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Voltage Stability Improvement Using Fuzzy Logic Control System

Pejush Chandra Sarker, Md. Nagib Mahafuzz, Subarna Saha

Abstract— At any point of time, a power system operating condition should be stable, meeting various operational criteria, and it should also be secure in the event of any credible contingency. Voltage instability has been given much attention by power system researchers and planners in recent years, and is being regarded as one of the major sources of power system insecurity. Voltage instability phenomena are the ones in which the receiving end voltage decreases well below its normal value and does not come back even after setting restoring mechanisms such as VAR compensators, or continues to oscillate for lack of damping against the disturbances. Voltage collapse is the process by which the voltage falls to a low, unacceptable value as a result of an avalanche of events accompanying voltage instability. Once associated with weak systems and long lines, voltage problems are now also a source of concern in highly developed networks as a result of heavier loading. The main factors causing voltage instability in a power system are now well explored and understood. Now a day's one of the best ways to control system stability is to use Fuzzy logic controller. The advantages of this controller are that it has so many options to control the instability of voltage. A brief introduction to the basic concepts of voltage stability and some of the conventional methods of voltage stability analysis including Fuzzy Logic controller are presented in this paper.

Index Terms— Automatic Voltage Regulator (AVR), Amplifier Model, Exciter Model, Generator Model, Sensor model, Voltage Stability, PID Controller, Fuzzy Inference System (FIS)

1 Introduction

This paper deals with active and reactive power control in order to keep the system in the steady-state. In addition, simple models of the essential components used in the control systems are shown here. The idea 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 within permissible limits. Changing the real power affects mainly the system frequency, while reactive power is less sensitive to change in frequency and is mainly dependent on changes in voltage magnitude. Thus, real and reactive powers are controlled separately. The load frequency control controls the real power and frequency and the automatic voltage regulator loop regulates the reactive power and voltage magnitude. Thus real and reactive powers are controlled separately. Here we discuss about the reactive power control which is cotrolled by the Automatic Voltage Regulator. It also controls voltage magnitude. Fuzz logic controller is one of the advance controller uses to steady a system. The advantages of using fuzzy logic system are that it has many options to steady the system. In this thesis work we use some basic element of a power system. We used FUZZY LOGIC controller and compare the performances with other controllers.

2 Power System Control

2.1 Automatic Voltage Regulator (AVR):

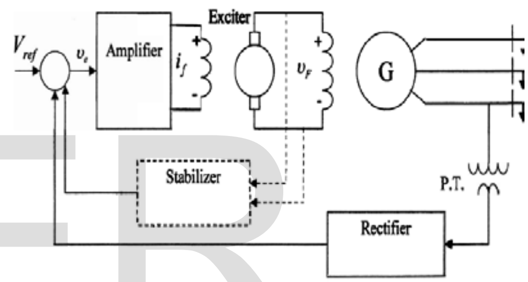

Fig 1: Block diagram of automatic voltage regulator

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

2.2 Amplifier Model:

The excitation system amplifier may be a magnetic amplifier, rotating amplifier or modern electronic amplifier. The amplifier is represented by a gain K_A and a time constant τ_A and the transfer function is

$$\frac{V_R(S)}{V_e(S)} = \frac{K_A}{1+\tau_A s} \qquad (1)$$

Typical values of K_A are in the range of 10 to 400. The amplifier time constant is very small, in the range of 0.02 to 0.1 second, and often is neglected.

2.3 Exciter Model:

- *Pejush Chandra Sarker , Lecturer , Dept. of EEE, University of Asia Pacific , Bangladesh ,E-mail:* pejush01@yahoo.com
- *Md. Nagib Mahafuzz completed his B.Sc. in Electrical and Electronic Engineering from University of Asia Pacific , Bangladesh , E-mail:* mahafuzz@yahoo.com
- Subarna Saha, Lecturer,dept. of Mechatronics, World University of Bangladesh. E-mail: subarna_051113@yahoo.com

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Modern excitation system uses ac power source through solid-state rectifies such as SCR. The output voltage of the exciter is a nonlinear function of the voltage because of the saturation effects in the magnetic circuit. Thus, there is no simple relationship between the terminal voltages and the field voltage of the exciter. Many models with various degrees of sophistication have been developed and are available in the IEEE recommendation publications. A reasonable model of a modern exciter is a linearized model, which takes into account the major time constant and ignores the saturation or other nonlinearities. In the simplest form, the transfer function of a model exciter may be represented by a single time constant τ_E and gain K_E

$$\frac{V_F(S)}{V_R(S)} = \frac{K_E}{1+\tau_E s} \quad (2)$$

2.4 Generator Model:

The Synchronous machine generated emf is a function of the machine magnetization curve, and its terminal voltage is dependent on the generator load. In the linearized model, the transfer function relating the generator terminal voltage to its field voltage can be represented by a gain K_G and a time constant τ_G, and the transfer function is

$$\frac{V_t(S)}{V_F(S)} = \frac{K_G}{1+\tau_G s} \quad (3)$$

2.5 Sensor Model:

The voltage is sensed through a potential transformer and in one form; it is rectified through a bridge rectifier. The sensor is modeled by a simple first order transfer function, given by

$$\frac{V_S(S)}{V_t(S)} = \frac{K_R}{1+\tau_R s} \quad \textbf{(4)}$$

K_R is very small, and we may assume a range of 0.01 to 0.06 second. Utilizing the above model results in the AVR block diagram shown in Fig: 2

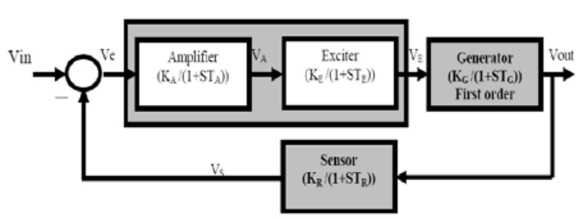

Fig. 2: Automatic Voltage Regulator (AVR).

Since:
Vin(s) = Reference input voltage Ve(s) = Error voltage signal
V_A(s) = Amplifier Voltage V_E(s) = Exciter Voltage
Vout (s) = Output Voltage Vs(s) = sensor voltage
K_A =Amplifier gain constant K_E = Exciter gain constant
K_G = Generator gain constant, K_R = Sensor gain constant
Note: All values of required constant are in per unit.

3 Power System Stability:

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. The stability of an interconnected power system is its ability to return to normal or stable operation after having been subjected to some form of disturbance. Conversely, instability means a condition denoting loss of synchronism or falling out of step. Stability considerations have been recognized as an essential part of power system planning for a long time. With interconnected systems continually growing in size and extending over vast geographical regions, it is becoming increasingly more difficult to maintain.

4 Voltage Stability:

Power system voltage stability refers to the system's ability to maintain acceptable voltage profiles under different system topologies and load changes. This is a stability phenomenon, where the power system loses its ability to control load bus voltage due to various reasons. This phenomenon can lead to failure of the total or partial power system due to interventions of various control and protection actions. Voltage instability occurs mainly due to the fact that, unlike active power, reactive power cannot be transported over long distances. Therefore, a power system rich in reactive power resources is less likely to experience voltage stability problems. The voltage stability assessment of a power system is of paramount importance in the planning and daily operation of electrical networks.

4.2 Simulation of Voltage Stability:

A Voltage Stabilizer is added in the feedback path of the AVR system shown in Fig.3

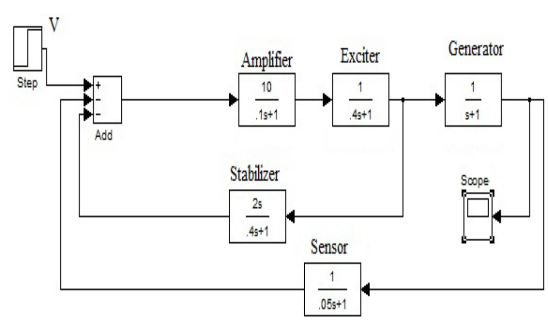

Fig .3: Block Diagram of Voltage Stabilizer

The simulation result for the above block diagram is shown in

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Fig. 4.

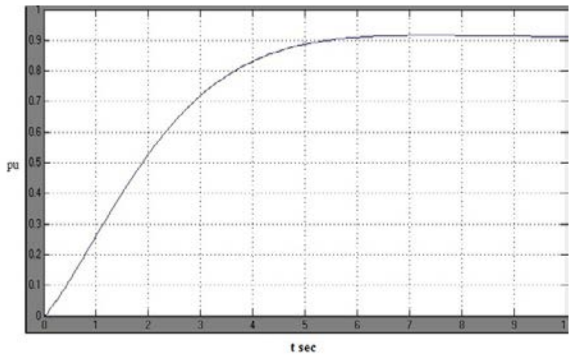

Fig. 4: The simulation result for the block diagram.

5 PID CONTROLLER

5.1 PID Controller:

The P stands for proportional control, I for integral control and D for derivative control. This is also what is called a three term controller. The basic function of a controller is to execute an algorithm (electronic controller) based on the control engineer's input (tuning constants), the operators desired operating value (set point) and the current plant process value. In most cases, the requirement is for the controller to act so that the process value is as close to the set point as possible. A typical structure of a PID control system is shown in equation 5 where it can be seen that in a PID controller, the error signal *e(t)* is used to generate the proportional, integral, and derivative actions, with the resulting signals weighted and summed to form the control signal *u(t)* applied to the plant model. A mathematical description of the PID controller is

$$n = K_p \left(e + T_d \frac{d_e}{d_t} + \frac{1}{T_i} \int_0^t e(\tau)\, d\tau \right) \qquad (5)$$

Where *u(t)* is the input signal to the plant model, the error signal *e(t)* is defined as *e(t) = r(t) − y(t)*, and *r(t)* is the reference input signal. The PID control algorithm is used for the control of almost all loops in the process industries, and is also the basis for many advanced control algorithms and strategies. In order for control loops to work properly, the PID loop must be properly tuned. Standard methods for tuning loops and criteria for judging the loop tuning have been used for many years, but should be revaluated for use on modern digital control systems. While the basic algorithm has been unchanged for many years and is used in all distributed control systems, the actual digital implementation of the algorithm has changed and differs from one system to another. Fig. 5 shows the block diagram of PID controller.

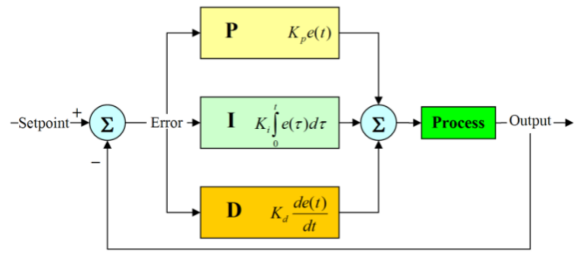

Fig. 5: The block diagram of PID controller

5.2 Simulation with PID Controller:

The block diagram of an AVR compensated with a PID controller is shown in fig .6 which consists of amplifier, exciter, generator and sensor.

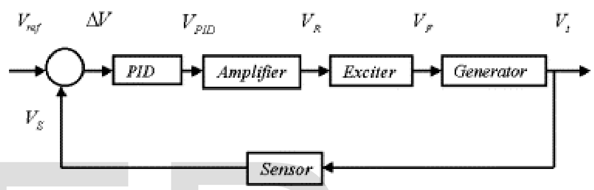

Fig. 6: AVR system with PID.

A PID controller is added in the forward path of the AVR system of an example shown in fig. 7, where the proportion gain, K_p=1.0 integral gain, K_I=0.25 and derivative gain K_D=0.28

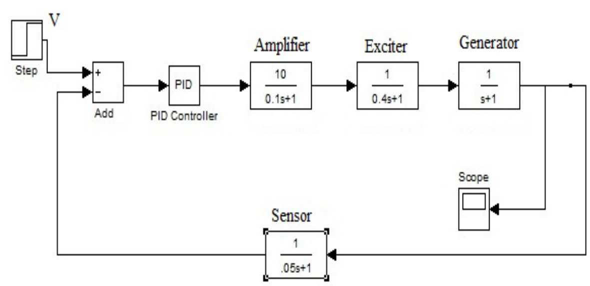

Fig.7: Block Diagram of AVR system with PID.

The response settles in about 2.8 seconds with a negligible small overshot. The simulation result for the above setting is shown in fig.8.

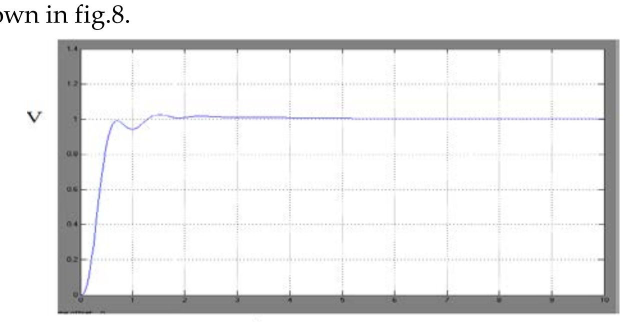

Fig.8: The response curve with PID

6 Fuzzy Logic Controller

6.1 Introduction of Fuzzy Logic:

Fuzzy Logic was initiated in 1965 [4], [5], [6], by Lotfi A. Zadeh, professor for computer science at the University of California in Berkeley. Basically, Fuzzy Logic (FL) is a multivalued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-like way of thinking in the programming of computers [7]. A fuzzy system is an alternative to traditional notions of set membership and logic that has its origins in ancient Greek philosophy. The precision of mathematics owes its success in large part to the efforts of Aristotle and the philosophers who preceded him. In their efforts to devise a concise theory of logic, and later mathematics, the so-called Laws of Thought were posited [8]. One of these, the Law of the Excluded Middle, states that every proposition must either be True or False. Even when Parmenides proposed the first version of this law (around 400 B.C.) there were strong and immediate objections: for example, Heraclitus proposed that things could be simultaneously true and not true. It was Plato who laid the foundation for what would become fuzzy logic, indicating that there was a third region (beyond True and False) where these opposites tumbled about other more modern philosophers echoed his sentiments, notably Hegel, Marx, and Engels. But it was Lukasiewicz who first proposed a systematic alternative to the bi–valued logic of Aristotle. Even in the present time some Greeks are still outstanding examples for fussiness and fuzziness, (note: the connection to logic got lost somewhere during the last 2 millenniums [3]). Fuzzy Logic has emerged as a profitable tool for the controlling and steering of systems and complex industrial processes, as well as for house hold and entertainment electronics, as well as for other expert systems and applications like the classification of SAR data.

6.2 The FIS Editor:

The FIS Editor handles the high-level issues for the system: How many input and output Variables? What are their names? The Fuzzy Logic Toolbox doesn't limit the number of inputs. However, the number of inputs may be limited by the available memory of your machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools. The Membership Function Editor is used to define the shapes of all the membership functions associated with each variable behavior of the system. The Rule Viewer and the Surface Viewer are used for looking at, as opposed to editing, the FIS. They are strictly read-only tools. The Rule Viewer is a MATLAB based display of the fuzzy inference diagram shown

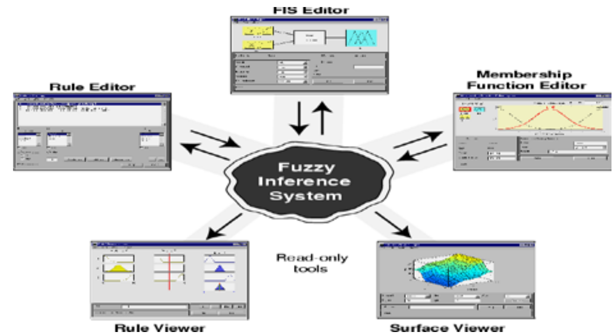

Fig.9: Fuzzy Inference System

in fig. 9. Used as a diagnostic, it can show (for example) which rules are active, or how individual membership function shapes are influencing the results. The Surface Viewer is used to display the dependency of one of the outputs on any one or two of the inputs — that is, it generates and plots an output surface map for the system.

6.3 Simulation with Fuzzy Logic Controller:

Replacing PID controller as shown in Fig. 7 , a Fuzzy Logic controller is added in the feedback path of the AVR system shown in Fig.10

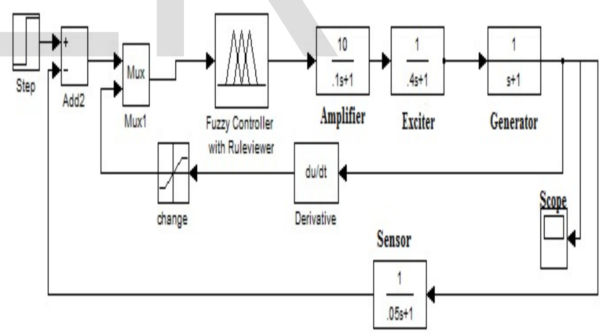

Fig.10: Block Diagram of AVR system with Fuzzy Logic Controller.

The simulation result for the above block diagram is shown in Fig.11

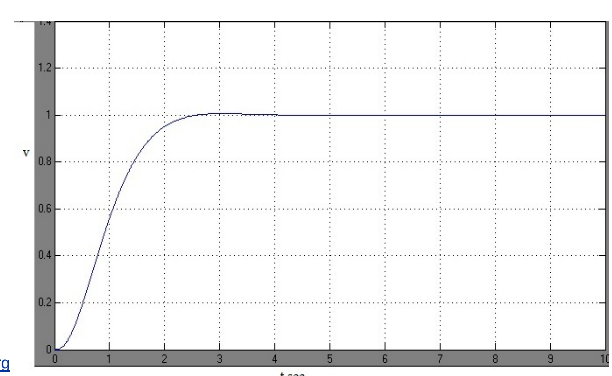

Fig.11: The response curve with Fuzzy Logic Controller.

7 Performance Comparisons of Controllers

In this paper we discuss about different controllers. We put fuzzy logic controller in the system and observed the response curve. Here in Fig.12 we put all the controllers in a single bus and observed the response curves at a same time.

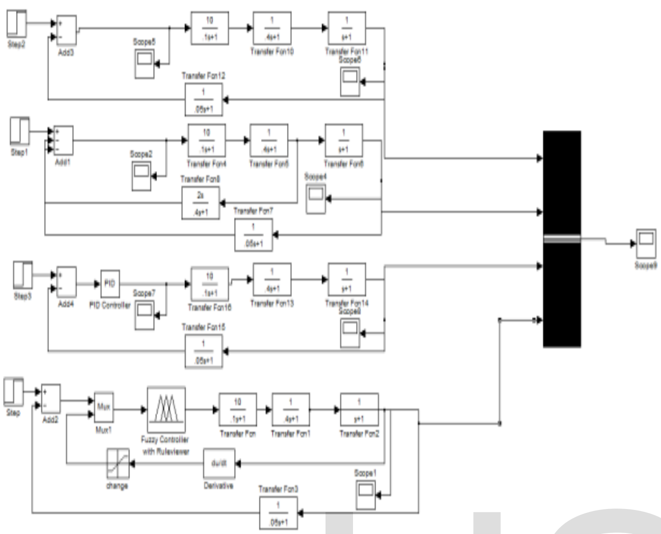

Fig.12: The block diagram of all controllers (stabilizer, PID, FLC) in system.

The Responses of the block diagram showed in Fig.13 is given below

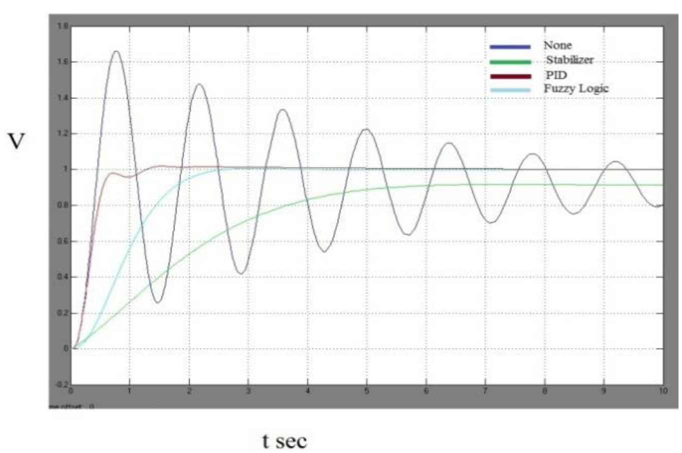

Fig .13 : Terminal voltage step responses of all controllers.

In Fig. 13 the Blue curve represents the power system without any control system. The Light Green response curve represents the control system having stabilizer with it. Power system with PID controller is represented by the Red response curve and the power system which is controlled by the FLC is represented by the Light Blue response curve.

8 Discussion

The output responses of all controllers (Stabilizer, PID, and Fuzzy Logic) are compared. Table 1 shows the comparison of the output responses using the controllers. From the analysis and comparison of all controllers, we see that a power system without any controller has a lot of fluctuations and the system was highly instable. In case of stabilizer controller, though the response curve showes us stable but it takes very long time to reaches stable point. When we analyse with PID controller, we see that the system gets stable at 2.8 sec & there is a little fluctuations in the system. In case of Fuzzy Logic controller, we see that it takes 2.6 sec to get stable and it has no fluctuation at all. Table 1 shows the overall view of performances of the controllers.

Table.1

Name of Controller Used	Fluctuation	Time to get stable
Stabilizer	No	5.2 sec
PID	Yes	2.8 sec
Fuzzy Logic	No	2.6 sec

9 Conclusion

Fuzzy logic controllers are commonly used to regulate the real time control. This paper presents the comparisions of different types of controllers. From Table .1, it is seen that Fuzzy logic controller shows the better performance compared to other controllers.

Acknowledgment

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