Design and Evaluation of a PID Controller for a Power System

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Introduction

Concerning about the behavior of the synchronous machines after a disturbance is known as the stability problem, and how to solve this problem is the aim of this project. A power system is said to be stable, if it can regain its equilibrium state around its operating points after a physical disturbance, and has a bounded output for most of its system variables

Objectives

This project objective is to design the PI and the PID controllers on a single machine infinite bus power system by implement that in laboratory and in MATLAB.

Nonlinear Model:

The power system model is described by a 4th order nonlinear system as the following:

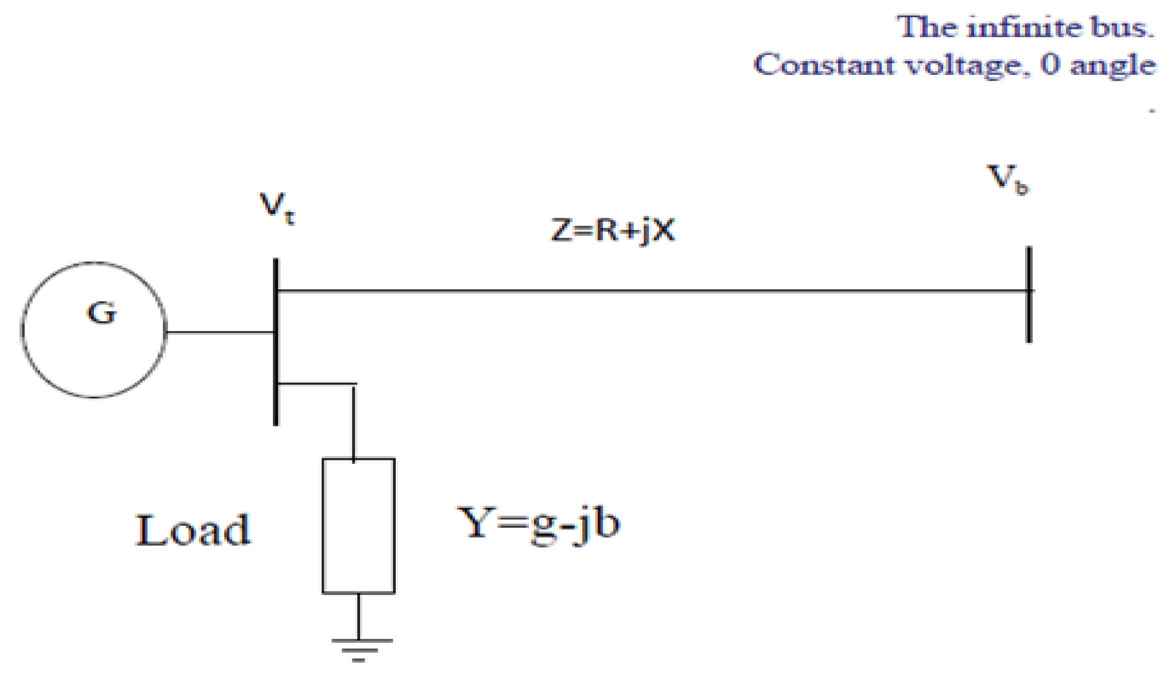
$$\dot{\delta} = \dot{\omega} - \omega_o$$
$$\dot{\omega} = \frac{1}{M}[Pm - Pe]$$
$$\dot{e}'_q = \frac{1}{T_{do}'}[E_{fd} - e_q]$$
$$\dot{E}_{fd} = -\frac{1}{T_A}(E_{fd} - E_{fdo}) + \frac{K_A}{T_A}(V_{to} - V_t + u)$$

Procedure:

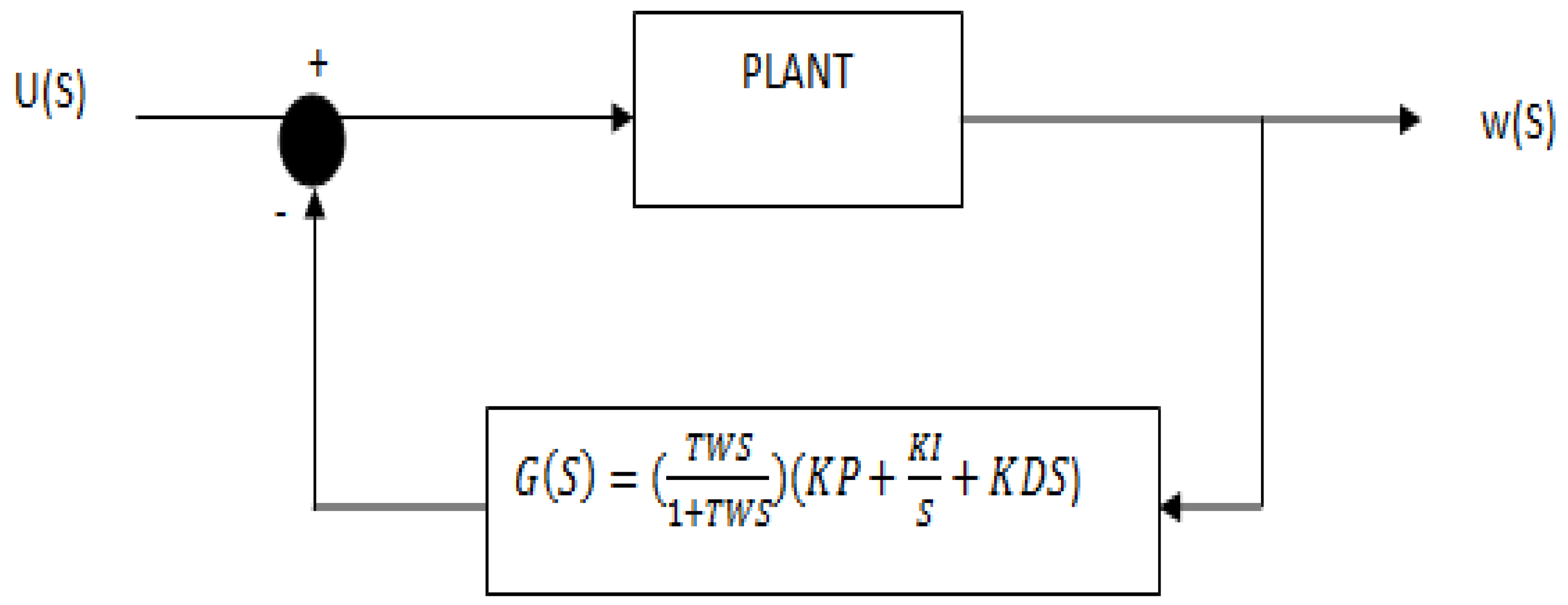
1- Linearization:

For the dynamic stability, dealing with linear model is better because it is easier to be used in the control design. The linearized system will have almost the same behavior as the nonlinear one around its operating point. So, we will linearize the system and then apply the PI, and PID controllers.

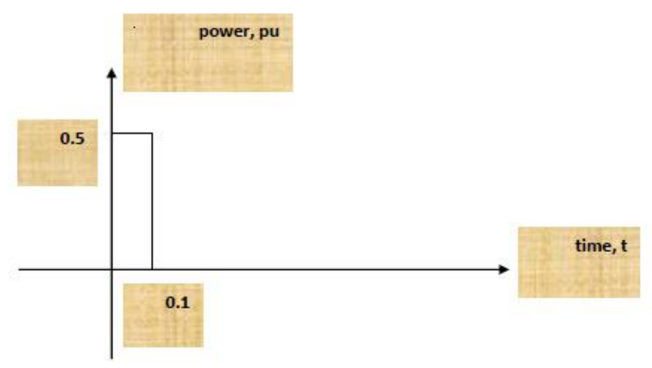
Block Diagram



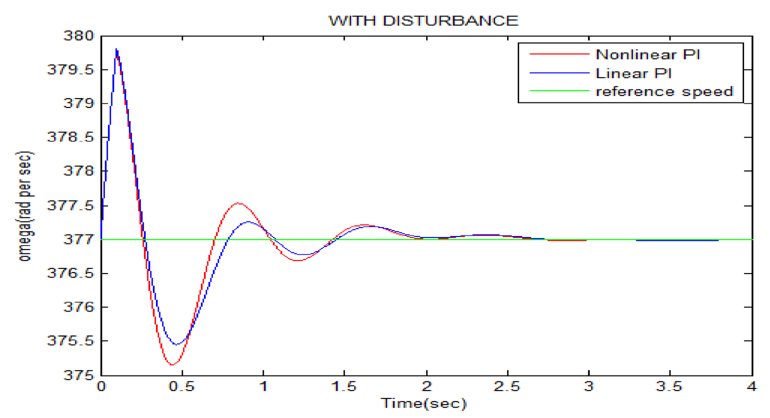
System Block Diagram



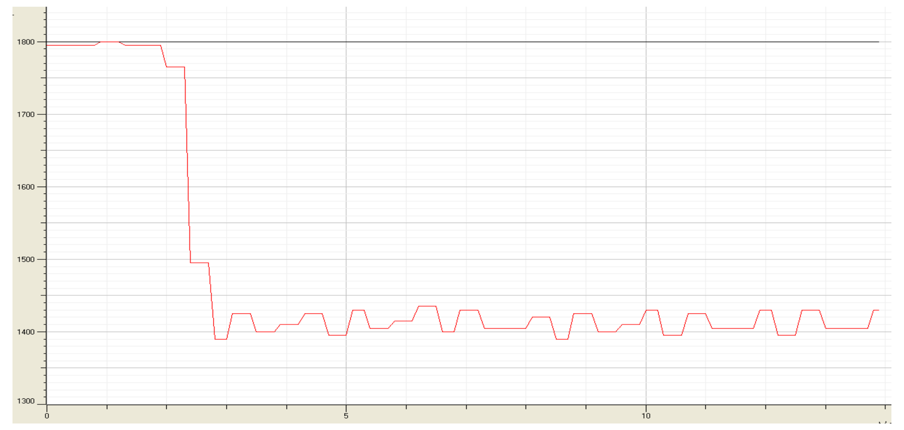
Results



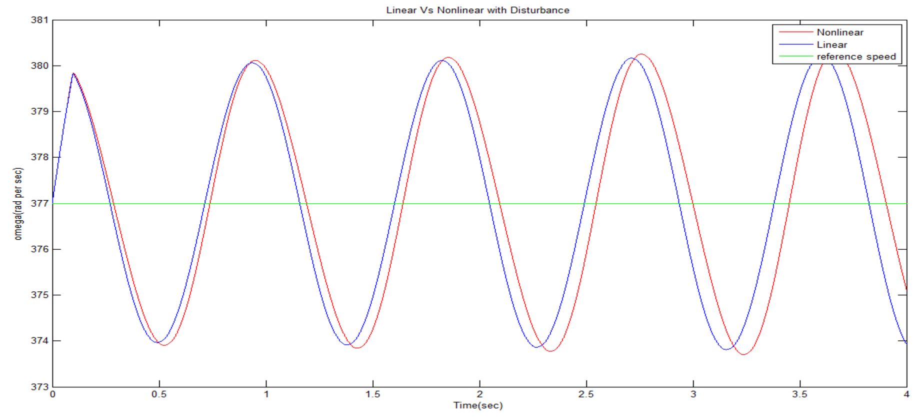
Disturbance Input



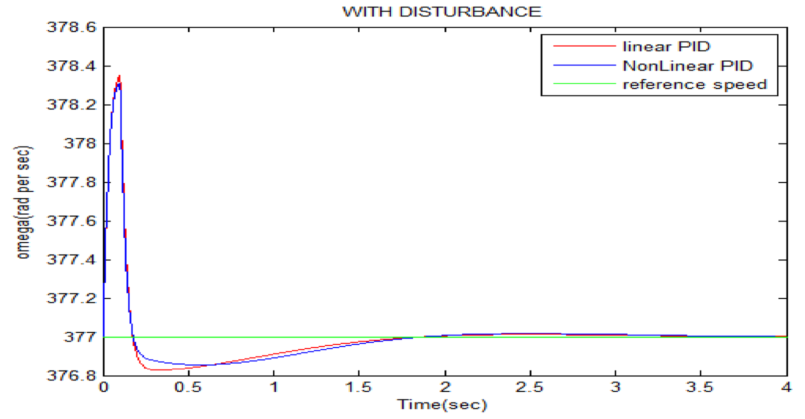
Speed response with PI controller



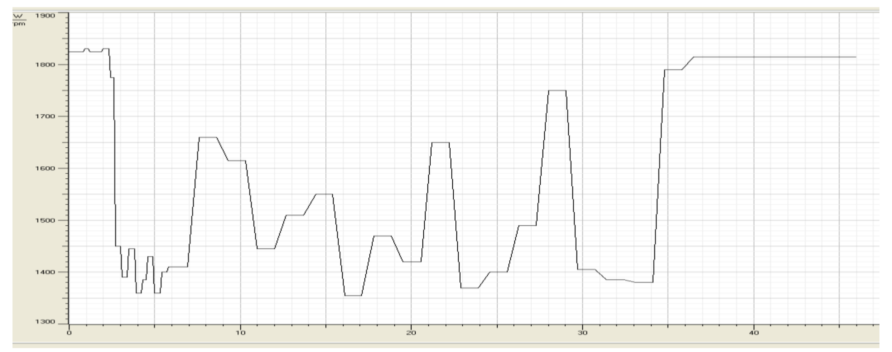
Synchronous generator with disturbance and without controller



Speed response without controller



Speed Response with PID controller



Synchronous generator with disturbance and with PI controller

After computations we got the linearized model as:

$$\begin{pmatrix} \Delta\dot{\delta} \\ \Delta\dot{\omega} \\ \Delta\dot{e}'_q \\ \Delta\dot{E}fd \end{pmatrix} = \begin{pmatrix} 0 & \omega_o & 0 & 0 \\ -\frac{K1}{M} & 0 & -\frac{K2}{M} & 0 \\ -\frac{K4}{T_{do}'} & 0 & -\frac{1}{K3\,T_{do}'} & 0 \\ -\frac{KeK5}{Te} & 0 & \frac{-KeK6}{Te} & -\frac{1}{Te} \end{pmatrix} \begin{pmatrix} \Delta\delta \\ \Delta\omega \\ \Delta e'_q \\ \Delta Efd \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ \frac{Ke}{Te} \end{pmatrix} u$$

$$y = (0\,1\,0\,0)\begin{pmatrix} \Delta\delta \\ \Delta\omega \\ \Delta e'_q \\ \Delta Efd \end{pmatrix} + [0]u$$

2-PI Controller Design:

The PI control method help us to control the pole position to some degree .The PI controller transfer function has two gains .The first term is KP which is the proportional gain .The second is KI which is the integral term that react to past errors .for our system ,which is fourth order system ,and have only two unstable poles. We used the pole placement method to find the parameters of the PI controller.

3-PID Controller Design:

When we add the derivative term we can assign an extra pole, thus making the system more stable.

Results:

We have succeeded in stabilizing our power system using PI and PID controllers. Also, by comparing the PI VS PID controlled response, we got an improvement of 48.8% in the P.O and 16.7% in the settling time in the PID case. Thus, we can see that The PID controllers are superior to PI control.

Conclusion

In this project we have designed a PI and PID controllers to stabilize a power system. We have done that by first modeling the system, then linearizing the nonlinear model, and finally analyzing the system to get the optimal KP, KI, and KD. Also, we have implanted a PI controller for a synchronous machine in the lab and controlled it using only PI controller, to relate the simulation part to the laboratory machine. This part is not in the scope of our project.