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Load-Frequency Controller of electrical Power plant using Ziegler-Nichols (ZN) tuning controller

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Abstract

This paper describes a brief study of the Ziegler Nichols Method (ZN) for tuning of PID controller. The PID control method is most flexible and simple method. The conventional PID controller is replaced by Z-N tuning PID controller, the load-frequency control (LFC) is used to restore the balance between load and generation in each control area by means of speed control. The objective of Load-Frequency control (LFC) is to minimizing the transient and steady state error to zero. This paper investigates Load-Frequency control (LFC) with time delays using Z-N tuning PID controller for power plant using Matlab/Simlink.

Keywords: *Ziegler-Nichols Tuning, PID controllers ,* Load-Frequency Control, Power Systems.

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1. Introduction

In the last decades, an enormous number of Load-Frequency Control (LFC) methods are proposed [1].Load Frequency control (LFC) 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. Many research has been done and different approaches has been proposed over the past decades regarding the load-frequency control of single and multi area power systems [2]. The main purpose of load frequency controllers is to ensure the stable and reliable operation of power systems. Load frequency control in power systems introduces as one of the most important items in order to supply reliable electric power with good quality some of the proposed methods in literature deal with system stability using fixed local plant models ignoring the changes on some system parameters. Nowadays, with the development in digital technology, it has become possible to develop and implement new controllers based on modern and more sophisticated synthesis techniques. Indeed, controllers based on robust optimal control, adaptive control, artificial intelligence (Fuzzy logic, neural networks, and genetic algorithms) are being developed. This paper PID controller has been designed for higher order system using Ziegler-Nichols frequency response method and its Performance has been observed with plant data. The most popular tuning technique is the Ziegler-Nichols method. However, besides being suitable only for system with monotonic step response, the compensated system whose controllers are tuned in accordance with the Ziegler-Nichols method have generally a step response with a high- percent overshoot. Ziegler and Nichols proposed the manual tuning of PID controller. The Ziegler Nichols tuned controller parameters are fine tuned to get satisfactory performance.

2. Load Frequency Control

Two parts of this system can be considered. A considerable attention should be pay to the LFC (Load Frequency Control) section. Changes in real power mainly affect the system frequency, while reactive power is less sensitive to changes in frequency and is mainly dependent on changes in voltage magnitude. The LFC thus controls the real power and the frequency of the system. It also has a major role in the interconnection of different power plants [1], for satisfactory operation of a power system; the frequency should remain nearly constant. This is the reason why system frequency must not be allowed to deviate from a chosen constant value. Most types of ac motors run at speeds that are directly related to the frequency. The generator turbines, particularly steam driven ones, are designed to operate at a very precise speed. The overall operation of a power system can be much better controlled if the frequency error is kept within strict limits. A large number of electrically operated clocks are used. They are all driven by synchronous motor, and the accuracy of these clocks is a function not only of the frequency error but actually of the integral of this error. The frequency of a system is dependent on active power balance. As frequency is a common factor throughout the system, a change in active power demand at one point is reflected throughout the system by a change in frequency. Because there are many generators supplying power into the system, some means must be provided to allocate change in demand to the generators. A speed governor on each generating unit provides the primary speed control function, while supplementary control originating at a central control Centre allocates generation. The control of generation and frequency is commonly referred to as load frequency control [6].

3.PID controller

Frequency response method suggested by Ziegler-Nichols is applied for design of PID controller. [8] PID controller parameters consist of three separate parameters: proportionality, integral and derivative values are denoted by *kp*, *ki*, and *kd*. Appropriate setting of these parameters will improve the dynamic response of a system, reduce overshoot, eliminate steady state error and increase stability of the system [3]
The transfer function of a PID controller is:

$$C(s) = \frac{U(s)}{E(s)} = k_p + \frac{k_i}{s} + k_d s \qquad (1)$$

The combined plant with PID controller is shown in Fig. 1.

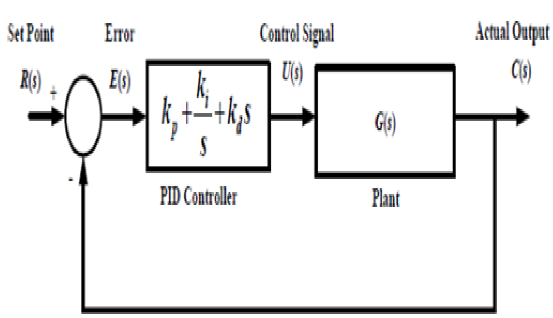

Fig 1 combined plant with PID controller

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.

3.1Ziegler Nichols Tuning 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 [4]. 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 [5]. 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.

3.2 Ziegler-Nichols tuning rule:

Ziegler-Nichols tuning rule was the first such effort to provide a practical approach to tune a PID controller. According to the rule, a PID controller is tuned by firstly setting it to the P-only mode but Adjusting the gain to make the control system in continuous oscillation.

Ziegler-Nichols step response method [9]
The most employed PID design technique used in the industry is the Ziegler-Nichols method which is based on the open loop step response of the system and characterized by two parameters ‘a’ and ‘L’. The parameter setting according to Ziegler-Nichols method is carried out in four steps:
(1) Obtain the plant open loop step response
(2) Draw the steepest straight line tangent to the response;
(3) The intersections of this tangent with the vertical and the horizontal axis gives ‘a’ and ‘L’ respectively;
(4) Set the parameters Kp, Ti and Td according to Table . 1.

Table 1 Ziegler-Nichols tuning table [4]

Controller	K_p	T_i(sec)	T_d(sec)
P	1/a		
PI	0.9/a	3L	
PID	1.2/a	2L	L/2

4. The Structure of Power Systems

In a power plant, both active and reactive power demands continually vary the rising or falling trend. Power input must therefore be continuously regulated to match the active power demand; otherwise the machine speed will change with consequent change in frequency, which may be highly undesirable. Also the excitation of generators must be continuously regulated to match the reactive power demand with reactive generation, failing which the voltage at various system buses may go beyond the prescribed limits. Ziegler Nichols frequency response method and PID controller .

Governor (Tg)=$\frac{1}{1+T_g s}$, Turbine (Tt)= $\frac{1}{1+T_t s}$, Rotating mass & load=$\frac{1}{2Hs+D}$, Speed regulation =$\frac{1}{R}$

Open loop transfer function (TF) of given plant is

$$G(s) = \frac{1}{[(0.2S+1)(0.5S+1)(10S+0.8)]} \quad \ldots\ldots(1)$$

$$G(s) = \frac{1}{s^3+7.08s^2+10.56s+0.8} \quad \ldots\ldots\ldots(2)$$

5.SIMULATION RESULTS

The system dynamic performance is observed for two different controller structures, PID and Z-N tuning controller. We can construct the model with the environment MATLAB (R2010a) Simulink and PID controller is design for Power plant model using MATLAB Simulink , Plant data show in the table 2,The plant model below shown fig 2 is completely designed in control system tool using Z-N tuning method.

Table 2 plant data[4]

s.no	Name of parameter	value
1	Turbine time constant	0.5 s
2	Governor time constant	0.2 s
3	Generator Angular Momentum	10Mjrad/s
4	Governor Speed regulation	0.05
5	Load change	0.8%
6	D	0.8
7	Turbine rated output	250MW

The simulation results are shown in Figs. 3-5 in this study, and Table 3 shows the comparison of ZN-P,ZN-PI and ZN-PID controller. its clear that minimum rise time and minimum setting time achieved by ZN –PID controller and good overshoot of ZN-PID controller then ZN-P or ZN-PI controller.

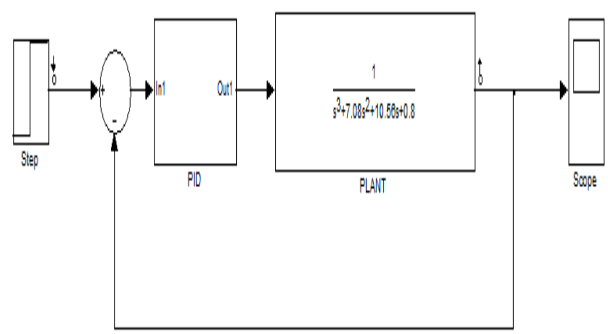

Fig 2 simulink model of plant with PID controller

Table 3 Comparison of different controller

Method	Rise time (Tr)	Setting time (Ts)	Over shoot (%)
ZN-P	1	5.37	20.9
ZN-PI	1.16	5.99	16.2
ZN-PID	0.892	4.22	8.79

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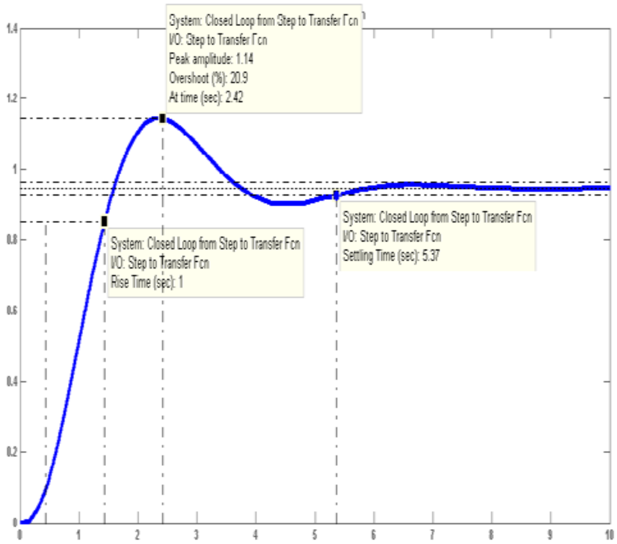

Fig 3 ZN-P controller

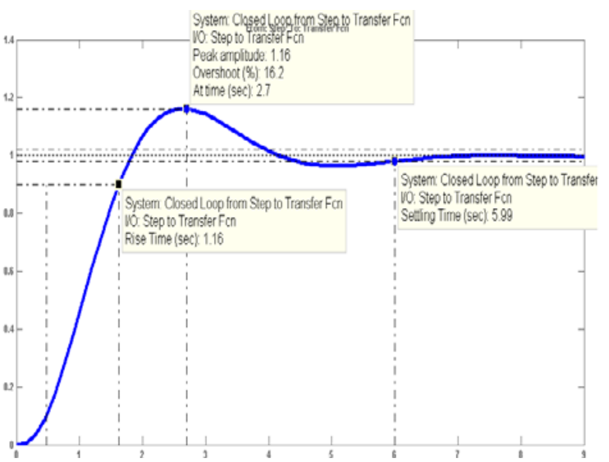

Fig 4 ZN-PI controller

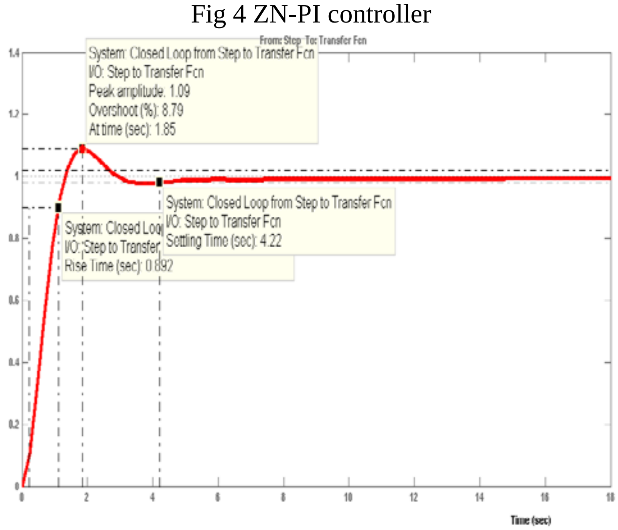

Fig 5 ZN-PID controller

6. CONCLUSION

in this paper firstly, design of PID controller using ZN technique is used for control higher order process, result shows that ZN-PID gives better dynamic performance over ZN-PI or ZN-P, Controller as the frequency settling time and overshoots decreases using ZN-PID controller respect to ZN-PI controller. 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. The proposed ZN controller still achieves good dynamic performance when the other controller such as P, PI and PID Controller. The simulation results show that the proposed controller can perform an efficient search that achieves better performance criterion through Also, the ZN-PID controller is more superior.

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