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Optimization of PID Controller by ZN Method for Load Frequency Control for Isolated Power System

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Abstract - *In the Electrical Power System the load demand is not steady with the time and also there is always a chance of faults on transmission lines which creates power mismatch which leads to undesired variation in load frequency. This paper is devoted to designing a controller for controlling the load frequency when an isolated power station is subjected to a fault. The main aim of considering the isolated plant is, there quite number of plant which are on remote location and not connected to the Grid due to economic constraints. A sophisticated PID controller is designed and there gain constants are optimized by Ziegler-Nichols method. The approach is quite easy and its model is simulated on MATLab/Simulink. The obtained results show that the desired performance specifications could be achieved by the proposed method.*

***Key Words*: Load Frequency Control, Automatic Generation Control, PID Controller, ZN method.**

1. INTRODUCTION

Load Frequency control is an important task in electrical power system design, operation and control. The power plant load demand varies without any prior schedule, the power generation is expected to overcome these variations without any voltage and frequency instabilities. Therefore voltage and frequency controllers are required to maintain the generated power quality in order to supply constant voltage and frequency to the utility grid. In an electric power system, automatic generation control is a system for adjusting the power output of multiple generators at different power plants, in response to changes in the load. Since a power grid requires that generation and load closely balance moment by moment, frequent adjustments to the output of generators are necessary. The frequency control is done by load-frequency controllers, which deals with the control of generator loadings depending on the frequency.

The most critical component in generator control system is the controller. It is designed in such a way that the concerned parameter as frequency and tie line power flowing as to maintain power system stable and secure [9].

There were several approach was proposed to optimize the gain constants with considering the uncertainties of power system [2] i.e. generating rate constraints [6], valve speed limit to handle the nonlinearities in power system. Decentralized PID controller based on the Kharitonov's theorem and stability boundary locus [10] was proposed to taking care of uncertainties in each control area. Laurent series expansion methods was suggested to tuning the controller parameters and with simulation achieves better damping for frequency and tie-line power flow deviations. Plotting the stability boundary locus in the $K_P - K_I$ plane and then computing the stabilizing values of the parameters of a P-I controller proposed in [8] and with the time delay in [11]. Internal model control method is proposed in [12] with the additional degree of freedom to cancel the effect of undesired poles of disturbances.

1.1 PID Controller

PID control stands for proportional–integral–derivative control. PID control is a feedback mechanism used in a control system. This type of control is also termed as three-term control, and is implemented by a PID Controller. By calculating and controlling three parameters which are the proportional, integral and derivative of how much a frequency deviates from the desired set point value we can achieve different control actions for load frequency control. Fig.-1 shows the basic control configuration where in the controller input is the error between the desired output (command, set point, input) and the actual output [5]. This error is manipulated by the controller to produce a command signal for the plant according to the relationship.

$$U(s) = K_p\left(1 + \frac{1}{\tau_i s} + \tau_d s\right)E(s) \quad (1)$$

In time domain

$$u(t) = K_p\left[e(t) + \left(\frac{1}{\tau_i}\right)\int_{-\infty}^{t} e\,dt + \tau_d\left(\frac{de}{dt}\right)\right] \quad (2)$$

Where

K_p = Proportional gain

τ_i = integral time constant

τ_d = derivative time constant

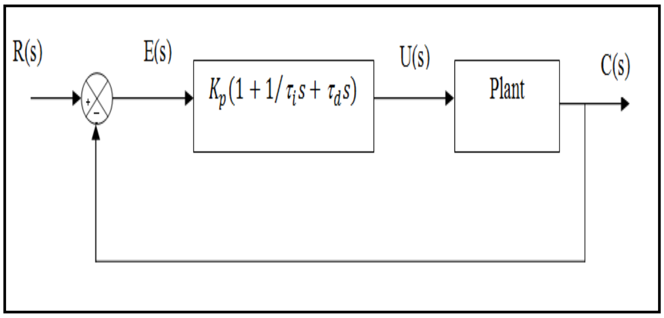

Fig.1: PID Control Configuration

1.2 Performance Specifications by PID

There are some control actions which can be achieved by using any of the two parameters of the PID controller. Two parameters can work while keeping the third one to zero. So PID controller becomes sometimes PI (proportion-integral), PD (proportional-derivative) or even P or I. The derivative term D is responsible for noise measurement while the integral term is meant for reaching the targeted value of the system. The proportional, derivative and integral parameters can be expressed as K_p, K_d and K_i. All these three parameters have an effect on the closed loop control system. It affects rise time, settling time and overshoot and also the steady state error.

Table 1: Performance Specifications by Controller

Control Respose	K_p	K_d	K_i
Rise Time	decrease	small change	decrease
Setting Time	small change	decrease	increase
Overshoot	increase	decrease	Increase
Steady State Error	decrease	no change	eliminate

Once the set point has been changed, the error will be computed between the set point and the actual output. The error signal, E(s), is used to generate the proportional, integral, and derivative actions, with the resulting signals weighted and summed to form the control signal, U(s), applied to the plant model. The new output signal will be obtained. This new actual signal will be sent to the controller, and again the error signal will be computed. New control signal, U(s), will be sent to the plant. This process will run continuously until steady-state error.

2. PID CONTROLLER TUNING BY TRIAL AND ERROR METHOD

The proportional, derivative and integral parameters can be expressed as K_p, K_d and K_i are need to tuned for the specific control action with the knowledge of desired performance specifications. A simple and dynamic approach is taken to quantify the numerical value of PID control parameters which is trial and error method yet the method is very tedious but gives the understanding of effects of individual parameter.

A single area network or isolated plant is selected for this study as shown in Fig. 2. An isolated power has rated turbine power is 250MW at nominal frequency of 50Hz, is subjected to a sudden load change of 50 MW. The governor speed regulation is set to 0.05 pu. The load varies by 0.8% for 1% change in the frequency. The remaining parameters are tabulated in Table 5.2.

Table 2: System Parameters for Isolated Power System

Particular	**Value**
K_{sg} (**Gain of speed governor**)	1
T_{sg} (Time constant of speed governor in sec.)	0.20
K_t (**Gain of turbine tranfer function**)	1
T_t (Time constant **of turbine in sec.**)	0.50
H(**Inertia constant**)	5
D(pu MW /Hz)	0.80
1/R(Speed regulation)	20=1/0.05
ΔP_D (**Alteration in load Demand**)	0.2=50/250

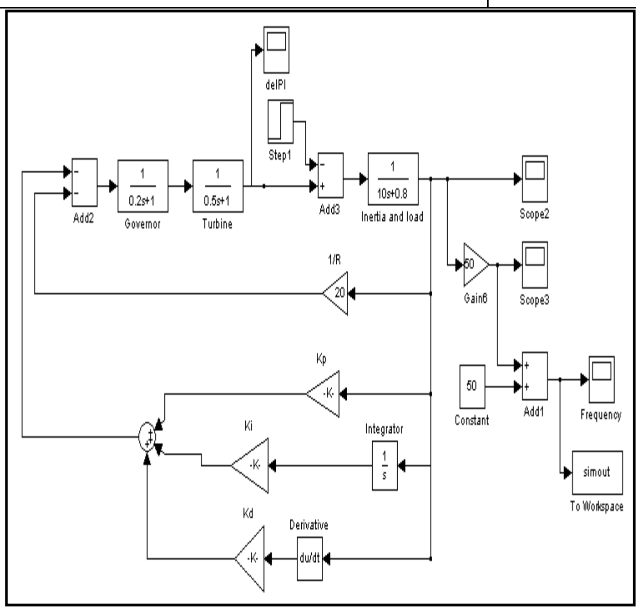

Fig. 2: Simulink Model of Isolated power system

Fig. 3 represents frequency deviation following sudden load increment. To maintain the frequency variation zero PID controller is installed in feedback having controller gain of

$$K_p = 5$$

$K_i = 3$

$K_d = 1$

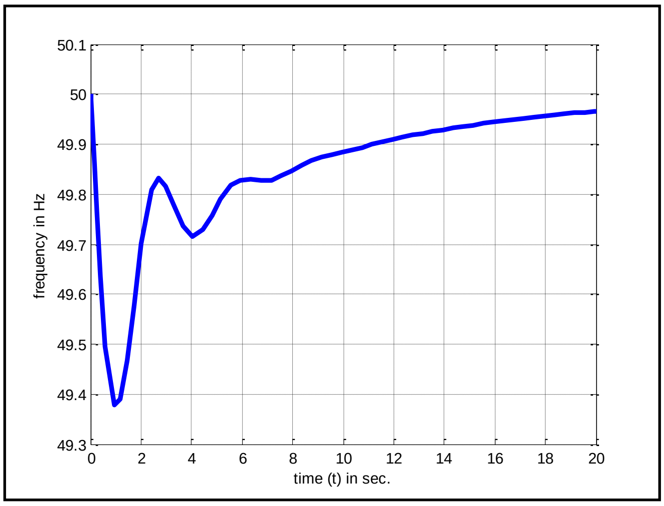

Fig. 3: PID with $K_p = 5, K_i = 3$ & $K_d = 1$

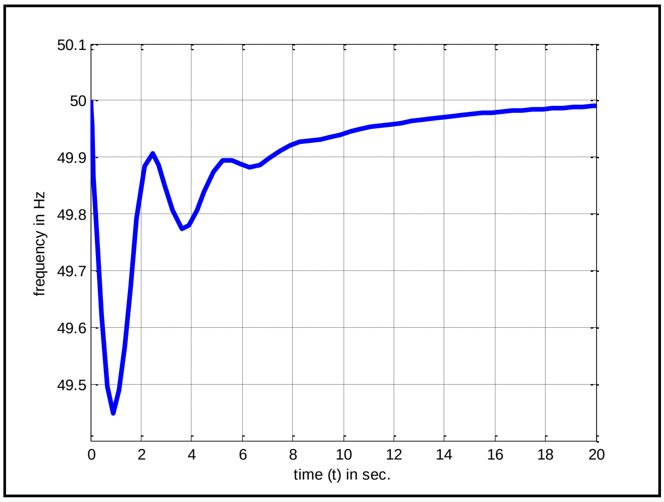

Fig. 4: PID with $K_p = 10, K_i = 5$ & $K_d = 2$

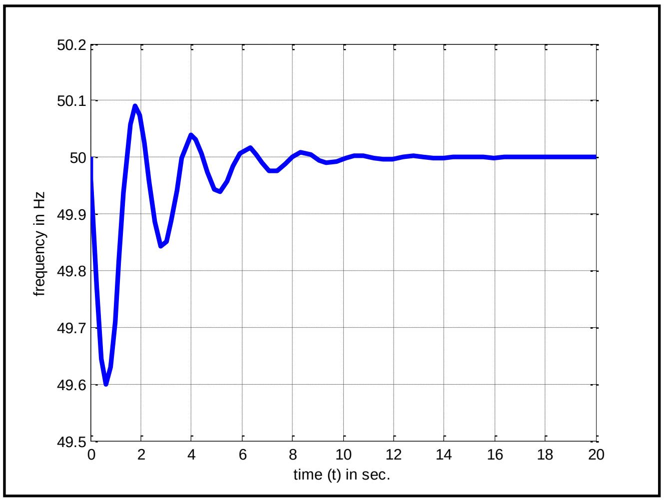

Fig. 5: PID with $K_p = 30, K_i = 20$ & $K_d = 5$

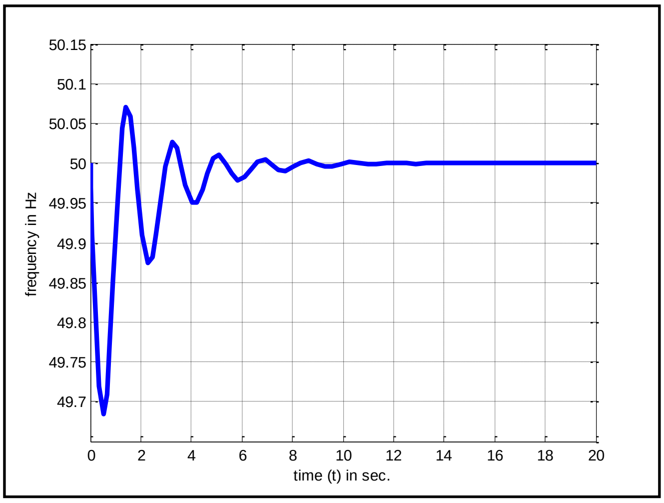

Fig. 6: PID with $K_p = 50, K_i = 30$ & $K_d = 10$

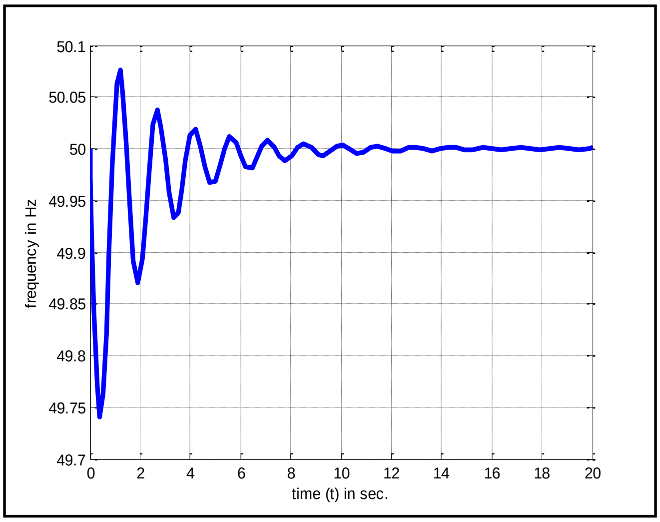

Fig. 7: PID with $K_p = 80, K_i = 40$ & $K_d = 15$

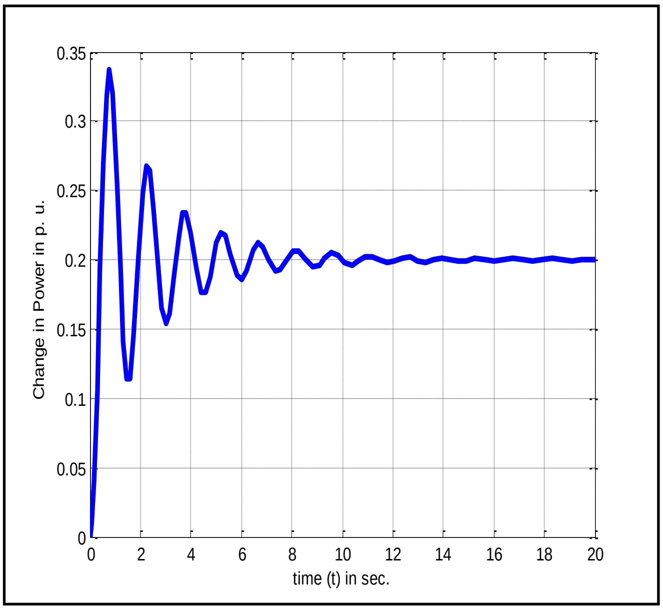

Fig. 8: Turbine output vs. time

After analyzing all the frequency deviation results the optimum values of the gains of PID controller are$K_p = 50, K_i = 30$ & $K_d = 10$, having zero steady state error i.e. frequency came back to its nominal value 50 Hz, lower overshoot and damped oscillations. Turbine output shown in figure 5.6 depicts that output of prime-mover followed by speed governor which meets the increased load of 0.2pu i.e. 50 MW settles at 0.2 pu and a new equilibrium established.

3. TUNING BY ZIEGLER-NICHOLS METHOD

The most popular tuning methodology was proposed by Ziegler and Nichols in 1942. PID controller's on line auto tuning that is based on Ziegler Nichols tuning method. The advantage of Z-N PID controller tuning is also carry out for higher order systems. Z-N PID Controller is controlling the plant or system by continuously monitoring plant output which is known as process value with the desired process value known as set point of the system.

The PID controller manipulates on the difference between process value and set point called as error. In the conventional controlling method the transfer function of plant should be calculated in order to find out various parameters and the value of PID constants. But in this method there is no necessary to derive the transfer function of the system. Thus Z-N PID controller is monitoring the plant depending on set point and process value and irrespective of the nature of plant.

Various tuning sequences are applicable depending upon the dynamic model of the plant. When the dynamic model of the process, for which the PID constants are to be found, is not known, its open loop response for a step input is determined experimentally or by simulation. If the response is S-shaped Ziegler-Nichols method is applicable otherwise on specific tuning method available.

If the dynamic model of the system is known the PID controller can be tuned using Ziegler Nichols method. It is first assume that the controller has only proportional gain K_p term. We then proceed to determine the critical Gain K_{cr} for the closed loop system to just get into continuous oscillations the corresponding time period T_{cr} of the oscillations is determine knowing these two values the PID controller can be tuned using following result [5].

$$K_p = 0.6\, K_{cr} \quad (3)$$

$$\tau_i = 0.5\, T_{cr} \quad (4)$$

$$\tau_d = 0.125\, T_{cr} \quad (5)$$

The characteristic equation of isolated power system with speed governor, turbine and generator load transfer function of closed loop system with only proportional gain(K_p) constant is given by

$$s^3 + 7.08s^2 + 10.56s + K_p + 20.8 = 0$$

The critical gain is determined by Routh array Table 3 shown below for the characteristic equation

Table 3: Routh Array to Determine K_{cr} for Continuous Oscillations

s^3	1	10.56
s^2	7.08	$K_p + 20.8$
s^1	$\frac{74.7648 - (K_p + 20.8)}{7.08}$	0
s^0	$K_p + 20.8$	

It easily seen from the Routh array that the power system would be unstable for

$$\frac{74.7648 - (K_p + 20.8)}{7.08} < 0$$

Hence

$$K_{cr} = 53.9648$$

To find frequency of oscillation

$$7.08s^2 + (K_p + 20.8) = 0$$

$$7.08s^2 + 74.7648 = 0$$

$$s = \pm j\sqrt{74.7648/7.08} = \pm j3.2496 \text{ rad./sec.}$$

Therefore

$$T_{cr} = \frac{2\pi}{3.2496} = 1.9335 \text{ sec.}$$

According to Ziegler and Nichols Method

$$K_p = 0.6 \times K_{cr} = 32.3789$$

$$K_i = \frac{K_p}{0.5 \times T_{cr}} = 27.4235$$

$$K_d = K_p \times 0.125 \times T_{cr} = 9.5583$$

After applying these values to gains of PID, frequency deviation plot shown in Fig. 9 depicts minimum overshoot and least settling time. Fig. 10 shows variation of turbine output.

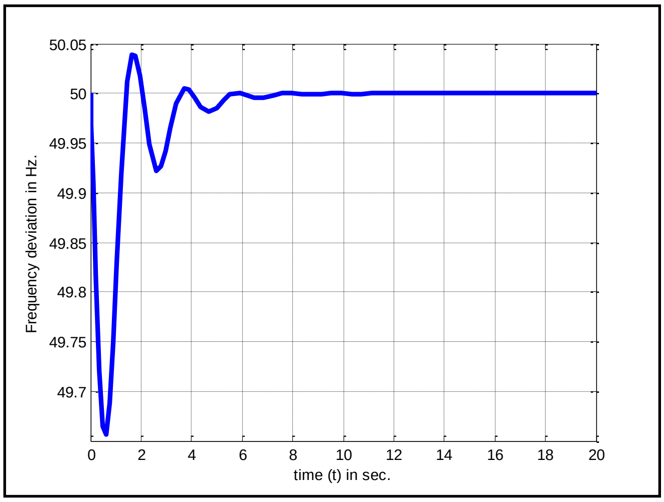

Fig. 9: Frequency Deviation with Tuned PID by ZN Method

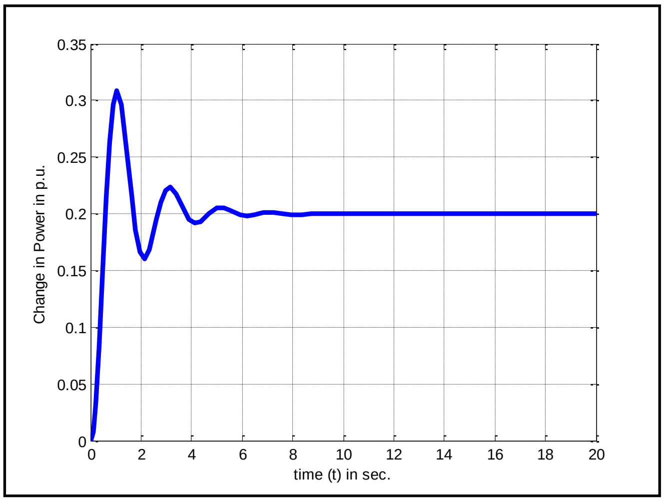

Fig. 10: Mechanical Power output by Turbine with Tuned PID by ZN Method

4. CONCLUSIONS

In this paper we tried to tune the PID controller for load frequency control by Trial and Error and Ziegler and Nichols Method. The output of the load change was controlled with less overshoot and shorter settling time using the ZN-PID based controller, the computer simulations results show that the proposed ZN controller is more effective means for improving the dynamic performance of the power plant compared to the conventional integral controller. Although the tuning method is quite easier compare to cumbersome trial and error method for all desired aspects of dynamic performance specifications.

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