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Matlab Design and Simulation of AGC and AVR For Single Area Power System With Fuzzy Logic Control

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Abstract— **This paper deals with the combination of automatic generation control (AGC) of thermal system with automatic voltage control (AVR). In this particular work thermal unit is considered with single area concept. The primary purpose of the AGC is to balance the total system generation against system load and losses. Any mismatch between generation and demand causes the system frequency to deviate from scheduled value. Thus high frequency deviation may lead to system collapse. Further the role of automatic voltage regulator is to hold terminal voltage magnitude of synchronous generator at a specified level. The interaction between frequency deviation and voltage deviation is analyzed in this paper. System performance has been evaluated at various loading disturbances. This paper describes the design, implementation and operation performance of fuzzy controller as part of the combined loop of AGC & AVR for single area power system. The fuzzy controller is implemented in the control of ACE calculation in the case of AGC & excitation in case of AVR, which determines the shortfall or surplus generation that has to be corrected. In the case of AVR, fuzzy with PID has been implemented.**

***Index Terms*— Automatic Generation Control (AGC), Automatic Voltage Regulator (AVR), Area Control Error (ACE), Frequency Response, Voltage Response, Govemor Action, Power System Operation, Fuzzy logic, Fuzzy control.**

I. INTRODUCTION

Automatic Generation Control (AGC), is very important issue in power system operation and control for supplying sufficient and both good quality and reliable electric power [1]. Investigations have shown [3] that following a sudden load change or disturbances in a single area power system, the frequency undergoes a fluctuation which persists for a very long time. This fluctuation is very poorly damped. Since these oscillations are the result of imbalance of power [3, 4]. The generation is adjusted automatically by Automatic Generation Control to restore the frequency to the nominal value as the system load changes continuously [5].

The generator excitation system maintains generator voltage and controls the reactive power flow. The generator excitation of older system may be provided through slip rings and brushes by means of DC generators mounted on the same shaft as the rotor of the synchronous machine. A change in the real power demand affects essentially the frequency, whereas a change in the reactive power affects mainly the voltage magnitude. The interaction between voltage and frequency controls is generally weak enough to justify their analysis separately. The sources of reactive power are generators, capacitors, and reactors. The generator reactive powers are controlled by field excitation. Other supplementary method of improving the voltage profile in the electric transmission systems are transformer load tap changers, switched capacitors, step voltage regulators and static Var control equipment. The primary means of generator reactive power control is the generator excitation control using automatic voltage regulator (AVR). The role of an AVR is to hold the terminal voltage magnitude of synchronous generator at a specified level [7].

The proportional integral (PI) control approach is successful in achieving zero steady-state error in the frequency of the system, but exhibits relatively poor dynamic performance as evident by large overshoot and transient frequency oscillations. Moreover, the transient settling time is relatively large [9]. Fixed integral gain controllers have been proposed for nominal operating conditions but they fail to provide best control performance over a wide range off-nominal operating conditions. In this paper, the fuzzy logic is effectively used to change the integral gain, K_i of AGC settings automatically to restore nominal system frequency for various wide-range off-nominal power system parameters and load changes [12]. 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. This voltage is rectified and compared to DC set point signal. The amplified error signal controls the exciter field 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 increased to a new equilibrium, raising the terminal voltage to the desired value. This paper presents a development of voltage control of AVR or excitation system by using a self-tuning fuzzy PID controller to overcome the appearance of nonlinearities and uncertainties in the systems [10]. The self-tuning fuzzy PID controller is the combination of a classical PID and fuzzy controller. A typical single area combined loop of AGC and

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AVR power system is considered as a test network and simulation results are presented and discussed.

II. MAIN ASPECTS CONCERNING WITH SYSTEM MODELING

The first step in the analysis and design of a control system is mathematical modeling of the single area power system. Proper assumptions and approximations are made to linearize the mathematical equations describing the system, and a transfer function model is obtained for the component [9]. The dynamic models in state-space variable form, obtained from the associated transfer function, is

$$\dot{X} = AX + BU, \qquad Y = CX \qquad (1)$$

Where,

$$X = [\Delta f\ \Delta P_t\ \Delta P_g\ \Delta P_{ref}]^T; \quad U = [\Delta P_L]^T \qquad (2)$$

$$Y = [\Delta f] \qquad (3)$$

are the state vector, the control vector and the output variables, respectively.

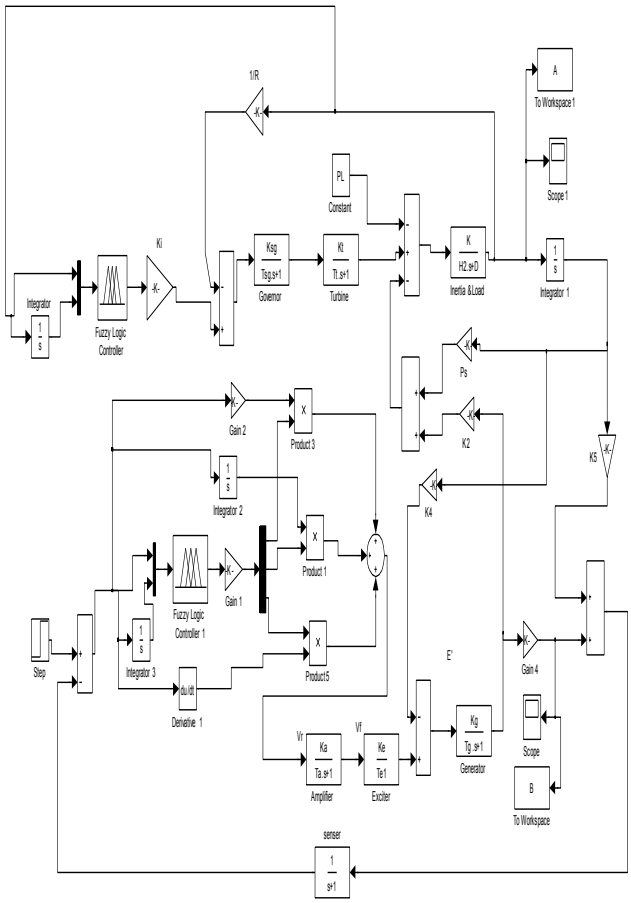

Fig. 1: Simulink model of Fuzzy based AGC and AVR for a typical single area power system.

Fig. 1 shows the simulink model of fuzzy based combined loop of AGC and AVR. In this paper, the fuzzy logic controller is used to tune the integral gain, K_i of AGC in a single area power system to restore the nominal system frequency for various system load changes [11]. The critical value of K_I of conventional PI controller is considered as the base value in the design of the proposed fuzzy logic control scheme. In AVR system fuzzy with PID control scheme has been implemented [12].

III. FUZZY LOGIC CONTROLLER FOR INTEGRAL GAIN SCHEDULING

Fuzzy control is special form of knowledge-based control. In designing a fuzzy control system, the precise mathematical model of target plant is not needed. Only the relevant experiences and heuristics concerning the plant are utilized to form a set of fuzzy control rules. These are linguistic in nature, and often use the simple cause-effect relationship to link a fuzzy partitioning of certain state-space of the plant with a fuzzy partitioning of the control action. The final control signal is generated by an appropriate defuzzifying process.

A. Fuzzification

The precise numerical values obtained by measurements are converted to membership values of the various linguistic variables.

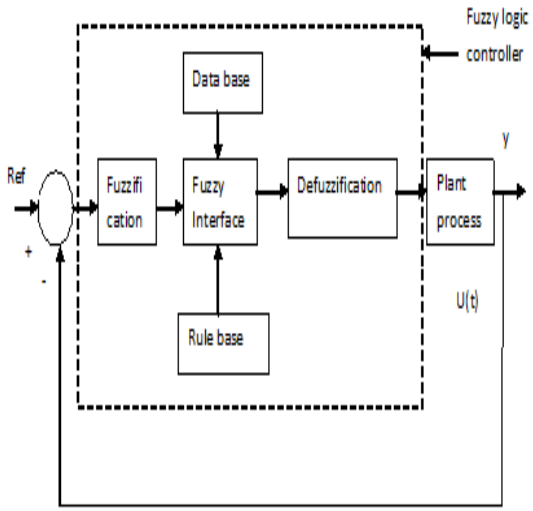

Fig. 2: Block diagram of a typical closed-loop Fuzzy control system.

For the FL controller the inputs are the frequency variation (i.e. error) and the rate of change in the error defined as:

input 1: error = $\Delta f = f_{nom} - f_t = e_t$ (4)

input 2: rate of change in error =

$$\Delta f = f_{nom} - f_t = \dot{c}e_t \qquad (5)$$

B. Fuzzy Rule Base

The heuristic rules of the knowledge base are used to determine the fuzzy controller action. For example the FL controller employs a rule: If e_t is NB and ce is NB then the controller action (K_i) is PB. The part e_t is NB and ce is NB defines another linguistic variable.

C. Membership Functions For Agc For The Fuzzy variables Of The Proposed FLC

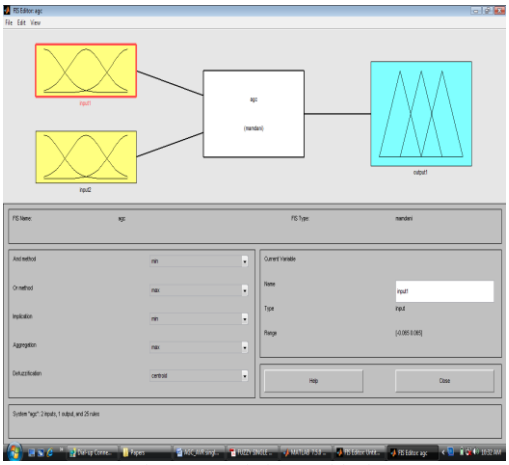

Fig 3: Fuzzy inference block

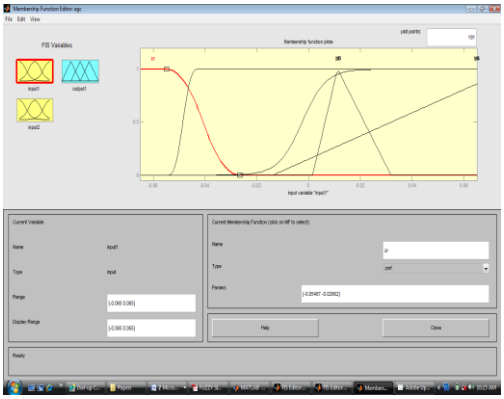

Fig 4: Membership functions of e(t)

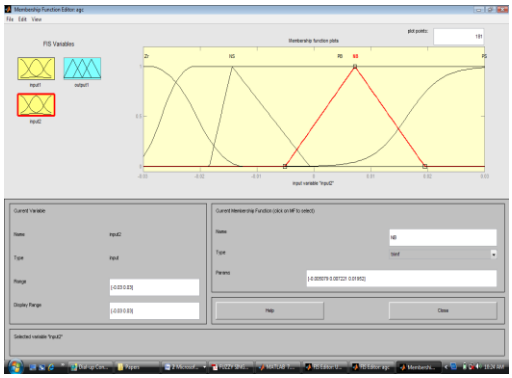

Fig 5: Membership functions of de(t)

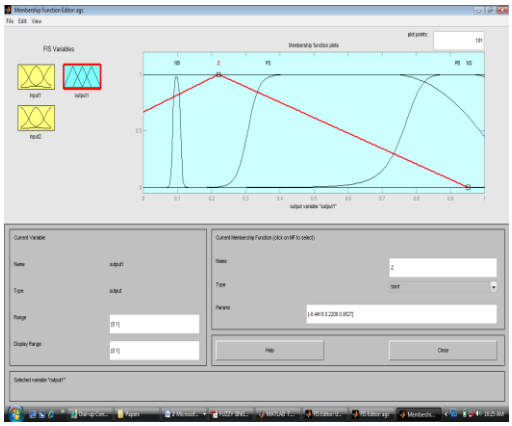

Fig 6: The output membership function

D. Membership Functions For AVR For The Fuzzy Variables Of The Proposed FLC

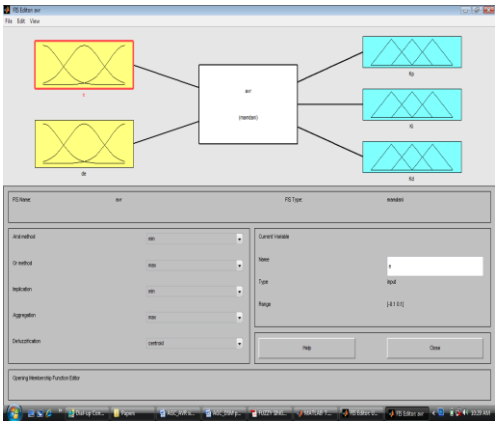

Fig 8: Fuzzy inference block

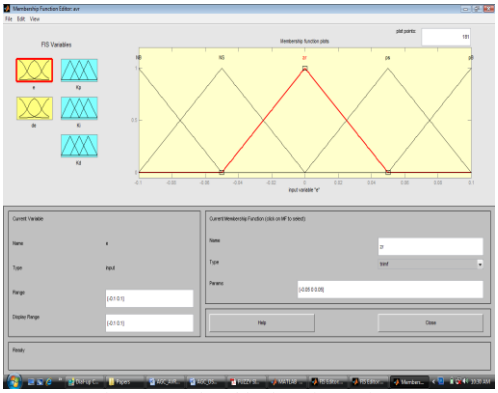

Fig 9: Membership functions of e(t)

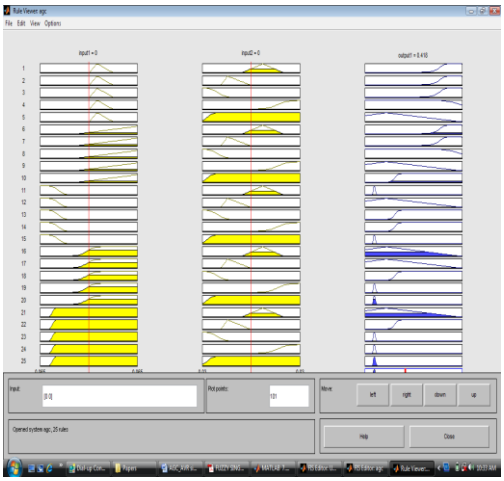

Fig 7: Fuzzy rules viewer

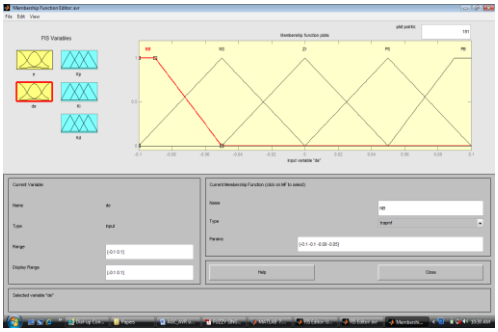

Fig 10: Membership functions of de(t)

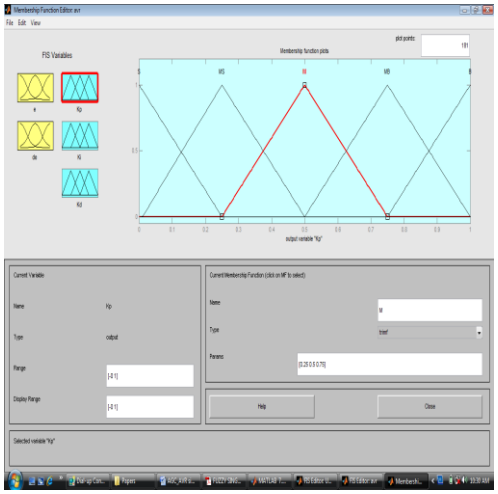

Fig 11. Membership functions of Kp, Ki and K_d.

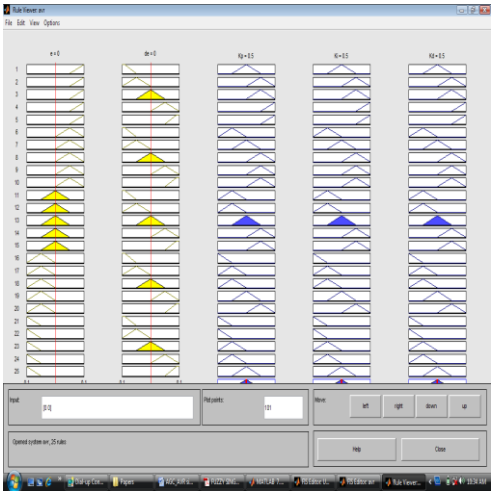

Fig 12: Fuzzy rules viewer

Though it is possible to derive a membership value for this variable in many possible ways, one of the rules that has been chosen is

$$\mu(e_t, c\ \dot{e}_t) = \min\ [\mu(e_t), \mu(c\ \dot{e}_t)] \quad (6)$$

The fuzzy rule bases are constructed by using trial and error methods.

E. Defuzzification

The well-known center of gravity defuzzification method has been used because of its simplicity:

$$K_I = \sum_{j=1}^{n} \mu_j u_j / \sum_{j=1}^{n} \mu_j \quad (7)$$

Where, μ_j, is the membership value of the linguistic variable recommending the fuzzy controller action, and u_j is the precise numerical value corresponding to that fuzzy controller action. The membership functions, knowledge base and method of defuzzification essentially determine the controller performance [13].

IV. SIMULATION RESULTS AND PERFORMANCES

The simulation results of the studies are depicted in fig 13, 14, 15 & 16. Fig 13 shows the AGC and AVR frequency response for single Area without fuzzy controller. Here the frequency oscillations are controlled near about 35 seconds. With the addition of proposed schemes, the damping is improved significantly. Fig 14 shows the AGC and AVR frequency response for Single Area with fuzzy control, here the frequency oscillation has been controlled near about 10 seconds. Fig 15 shows the AGC and AVR voltage response for single Area without fuzzy controller. Here the voltage oscillations are controlled near about 2.5 seconds. With the addition of proposed schemes, the damping is improved significantly. Fig 16 shows the AGC and AVR voltage response for Single Area with fuzzy control here the voltage has been controlled in 2 seconds.

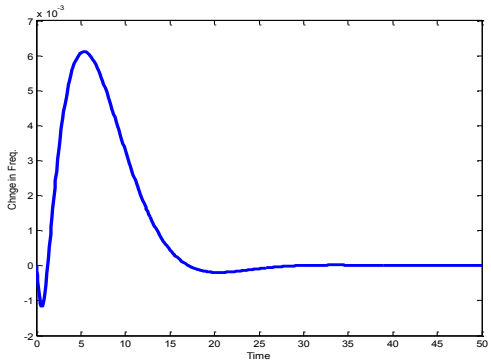

Fig 13: AGC and AVR frequency response for single Area without fuzzy controller

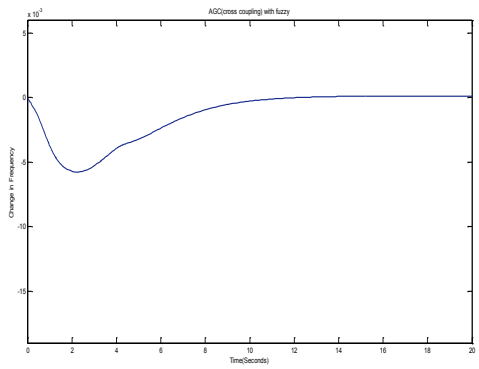

Fig 14: AGC and AVR frequency response For Single Area with fuzzy controller

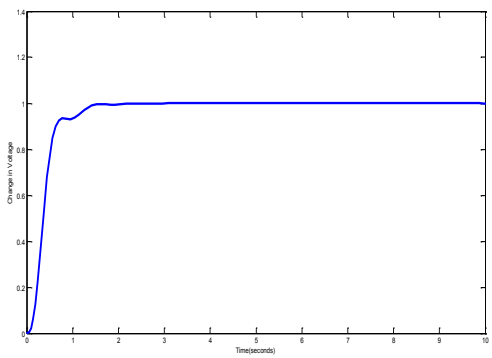

Fig 15: AGC and AVR voltage response for Single Area without fuzzy controller

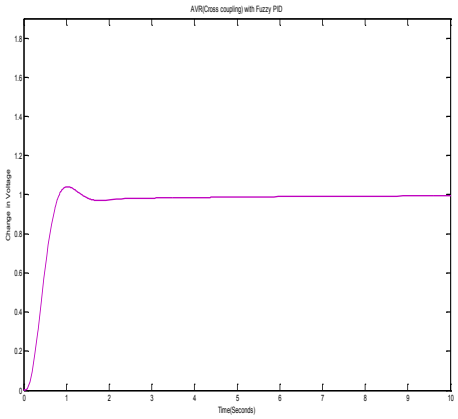

Fig 16 AGC and AVR voltage response for single Area with fuzzy controller

V. CONCLUSION

The fuzzy gain scheduling of AGC in a single area power system has been implemented The fuzzy logic approach to integral gain scheduling yields overall better performance regarding transient responses in comparison to the case of fixed integral gain. The settling time is reduced to a great extent with the proposed mode of scheduling. The gain scheduling approach yields automatic, self-adjusting outputs irrespective of widely varying, imprecise, uncertain off-nominal conditions. The memory and the computational burden have been reduced and also settling time reduces drastically in the fuzzy logic approach scheme.

I: ASSUMPTIONS USED IN THE SIMULATION RUNS FOR AGC

Quantity	Area–I
Governor speed regulation	$R_1 = 0.051$
Frequency bias factors	$D_1 = 0.62$
Inertia constant	$H_1 = 5$
Base power	1000MVA
Governor time constant	$T_{sg1} = 0.2$ sec
Turbine time constant	$T_{t1} = 0.5$ sec
Constant	$k = 1/2\pi = 0.159$
Nominal frequency	$f_1 = 50$ Hz
Load change	$\Delta P_{L1} = 180.2$ MW
Load disturbance in per unit	$(\Delta P_{L1})_{p.u} = 0.1802$

II. ASSUMPTIONS USED IN THE SIMULATION RUNS FOR AVR

Quantity	Gain	Time Constant
Amplifier	9	0.1
Exciter	1	0.4
Generator	1	1.0
Sensor	1	0.05

Quantity	Gain
PID Controller	$K_P = 1.0$ $K_i = 0.25$ $K_d = 0.28$

ACRONYMS

B : Frequency Bias factor
D : Percent change in load divided by the percent change in frequency
Ki : Supplementary control constant
H : Inertia Constant
ΔP : Change in power
ΔP_{Mech} : Change in mechanical power input
ΔP_D : Change in power demanded by the load in an area
$\Delta P_{Tie\text{-}flow}$: Change in power transmitted over tie line
ΔP_{Valve} : Change in valve position from nominal
R : Speed Droop Characteristic
T_{Ps} : Power system time constant
Ts_G : Speed governor time constant
Tt : Turbine time constant
f : Frequency of system
f_{ref} : Reference frequency for system
Δf : Change in system frequency
X_{tie} : reactance of tie line

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BIOGRAPHIES

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