International Journal on Future Revolution in Computer Science & Communication Engineering ISSN: 2454-4248
Volume: 4 Issue: 1 53 – 56

Comparative Analysis of PID Tuning of AVR

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Abstract: - A voltage regulator is intended to automatically maintain a constant voltage level. A voltage regulator may be a simple Feed forward design or may consist of negative feedback. It may use an electro-mechanical, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages. In the first deliver the AVR monitors the output voltage and controls the input voltage for the exciter of the generator. By increasing or decreasing the generator control voltage, the output voltage of the generator increases or decreases accordingly. The AVR calculates how much voltage has to be sent to the exciter frequent times a second, therefore stabilizing the output voltage to a preset set point. When two or more generators are powering the same system (parallel operation) the AVR receives information from more generators to equivalent all amount produced. A PID controller calculates an error value as the difference between a measured process changeable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable. [1]

In this paper we have a comparative analysis of tuning of PID controllers to realize automatic voltage regulation. Now we have Review design model of PID controlled AVR system using MATLAB simulink, SISO compensator design tool and automated PID tuner. The controller has been tuned using Zieglar Nichols closed loop Tyerus-Luyben and Astrom Hugglund methods, Singular Frequency method and IMC method. It has been observed that Internal Model Control type of controller gives least maximum overshoot but takes tile more time to settle. It therefore bears competitive quality in providing automatic voltage regulation viz-a-viz ZN- Tyerus Luyben Zieglar Nichols-Tyerus Luyben tuner gives best results among listed method. It gives minimum transient and settles in least time of 6 seconds after the occurrence of disturbance which can be taken as best performance among all.

Keywords: *AVR, PID Controller, Automated PID Tuning, SISO Tool, Tyerus-Luyben (TL), Astrom Hugglund (AH), Singular Frequency (SF) and Internal Model Control (IMC).*

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1. Introduction of AVR

Generators, as used in control stations or in standby power systems, will have automatic voltage regulators (AVR) to stabilize their voltages as the load on the generators changes. The first automatic voltage regulators for generators were electromechanical systems, but a modern AVR uses solid-state devices.

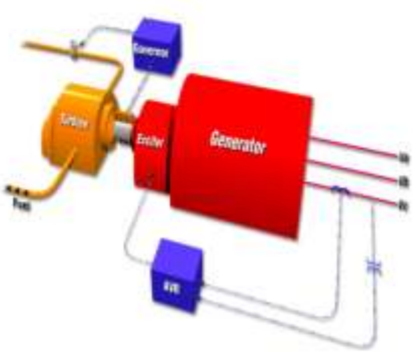

Fig.1. AVR with Generator

An AVR is a feedback control system that measures the output voltage of the generator, compares that output to a set point, and generates an error signal that is used to adjust the excitation of the generator. As the excitation current in the field winding of the generator increases, its terminal voltage will increase.The AVR will control current by using power electronics devices; generally a small part of the generator's output is used to provide current for the field winding. Where generator is connected in parallel with other sources such as an electrical transmission grid, changing the excitation has more of an effect on the reactive power produced by the generator than on its terminal voltage, which is mostly set by the connected power system. Where multiple generators are connected in parallel, the AVR system will have circuits to ensure all generators operate at the same power factor. AVRs on grid-connected power station generators may have additional control features to help stabilize the electrical grid against upsets due to sudden load loss or faults.

2. Controller

We have designed the AVR using first order transfer function model of Amplifier, Exciter and Generator. The simulink Model is given in Fig.2. and its natural output on unit step input is shown in Fig.3.

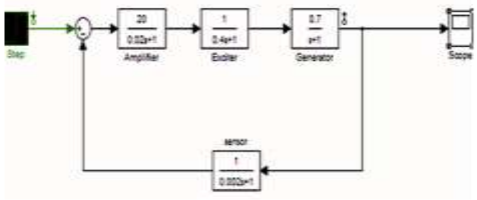

Fig.2. Simulink Model for AVR

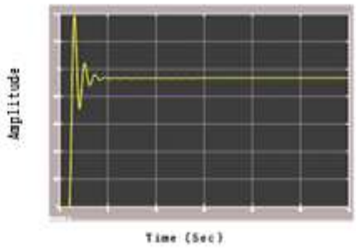

Fig.3. Output of AVR

3. PID Tuning

Proportional-integral-derivative (PID) controllers are widely used in power system and control systems to damp system oscillations, increase stability and reduce steady state error as they are simple to realize and easily tuned. A PID controller calculates error significance as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable. The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Simply these values can be interpreted in terms of time, P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of alteration.

The proportional, integral, and derivative conditions are summed to calculate the output of the PID controller.

Defining u(t) as the controller output, the final form of the PID algorithm is

$$\mathbf{u(t)} = \mathbf{MV(t)} = \mathbf{K_p e(t)} + \mathbf{K_i}\int_0^t \mathbf{e(\aleph)d(\aleph)} + \mathbf{K_d}\frac{d}{dt}e(t) \qquad (1)$$

Where,

MV=manipulated variable

U (t) =controller output

ℵ =Variable of integration

e=error

K_p=proportional tuning parameter

K_i= proportional tuning parameter

K_d= proportional tuning parameter

t= instantaneous time

3.1 Controller for AVR

The AVR with PID Controller is given in Fig.4.

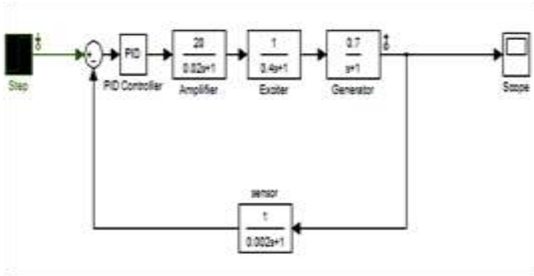

Fig.4. AVR with PID Controller

We have used SISO design tool & automated PID tuning to tune the PID controller for AVR. The basic steps of SISO design and automated PID tuning are given below.

3.2 SISO Tool Design Configuration

The single input single output design tool is part of Matlab's Control Systems Toolbox that enables us to analyze simple SISO system interconnections. The optimal tool for this task is Simulink, but this toolbox helps us understand the basic capabilities of Matlab. The enhanced SISO Design Task lets you tune compensators using functionality from the Control System Toolbox software and the Simulink Design Optimization software. The SISO design task includes several tools for tuning the response of SISO systems:

1. A graphical editing environment in the SISO design tool window that contains design plots such as root-locus, and Bode diagrams etc.
2. An LTI Viewer window where you can view time and frequency analysis plots of the system.
3. Compensator editors where one can directly edit the block mask parameter or the poles and zeros of compensators in your system.
4. Optimization-based tuning methods that automatically tune the system to satisfy propose requirements.

A tool that automatically generates compensators using PID tuner which cover following tuning methods viz Internal Model Control (IMC), ZN-TL, ZN-AH, Singular frequency .

3.3 Methods for Automated PID tuning

Step-1:- In MATLAB after design the block diagram selects tools.

Step-2:- Select Control Design from tools.

Step-3:- In control design select compensator design and open control and estimation manager.

Step-4:- Select blocks and tune PID block now open design configuration wizard.

Step-5:- Select step analysis plot.

Step-6:- Click finish automatically open SISO design task.

Step-7:- Select Automated tuning and now selects PID tuning methods.

ISSN: 2454-4248
53 – 56

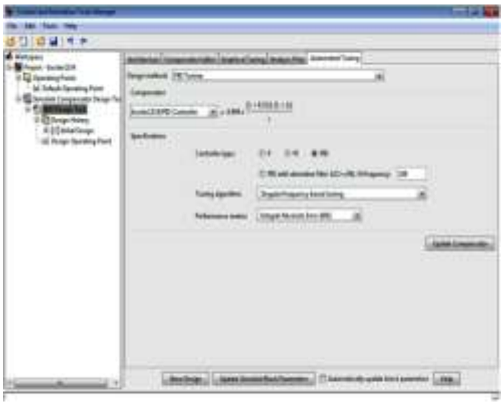

Fig.5. SISO Tool with Automated Tuning

4. Simulation Results

(A) Zieglar Nichols Tyerus-Luyben Method

The Tyreus-Luyben procedure is quite similar to the Ziegler–Nichols method. but the final controller settings are different. Also this method only proposes settings for PI and PID control. The output response of Automatic voltage regulator with ZN-TL method is shown in Fig.6.

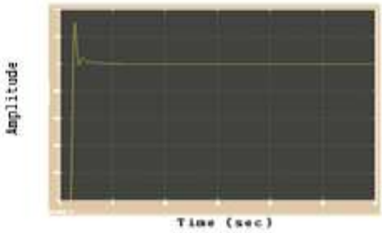

Fig.6. Output of AVR by ZN T-L method

(B) Zieglar Nichols Astrom Hugglund Method

Astrom and Hugglund have proposed a method for tuning PID controller in the frequency domain which is a generalization of the Ziegler-Nichols tuning rules. The output response of Automatic voltage regulator with ZN-AH method is shown in Fig.7.

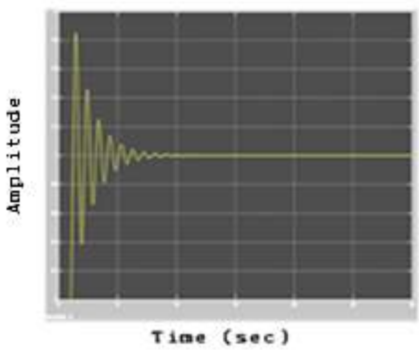

Fig.7. Output of AVR by ZN A-H method

(C) Singular Frequency Method

To acquire the singular frequency based design tuning is simulated in SISO tool. The frequency response for such a system is computed using the linear approximation.The output response of Automatic voltage regulator with Singular frequency is shown in Fig.8.

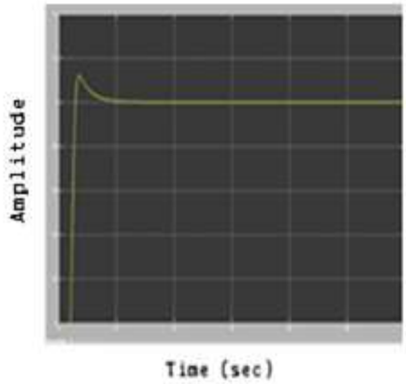

Fig.8. Output of AVR by SF method

(D) Internal Model Control (IMC) method

Internal model control (IMC) is one of the recent methods of tuning. IMC is a popular control structure in process control. The IMC structure was given by Garcia & Morari, 1982. It is the main part of the design of controllers. Its conceptual usefulness lies in the fact that it allows to concentrate on the controller design without having to be concerned with control system stability provided that process model is a perfect representation of stable process.The output response of Automatic voltage regulator with IMC method is shown in Fig.9.

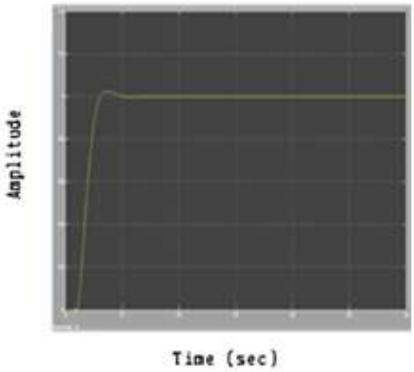

Fig.9. Output of AVR by IMC method

5. Tuning Results

Comparative study of PID controller use for Automatic voltage regulator shown in Table-1

Table-1

Tuning	K_p	K_i	K_d	M_p	T_r	T_p	T_s
Without PID Controller	-	-	-	.3	.6	.9	16
ZN T-L	2.2	1.98	0.1	0.3	0.5	0.7	6
ZN A-H	1.2	6.3	0.08	0.8	0.	0.	12

		8		1	6	8	
SF	1.3	1.0 0	0.2	0.1	1	1. 1	6. 7
IMC	0.0 8	0.0 8	0.00 1	0.0 2	1. 8	2. 1	7

Conclusion

In this paper, we have tuned the PID controller for AVR system using different methods like ZN-Tyerus Luyben, ZN-Astrom Hugglund, Singular frequency and Internal Model Control. It is worth quoting that Internal Model Control type of controller gives least maximum overshoot but takes title more time to settle. ZN-Tyerus Luyben tuner gives best results among listed method. It gives minimum transient and settles in least time of 6 seconds after the occurrence of disturbance which can be taken as best performance among all. It therefore bears competitive quality in providing automatic voltage regulation viz-a-viz ZN- Tyerus Luyben.

Future Scope

Presently the controller has been designed using PID technique. The performance can be improved by applying more rigorous technique like Lyapunov analysis, Contraction theory etc. an improvement would reduce the maximum overshoot and settling time of transient.

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