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PID Controlled Automatic Voltage Regulator with Load Frequency Control

Priyanka Andhare* and Naveen Asati**
**M. Tech. Control System, Department of Electrical Engineering, LNCT, Bhopal, (Madhya Pradesh), INDIA*
***Associate Professor, LNCT, Bhopal, (Madhya Pradesh), INDIA*

(Corresponding author: Priyanka Andhare)
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ABSTRACT: Change in real power mainly affects the system frequency and reactive power is mainly dependent on the changes in voltage magnitude. Reactive power is less sensitive to changes in frequency [6]. So, the real power and reactive power are controlled separately. Real power and frequency are controlled by the Load Frequency Control (LFC) and the reactive power and voltage magnitude are controlled by the Automatic Voltage Regulator (AVR). AVR and LFC together form Automatic Generation Control (AGC) [3]. In the proposed work, the role of Automatic Generation Control in power system operation is analyzed. Here, we have analyzed AGC system with automatic voltage regulator (AVR) and load frequency control (LFC) both. We have employed the PID controller to improve the dynamic response as well as to reduce the steady state error. The PID controller is tuned using the manual tuning technique to get the approximate optimized values of proportional, integral and derivative which results in satisfactory response of the system. Simulations are carried out and the results obtained with LFC system are improved and satisfactory.

Keywords: Automatic Generation Control (AGC), Automatic Voltage Regulator (AVR), PID Controller, Load Frequency Control (LFC), Manual Tuning Technique.

I. INTRODUCTION

Operational success of the power systems depends on the ability of the engineer concerned to ensure good, continuous and reliable service. In the ideal case, the load feeding ought to be at constant frequency and voltage. In practical applications, for satisfactory operation of the consumer devices, voltage and frequency should be maintained within tolerable limits. Voltage decrement of 10% to 15% or reduction in frequency can cause stalling of device loads [2]. So, high standards of electrical supply should be maintained for secure and satisfactory operation of consumer devices. The first requirement of this end is to maintain parallel operation of synchronous generator with sufficient ability to handle the load requirements [2]. Because, at any time, if synchronism between generator and the systems is lost, voltage and current fluctuations will occur and the system relays will disconnect the supply at faulty sections. The situation may arise that fluctuating synchronization of the machine may result in loss of synchronization of the system. Interruptions in power flow between high voltage transmission systems and load centers may lead to disturbances in the system operation [2].

This dissertation deals with the control of active and reactive power in order to keep the system in steady state. Real power and frequency are controlled by the Load Frequency Control (LFC) and the reactive power and voltage magnitude are controlled by the automatic Voltage Regulator (AVR) [3]. In addition to this, simple models of the essential components used in the control systems are presented here. The main objective of the control strategy is to generate and deliver power in an interconnected system as economically and reliably as possible while maintaining the voltage and frequency both within the permissible limits. One of the most common controllers available commercially is Proportional Integral Derivative (PID) controller. For control purpose, PID controllers are utilized in many power systems due to the robustness of these controllers. They offer a wide stability margin. So, for AVR also PID controller is suitable to use [1] along with LFC. The setting of PID controller parameters is cumbersome, especially in industrial systems that have nonlinearities, high order and delay time. Therefore, many PID tuning methods have been used for fine tuning of PID controllers.

The PID controller parameters are determined by using the Ziegler–Nichols method [7]. Generally, it is difficult to achieve the best performance of the system by using this method, and the designer has to depend on his experience for obtaining the best performance. Moreover, many artificial intelligence (AI) techniques, such as neural network technique, fuzzy logic, and neuro fuzzy system, have been proposed to fine tune the PID controller parameters. However, the artificial neural networks suffer from the convergence time and the length of the training process. Also, the fuzzy logic systems depend on the experience of the designer in tuning the membership functions. Furthermore, evaluation and tuning of PID controllers based on Bode's integrals have also been presented [4]. Recently, here we have employed manual tuning technique of PID controller for improved response of the AVR system. If the load on the system is increased, the turbine speed drops before the governor can adjust the input of the steam to the new load. As the change in the value of speed diminishes, the error signal becomes smaller and the position of the governor fly-balls gets closer to the point required to maintain a constant speed. However, the constant speed will not be the set point, and there will be an offset. One way to restore the speed or frequency to its nominal value is to add an integrator. The integral unit monitors the average error over a period of time and will overcome the offset. Because of its ability to return a system to set its point, the integral action is also known as the reset action. Thus, as the system load changes continuously, the generation is adjusted automatically to restore the frequency to the nominal value. This scheme is known as the automatic generation control (AGC). In modern large interconnected systems, manual regulation is not feasible and therefore automatic generation and voltage and frequency regulation equipment are installed on each generator [3].

In manual tuning method, the parameters are adjusted by watching system responses. K_P, K_I and K_D are changed until desired or required system response is obtained [5]. Although this method is simple, it should be used by experienced personal.

II. AVR MODEL

The heart of the excitation systems lies in the voltage regulators. It is a device that serves the output voltage change and provides corrective actions to take place [3]. For an isolated generator feeding a load the automatic voltage regulator (AVR) functions to maintain the bus bar voltage constant. The AVR has the following objectives:

(i) To keep the system voltage constant so that the connected equipment operates satisfactorily.

(i) To obtain a suitable distribution of reactive load between machines working in parallel.

(i) To improve stability.

The AVR which senses the terminal voltage and adjust the excitation to maintain a constant terminal voltage also maintains the reactive output at the required level since the latter depends on the effective voltage difference between generator terminals and its point of connection to the main system. The schematic diagram of a simplified AVR is shown in fig. 1.

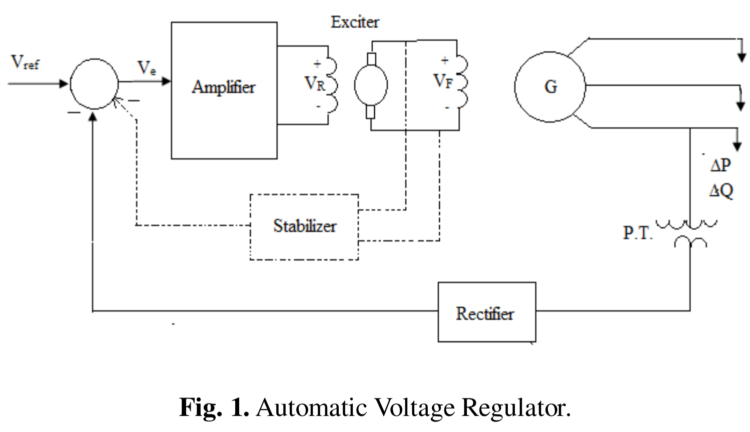

Fig. 1. Automatic Voltage Regulator.

An increase in the reactive power load of the generator is accompanied by the drop in the terminal voltage magnitude. On one phase, the voltage magnitude is sensed through a potential transformer. This voltage is rectified and compared to a dc set point signal. The amplified error signal controls the exciter field and then increases the exciter terminal voltage. Thus, the generator field current is increased, which in turn results in an increase in the generated emf. The reactive power generation is increased to a new equilibrium, raising the terminal voltage to the desired value.

The AVR block diagram is given as (Fig. 2):

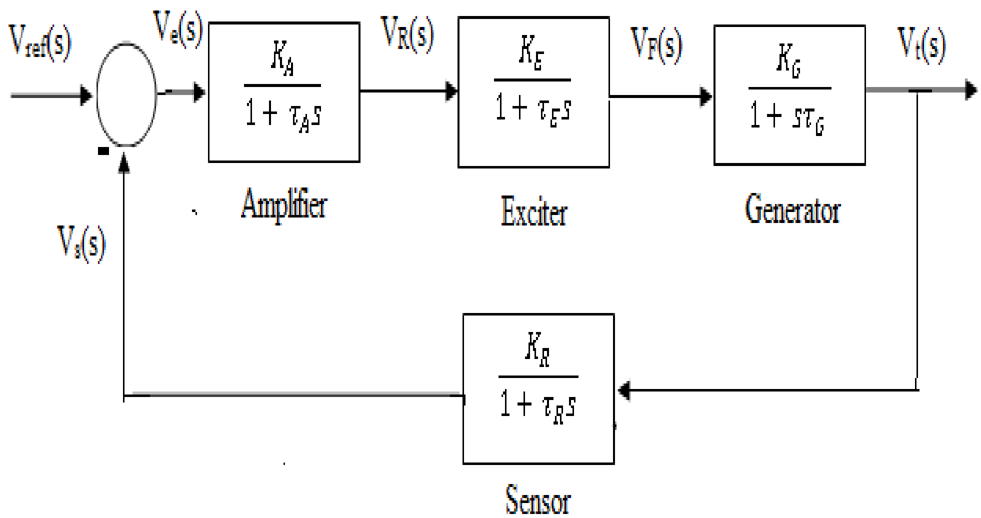

Fig. 2. Block Diagram of AVR.

The open loop transfer function of the given block diagram is

$$KG(s)H(s) = \frac{K_A K_E K_G K_R}{(1+\tau_A s)(1+\tau_E s)(1+\tau_G s)(1+\tau_R s)} \quad (1)$$

The closed loop transfer function relating the generator terminal voltage $V_t(s)$ to the reference voltage $V_{ref}(s)$ is given as

$$\frac{V_t(s)}{V_{ref}(s)} = \frac{K_A K_E K_G K_R(1+\tau_R s)}{(1+\tau_A s)(1+\tau_E s)(1+\tau_G s)(1+\tau_R s)+K_A K_E K_G K_R} \quad (2)$$

Or,

$$V_t(s) = T(s)V_{ref}(s) \quad (3)$$

III. LFC MODEL

In a power system, the load demand is continuously changing. In accordance with it, the power input has also to vary. If the input-output balance is not maintained, a change in frequency will occur. The control of frequency is achieved primarily through speed governor mechanism aided by supplementary means for precise control. In a large interconnected system, the manual regulation is not feasible. So, load frequency equipment is installed for each generator. Similarly, for voltage control, voltage regulation equipment is installed on each generator [3]. The controllers are set for a particular operating condition and they take care of small changes in load demand without voltage and frequency exceeding the pre specified limits. If the operating conditions change materially the controllers must be reset either manually or automatically.

The block diagram of LFC is shown in Fig. 3,

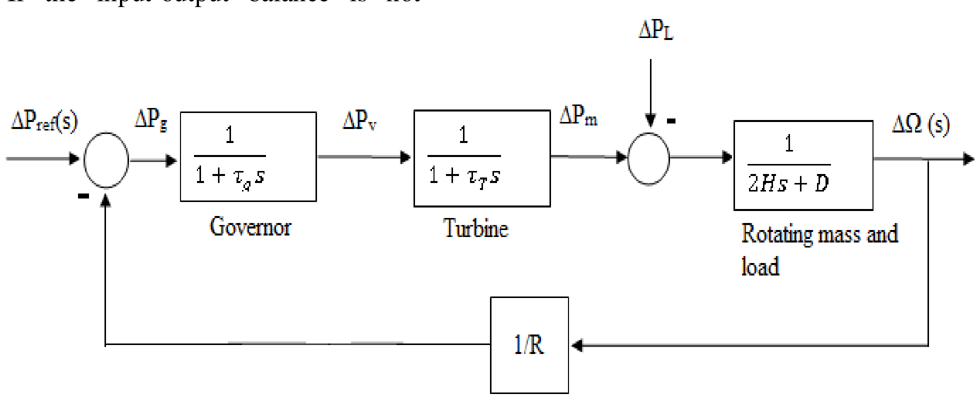

Fig. 3. Block Diagram of LFC.

IV. MODEL OF AVR SYSTEM WITH PID CONTROLLER

The AVR system with PID controller is shown in figure below:

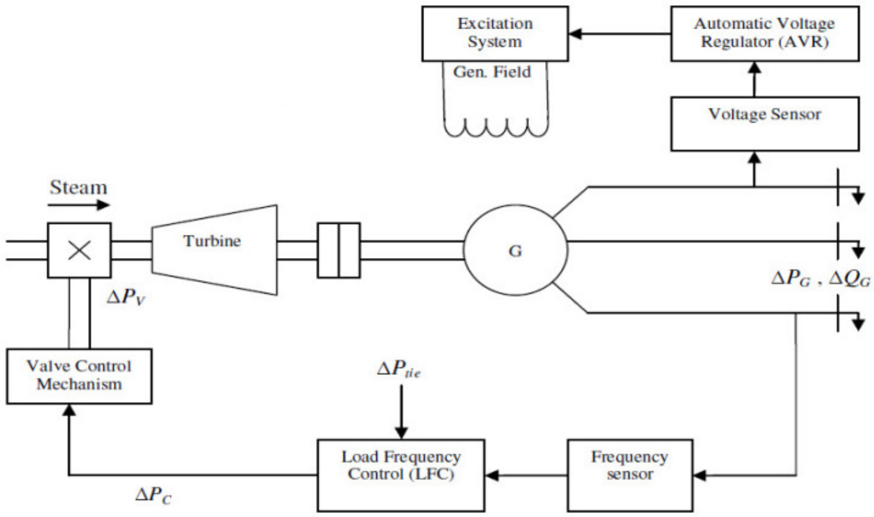

Fig. 4. Block Diagram AVR with PID Controller.

V. PID TUNING

Tuning is adjustment of control parameters to the optimum values for the desired control response [5]. Stability is a basic requirement. However, different systems have different behavior, different applications have different requirements, and requirements may conflict with one another. PID tuning is a difficult problem, even though there are only three parameters and in principle is easy to describe, because it should satisfy the complex criteria within the limitations of PID control.

PID controller has all the necessary dynamics:
(a) Fast reaction on change of the controller input (D mode)
(b) Increase in control signal to lead error towards zero (I mode)
(c) Suitable action inside control error area to eliminate oscillations (P mode).
Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response.

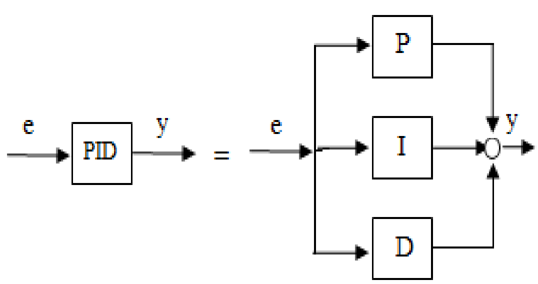

Fig. 5. Basic PID controller block diagram.

Here, $y = K_P \cdot e + K_I \int edt + K_D \frac{de}{dt}$ …(4)

With $K_I = \frac{K_P}{T_n}$ and $K_D = K_P \cdot T_v$ …(5)

The PID controller transfer function is given as [5]

$G_C(s) = K_P + \frac{K_I}{s} + K_D s$ …(6)

A. Proposed Method

Here, we have used manual tuning method of PID controller to fine tune it and to improve the system response. Here, we have used the values of K_P, K_I and K_D, initially as given by the soft computing techniques genetic algorithm and particle swarm optimization.

Using these values, various experiments are performed to get the optimized values of the controller gains.

1. In the first step, only K_P values are changed one by one to get the satisfactory terminal voltage response and K_I and K_D are kept constant at the given values.
2. We get the optimal value of K_P as 1. Now, in the second step, set the value of K_P as 1 and make changes in the values of K_I only until we get a better response.
3. As noted from the simulation results, K_P=1 and K_I= 0.2 makes a good combination of optimized values of gain which gives a satisfactory response. Now, set K_P=1 and K_I= 0.2 and repeat the process with K_D to find its optimized value.
4. As noted from the table 7.3 and simulation results, we can get much better response with the values K_P=1, K_I= 0.2 and K_D=0.28.

For more optimized values of the three gains, we performed some more experiments where we adjusted the values of K_I only ranging from 0.21 to 0.25 as shown.

The parameters obtained after every step of tuning are shown in the tables below:

Table 1 Step 1:

Exp.No.	**K_P**	**K_I**	**K_D**
1	0.67	0.59	0.26
2	0.7	0.59	0.26
3	0.8	0.59	0.26
4	0.9	0.59	0.26
5	1	0.59	0.26

Table 2 Step 2:

Exp.No.	K_P	K_I	K_D
1	1	0.5	0.26
2	1	0.4	0.26
3	1	0.3	0.26
4	1	0.2	0.26
5	1	0.1	0.26

Table 3 Step 3:

Exp.No.	K_P	K_I	K_D
1	1	0.2	0.26
2	1	0.2	0.27
3	1	0.2	0.28
4	1	0.2	0.29
5	1	0.2	0.3

Table 4 Step 4:

Exp. No.	K_P	K_I	K_D
1	1	0.21	0.28
2	1	0.22	0.28
3	1	0.23	0.28
4	1	0.24	0.28
5	1	0.25	0.28

B. Results

Hence, with these experiments, we get the final optimized values of the PID controller gains in order to bring our proposed system in the steady state. The values obtained provide much better results and improve the terminal voltage response to the desired level. Final values of the gains of PID controller are obtained experimentally as K_P=1, K_I= 0.24 and K_D=0.28.

VI. SIMULATION RESULTS

The AVR and LFC system step response before the tuning of the PID controller is

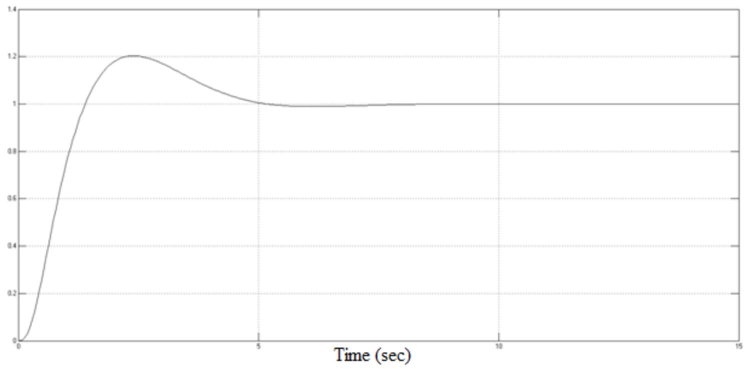

Fig. 6. Response before tuning.

And after the tuning of controller and using optimized gain values, the response is

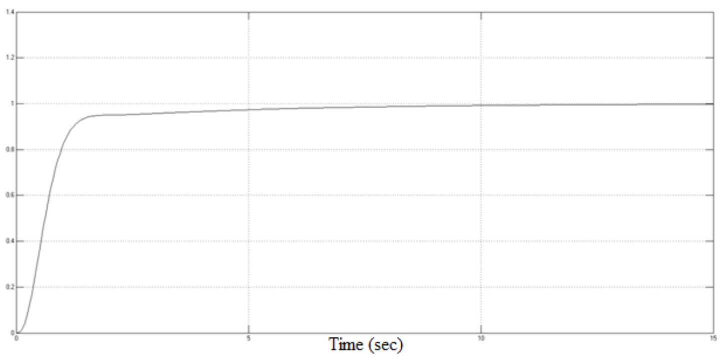

Fig. 7. Response with optimized values.

Hence, from both the figures, the results are compared and with the proposed method the response obtained is satisfactory because it has reduced the overshoot of the system response and the system is achieving steady state smoothly than the previous one.

VII. CONCLUSION

In this paper, manual tuning of PID controller in an automatic voltage regulator system with load frequency control has been presented to obtain optimal values of controller gains for improving the step response of the terminal voltage. The optimized step response of the terminal voltage using manual tuning method has been improved and compared to an earlier response. Simulation result show that the steady state has been achieved without overshoot and oscillations has been reduced to a satisfactory level, using this method.

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