CHAPTER 6

PERFORMANCE ANALYSIS OF ROBUST MULTIPLE MODEL ADAPTIVE CONTROLLER

Describes the design of Graphical User Interface for the application suing MATLAB. The MMAC framework is discussed in chapter 5. The fuzzy decision is used to identify the better control strategy for control problem with help of performance assessment. The detail of membership functions design, rule base and its implementation are discussed in this chapter.

6.1 Introduction

This chapter deals with the various controller designs for power system stabilization using robust multiple model adaptive controller. The fuzzy logic is used to identify the better control strategy for control problem. Three controllers are designed by using fuzzy logic controller i.e.Conventional control, intelligent control & Smart control.

6.2 Design of various controller for power system stabilization

6.2.1 Conventional controller

Conventional controller is designed using classical method of conventional power system stabilizer. This controller is design based on the improvement of performance criteria such as Rise time, Settling Time, Overshoot, Steady state Error, Integral of Absolute Error, Integral Time of Absolute Error, Integral of Squared Error, Integral Time of Squared Error [1] [2].

6.2.2 Intelligent controller

Intelligent controller is designed using fuzzy logic. Two variables are selected as input variable i.e. Acceleration and speed Deviation and one as output variable i.e. voltage [3]. The MF for i/p & o/p are selected as per table 6.1 after simulations.

Table 6.1Fuzzy set for variable

Parameter	Range	Name of MF	Type of MF	Range
Acceleration	[-1 1]	NB	Triangular	[-1.33 -1 -0.6666]
		NM		[-1 -0.6666 -0.3334]
		NS		[-0.6666 -0.3334 0]
		ZE		[-0.3334 0 0.3334]
		PS		[0 0.3334 0.6666]
		PM		[0.336 0.669 1]
		PB		[0.6666 1 1.334]
Speed Deviation	[-1 1]	NB	Triangular	[-1.33 -1 -0.6666]
		NM		[-1 -0.6666 -0.3334]
		NS		[-0.6666 -0.3334 0]
		ZE		[-0.3334 0 0.3334]
		PS		[0 0.3334 0.6666]
		PM		[0.336 0.669 1]
		PB		[0.6666 1 1.334]
Voltage	[-1 1]	NB	Triangular	[-1.33 -1 -0.6666]
		NM		[-1 -0.6666 -0.3334]
		NS		[-0.6666 -0.3334 0]
		ZE		[-0.3334 0 0.3334]
		PS		[0 0.3334 0.6666]
		PM		[0.336 0.669 1]
		PB		[0.6666 1 1.334]

6.2.3 Smart controller

Smart controller is designed using artificial neural network. The ANN controller is obtained as below [4].

Table 6.2 Parameters for ANN control

No of hidden layers	26	Training algorithm	Traingdm
No of epochs	3000	Goal	1e-3
Network	feedforward		

6.3 Fuzzy logic based Robust MMAC

6.3.1 Fuzzy Sets

Fuzzy set is developed as shown in Table 6.3.

Table 6.3Fuzzy sets

I/P Parameter	Range	Name of MF	Type of MF	MF Range
Rise time	[0 1]	Fast	Triangle	[0 0.6 1]
		Average	Trapezoidal	[0 0.4 0.8 1]
		Slow	Trapezoidal	[0 0.3 0.6 1]
Settling Time	[0 20]	Fast	Triangle	[0 12 20]
		Optimum	Trapezoidal	[0 12 16 20]
		Slow	Trapezoidal	[0 12 16 20]
Overshoot	[0 100]	High	Trapezoidal	[0 25 40 100]
		Low	Triangle	[0 55 100]
Steady state Error	[0 1]	High	Trapezoidal	[0 0.3 0.6 1]
		Medium	Triangle	[0 0.6 1]
		Negative	Trapezoidal	[0 0.4 0.8 1]
Integral of Absolute Error	[0 0.0001]	Negative	Trapezoidal	[0 0.00004 0.00006 0.0001]
		Medium	Triangle	[0 0.00005 1]
		Positive	Trapezoidal	[0 0.00004 0.00006 0.0001]
Integral Time of Absolute Error	[0 0.01]	Negative	Trapezoidal	[0 0.004 0.006 0.01]
		Medium	Triangle	[0 0.005 0.01]
		Positive	Trapezoidal	[0 0.004 0.006 0.01]
Integral of Squared Error	[0 0.0001]	Negative	Trapezoidal	[0 0.00004 0.00006 0.0001]
		Medium	Triangle	[0 0.00005 1]
		Positive	Trapezoidal	[0 0.00004 0.00006 0.0001]
Integral Time of Squared Error	[0 0.0001]	Negative	Trapezoidal	[0 0.00004 0.00006 0.0001]
		Medium	Triangle	[0 0.00005 1]
		Positive	Trapezoidal	[0 0.00004 0.00006 0.0001]

6.3.2 Fuzzy Rule base

The fuzzy logic in the proposed section is used as Robust multiple model adaptive controller for single machine & multimachine Infinite system. The rule base is determined by the simulation of each of the switching logic input parameters & output parameters [5-7].

Table 6.4Rule base

Rule No	Rule	Activated control
1	Rise Time is Fast and Settling Time is Fast	Smart control
2	Overshoot is high & steady state Error is medium	Conventional Control
3	Integral of Absolute Error is Negative	Conventional Control
4	Rise time is slow & Settling time is Fast	Intelligent control
5	Integral of Squared Error is positive	Intelligent control
6	Overshoot is high & Steady state Error is Low	Smart control
7	Integral Time of Absolute Error is medium	Intelligent control
8	Integral Time of Squared Error is medium	Smart control
9	Rise Time is Fast & Settling time is slow	Conventional Control
10	Overshoot is high & Steady state Error is high	Intelligent control

So selection of the appropriate functions is an important design problem. So in order to design an optimal fuzzy system the proper MF are searched by using several simulations. The fuzzy input & output variable are characterized by three fuzzy MF.From the point of view of simplicity & computational complexity, the fuzzy values are represented by Triangular(TriMF) & Trapezoidal (TrapMF) with not more than two MF overlapping. But fuzzy MF can have different shapes & sizes depending on the designer's preference [8].

The TriMF curve is a function of a vector x and depend on three scalar parameters a, b and c as given by equation 8.1.

$$\mathrm{F(x,a,b,c)} = \begin{Bmatrix} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{Bmatrix} \tag{6.1}$$

The TrapMF curve is a function of a vector x and depend on four scalar parameters a, b, c and d as given by equation 8.2.

$$F(x,a,b,c,d) = \begin{Bmatrix} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{d-x}{d-c}, & c \le x \le d \\ 0, & d \le x \end{Bmatrix} \tag{6.2}$$

6.2.3 Fuzzy inference procedure

At each stage the switching logic input parameters are compared with their desired values using their fuzzy sets. The graphical user interface is developed for simulation study of single machine infinite bus system and multimachine system for light, normal & heavy loading condition [9][10].The Centre of sums defuzzification method is used for the selection of one controller at a time. Fig 6.1 shows the GUI for performance analysis of Robust multiple model adaptive controllers.

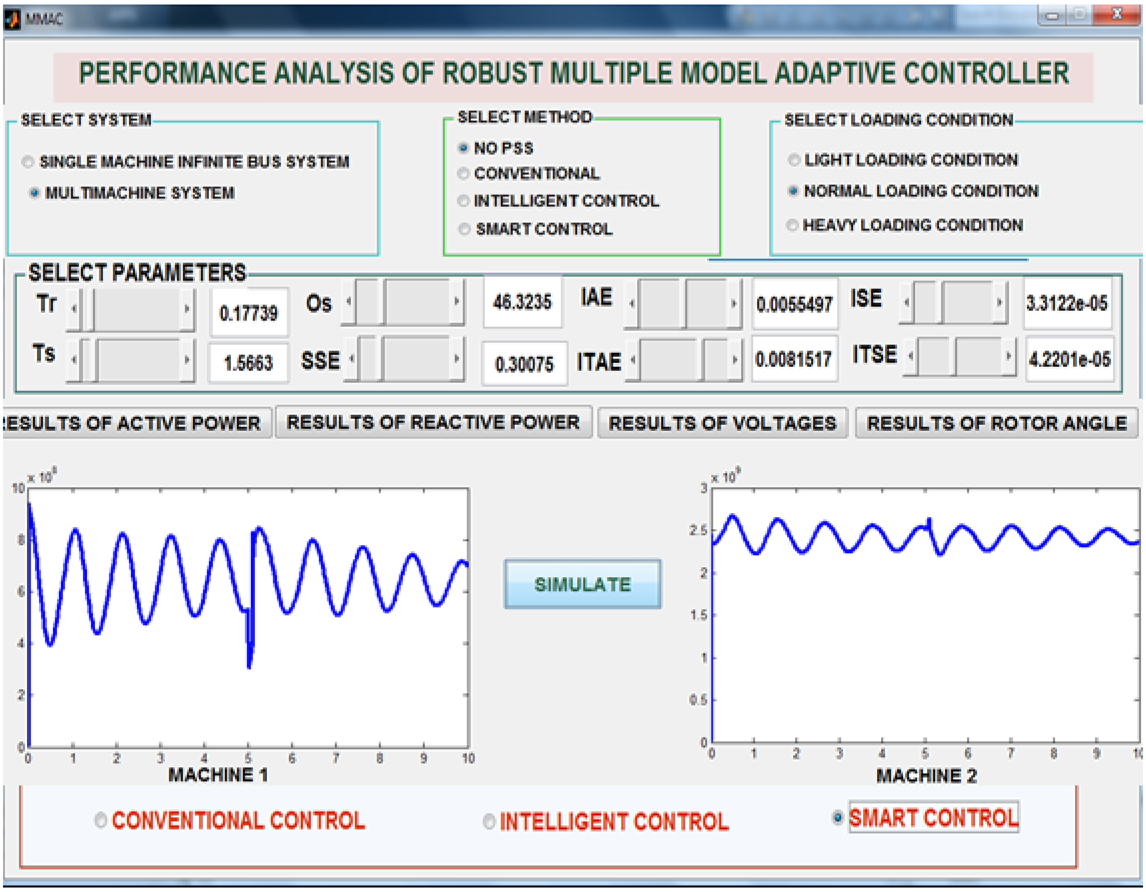

Fig. 6.1 Graphical user interface for Robust MMAC

Fig 6.2 depicts that the controller 1 i.e. conventional control is activated for the power system stabilization which considers the rules define as shown in table 6.2.

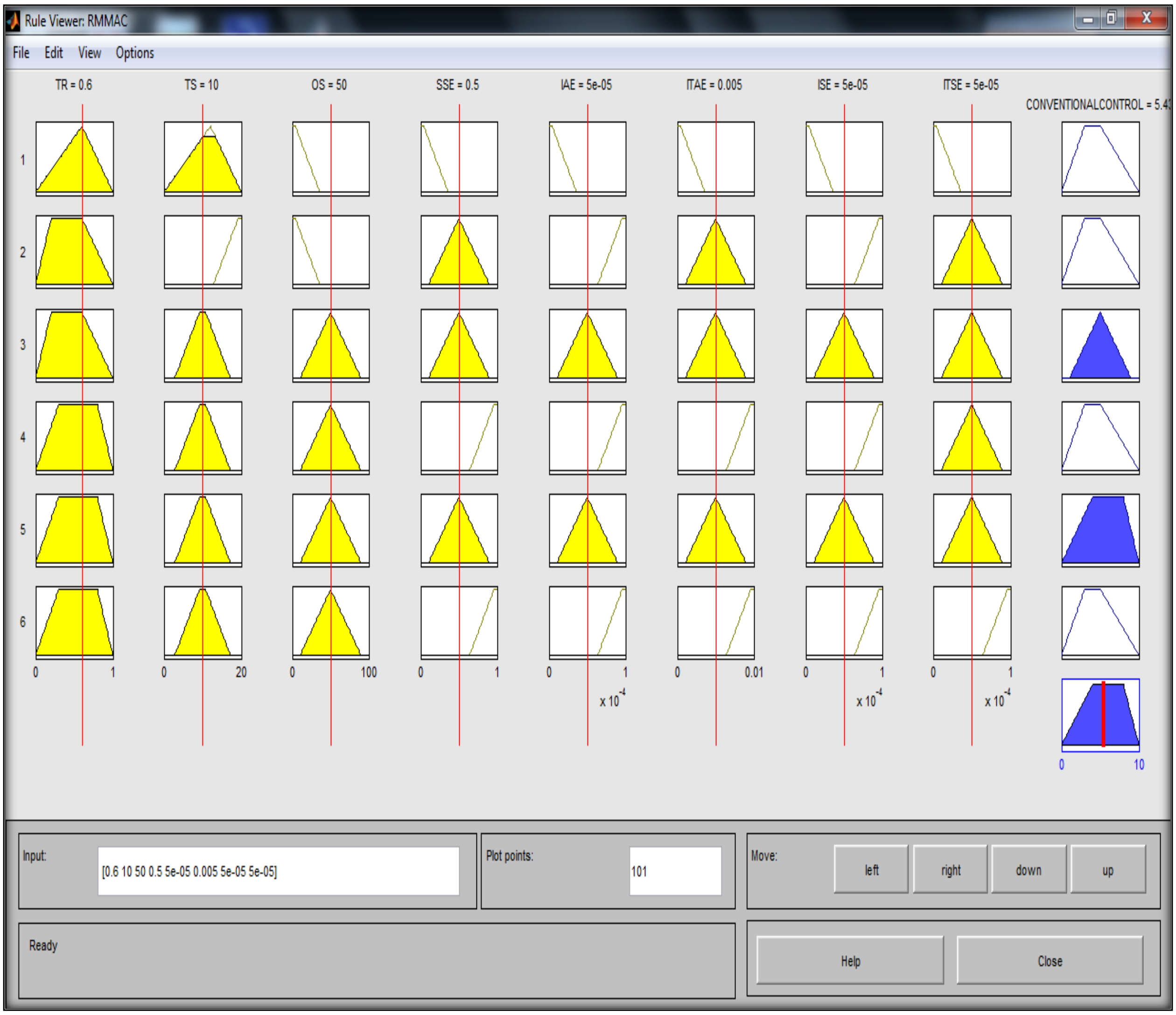

Fig. 6.2 Controller 1 (Conventional control) is activated for the power system stabilization

Fig 8.3 shows that the controller 2 i.e. intelligent control is activated for the power system stabilization. Intelligent controller indicates the use of fuzzy logic system for the performance evaluation.

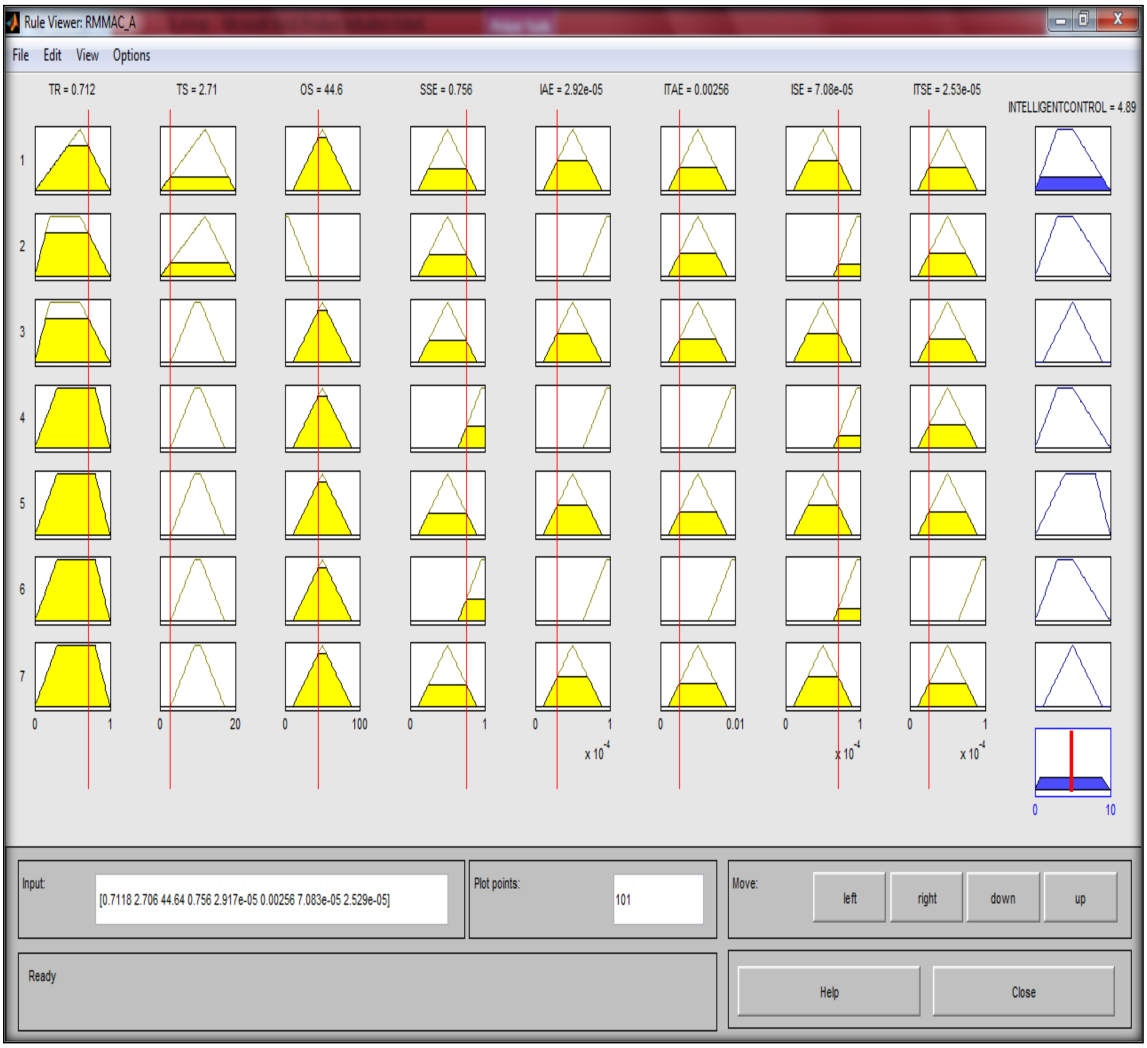

Fig. 6.3 Controller 2 (Intelligent control) is activated for the power system stabilization

Table 6.5Performance parameters & controller response for various loading condition.

Operating Conditions	**Light loading**	**Normal loading**	**Heavy loading**
Change of Parameters	P=0.5 Q=0.3	P=1.0 Q=0.4	P=1.5 Q=0.8
K1	0.9339	1.1053	0.8894
K2	1.0191	1.3287	1.3888
K3	0.3600	0.3600	0.3600
K4	1.3044	1.7008	1.7776
K5	0.0500	-0.1001	-0.2697
K6	0.4512	0.3607	0.3371

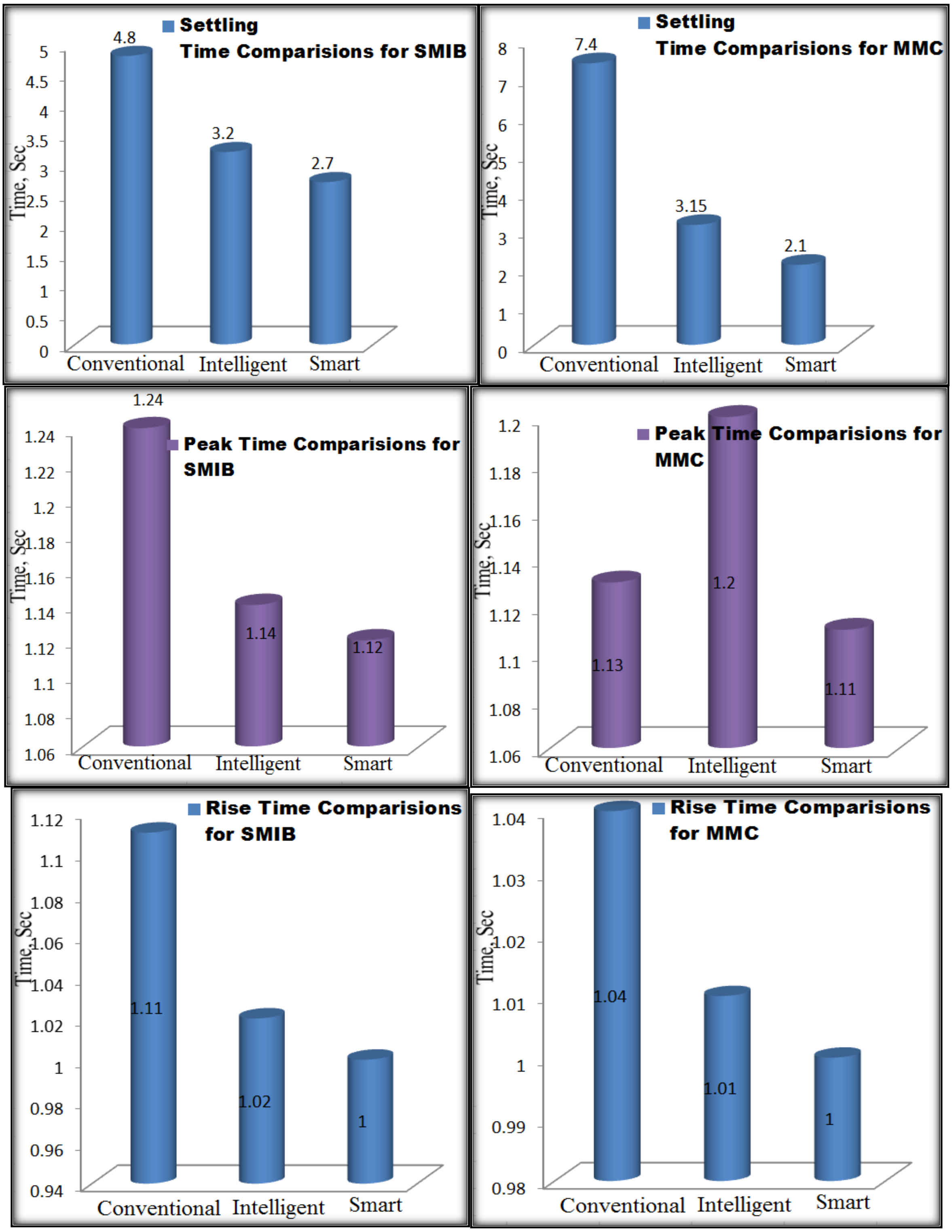

Fig. 6.4 Performance comparisons of developed Controllers

Fig 6.5 depicts that the controller 3 i.e. smart control is activated for the power system stabilization. Smart controller indicates the use of artificial neural network (ANN) system for the performance evaluation. The controller is applied on the Heffron Philips model of the SMIB system. Table 6.3 shows the controller result, performance parameters & selection of control agent for various operating points with changes of light loading to normal loading and heavy loading values of process parameters.

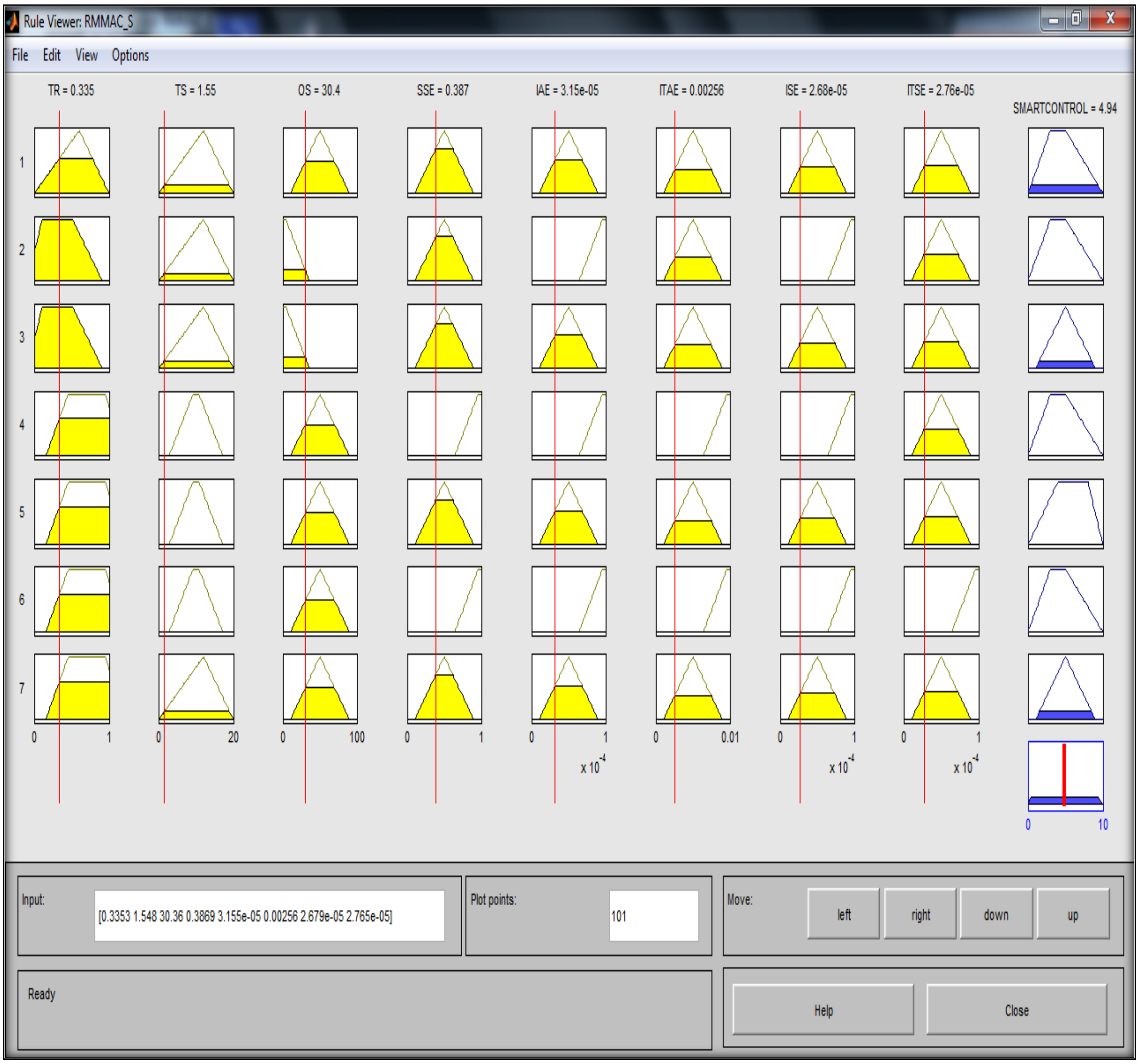

Fig. 6.5 Controller 3 (Smart control) is activated for the power system stabilization

6.4 Concluding Remarks

In this chapter, new technique for power system stabilization is developed for multiple model adaptive controllers. Various parameters for control algorithm are calculated online using performance criteria. The fuzzy logic is used to identify the best control algorithm for the power system(6). From simulation study, the fuzzy set, fuzzy rules & inference are developed. The overview of whole robust MMAC is discussed in detail.

(6) Paper entitled "Performance Evaluation of PSS Under Different Loading Condition", Global Conference on communication technologies GCCT, IEEE Conference at Tamilnadu during 23-24 April, 2015.