CHAPTER 6

APPLICATION OF PROPOSED PFPID CONTROLLER FOR 12/14 SELF BEARING SWITCHED RELUCTANCE MOTOR

6.1 INTRODUCTION:

In this chapter, the application of proposed PFPID controller for 12/14self bearing switched reluctance motor is presented. The results are compared with the results obtained from real time application of the proposed controller.

6.2 RAPID CONTROL SCHEME PROTOTYPE:

The Real time input- output (RTIO) board and MATLAB/ Simulink successfully formed a rapid control environment shown in Figure 6.1, in which controller has been designed using Simulink environment rather than programming control languages. The reference signals for X-directional displacement, Y-Directional displacement and speed are shown in Figure 6.1. These reference signal blocks can be dragged from the Simulink environment. These three reference signals are amplified using gain blocks and compared with the actual outputs of the 12/14 SBSRM. Comparators are designed to compare reference and actual signals and to generate the error signal to the proposed controller. Each fuzzy Sub controller shown in Figure 6.2 has been performed independently to control the overall tracking goal. Classical PID controller output is compared with the output of fuzzy PID controller. This fuzzy PID controller in X-displacement has three individual sub controllers and the output of these sub controllers are summed to get overall controller output and then compared with conventional PID controller. This process is similar in Y-directional displacement and speed. Once the controller is designed using Simulink's block diagram, the feedback signals can be given to the controller and the controller taken care the feedback signals and generates the pulse width modulation (PWM) signals according to the controlling algorithm. These generated PWM signals can be given to the driver circuit to drive the IGBT's.

Using this RTIO, one can skip the process of generating the C-code form the Simulink building blocks, hence every change in Simulink controller algorithm shows the instantaneous effect on real-time hardware. The designers are having much sufficient basic knowledge in MTLAB/Simulink for designing the controller. The sampling frequency of 10 kHz is used. Using this RTIO environment, designers can well carry out MATLAB/simulations, develop both conventional as well as intelligent control laws and can easily evaluate the simulated response, easily developed the controllers to the real-time environment.

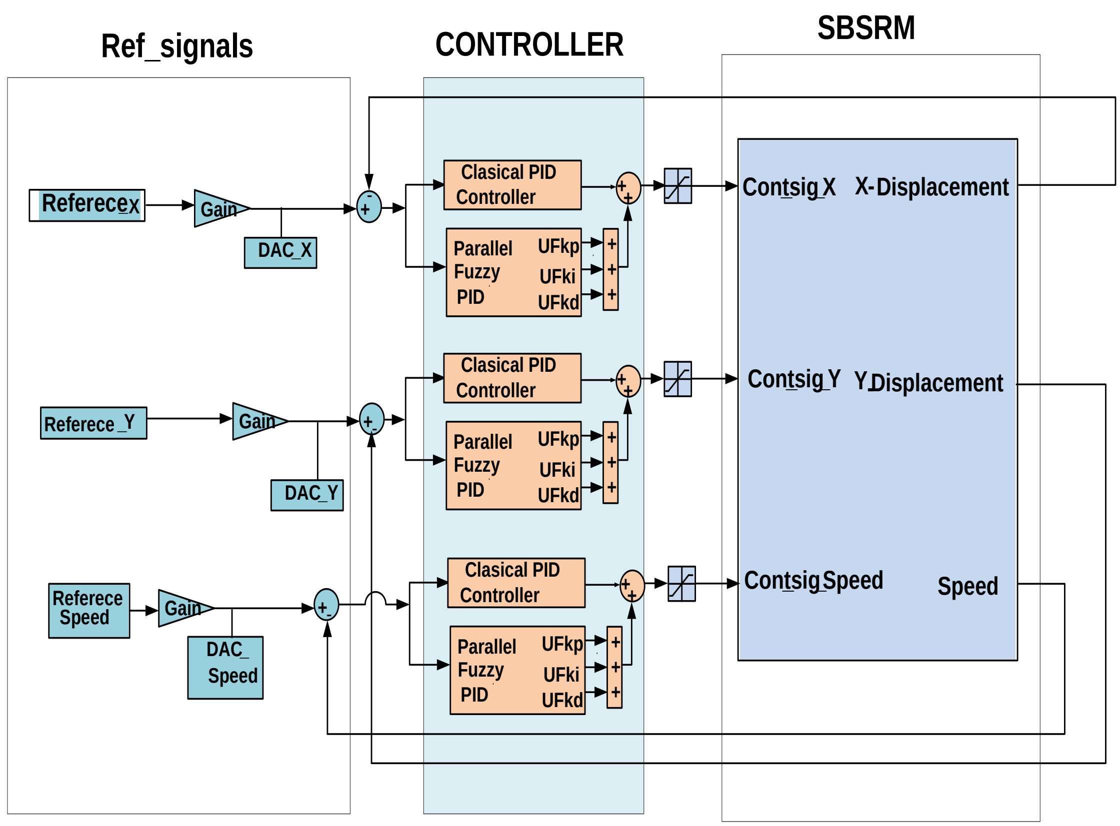


Fig.6.1. Rapid Control Prototype of 12/14 SBSRM

6.3 RESULTS AND DISCUSSION

6.3.1 Hardware System Description

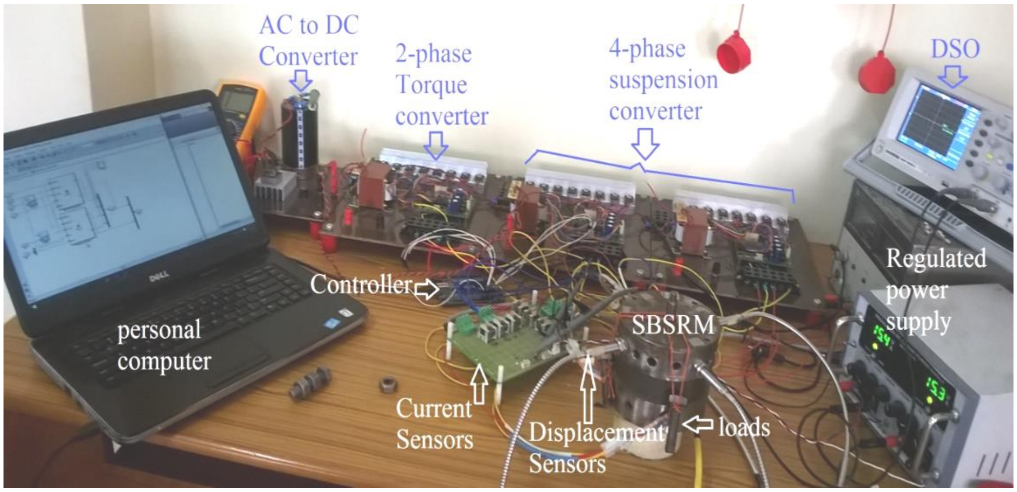
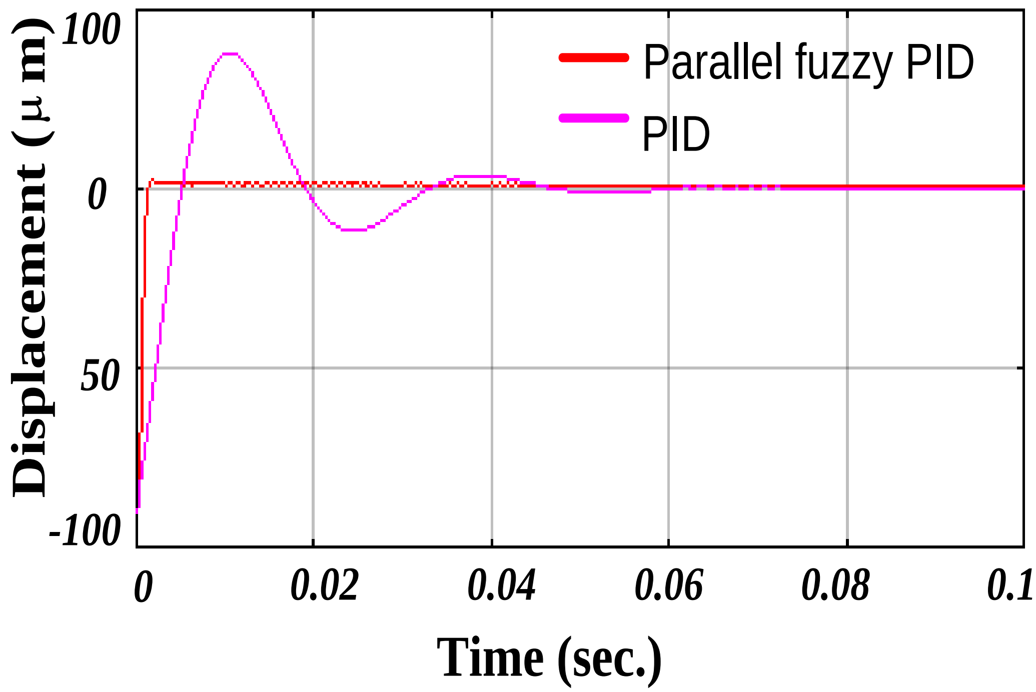


Fig.6.2. Photograph of the experimental setup.

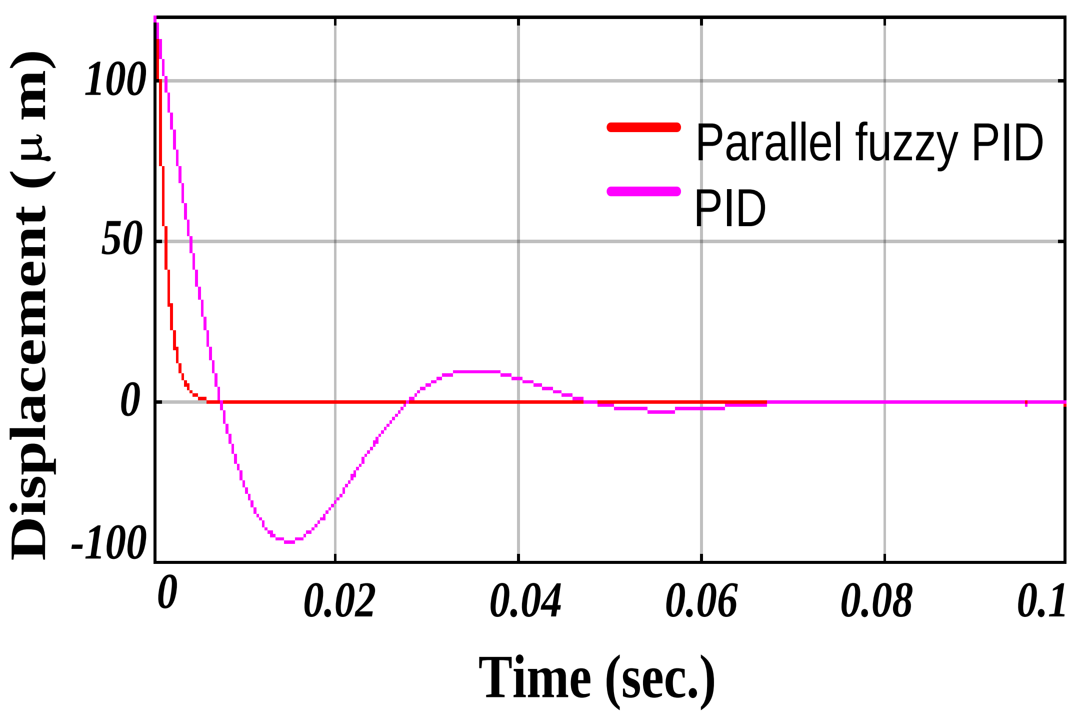
The hardware Set up is shown in Figure 6.2. this setup consists of Real time input- output (RTIO) board, personal computer (PC), an AC to DC converter for, which provides DC power supply to the torque winding asymmetric converter, (0-230V) separate regulated power supply for suspending winding radial force converter, a driver circuit to drive the both torque and suspending converters, a novel structured self-bearing switched reluctance motor (SBSRM) with X- directional loading arrangement is shown in hardware setup. The DSP control board forms closed loop operation with proper feedbacks from encoder and displacement sensors for the effective controlling of SBSRM with loading and external disturbances. The acquired feedback signals are computed and generates error signal for the proposed controller and this controller will calculate the error information and responds in an intelligent manner with reference to the given rule-based data. This entire controller algorithm is placed in Simulink environment and Interfacing with 28377 DSP board. The motor is 280V, 3A, 400W, four phase suspensions and two-phase motor. PWM controlling algorithm is placed in personal computer. Generated Pulses are amplified with driver circuit and given to the torque and radial for converters. For torque winding converter DC power supply is given form the AC to DC rectifier and for suspension converter DC power supply is given form the Regulated power supply, with can deliver maximum of 10A. ACS 712 current sensors are used to measure the feedback currents form torque and suspension winding and these currents can be shown in digital oscilloscope (DSO).

Case1: Suspending the rotor to the center position:

Figure 6.3(a) shows the rotor eccentricity displacement in X-Direction and 10(b) shows the rotor eccentricity displacement in Y- Direction when the suspension control algorithm is applied, eccentric errors in the two directions can be rapidly reduced to zero, which means that the rotor can be kept in the center position. Figure 6.4 shows Suspending force winding currents (Ixp, Ixn, Iyp and Iyn), form suspension winding currents it is cleared that the windings in negative x-directional and positive y-directional windings only drawing the current to bring the rotor to the center position. The currents in positive X-directional and negative Y-directional windings are zero. It means that the de-centered rotor has been centered by beans of energizing the respective stator suspension poles. From Figure 6.4 it is also obvious that the proposed controller exhibits better performance than the conventional controller. The suspension currents drawn by the PID controller is 2A in both X and Y- Displacements and also having ripples. The suspension currents drawn by the proposed PFPID controller is 1A in both X and Y- suspension windings and has no current ripples. Hence copper losses are reduced hence efficiency is being improved. Figure 6.5 shows the comparison of the Suspension forces (Fx & Fy) in X and Y- Directions with Proposed PFPID controller. The load of 10N has been applied in X and Y- Directions. Form the Suspension forces it is cleared that the PFPID controller generates more force than the conventional controller in both negative x-directional and positive y-directional windings to bring the rotor to the center position. Consequently, the respective suspension winding currents drawn by the coverer is less.

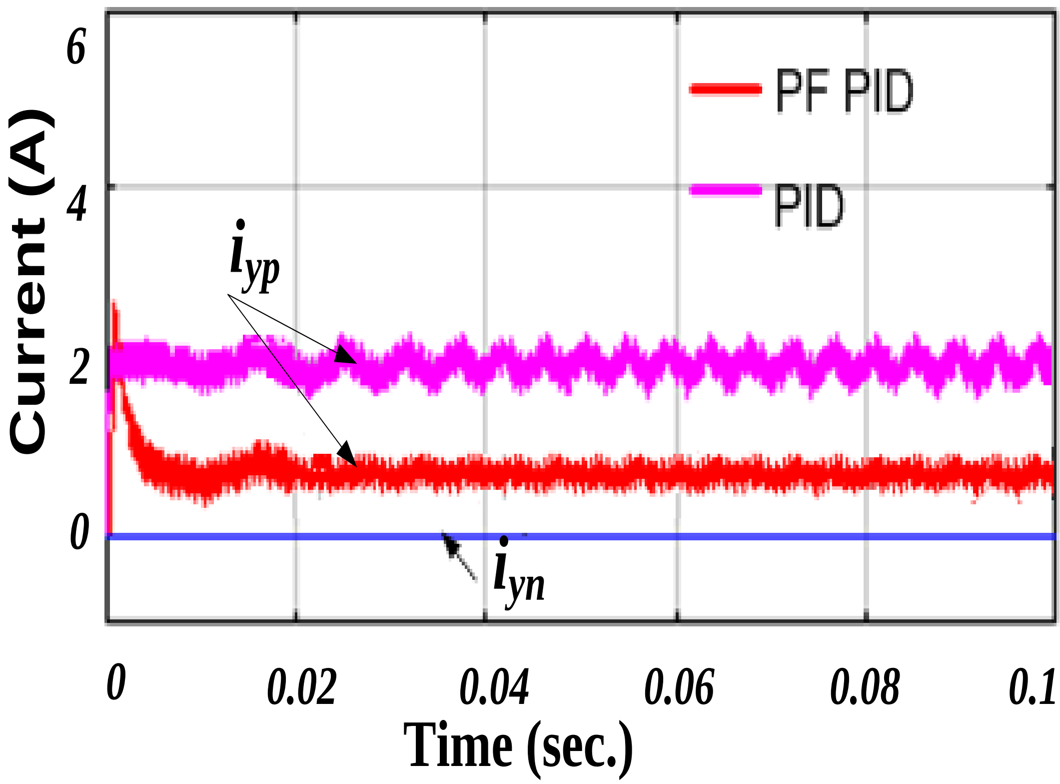


(a) X-Displacement.

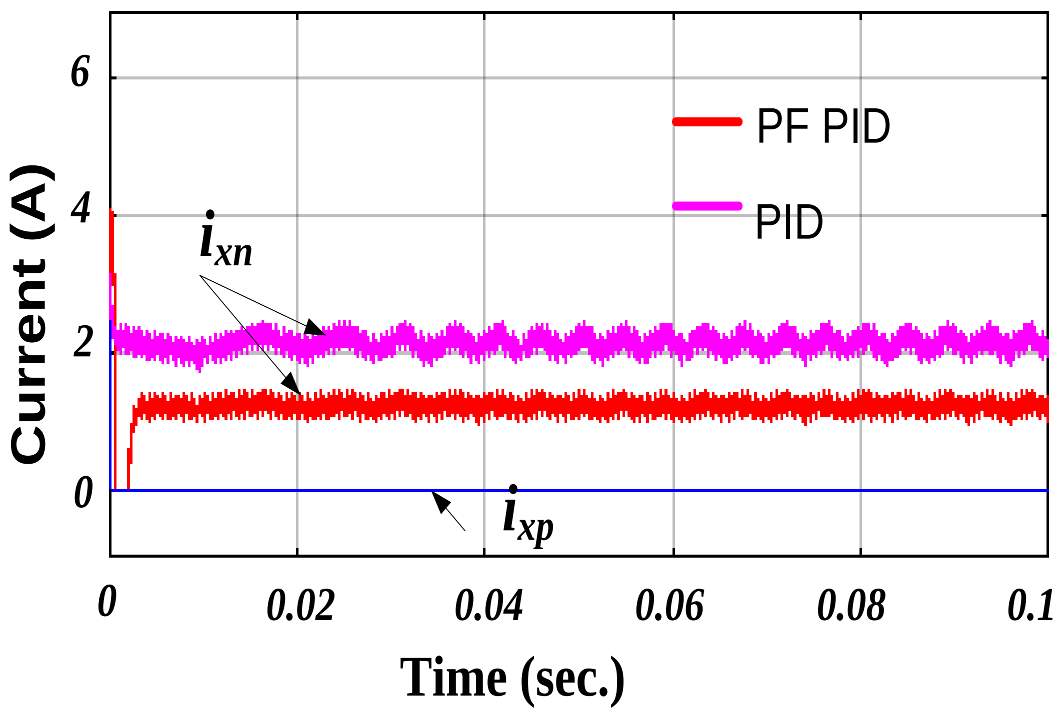


(b) Y- Displacement

Fig.6.3. Rotor eccentricity displacement at suspending condition

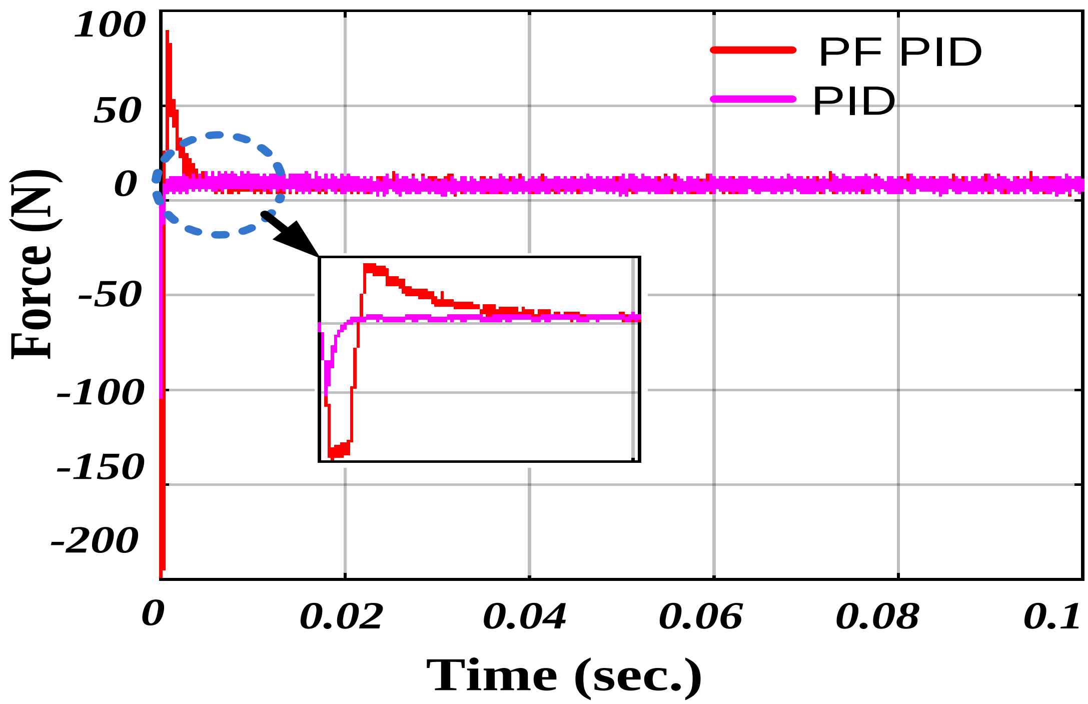


(a) Negative x-directional pol.

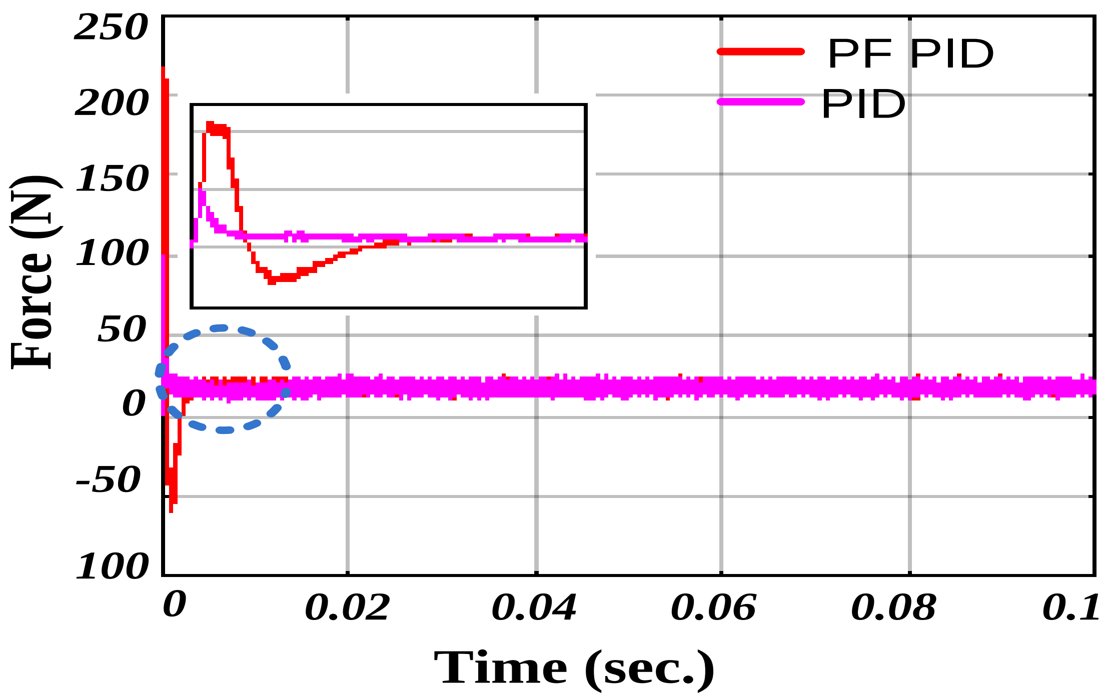


(b) Positive y-directional pole

Fig.6.4. Suspending force winding currents at suspending condition



(a) X-Direction.



(b) Y-Direction

Fig.6.5. Radial force at suspending condition

Case2: Accelerating the rotor to the desired speed

Initially in case-I there are no torque winding currents for the SBSRM. In this case load (N-m) has been placed on the shaft, and hence torque winding currents are taken from the 2-phase asymmetric converter to reach the desired or set speed as shown in Figure 6.6. Motor starts rotate and can reach the set speed value in a faster rate with the parallel fuzzy PID controller when comparing with the conventional PID controller and also exhibits no ripples in speed during steady state period. Figure 6.7. Shows comparison of A-phase and B-phase winding currents with proposed controller, here noticed that magnitude of phase winding currents is less after reaching the motor to a set speed with the proposed controller and hence the losses in the converter can be reduced and rating of the device can also be reduced in order to save the converter cost. Figure 6.8. shows the comparison of shaft torque with proposed controller, as we know that the generated torque in the SBSRM is proportional to the phase winding currents and hence the generated torque is at starting is about 0.8 N.m, which is same as that of the conventional PID controller but at the steady state condition the torque generated by the proposed controller generates optimized torque for the same load. Figure 6.9 shows that shaft displacements at both suspending and rotating conditions applied simultaneously. As we know that both suspension and torque controlling are completely individual to each other hence the injection of torque winding currents in case (ii) has not been showing any effect on the suspension winding currents, even though little fluctuations can be observed, the shaft is still in center position. These fluctuations are now reduced with the proposed controller as shown in the Figure 6.10. The forces generated to bring the rotor shaft to the center position are shown in Figure 6.11 it can be noticed that with the proposed controller the suspension force generated is more at the time of starting to bring the rotor to the center position quickly.

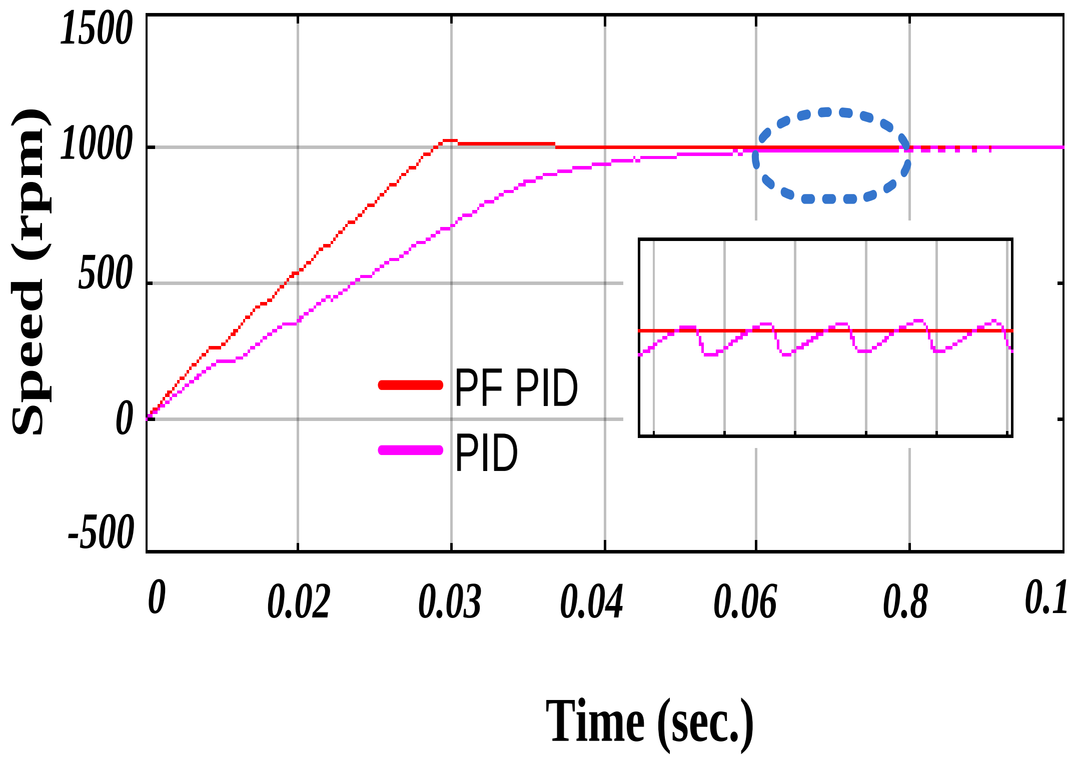
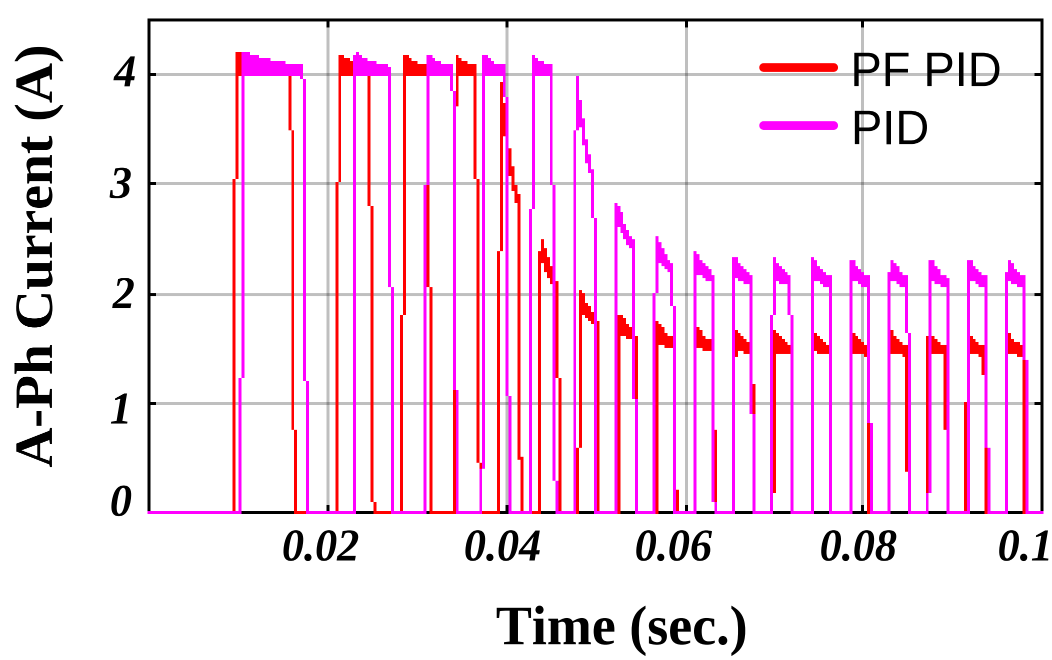
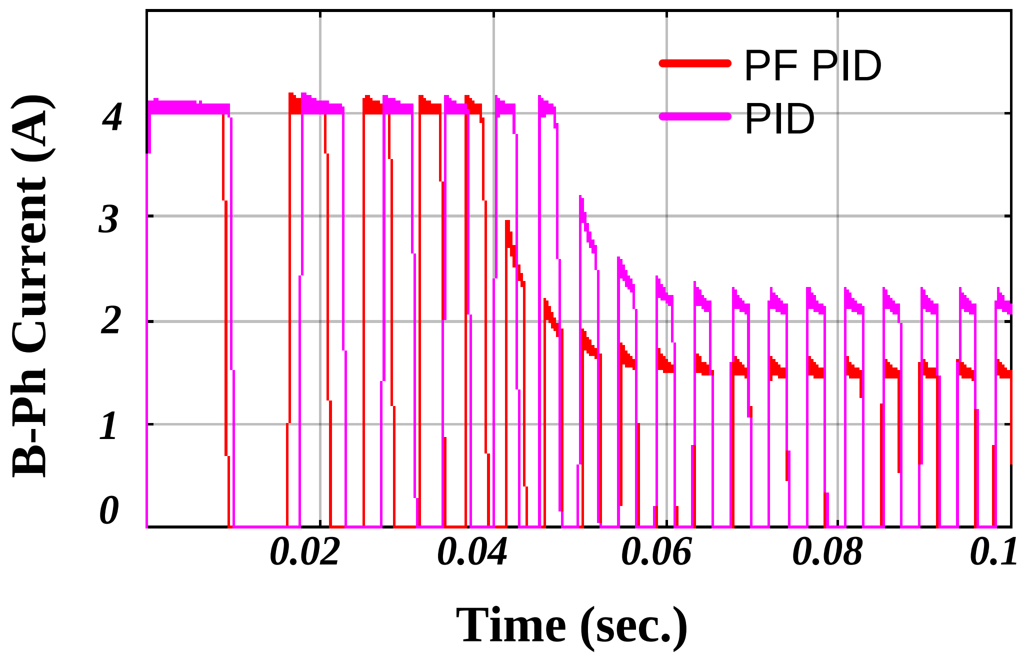


Fig.6.6. Comparison of speeds with proposed PFPID controller



(a) A-Phase winding current



(b) B-Phase winding current.

Fig. 6.7. Comparison of phase winding currents with proposed PFPID controller

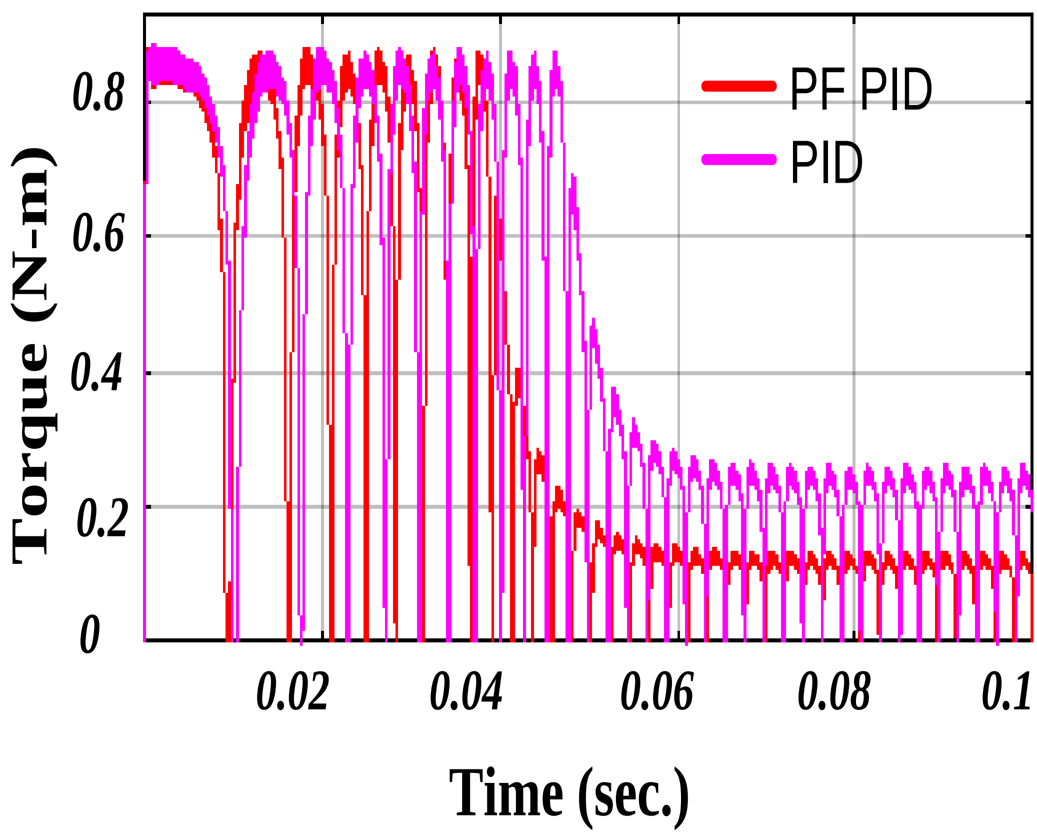
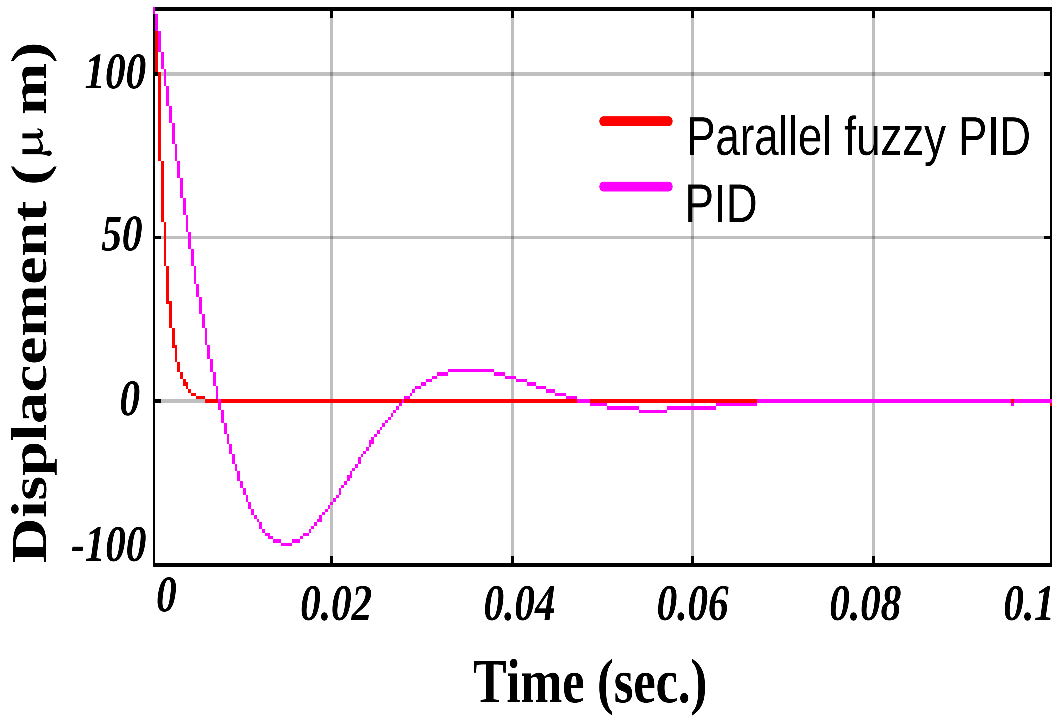
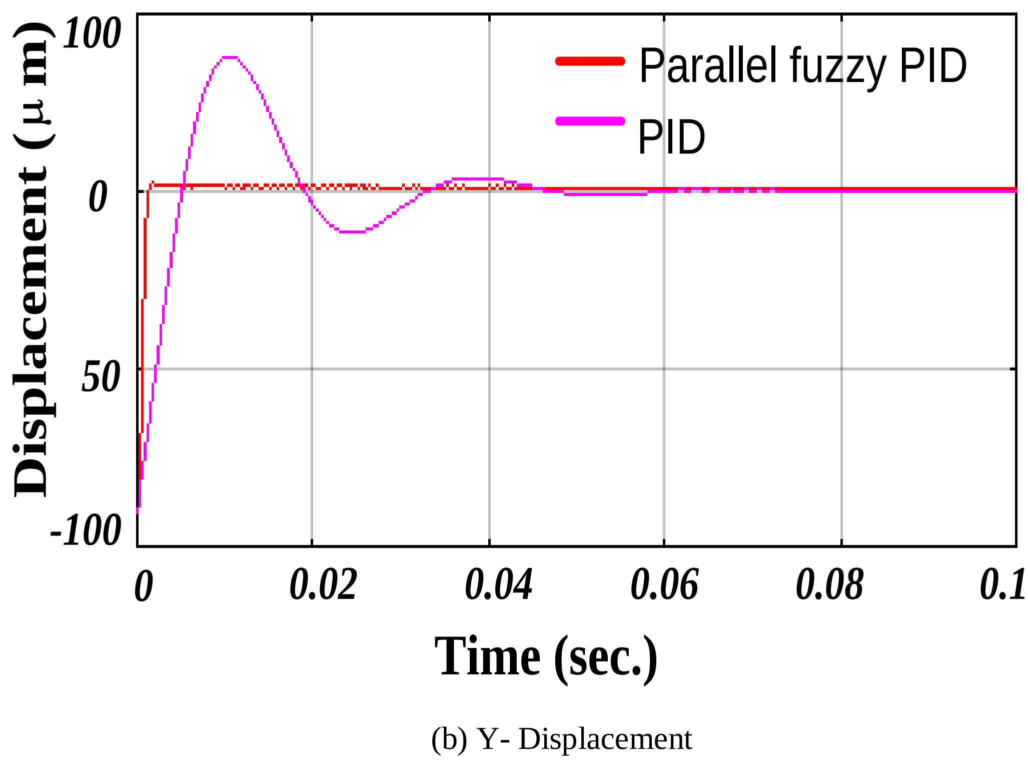


Fig.6.8. Comparison of shaft torque with proposed PFPID controller

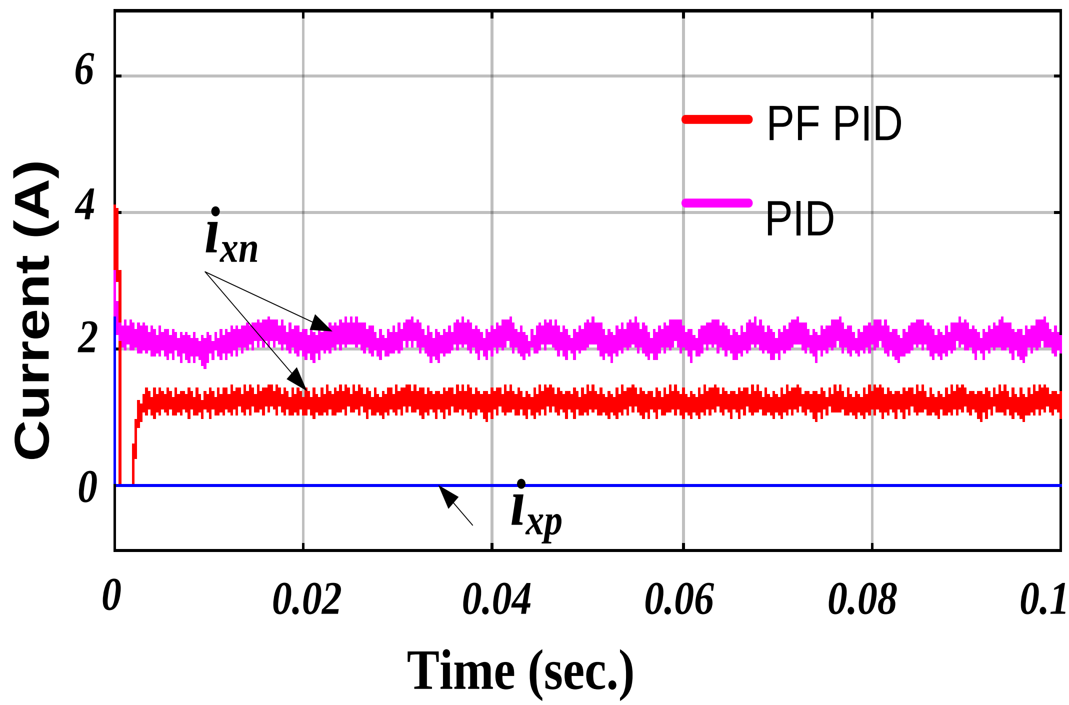


(a) X- Displacement

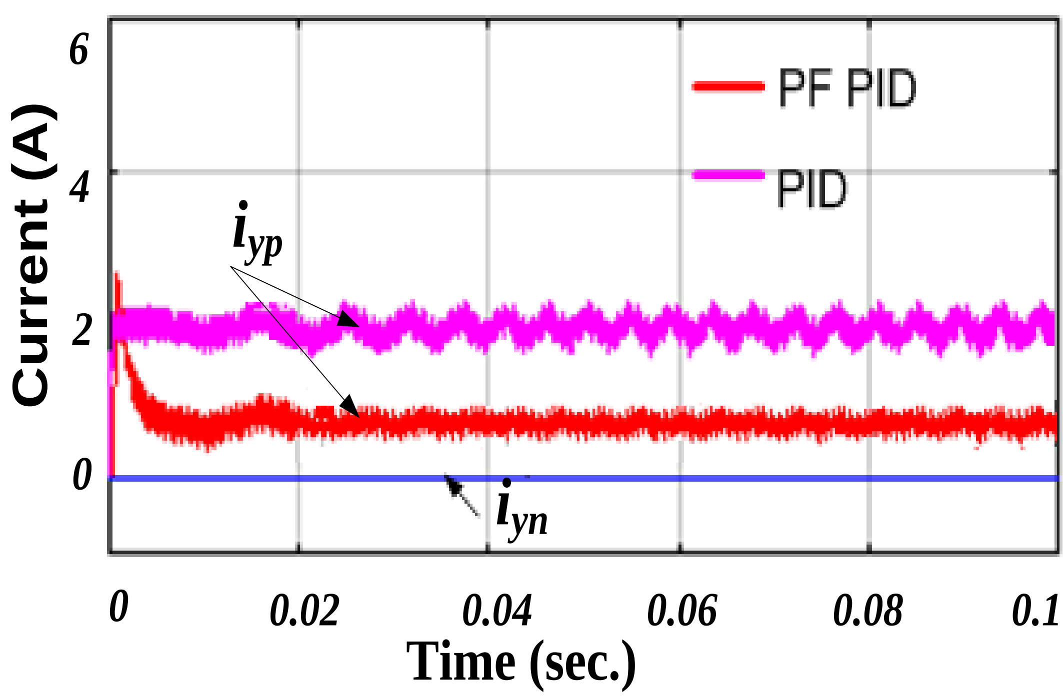


(b) Y- Displacement

Fig. 6.9 Shaft displacements at both suspending and rotating condition

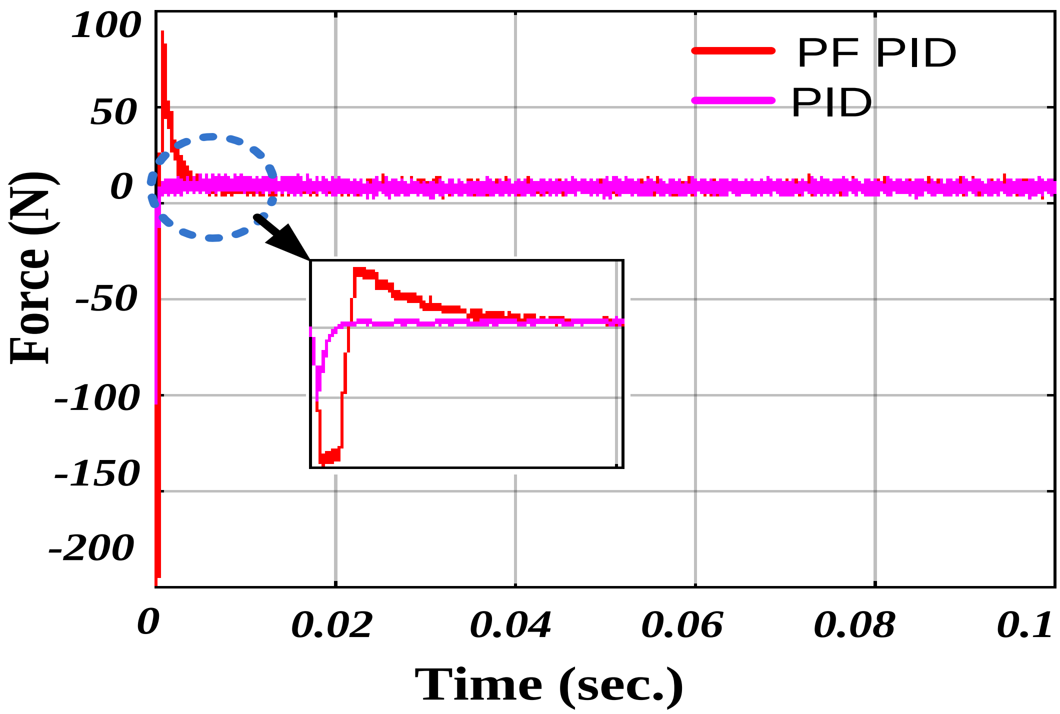


(a) Positive x-directional pole.

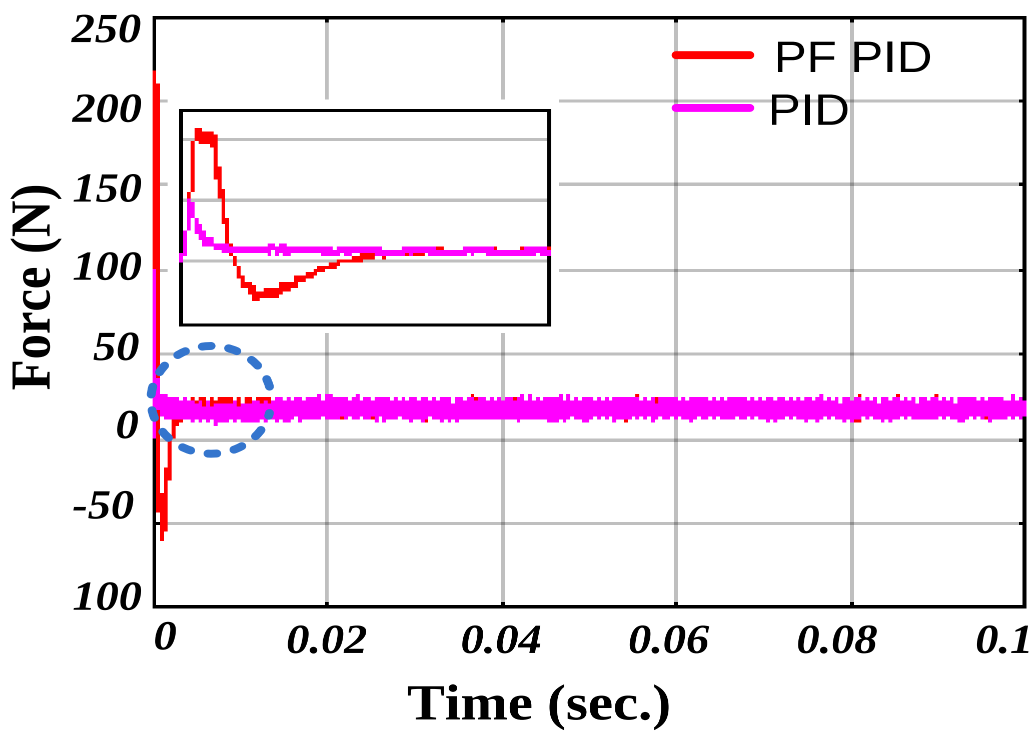


(b) Negative y-directional pole

Fig. 6.10 Suspending force winding currents at suspending and rotating condition



(a) X-Direction.



(b) Y-Direction

Fig. 6.11 Suspending force at suspending and rotating condition

6.4 Experimental results

Figure.6.12. Shows that X-directional and Y-directional displacements for suspension algorithm alone, it can be observed that these displacements have been settled at zero positions. Figure 6.13 (a) shows that displacements with PID controller when suspension load is decreased suddenly form 2N to 1N, it can be observed that conventional PID controller is showing unstable performance. Figure 6.13 (b) shows displacements with proposed PFPID controller, it can be observed that proposed controller exhibits stable operation when comparing with the conventional PID controller when the suspension load is suddenly decreased from 2N to 1N. Figure.6.14 (a) shows that the speed of the SBSRM with the conventional PID controller, it can be seen that it has been settled to the desired speed with more oscillations and settled after four-time divisions. Figure.6.14 (b) shows the A-Phase and B-Phase torque winding currents with PID controller, it can have observed that initially torque winding currents are more nearly 4A at the time of starting and later on settled to the lower currents after motor reached to the set speed. Up to five-time divisions these huge currents has been carried out hence device gets heated up. Figure.6.15 (a) shows the speed with the parallel fuzzy PID controller, it can be observed that the speed is exhibiting less ripples and also has settled to a command speed in a short duration. Figure.6.15 (b) shows the A-Phase and B-Phase torque winding currents with parallel fuzzy PID controller, it can have observed that magnitude of starting currents are reduced from 4A to 2A and later on settled to the lower currents nearly to 1A after motor reached to the command speed. As the speed has settled in a faster rate with proposed controller, the torque winding currents also has been settled quickly to the lower values immediately after motor reaches to the command speed. Hence the IGBT device is no longer carry large currents for longer duration and the possibility of device getting heated up is reduced. Hence one can go for lower ratings of the device and cost can be reduced and efficiency also can be improved.

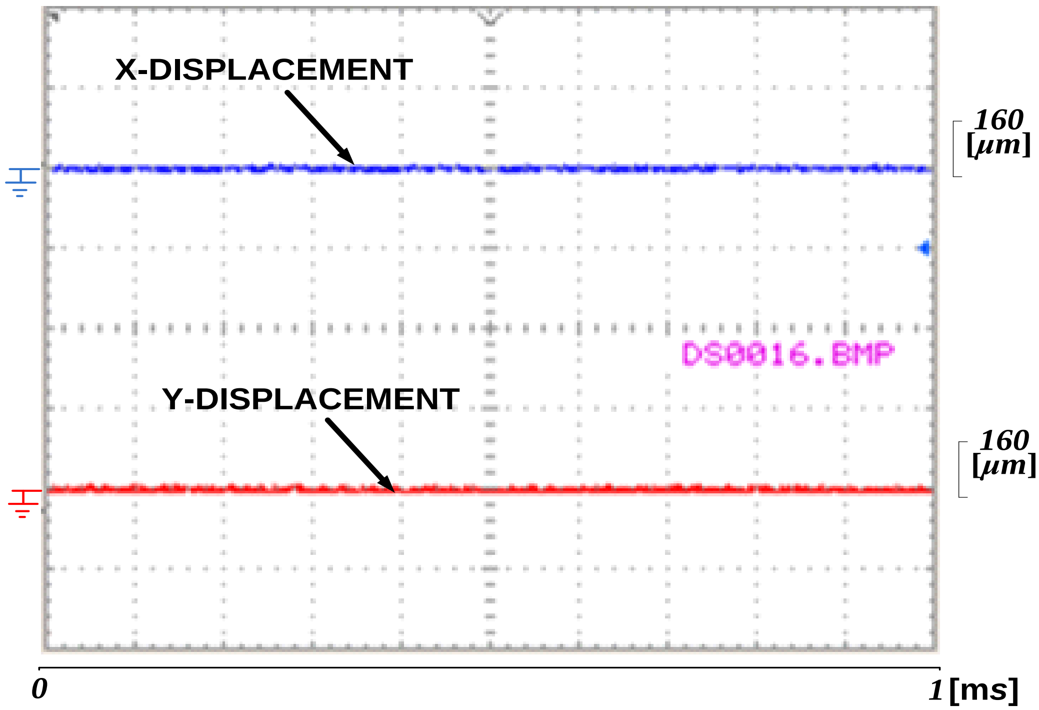
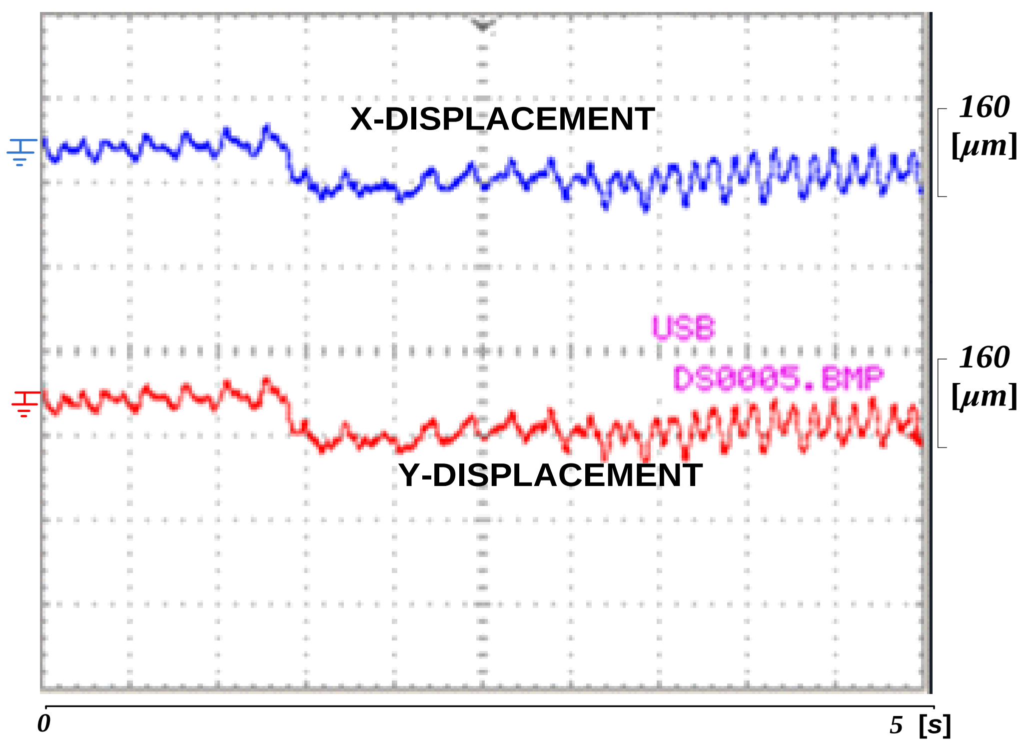
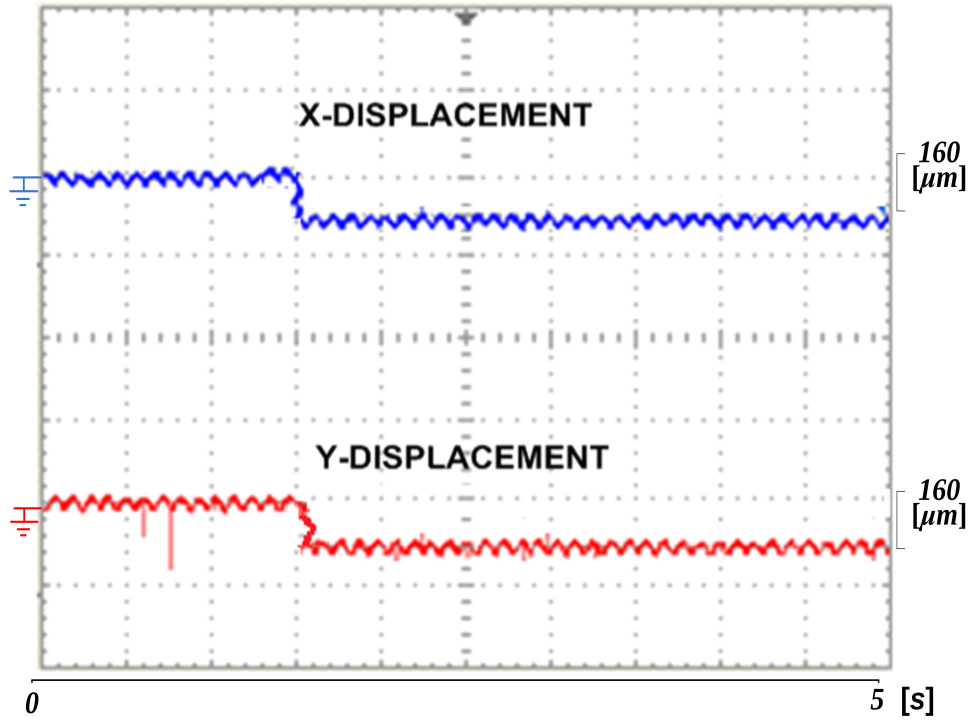


Fig.6.12. Displacements settled at zero positions without rotor rotation

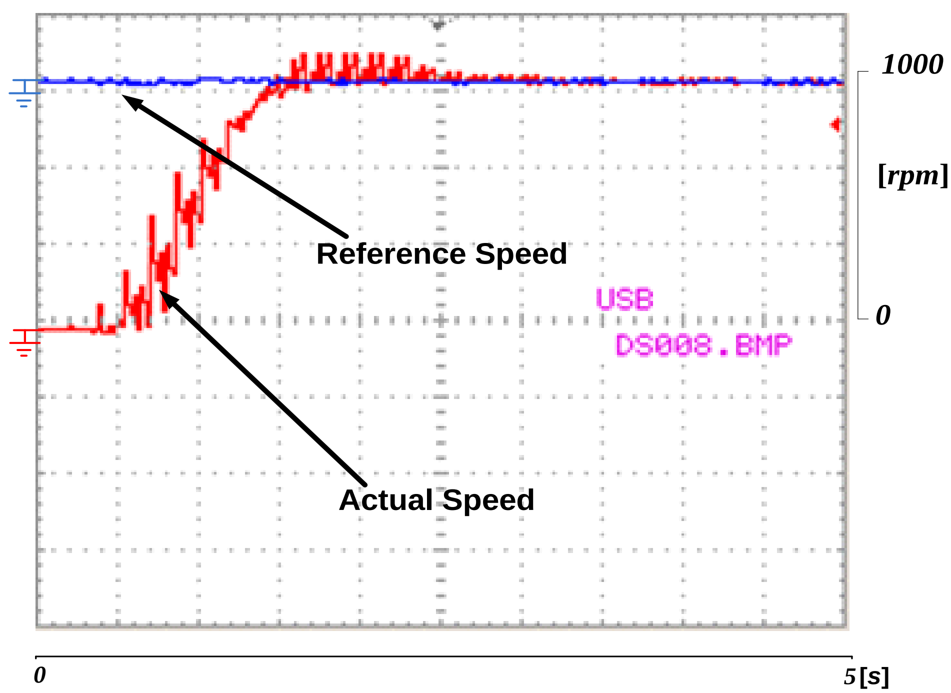


(a) Displacements With PID controller with increased levitation load from 1N to 2N.

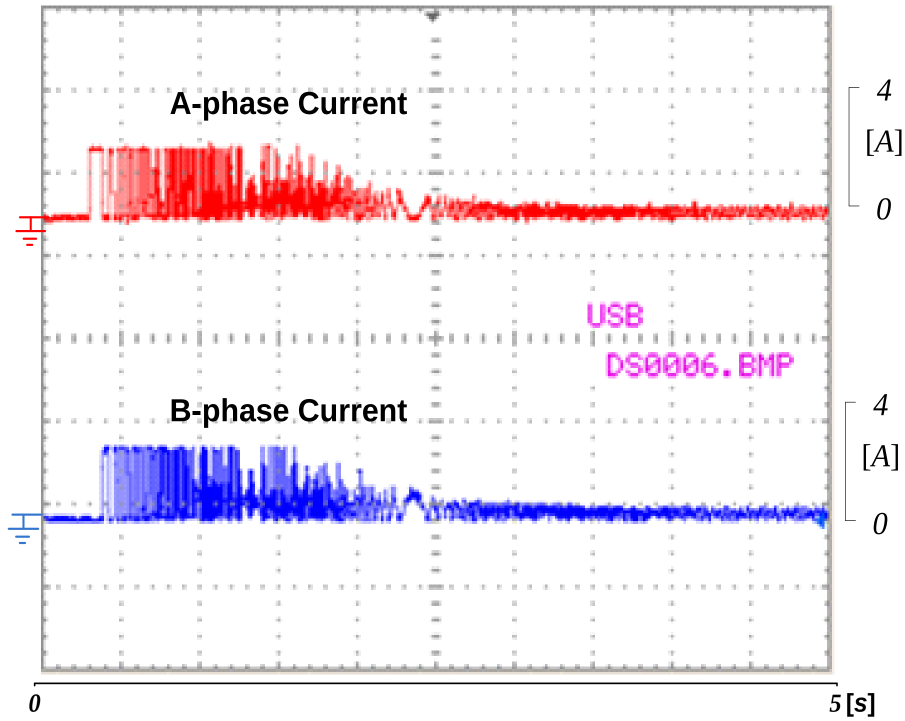


(b) Displacements with proposed PFPID controller with increased levitation load from 1N to 2N.

Fig.6.13. Displacements when suspension load is increased suddenly form 2N to 1N

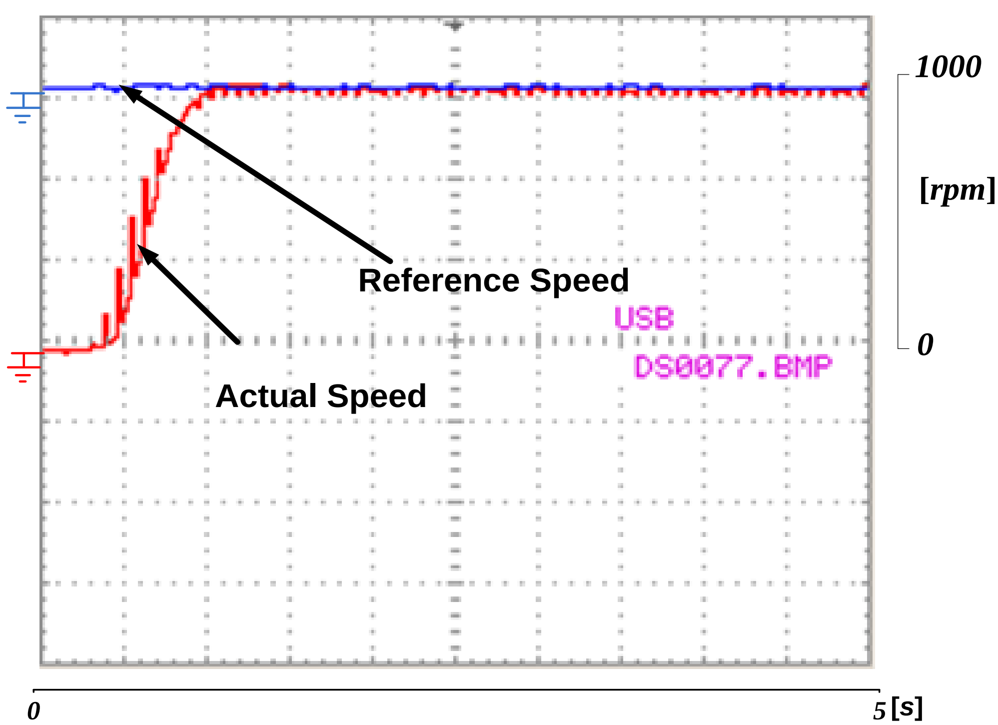


(a) Speed with PID controller

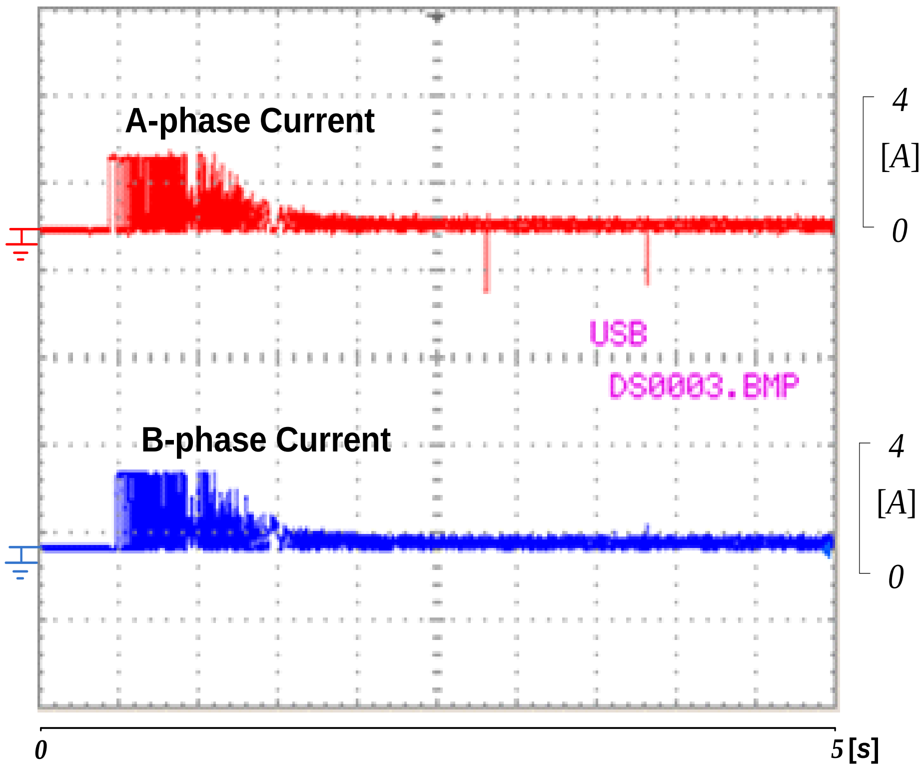


(b) Torque winding currents with PID controller

Fig.6.14. Speed and Torque winding currents with PID controller



(a) Speed with PFPID Controller



(b) Torque Winding currents with PFPID controller

Fig.6.15. Speed and Torque Winding currents with Fuzzy controller

6.5 CONCLUSIONS

A robust fuzzy PID controller in a parallel structure has been developed in real-time to Hybrid Pole type 12/14 Self Bearing Switched Reluctance Motor and described in detail. The integrated fuzzy with conventional PID controller has been put into practice and tested practically. Results have been proved with an excellent unique tracking performance with proposed PFPID controller and established the usefulness of this controller in motor drive with uncertainties of rotor displacement parameters in both X-direction and Y-direction respectively. The effectiveness of the proposed controller has been shown in results by comparing with the conventional PID controller and has been proved that it is efficient. The practical implementation has been based on RTIO (Real Time input output) and MATLAB/Simulink environment. The combination of RTIO and MATLAB/ Simulink created an effective rapid prototype control environment. This chapter has mainly focused on designing and practical implementation of parallel fuzzy type controller with PID controller for speed as well as for x & y directional rotor eccentric displacements controlling of the Hybrid Pole type 12/14 Self Bearing SRM.