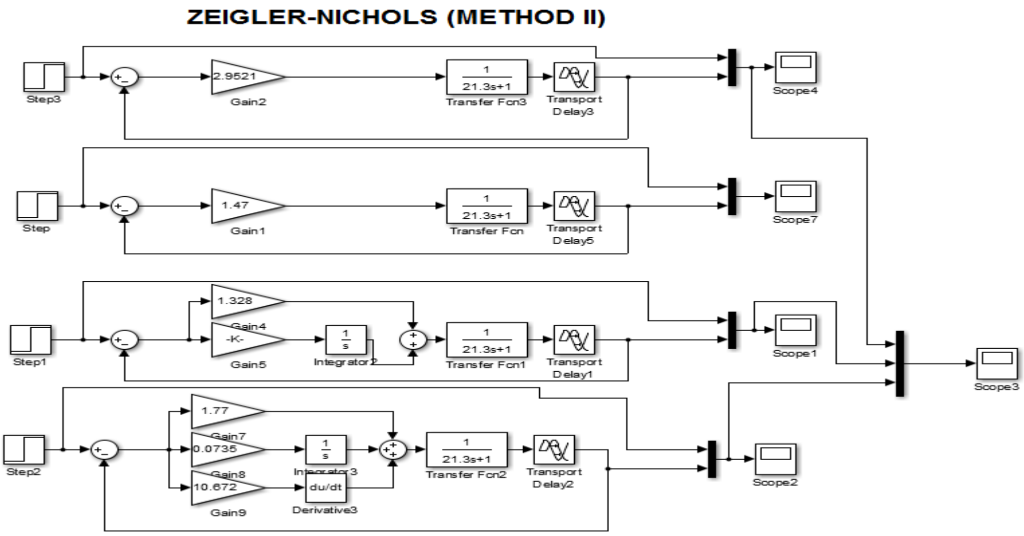


Figure 14: Simulink model for Ziegler-Nichols open loop method

## RESULTS

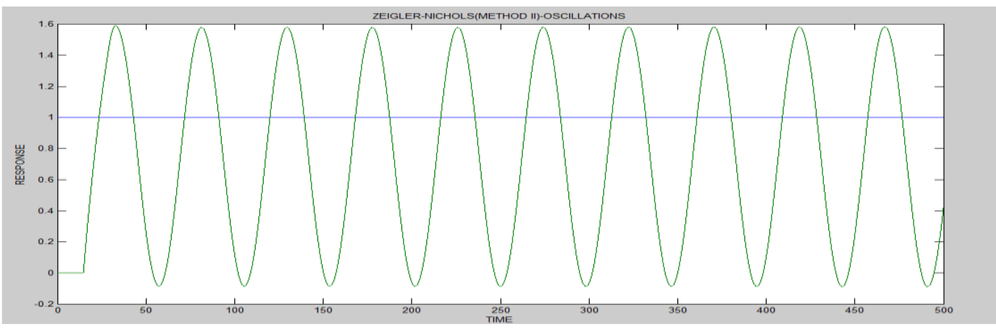


Figure 15: Sustained oscillations for Zeigler-Nichols method

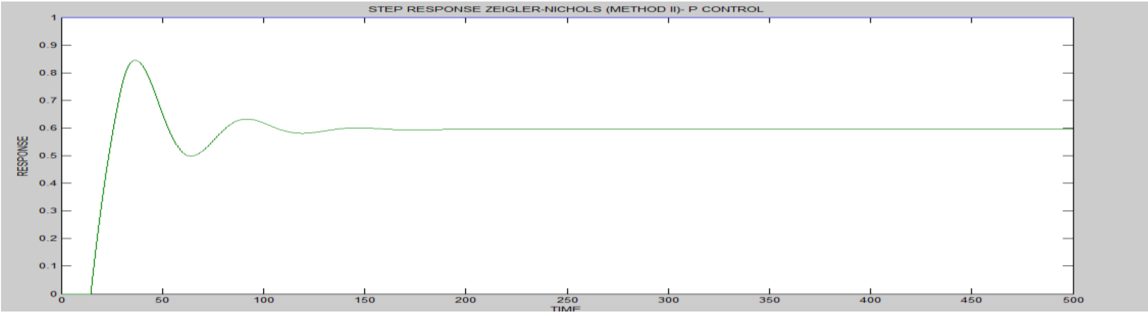


**Figure 16: Response with P controller (Zeigler-Nichols method)**

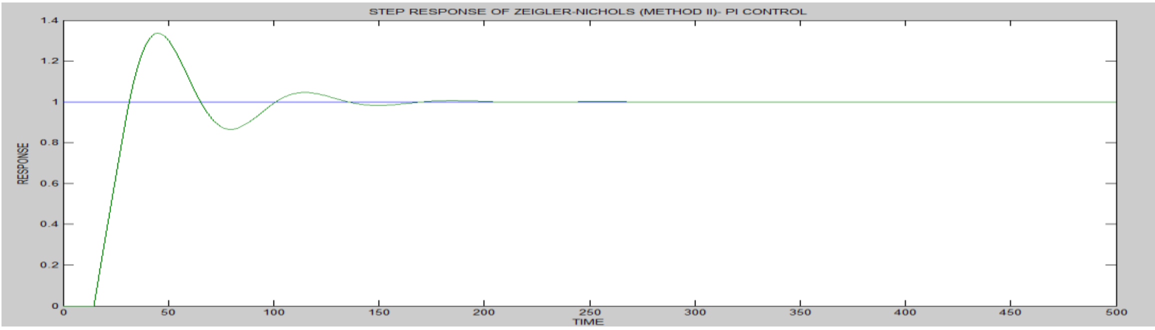


**Figure 17: Response with PI controller (Zeigler-Nichols method)**

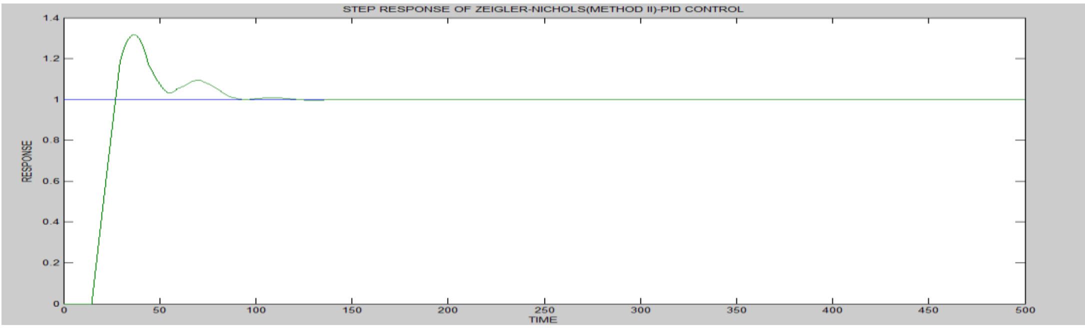


**Figure 18: Response with PID controller (Zeigler-Nichols method)**

## C. SIMULINK MODEL FOR COHEN-COON METHOD

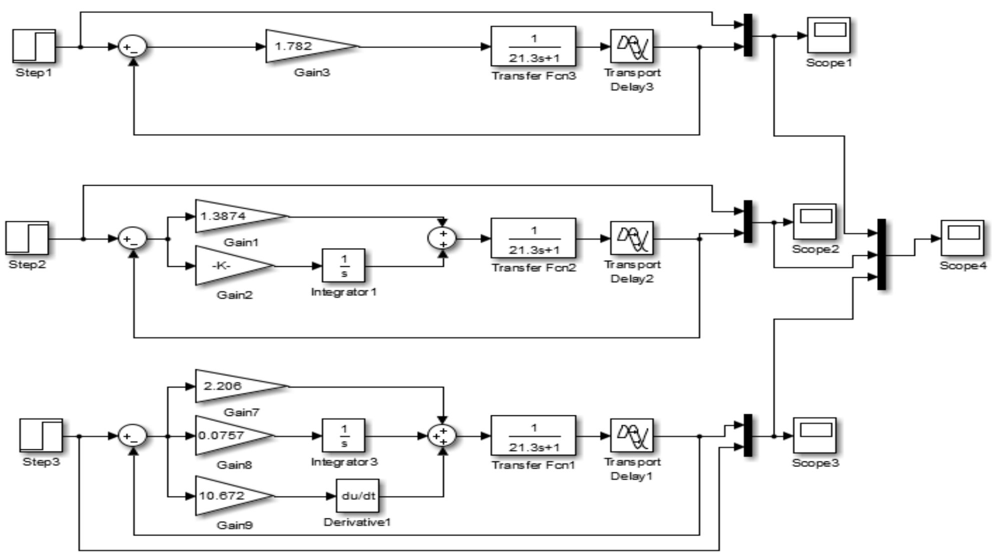


**Figure 19: Cohen-Coon MATLAB SIMULINK MODEL**

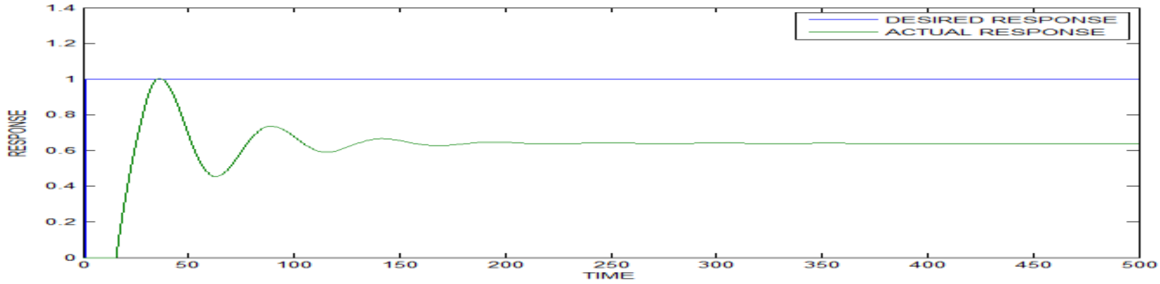


Figure 20: Response with P controller (Cohen-Coon method)

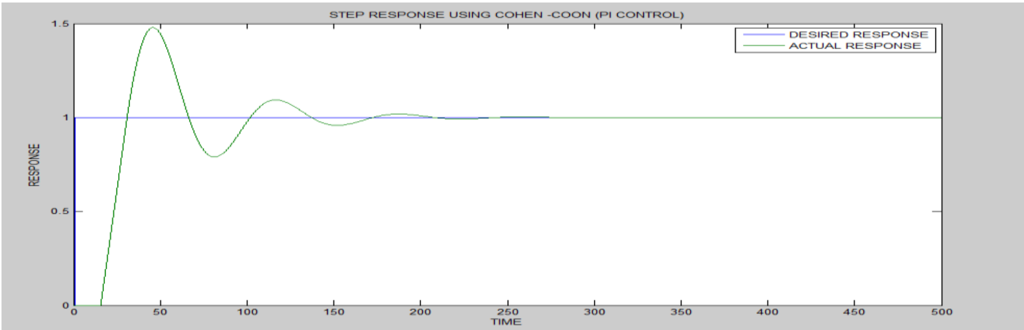


Figure 21: Response with PI controller (Cohen-Coon method)

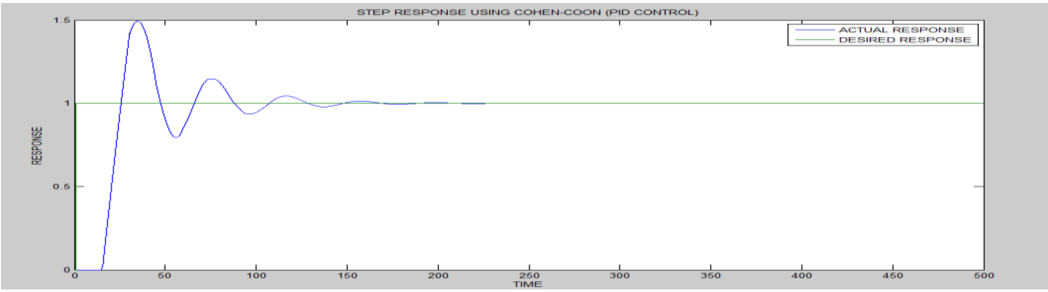


Figure 22: Response with PID controller (Cohen-Coon method)

## D. SIMULINK MODEL FOR FUZZY LOGIC METHOD

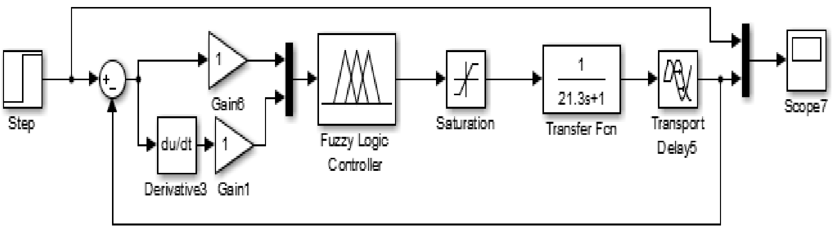


Figure 23: Simulink model for fuzzy logic controller.

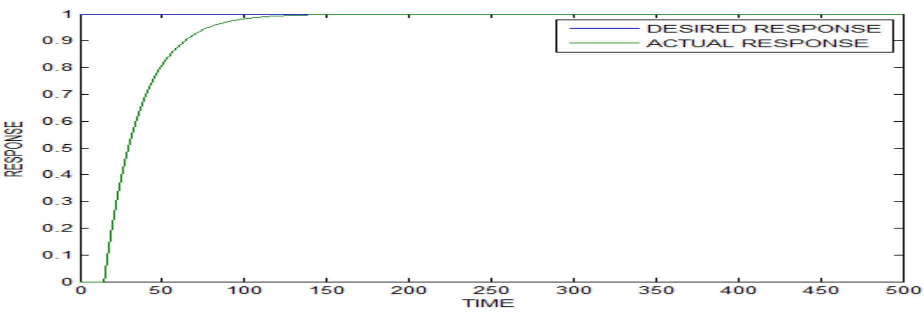


Figure 24- Step response for fuzzy logic controller.

## E. SIMULINK MODEL OF TYREUS-LUYBEN METHOD

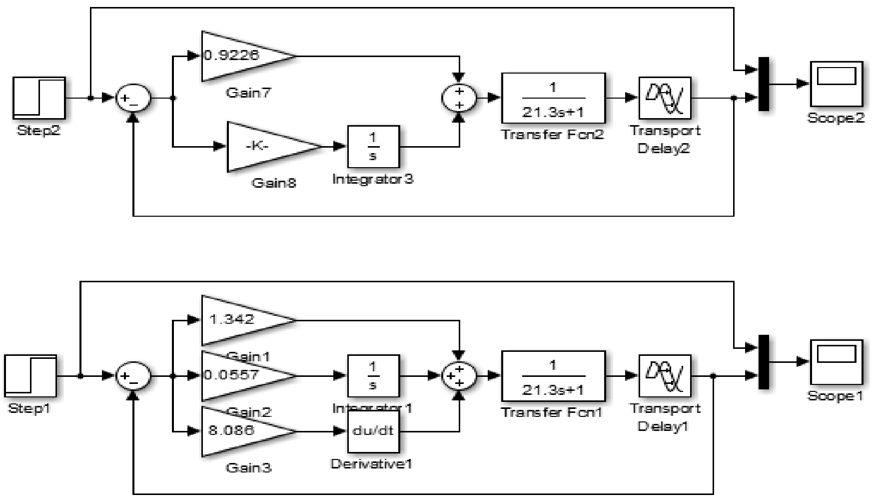


Figure 25 - Simulink model of Tyreus-Luyben method.

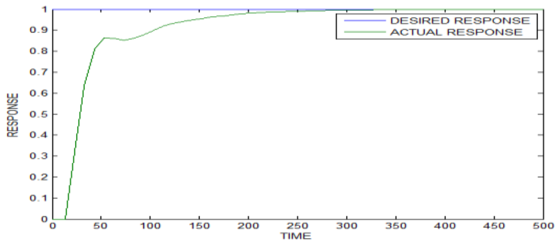


Figure 26- Step response for Tyreus-Luyben PI controller

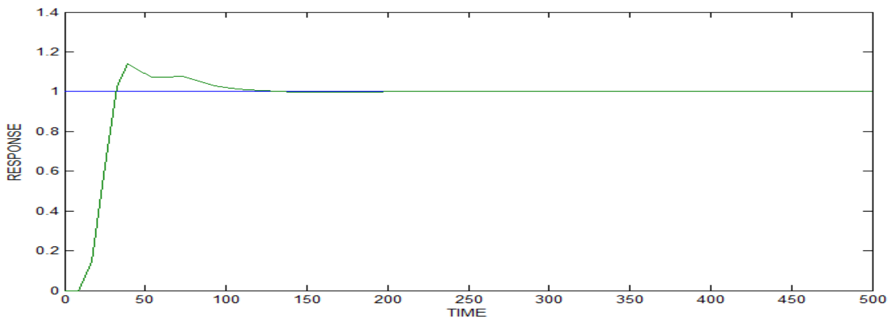


Figure 27- Step response for Tyreus-Luyben PID controller

## F. SIMULINK MODEL FOR AMIGO METHOD

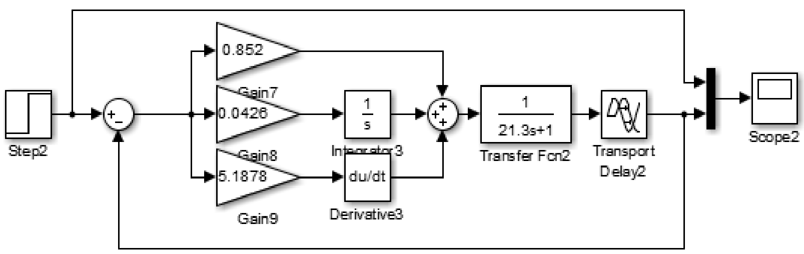


Figure 28- Simulink model for AMIGO method.

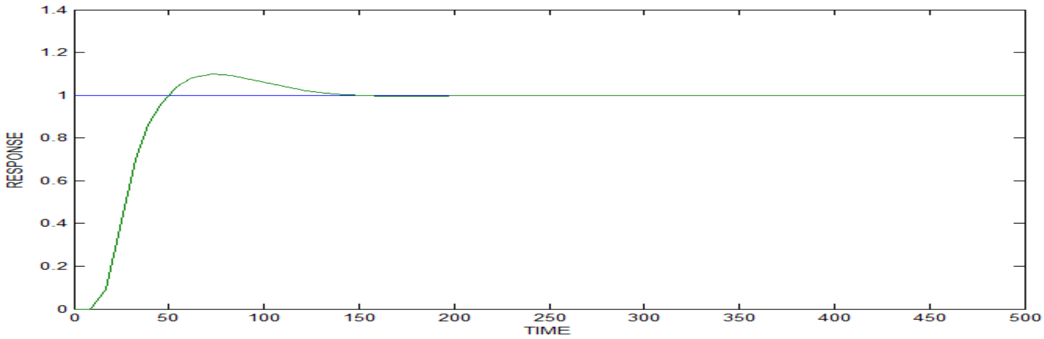


Figure 29- Step response for AMIGO method

**Table 1: Comparisons of various methodologies done earlier.**

| | PEAK AMPLITUDE | OVERSHOOT | SETTLING TIME (in sec) | RISE TIME (in sec) |
|---|---|---|---|---|
| Trial and Error | 1.011 | 1.13% | 62 | 28.6 |
| Z-N(open-loop) | 1.1583 | 15.8 % | 111 | 10.65 |
| Z-N(closed-loop) | 1.31 | 31.6% | 85.32 | 9.91 |
| T-L PID | 1.11 | 11.2% | 100 | 13.21 |
| C-C PID | 1.49 | 49.9% | 139 | 5.52 |
| AMIGO | 1.10 | 10.4% | 121.98 | 24.88 |
| FLC | 1 | 0 | 98 | 46.81 |

**Table 2 Comparisons of various methodologies done by me.**

| | PEAK AMPLITUDE | OVERSHOOT | SETTLING TIME (in sec) | RISE TIME (in sec) |
|---|---|---|---|---|
| Trial and Error | 1.0162 | 1.6% | 57 | 27.25 |
| Z-N(open-loop) | 1.017 | 1.7 | 208.5 | 17 |
| Z-N(closed-loop) | 1.336 | 33.6% | 150 | 13.30 |
| T-L | 0 | 0 | 200 | 88 |
| C-C | 1.478 | 47.8% | 173 | 12.17 |
| FLC | 1 | 0 | 98 | 46.81 |

## V. CONCLUTION

This paper has presented the comparison of PID controllers with the help of Simulink. The use of PID controllers for the control of frequency in the form of dead time processes hasbeen addressed.Then, starting from the model obtained, different approaches have been presented for the tuning of the PID parameters with the aimof showing that the tuning problem can be tackled from different viewpoints, eachwith specific features, methodology for the performance assessment and retuning of PIDcontrollers has been described. We need simple way to use, intuitive methods that require little information and that give moderate performance. There is also a need for sophisticated methods that give the best possible performance even if they require more information and more computation.

A good tuning method should be based on a rational design method that considers trade-offs between:

- Load disturbance attenuation
- Model requirements
- Robustness
- Response to set point change

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