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Power Plant Load Frequency Control in Single area with Traditional Ziegler-Nichols-PID Tuning Controller

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Abstract: *This paper deals with an optimal tuning of Ziegler Nichols Proportional Integral Derivative (PID) controller for both Load Frequency Control (LFC) and Automatic Voltage Regulation (AVR) of interconnected power system.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. 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 integrator gain is set to a level that the 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 condition and non-linearities in the generator unit. The conventional PID controller is replaced by Z-N tuning PID controller, to make them more general and to achieve minimum steady-state error, also to improve the other dynamic behavior (overshoot). This paper studies control of load frequency in single area power system with PID-ZN controller. In this study, PID parameters are tuned using different adaptation techniques. The overshoots and settling times with the proposed controllers are better than the outputs of the conventional PID controllers. As constancy of frequency and voltage are important factors in determining the quality of power supply, the control of active power and reactive power is vital to the satisfactory performance of power system. The real power and frequency is controlled by LFC and the reactive power and voltage is controlled by AVR.The effectiveness of the proposed scheme is confirmed via extensive study using MATLAB/SIMULINK software.*

Keywords: *Load Frequency Control, AVR system, Proportional-Integral-Derivative controls, Ziegler-Nichols Tuning.*

1. INTRODUCTION

In the last decades, an enormous number of Load-Frequency Control (LFC) methods are proposed however, the present publications in this field are still showing a continuous interest for designing LFC systems [1].The modern power systems with industrial and commercial loads need to operate at constant frequency with reliable power. Load Frequency Control (LFC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. The main goal of the LFC is to maintain zero steady state errors for frequency deviation and good tracking load demands in a multi-area restructured power system [8]. Frequency is a key stability criterion in power systems. Toprovide the stability, active power balance and constantfrequency are required. Frequency depends on active powerbalance. If any change occurs in active powerdemand/generation in power systems, frequency cannot behold in its rated value. So oscillations increase in both powerand frequency. Thus, system subjects to a serious instabilityproblem. To improve the stability of the power networks, it isnecessary to design Load Frequency Control (LFC) systemsthat control the power generation and active power. Becauseof the relationship between active power and frequency, threelevel automatic generation controls have been proposed bypower system researchers [2].The modern power systems with industrial and commercial loads need to operate at constant frequency with reliable power. Load Frequency Control (LFC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. The main goal of the LFC is to maintain zero steady state errors for frequency deviation and good tracking load demands in a multi-area restructured power system [6].Since power system dynamic characteristics are complexand variable, conventional control methods cannot providedesired results. Intelligent controllers can be replaced withconventional controllers to get fast and good dynamicresponse in load frequency control problems [10].Nowadays, voltage and frequency control has gained more importance with the growth of interconnected power system. The real power is sensitive to frequency variations and it is regulated with LFC loop and the reactive power is sensitive to the voltage variations and it is regulated with AVR loop. This LFC and AVR control loops together are known as Automatic generation control (AGC). During the last decades the researchers have more attention to LFC over AVR although the main objective of the control strategy in an interconnected power system is, to generate both voltage and frequency within permissible limits. Recently, lot of research works were documented with an improved transient response by designing proper coupling effects between LFC and AVR and hence proves the necessity of AVR along with LFC. The flows of active power and reactive power in a transmission network are fairly independent of each other and hence this paper deals with individual control mechanism for LFC and AVR in order to improve the transient stability of power system [3].

This paper PID controller has been designed for higher order system using Ziegler-Nichols frequency response method and its Performance has been observed. 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. LINEARIZED MODEL OF THE PLANT

In an interconnected power system, LFC and AVR equipment are installed for each generator. The schematic diagram of the voltage and frequency control loop is represented in fig.1. The controllers are set for a particular operating condition and take care of small changes in load demand to maintain the frequency and voltage magnitude within the specified limits. Small changes in real power are mainly dependent on changes in rotor angle and, thus, the frequency f. The reactive power is mainly dependent on the voltage magnitude Change in angle caused by momentary change in generator speed. Therefore, load frequency and excitation voltage controls are non-interactive for small changes and can be modeled and analyzed independently excitation control is fast acting while the power frequency control is slow acting since, the major time constant contributed by the turbine and generator moment of inertia-time constant is much larger than that of the generator field. The cross coupling between the LFC loop and the AVR is negligible and load frequency and excitation voltage control are analyzed independently [4].

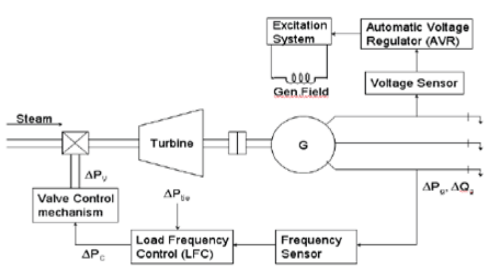

Fig. 1: Schematic block diagram of load frequency control & AVR control

3. LOAD FREQUENCY CONTROL (LFC)

The aim of LFC is to maintain real power balance in the system through control of system frequency. Whenever the real power demand changes, a frequency change occurs. This frequency error is amplified, mixed and changed to a command signal which is sent to turbine governor. The governor operates to restore the balance between the input and output by changing the turbine output. This method is also referred as megawatt frequency or Power-frequency (P-f) control [4,5,9]. The change in active power depends on frequency deviations and hence, the change in frequency in any point of the interconnected power system may affect the active power throughout the system. Fig. 1 shows the LFC in single area power system. Primary control action here is provided by the speed governor alone and the supplementary control.

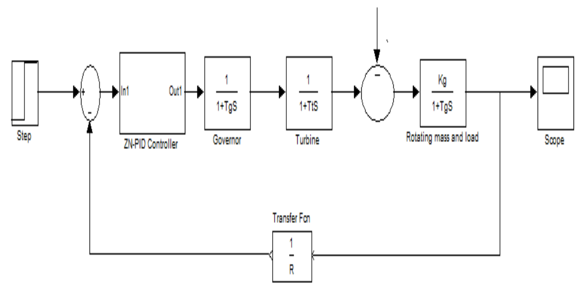

Fig. 2: Schematic block diagram of load frequency control

Originating at central control center allocated generation. The common nominal system parameters quoted in most of the references [5] are used in this paper. They are

Fixed Parameters: Tg= 0.2 ,T_t=0.5 ,kg=1 , H = 5,D=0.8

$$G(S)\quad H(S) \quad = \frac{1}{R \quad (2Hs+D)(1+TgS)(1+Tts)} \qquad (1)$$

4. AUTOMATIC VOLTAGE REGULATOR (AVR)

The aim of this control is to maintain the system voltage between limits by adjusting the excitation of the machines automatic voltage regulator senses the difference between a rectified voltage derived from the stator voltage and a reference voltage. This error signal is amplified and fed to the excitation circuit. The change of excitation maintains the VAR balance in the network. This method is also referred as Megawatt volt amp Reactive (MVAR) control or Reactive-voltage control the simulink models of load frequency controller and automatic voltage regulator is constructed based on the block diagram approach as proposed by Hadi Sadat [7].

The main objective of AVR is to contribute for the effective control of voltage and enhancement of system stability.

Generally, the role of AVR is to hold the terminal voltage magnitude of synchronous generator at a specified level In addition, the AVR must be able to respond to a transient disturbance with field forcing consistent with the generator instantaneous and short term capabilities. It should also be capable of responding to disturbance so as to enhance transient stability and of modulating generator field so as to enhance small signal stability. Fig. 2 shows the functional block diagram of typical AVR loop. The primary means of generator reactive power control in this AVR loop is done with the excitation control and the supplementary control action is provided with a PID controller. The interaction between voltage and frequency control is generally weak. So in this paper the analysis of LFC and AVR are carried out separately. The nominal system parameters of AVR investigated in this paper are same as the parameter commonly quoted in most of the research papers [5]. They are

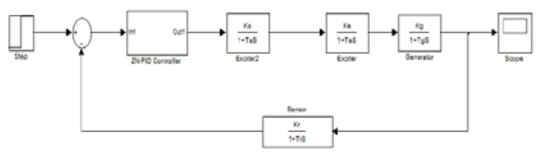

Fig. 3: Schematic block diagram of AVR

Fixed Parameters: Ka= 10 , Ta= 0.1 , Ke= 1, Te= 0.1, kg= 1 ,Tg = 1, Kr= 1.

$$G(S)\ \ H(S)\ \ = \frac{K_a K_e K_g\ \ K_r}{(1+TaS)\ \ (1+TeS)(1+Tgs)(1+TrS)} \qquad (2)$$

5. TUNING OF PID CONTROLLER

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. The PID type controller remains the most popular in industry. However, finding approximate gain parameters for this controller is still a difficult task. ZN continuous cycling method is the most excellent conventional tuning method used to predict the gain parameters of PID controllers. The procedural analysis to design the PID gain parameters using ZN continuous cycling method is as follows: The polynomial characteristic equation of LFC and AVR are designed as shown in the equation (1) and (2) and PID data is shown in the table 1 use in this paper.

$$G(S)\ \ H(S)\ \ = \frac{1}{R\ \ (2Hs+D)(1+TgS)(1+Tts)} \qquad (3)$$

$$G(S)\ \ H(S)\ \ = \frac{K_a K_e K_g\ \ K_r}{(1+TaS)\ \ (1+TeS)(1+Tgs)(1+TrS)} \qquad (4)$$

Table 1: PID Controller Parameters using Z-N tuning controller

Parameter Of PID Controller	K_P	K_I	K_D
Load Frequency Control (LFC)	0.83	0.54	0.14
Automatic voltage Regulator (AVR)	4.2155	4.5999	0.57889

6. RESULTS ANALYSIS

The simulation has been conducted in MATLAB (R2010a) package for single area power system with PID and Z-N tuning controller is design for Power plant model using MATLAB Simulink of AVR and LFC shown in the Fig. 4 and Fig. 5.The completely designed in control system tool using Z-N tuning method. Response of AVR system with ZN-P and ZN-PI controller shown in the table 2 and Fig. 6 or Fig. 7 and compare all the controller, it's clear that minimum setting time achieved by ZN –PID controller and good overshoot of ZN-PID controller than conventional PID ,fuzzy PID,GA-PID and PSO-PID controller. Response of AVR the system shown in the table 3 and Fig. 8.

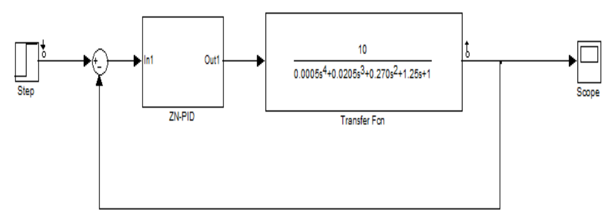

Fig. 4: MATLAB simulink of AVR control with ZN-PID control

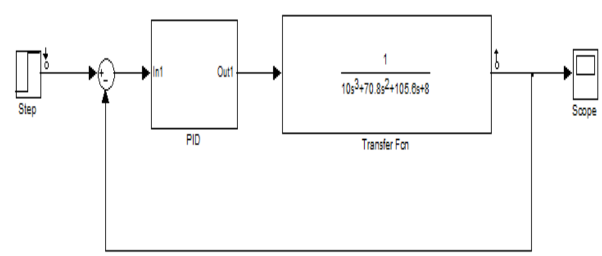

Fig. 5: MATLAB simulink of load frequency control with ZN-PID control

Table 2 AVR response of ZN-P and ZN-PI controller

parameter	Setting Time	Rise Time	Overshoot %
ZN-P controller	1.68	0.221	31.7
ZN-PI controller	1.78	0.255	27.3
ZN –PID controller	1.12	0.198	15.3

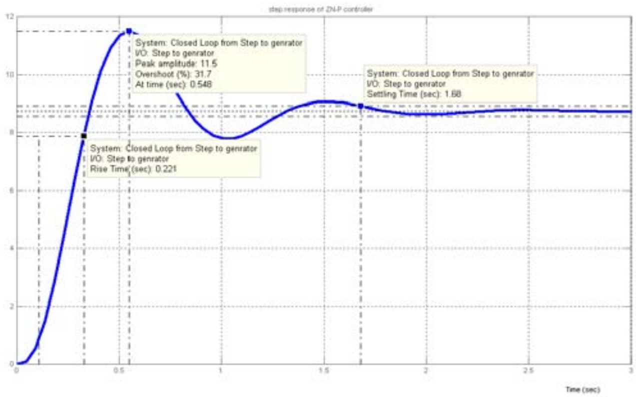

Fig. 6: AVR response of ZN-P controller

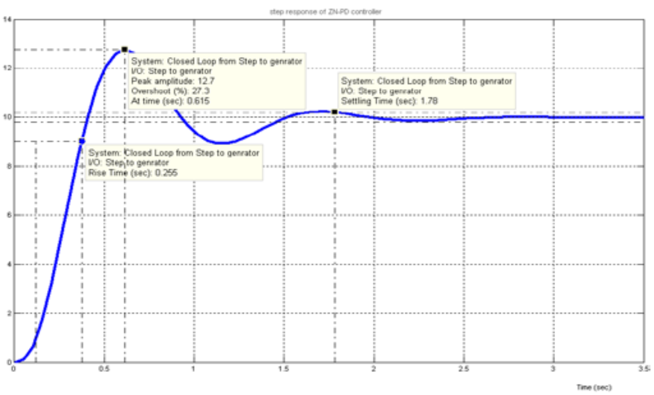

Fig. 7: AVR response of ZN-PI controller

Table 3: Comparative Transient Analysis of AVR system with ZN-PID controller

Parameter	Setting Time	Overshoot
Conventional PID	37.5	0.0
Fuzzy Controller	16.0	0.0
GA-PID	11.38	0.0
PSO-PID	8.22	0.0
ZN-PID	**1.12**	**15.3**

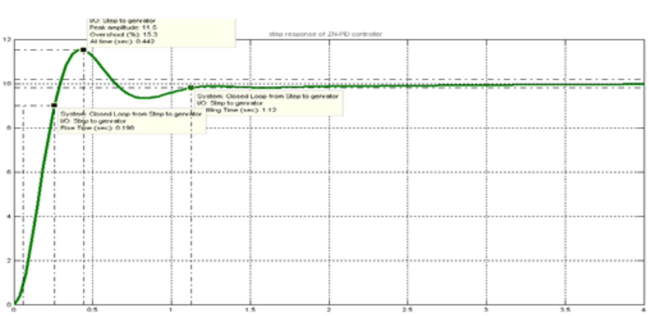

Fig. 8: AVR response of ZN-PID controller

Response of LFC system with ZN-P and ZN-PI controller shown in the table 4 and Fig. 9 or Fig. 10 and compare all the controller, it's clear that minimum setting time achieved by ZN –PID controller and good overshoot of ZN-PID controller than conventional PID ,fuzzy PID,GA-PID and PSO-PID controller. Response of AVR the system shown in the table 5 and Fig. 11.

Table 4: LFC response of ZN-P and ZN-PI controller

parameter	SettingTime	Rise Time	Overshoot %
ZN-P controller	5.37	1	20.9
ZN-PI controller	5.99	1.16	16.2
ZN –PID controller	4.22	0.892	8.79

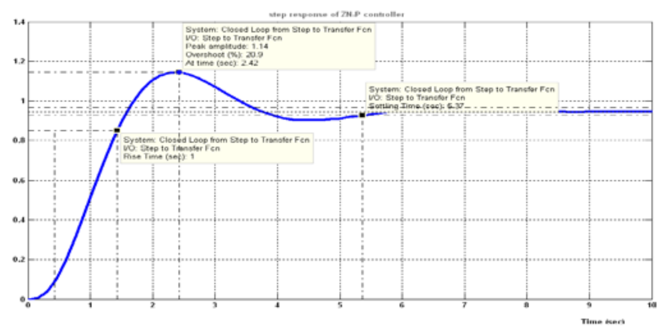

Fig. 9 LFC response of ZN-P controller

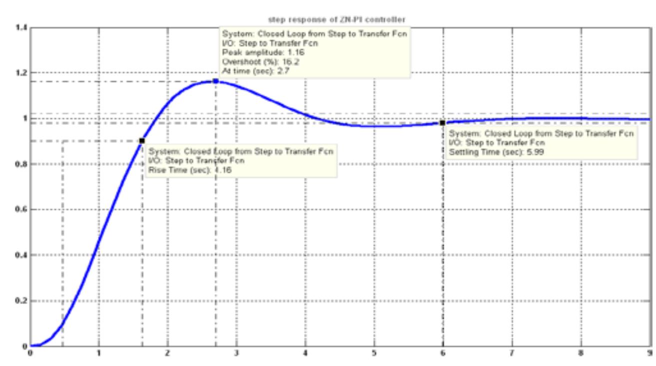

Fig. 10 LFC response of ZN-PI controller

Table 5 Comparative Transient Analysis of LFC system

Parameter	Settling Time	Overshoot
Conventional PID	51	-0.0083
Fuzzy Controller	20	-0.0052
GA-PID	10.25	-0.0026
PSO-PID	8.2	-0.0014
ZN-PID	**4.42**	**8.79**

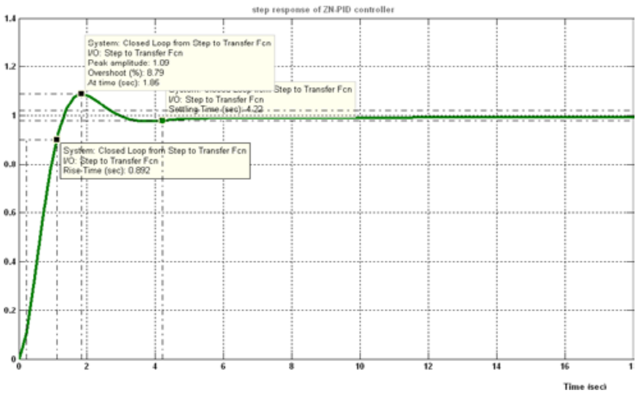

Fig. 11 LFC response of ZN-PID controller

7. CONCLUSION

In this paper conventional ZN controller is determined for P, PI, PID controller are discussed. For the analysis it is determined that PID controller gives the better performance in AVR and LFC Controller. The conventional PID controller gives the high overshoot and settling time. In Z-N Tuned PID Controller, Initial controller parameters obtained using Ziegler-Nichols formulas are adjusted by numerical computational technique to get satisfactory performance. Z-N Tuned PID Controller gives zero steady state error and smaller overshoot than controller than conventional PID ,fuzzy PID,GA-PID and PSO-PID controller. Z-N Tuned PID controller with simple approach can provide better performance comparing with the conventional PID controller. So simulation results show the superior performance of the system using Z-N Tuned PID controller.

8. ACKNOWLEDGEMENTS

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