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ACTIVE AND REACTIVE POWER ADJUSTMENT OF A SYNCHRONOUS GENERATOR CONNECTED TO INFINITE BUS SYSTEMS BY FUZZY LOGIC CONTROLLER

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Abstract: The fuzzy logic controller based on the fuzzy set theory provides a useful tool for converting the linguistic control from the expert knowledge into automatic control rules [1]. By using fuzzy automatic rules from the heuristic or mathematical strategies, complex processes can be controlled effectively in many situations. But the most important and difficult point is how to obtain the proper control rules for a given system. In this study, active and reactive power control of a generator connected to infinite bus system was fulfilled effectively by the fuzzy logic controller. And the software of the system's simulation results were given.

Introduction: Power system operation considered so far was under conditions of steady load. However, both reactive and active power demands are never steady and they continually change with rising or falling trend. Steam input to turbo generators (or water input to hydro-generators) must, therefore, be continuously regulated to match the reactive power demand with reactive power generation, otherwise the voltages at various system busses may go beyond the prescribed limits [2]. In modern large interconnected systems, manual regulation is not feasible and therefore automatic generation and voltage regulation equipment is installed on each generator.

1. Active and Reactive Power Control of a Synchronous Generator Connected to Networks

Where the word network's means is that it has a very small internal impedance, which can be ignored, with a constant voltage and is infinite power compare with considered machine [3]. Because of its connection of such a network, both terminal voltage (Vt) and parameters of synchronous machine (Ra,Xs) are constant. Thus for the reactive and active power adjustment of a synchronous generator, we can change both the excitation current and the torque is given to machine shaft , respectively.

1.1 Reactive Power Adjustment of a Synchronous Generator

Excitation current control of synchronous generator is operated paralleled to network (infinite bus systems) cause to change in its internal emk (Ef) and just only reactive power of the machine is effected. Active power of the machine stay at constant value [4]. Machine active power can be calculated in two ways. From the tap conditions of the machine, active power can be written for the first one as below:

$$P = Vt.Ia.\cos\theta \tag{1}$$

Where,
Vt = terminal voltage

Ia = armature current
Cosθ = power factor
For the second one, by ignoring the stator resistance equations (1) can be rewritten relative to load angle, synchronous reactance and internal emk by the excitation current.

$$P = \frac{Ef \cdot Vt}{Xs} \cdot \sin\delta \qquad (2)$$

Both terminal voltages (Vt) and active powers (P) stay at constant value. From the equations (1) and (2), the constant values k1 and k2 can be written as below:

$$\begin{aligned} Ia \cdot \cos\theta &= k_1 \\ Ef \cdot \sin\delta &= k_2 \end{aligned} \qquad (3)$$

By the increasing excitation current, the vector Ef and load current will change within the range of k2 and k1, respectively

Let both the new values of Ef and Ia is Ef' and Ia,' respectively (figure 1)

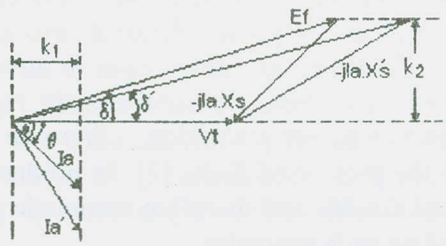

Figure 1. Reactive power control of a synchronous generator

1.2. Active Power Adjustment Of a Synchronous Generator

As explained above, active power is not based on the excitation current. When the field current is constant in the machine, Ef voltage is also constant. Thus for the Adjustment of the active power, the torque angle should be changed. To make bigger the angle δ as big as Δδ, the given torque to generator's shaft should be increased and accelerated in a short time by opening the valve of the water turbine or steam turbine (figure-2).

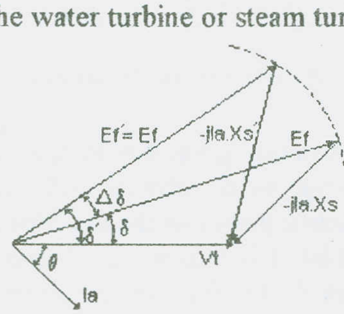

Figure 2. Active power control of a synchronous generator

For the above conditions, the machine gives the reactive power to networks as bellow:

From the tap conditions of the generator

$$Q = Vt \cdot Ia \cdot \sin\theta \tag{3}$$

And depending on the torque angle, terminal voltage, synchronous reactance and internal emk, equation (3) can be rewritten as equation (4) [5]

$$Q = -\frac{Vt}{Xs} \cdot \left(Ef \cdot \cos\delta - Vt\right) \tag{4}$$

2. Design of Fuzzy Logic Controller For Active And Reactive Power Control at Synchronous Generators Connected to Infinite Bus System

As known, active and reactive power demand changes in a various time of a day. Thus active and reactive power demand should be kept up with the power generations by adjusting field current (If) and torque angle (δ). For our system, fuzzy controller is designed as below :

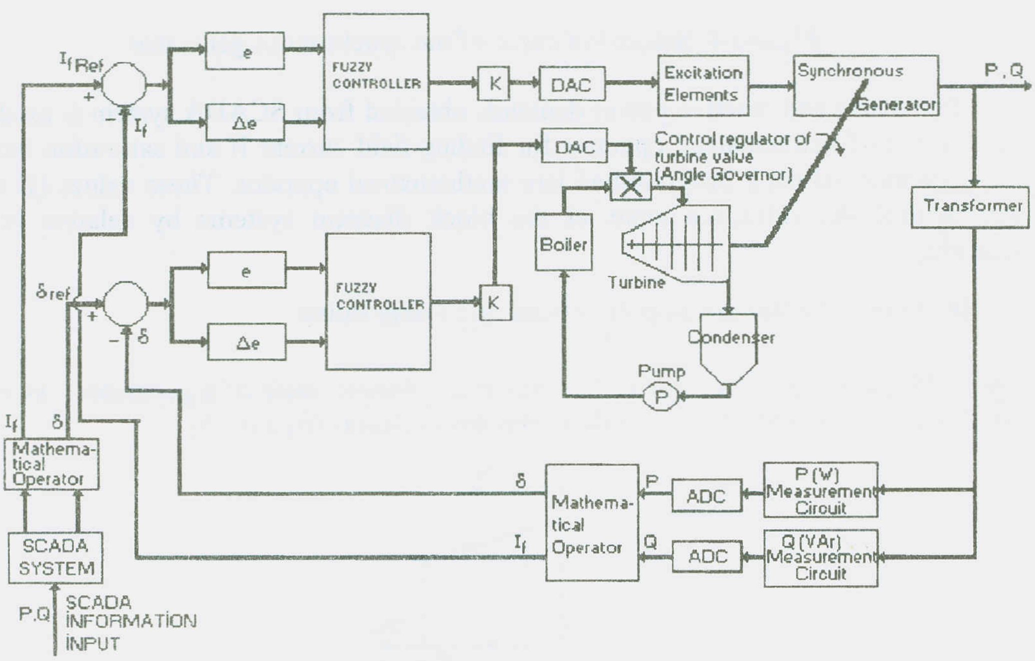

Figure 3. Design of fuzzy logic controller for active and reactive power control at synchronous generators connected to infinite bus system

As seen in the block diagram of the controller, information obtained from SCADA system measure some values at energy systems determine which generators should be loaded at which level of active and reactive power. [6]

From the equations (2) and (4) torque angle δ and internal emk Ef are determined as shown equations (5) and (6). As well as this, by using saturation curve of the synchronous generator (shown figure 4), If can be found.

$$Ef = \frac{P.Xs}{V.\sin\left(arctg\left[\left(\frac{V^2}{P\cdot Xs}-\frac{Q}{P}\right)^{-1}\right]\right)} \tag{5}$$

$$\delta = arctg\left[\left(\frac{V^2}{P\cdot Xs}-\frac{Q}{P}\right)^{-1}\right] \tag{6}$$

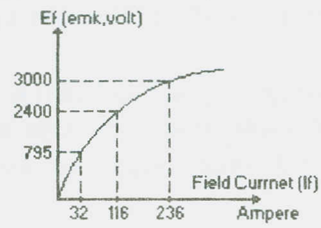

Figure 4. Saturation curve of the synchronous generator

The data active and reactive power demands obtained from SCADA system is used as an input value of mathematical operator for finding field current If and saturation curve of the generator, which is programmed into mathematical operator. These values (If and δ) are become the reference input of the block diagram systems by relative to load changing.

2.1. Distinguished Membership Functions and Fuzzy Rules

Figure (5) shows the governor of the exciter and torque angle of a generator. As seen in the figure (5) the characteristic cycle versus load is linear (figure - 5)

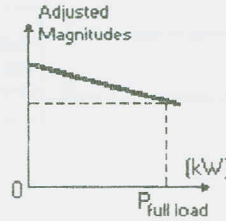

Figure 5. The governor characteristic of the exciter and torque angle of a generator

By searching the figure (1),(2) and (5), membership functions relative to error and changes in error were distinguished as triangular are shown in figure (6a-b) and (7a-b).

error and change in error are determined as below [7]:

e = Reference value - system output
ce = previous error - the present time error

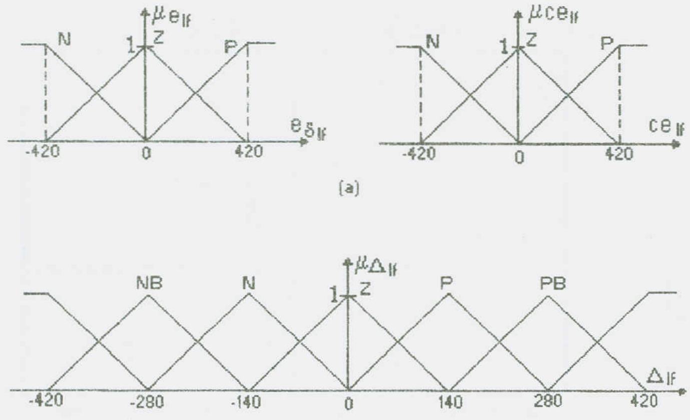

Figure 6. (a) Input membership functions for If and C_{If} (b) Output membership functions for Δ_{If}

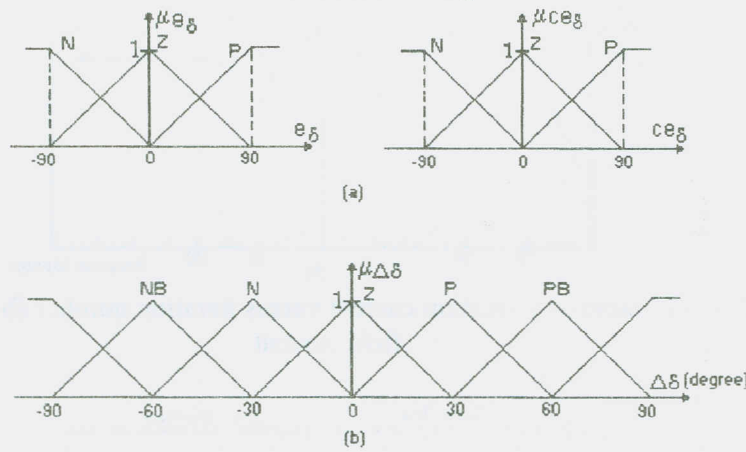

Figure 7. (a) Input membership functions for δ and C_{δ} (b) Output membership functions for Δ_{δ}

FAM (fuzzy associative memories) table was given in table 1. In the table, P,Z,N,PB and NB are represent the positive, zero, negative, positive big and negative big respectively.

Table 1. Fuzzy rules

e \ ce	P	Z	N
P	PB	P	Z
Z	N	Z	P
N	Z	N	NB

2.2. Simulation Results

Lets search the adjustments of active and reactive power of synchronous generator were considered in two time slice. For the first period of the time, lets adjust the both excitation current from zero to 2509 A and torque angle δ from zero to 15 degree. As well as this, for the second period of the time, lets adjust the both excitation current from 250A to 200A and torque angle δ from 15 degree to 12 degree. The software of the programme was written in Q - basic programming language and simulation results were given in figure (8a-b) and (9a-b)

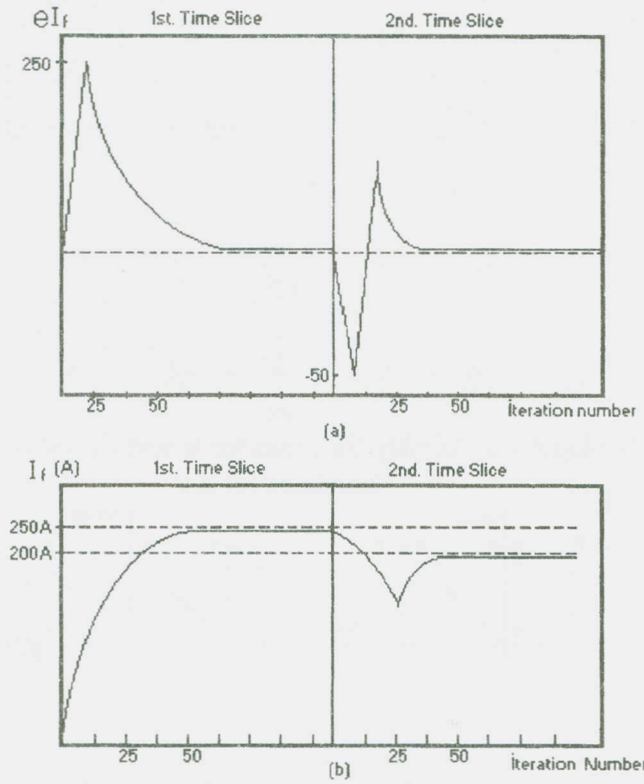

Figure 8. (a) Change of excitation current versus iteration number (b) Adjustment of field current

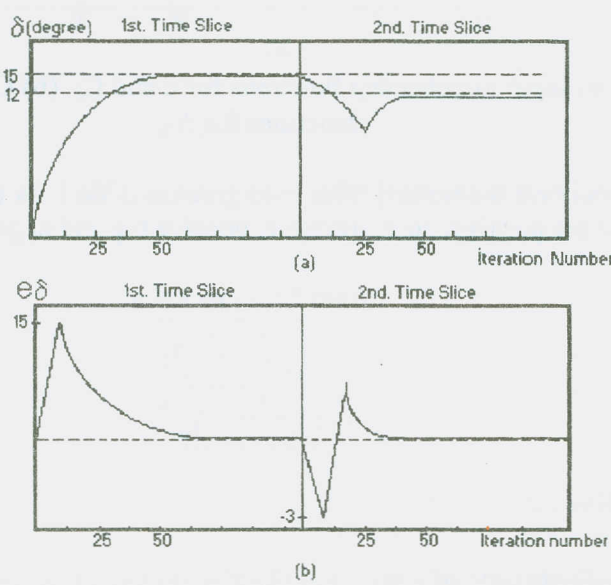

Figure 9. (a) Adjustment of torque angle (b) Change of torque angle versus iteration number

3. Conclusions

In this study, generalized fuzzy logic controller was resembled by writing its software in Q - basic programming language. As well as this, simulation's results for active and reactive power of a generator, connected to infinite bus systems, are given by the programme as bellow :

- In the control purposed studies, both shortness of response time and the result value of error take up important position. For the power system control, applied control system takes a decision on the control signal in a short time (it's approximately about at μsn degrees in the computer simulations). Consequently, by using this new approach technique, control signal will be adjusted to demand value effectively in a very short time with the small error.

- Proposed control system is less sophisticated and more effective than conventional system without many operator.

- Due to more quick and more sensitive control actions can be fulfilled by the method, it cause destroying the system stability effects are to be disappeared. So we can say that the method has a effect of improvement for the getting better power system stability.

- At the conclusion of control operation by fuzzy logic controller, negativeness sourced by the operator is absolutely annihilated.

- If we search the system at the point of cost, we can come to a conclusion as follow :

The additional cost sourced from the operation of the system with the error is disappeared by the method.

Because of shortness of response time in the developed method, occurring additional cost during the time of control actions by the operator is annihilated. Thus as soon as the undemand conditions occur, system will continue to operate in the demand limits. Consequently, minimum cost and maximum efficiency compared with the conventional system are provided by the method.

- Because of system's above feature, we can say that developed control system for active and reactive power of a generator, connected to infinite bus systems is the optimum control type.

References

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