TABLE III. Critical Parameters

	No load			Full load		
Parameter	proposed	MRAC	PI	proposed	MRAC	PI
Overshoot (%)	0.87	0.88	1.5	2.8	3	6
Rising time	0.014	0.013	0.018	0.004	0.003	0.006
Setteling time	0.016	0.017	0.031	0.009	0.010	0.026
IAE	0.01	0.01	0.015	0.014	0.014	0.025
ITAE	0.001	0.001	0.004	0.001	0.001	0.006

VI. Experimental Results

In this study, a DLSRM with dimensions and parameters outlined in Table 1 was selected. Then the proposed control strategy along with a conventional PI controller was applied to regulate the motor performance. The motor and its experimental drive are shown in Fig. 6. Steel sheets with 0.5 mm thickness were used to construct the stator poles and yoke. For creating the translator, nonlaminated iron was used which coils of AWG#15 wire placed on translator poles. In order to implement the control system, an ARM Cortex-M4 microcontroller STM32f407 was used with 72 MHz processing frequency. Four Hall sensors sensed the actual phase currents and sent them to the current control unit. All signals were stored in a flash memory. Also, the propulsion force was calculated by the corresponding equations and finite element analysis information. A magnetic sensor strip with 10 μm resolution runs alongside the stator giving the position feedback signal. The speed information was also obtained through a capture channel of the timer inside the microcontroller.

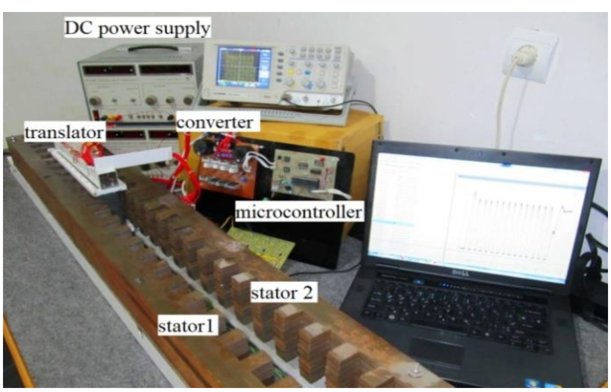

Fig. 6. Experimental setup

The results measured in the experimental test for three control strategies are shown in Fig. 7. The test conduct under the same conditions as the simulation in Fig. 5. According Fig. 7, force in the steady state condition is 12 N. At start and to overcome the moment of inertia, the generated force is higher. The pick start force is 17 N, 20 N, and 20.5 N for proposed fuzzy method, MRAC, and PI method, respectively. This also happens during braking.

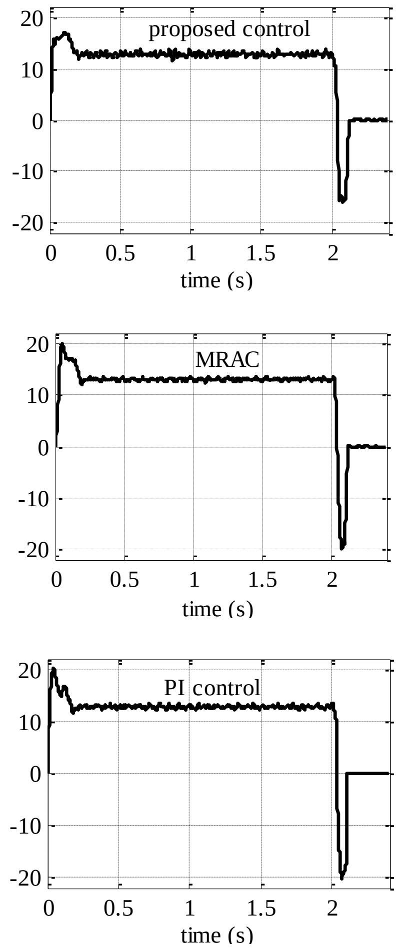

Fig. 7. Force comparison of three methods

The currents of a phase obtained from the experimental test for three control methods are demonstrated in Fig. 8. In order to have a better realization, the current is shown in all of the moving periods along with in a limited interval. Current profile in three strategies are approximately same, so only one profile is demonstrated.

The speed error for three control strategies obtained from simulation and experimental tests are shown together in Fig. 9. The figuers indicate that the experimental results are approximately same as the simulation results. According to

Fig. 9, the speed error in proposed fuzzy control strategy and MRAC method has same overshoot about 0.03 m/s while this exceeds 0.1 m/s in the conventional PI controller. So, the proposed fuzzy control method and MRAC strategy have almost the same performance but fuzzy control method has some benefits explained in section 3.

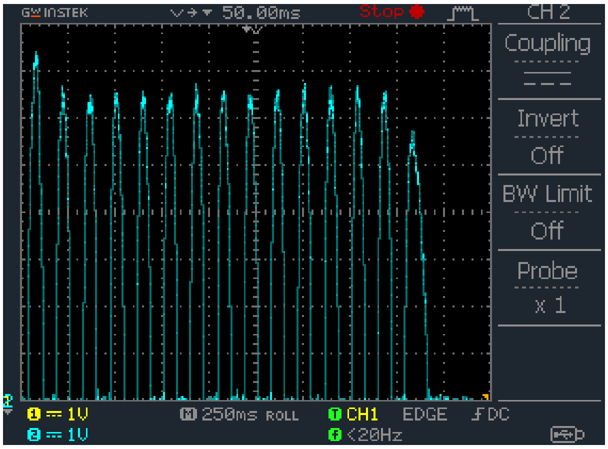

Fig. 8. a

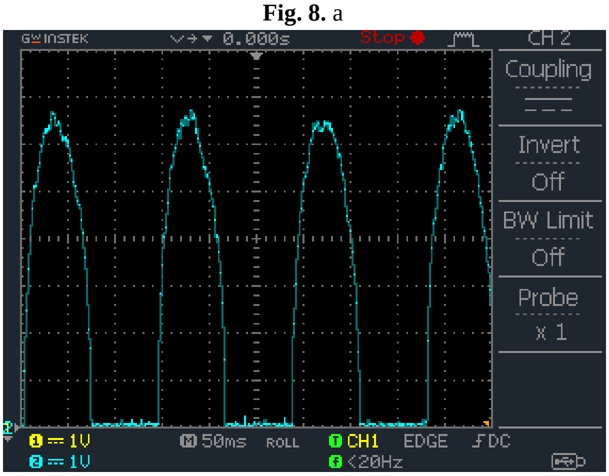

Fig. 8. b

Fig. 8. Experimental results, phase current, (a) total current, (b) current in a limited interval

VII. Conclusion

This work proposed the control of a double-sided linear switched reluctance motor by a simple fuzzy logic-based system. Linear switched reluctance motors are inherently non-linear systems with some unknown parameters such as saturation and end effect phenomena complicating their precise control. The proposed control strategy was applied to a motor along with a conventional PI and a modern MRAC strategies. The controller was able to control the position, speed, force and current of the motor simultaneously. To make the study more robust, simulation and experimental tests were performed and the obtained results were compared for three methods. The results confirmed that the fuzzy control approach outperformed the other methods. In addition, the proposed method was very simple requiring to additional information about the system when compared with the other methods.

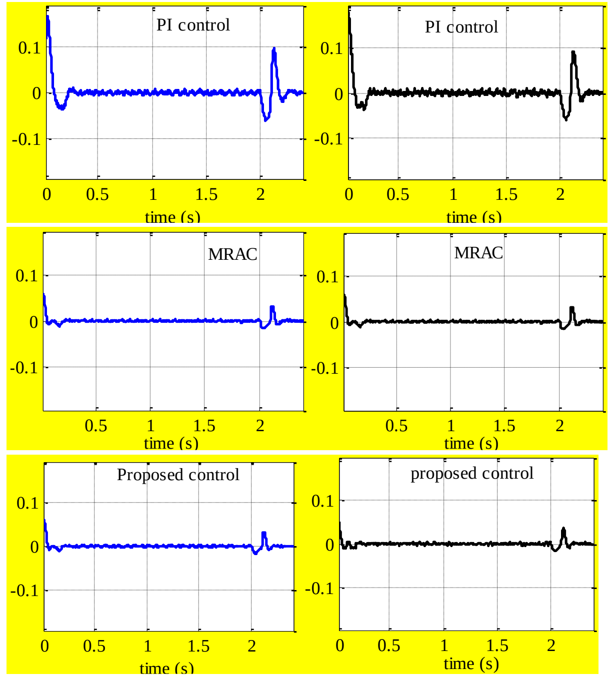

Fig. 9. a **Fig. 9.** b

Fig. 9. Speed error comparison, (a) simulation, (b) experimental

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