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Development of Hybrid Controller for Load Frequency Control of Hydro Thermal Power System

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Abstract:
This article a secondary controller with PDIC cum FLC for multi area hydro thermal model with multi source. Here, two control areas are connected via. tie line and also, every area consists of hydro and thermal power system. The traditional controllers are non-capable of manipulating the frequency gap as well as the power oscillation of it at load variable conditions. In order to stabilize the frequency deviation and improve the dynamic performance of multi area multi source hydro thermal system, PDIC along with FLC has been developed.

1. Introduction

Fuzzy set theory was first developed by Prof. Zadeh in1965 [127] and first application of Fuzzy Set theory in Control Engineering was done in 1970.For solving power system problems it was introduced in 1979. Generalization of classical set theory provides fuzzy set (FS) theory. A FS is a set without any round and plainly defined boundaries. It contains components with value of membership. Depending on the requirements and constraints of the problem, membership function is designed.

Fuzzy logic has been incorporated by many of the researchers in designing the controller. As explained by Prof. Zadeja [127] and many other researchers, the details of Fuzzy logic are explained in the section 2.2.1.

2.2.1 FLC

General structure of the FLC is shown in figure 2.1.

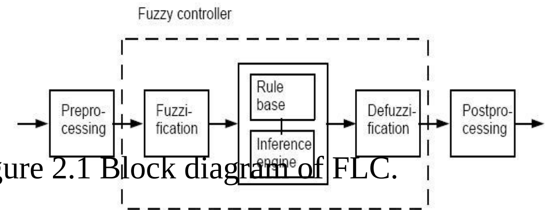

Figure 2.1 Block diagram of FLC.

From figure 2.1, it may be noted that FLC consists of four basic components viz.

i. Fuzzification interface
ii. Knowledge base
iii. Decision making logic and
iv. Defuzzification interface

Details of block are explained here

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The input space is sometimes referred to as the universe of discourse and the various types of membership functions are shown in figure 2.2.

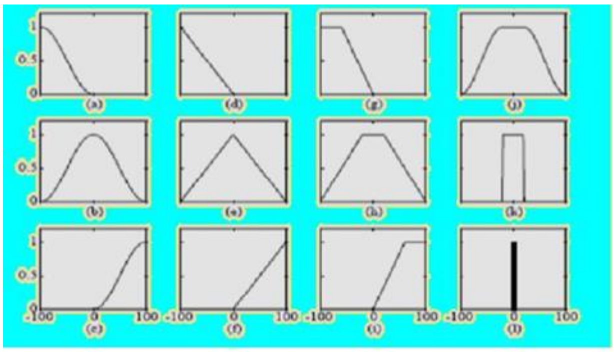

Figure 2.2 Types of membership functions.

From figure 2.2, it may be noted that the graph shown in is of the following types of functions.

(a) is 'S' MF
(b) is "a" MF
(c) is a 'z' MF
(d) to (f) -Triangular MF
(g) to (i) - Trapezoidal MF
(j) is a flat MF
(k) is a rectangular MF
(l) is a singleton MF

2.2.2 Specification of the designed controller

For the current design, total area capacity in each area is 1000MW and normal operating Load is assumed as 500MW.

Load damping= $\frac{\partial P}{\partial f}$

$$\frac{\partial P}{\partial f} = \frac{500MW}{50Hz} = 10\ MW/Hz \qquad (2.1)$$

Here the load damping is assumed linear and percentage is same. In p.u, the value of load damping is

$$D = \frac{10\ MW/Hz}{1000MW} = 0.01\ p.u.MW/Hz. \qquad (2.2)$$

Regulation of the speed governor in Thermal Power Plant=R1

R1 = 2 HZ / p.u.MW (2.3)

Regulation of the speed governor in Hydro Power Plant =R2

R2 = 2.2 HZ / p.u.MW (2.2)

Power System Gain constant= Kp

$$R_2 = 2.2\ HZ/p.u.MW \qquad (2.2)$$

Power System Gain constant= K_p

$$K_p = \frac{1}{D} = \frac{1}{0.01} = 100Hz/p.u.MW \qquad (2.5)$$

Power System Time constant= T_p

$$T_p = \frac{2H}{f_s D} = \frac{2X\,5.0}{50X\,0.01} = 20\ Sec. \qquad (2.6)$$

Where H =inertia constant and considered as 5sec.

2.2.3 Application of designed Hybrid controller

The basic combination of PDIC and FLC in multi source multi area Hydro Thermal system is shown in figure 2.3

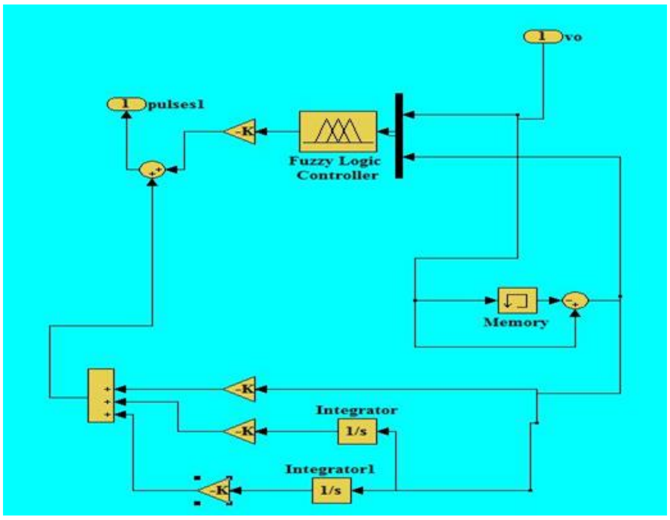

Figure 2.3-Configuration of PDIC and FLC controller

Here the parameters operated are proportional gain and two nos. of integrals are used along with Fuzzy Logic Controller. The inputs to the FLC are change

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in frequency (error) and change in error. Here triangular MF is used as input and output of the controller as shown in figure 2.2 (a), figure 2.2(b) and figure 2.2(c) respectively.

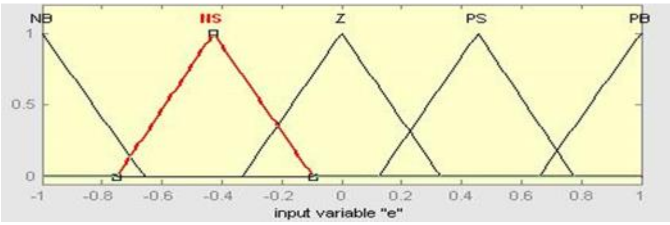

Figure 2.2(a) Membership's functions of FLC - error

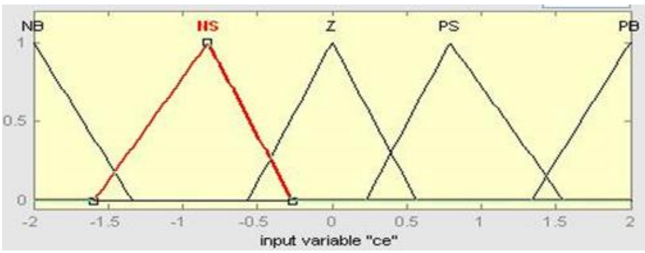

Figure 2.2(b) Membership's functions of FLC - Change in error

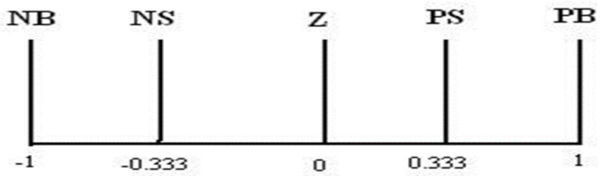

Figure 2.2 (c) Membership's functions of FLC-output (o)

Here in this study, the rules of the FLC are obtained based on the system performance. In this case, 25 rules are framed. The details of rule base are shown in table 2.1

Table 2.1 Fuzzy rule base table for Multi area Multi Source system

e / ce	NB	NS	Z	PS	PB
NB	NB	NB	NB	Z	Z
NS	NB	NS	NS	PS	PS
Z	NB	NB	Z	PB	PB
PS	NS	NB	PS	PS	PB
PB	Z	NB	PB	PB	PB

The rules are if and then type. If 'error (e)' is equal to Negative big (NB) and if 'change in error' is Negative Big, then the output is Negative big (NB).

Weighted average method is used for defuzzification. Multi area hydro thermal model. The values obtained are Kp=0.1 and ti=0.11s. Based on the change in the frequency response, Ki is chosen as 0.1 sec.

2.2.2 Performance of the combined PDIC and FLC hybrid controller

The Block diagram of Multi area Multi Source Hydro Thermal System block diagram with combined PDIC and FLC hybrid controller is shown in figure 2.5

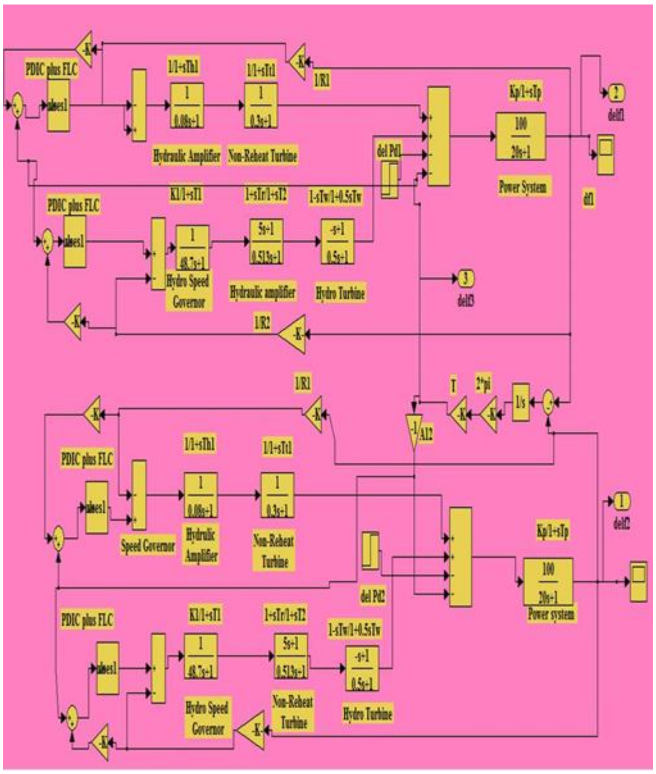

Figure 2.5 Two area two source hydro thermal system with hybrid controller.

Using MATLAB Simulink, the model is run and the performance of multi area multi source system with hybrid controller and PI controller are

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separately shown in figure 2.6, figure 2.7 and figure 2.8 respectively.

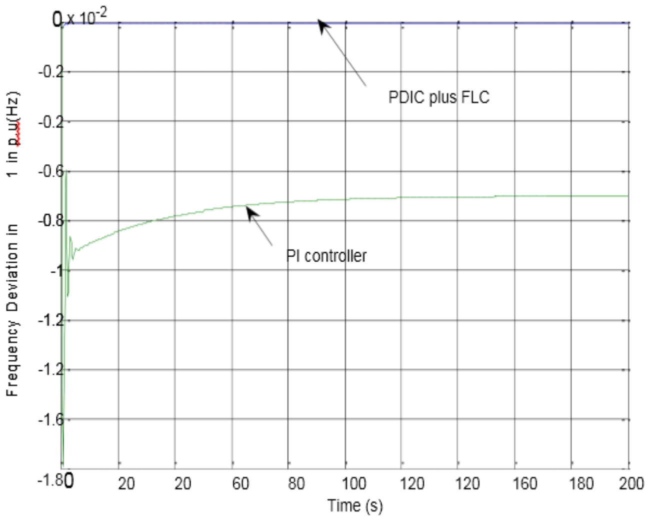

Figure 2.6 Response of Frequency deviation of area1in p.u Hertz using the designed controllers

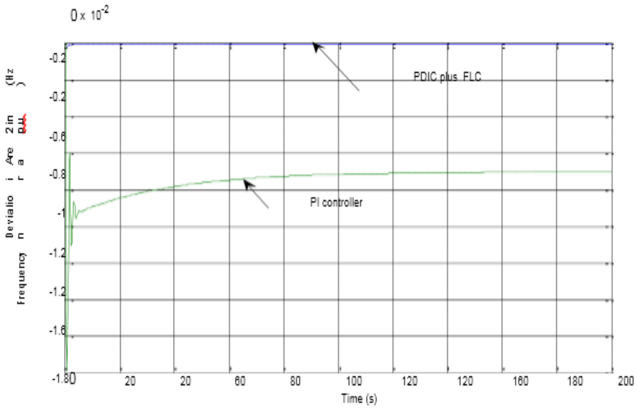

Figure 2.7 Area 2 in p.u (Hz) of the System with control

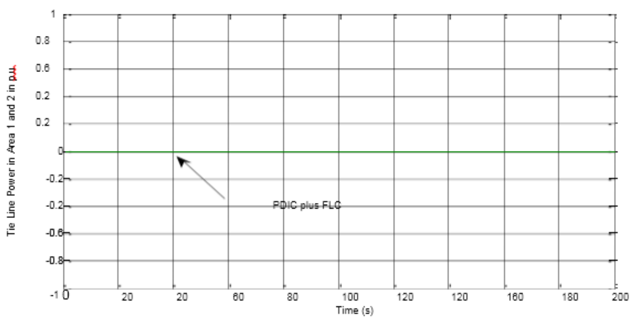

Figure 2.8 Response of Tie line power distributions between area 1 and 2 using PDIC plus FLC System response with the variations in load

The response of hybrid controller with load variations in area1and area 2 has been observed and the response is shown in figure 2.9 & figure 2.10 respectively

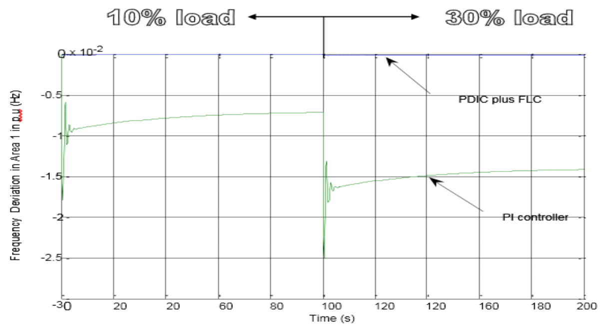

Figure 2.9 Response of frequency deviation of area 1 in p.u (Hz) of the system for step change load power from 10% to 30% in p.u

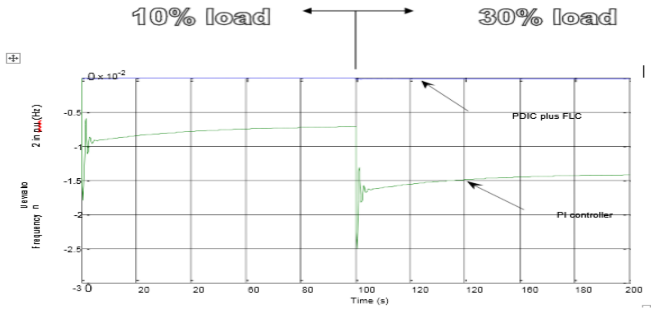

Figure 2.10 Response of frequency deviation of area 2 in p.u (Hz) of the system for step change load power from 10% to 30% in p.u

2.2.5 Performance of Hybrid Controller in multi area multi source system

The designed proportional double integral controller with Fuzzy logic controller is defined as Hybrid controller. With Kp=0.1 and Ki =0.1, the performance of designed hybrid controller i.e. PDIC and FLC controller in multi area multi source of hydro & thermal system in terms of peak value,

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Integral Absolute error, Integral square error, settling time is shown in table 2.2

Table 2.2 Performance of Hybrid controller in comparison with PI controller

Description of Parameters	Parameters	Multi source Multi area Both Thermal and Hydro power source in each area	
		Hybrid controller	PI controller
Peak value	Δf_1	-0.0002	-0.018
	Δf_2	-0.0002	-0.018
IAE(p.u)	Area1	0.0001	0.007
	Area2	0.0001	0.007
ISE (p.u)	Area1	0	0.0292×10^{-3}
	Area2	0	0.0292×10^{-3}
ITAE(average)	Area1	7.13659E-05	0.713626
	Area2	7.13659E-05	0.713626
Settling time in sec	Area1 and area2	1.0026	123.8129

The performance of the designed hybrid controller is shown in the bar graph and indicated in figure 2.11

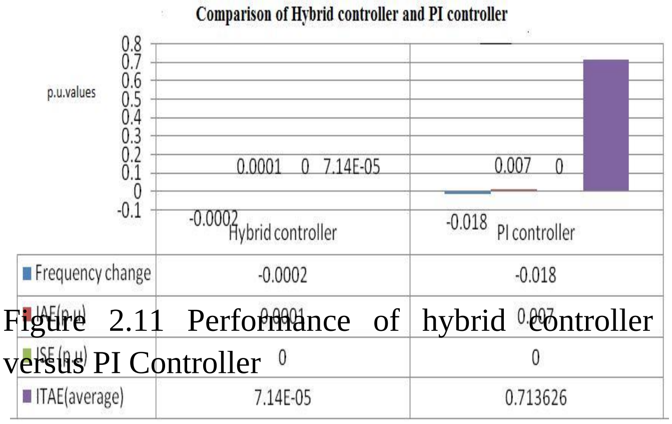

Figure 2.11 Performance of hybrid controller versus PI Controller

2.2.6 Comparative representation at various loads

Comparative representation of the "with no controller", "with PI controller" and "with designed hybrid controller" in Area1 and Area2 are shown at different loads are shown at figure 2.12(a), figure 2.12 (b) and figure 2.12(c).

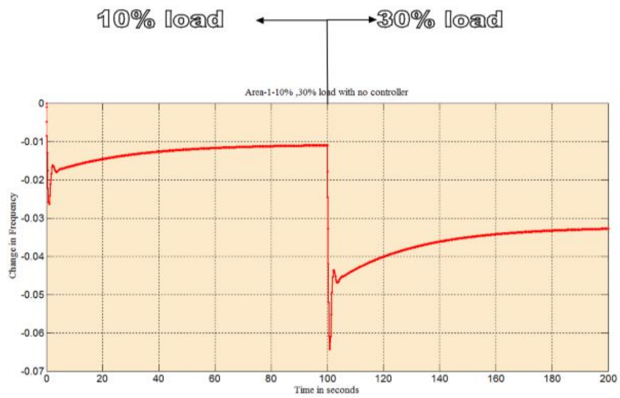

Figure 2.12(a) Frequency variation in area 1 with no secondary controller at 10% and 30% loads

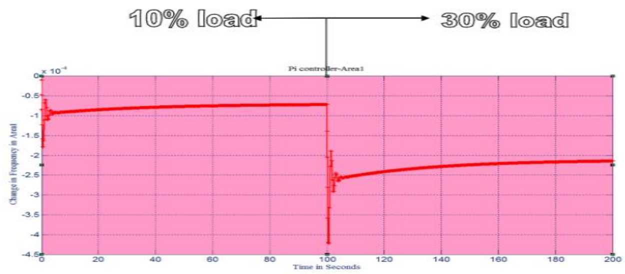

Figure 2.12(b) Frequency variation in area1 with PI Controller at 10% and 30% load

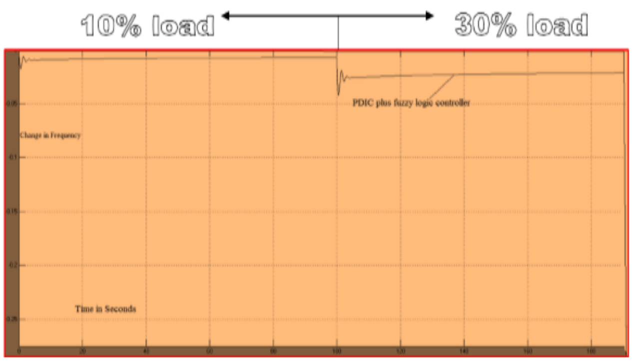

Figure 2.12(c) Frequency variation in area 1 with designed Proportional double Integral Controller and Fuzzy logic controller

With same scale on all three controllers, the performance in area1 is compared and it is represented in figure 2.13.

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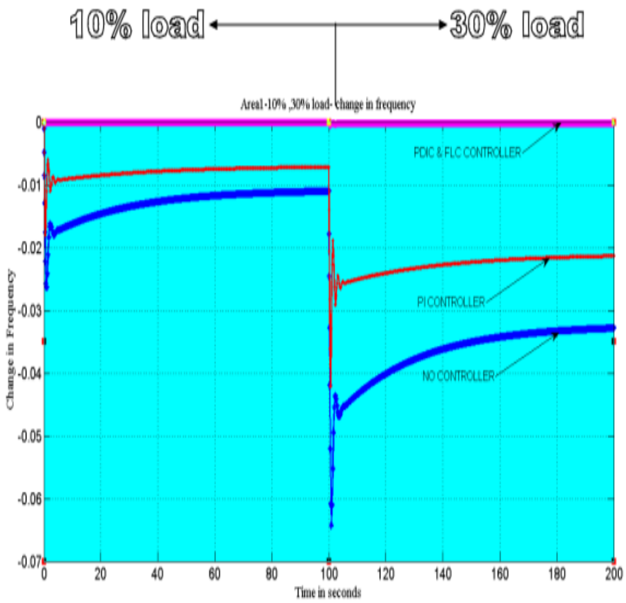

Figure 2.13 Frequency variations with the designed controller, PI controller and no controller on same scale in area1 at 10% load and 30% load.

Frequency response at 10% to 30% load in Area2 in respect of all three cases is shown in figure 2.12

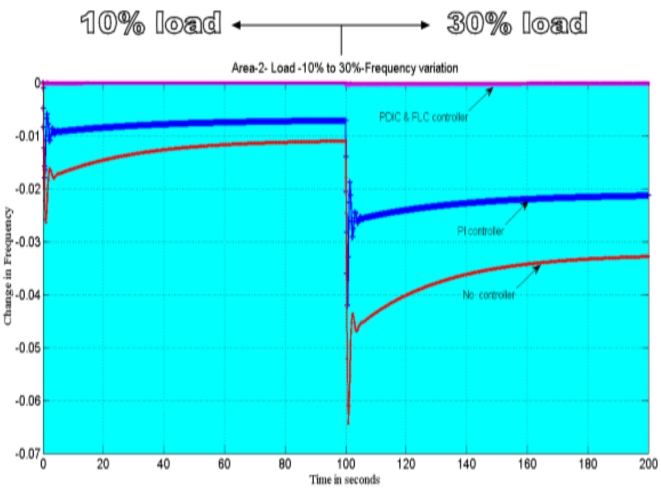

Figure 2.12 Response of designed controller, PI controller and "no secondary controller" on same scale in area 2 at 10% load and 30% load.

The performance of area 2 with hydro and thermal power sources on different scales of representation is shown in figure 2.15

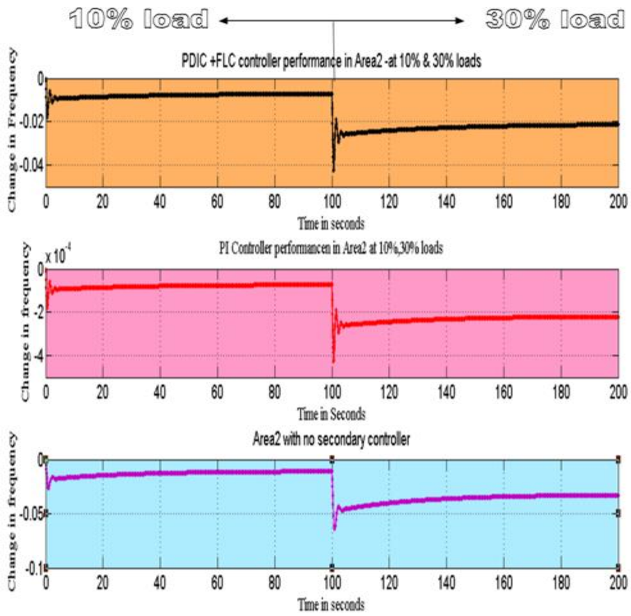

Figure 2.15 Response of designed controller, PI controller and with "no" controller on different scales in area 2 at 10% load and 30% load

The response of the system with 30% to 50% to load in area1 is shown in figure 2.16.

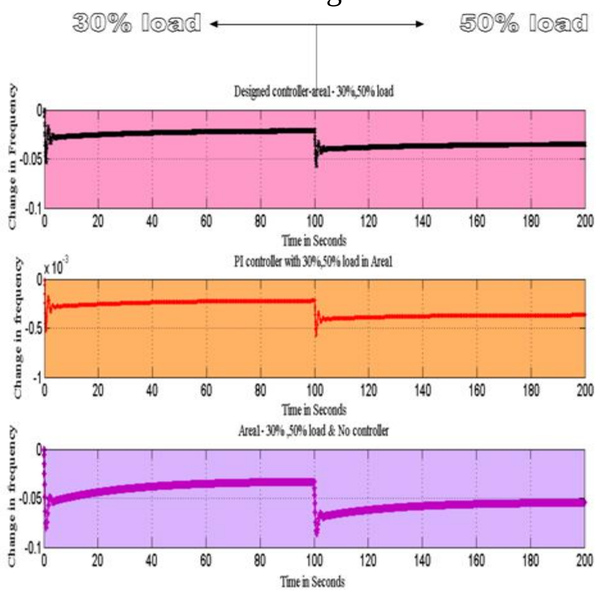

Figure 2.16 Change in frequency at 30% to 50% load in area1with designed controller, PI controller and no secondary controller on different scales

Performance of the designed controller in comparison with PI and no controller in area-1 on the same scale is shown in figure 2.17.

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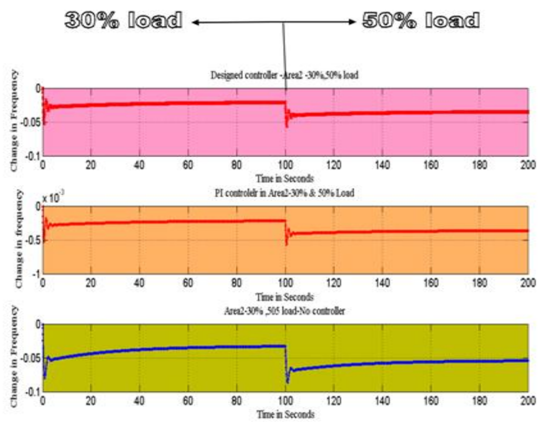

Figure 2.17 Designed controllers, PI controller and no controller at 30% load and 50% load in area 1.

Performance of designed controller, PI controller and no controller at 30% load and 50% load in area2 is indicated in figure 2.18.

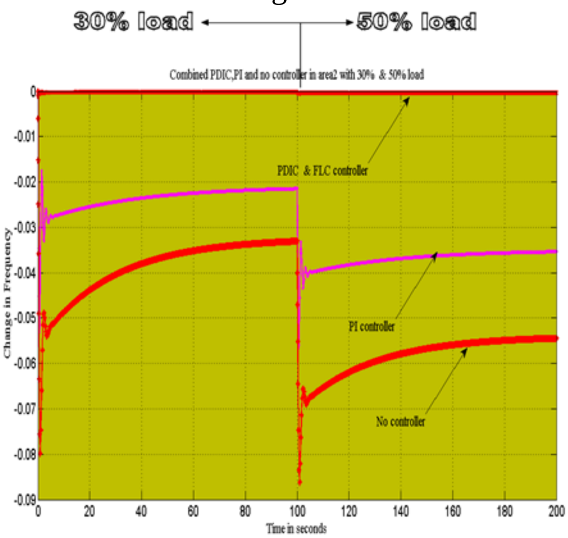

Figure 2.18 Designed controller, PI controller and with no Controller at 30% load and 50% load in area2

Designed controller, PI controller and with no controller, the performance is observed at 30% and 50% load with different scales and is indicated in figure 2.1

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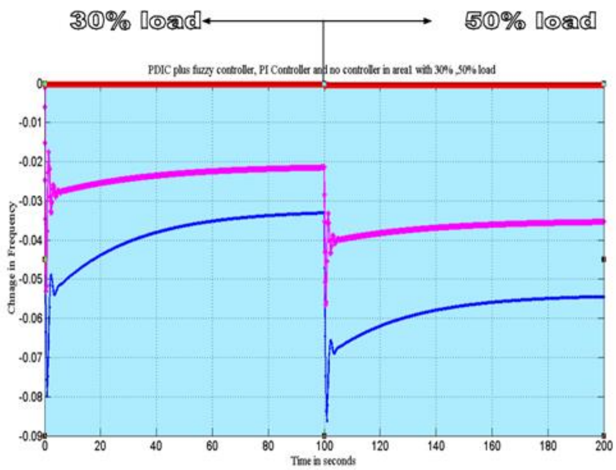

Figure 2.19 Designed controller, PI controller and with no controller at 30% load and 50% load in area2 with different scale

3. CONCLUSION

The designed proposed controller is a Proportional double integral and Fuzzy Logic Controller. With this controller, when compared with the PI controller, the response is very fast and it has reached minimum error, within 1.0026 seconds. The steady state error with the proposed controller is minimum. When only PI Controller is installed, the peak value is - 0.018Hz.With PI Controller, the error is 0.007 and steady state is reached within 123.8129sec.This shows that the proposed controller is comparatively better than conventional controller.

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