

Fig. 14. The slave linear velocity when there are obstacles.

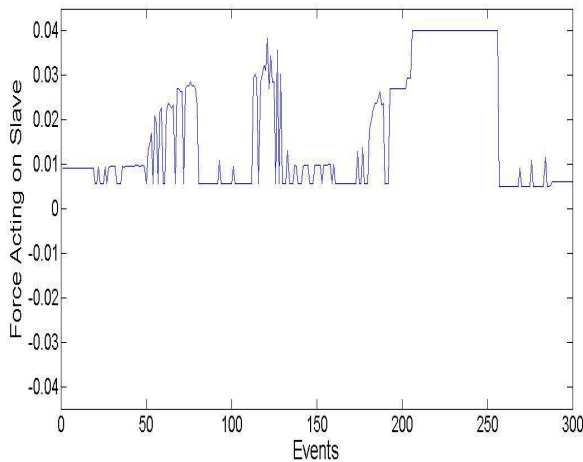


Fig. 15. The force acting on slave reflected to master device.

## VII. CONCLUSION AND FUTURE WORK

The above mentioned results have been plotted to analyze the performance of controller and the coordination between master and slave. The results are quite impressive and exhibit the excellent coordination between master and slave. In future work the map building will be added to the GUI so that the human operator can understand the environment around slave robot more precisely and the vision system will be used to detect and localize humans in the environment and then send to them the rescue robot after detection.

## REFERENCES

- [1] O. Linda and M. Manic, "Self-organizing fuzzy haptic teleoperation of mobile robot using sparse sonar data", *IEEE Transactions on Industrial Electronics*, vol. 58, no. 8, august 2011.
- [2] I. Farkhatdinov, J. H. Ryu, and J. An, "A preliminary experimental study on haptic teleoperation of mobile robot with variable force feedback gain," *IEEE Haptics Symposium Waltham, Massachusetts, USA*, 25 - 26 March 2010.
- [3] K. M. Al-Aubidy, M. M. Ali, A. M. Derbas, and A.W. Al-Mutairi, "Gprs-based remote sensing and teleoperation of a mobile robot," *10th International Multi-Conference on Systems, Signals & Devices (SSD) Hammamet, Tunisia*, March 18-21, 2013.
- [4] S. K. Cho, H. Z. Jin, J. M. Lee, and B. Yao, "Teleoperation of a mobile robot using a force-reflection joystick with sensing mechanism of rotating magnetic field," *IEEE/ASME TRANSACTIONS ON MECHATRONICS*, VOL. 15, NO. 1, FEBRUARY 2010.
- [5] Z. Szanto, L. Marton, P. Haller, and S. Gyorgy, "Performance analysis of WLAN based mobile robot teleoperation," *IEEE International Conference on Intelligent Computer Communication and Processing (ICCP)*, Cluj-Napoca, Romania, 5-7 Sept. 2013.
- [6] R. Lozano, N. Chopra, and M. W. Spong, "Passivation of force reflecting bilateral teleoperators with time varying delay," *In Mechatronics'02, Enschede, Netherlands*, 2002.
- [7] P. Berestesky, N. Chopra, and M. W. Spong, "Discrete time passivity in bilateral teleoperation over the Internet," *In Proceedings of the IEEE international conference on robotics and automation*, New Orleans, LA, USA, 2004.
- [8] J. H. Ryu, D. S. Kwon, and B. Hannaford, "Stable teleoperation with time domain passivity control," *IEEE Transactions on Robotics and Automation*, vol. 20, no. 2, April 2004.
- [9] C. Secchi, S. Stramigioli, and C. Fantuzzi, "Dealing with unreliabilities in digital passive geometric telemanipulation," *In Proceedings of the IEEE/RSJ international conference on intelligent robots and systems* Vol.3, 2003, pp. 2823-2828.
- [10] Y. Yokokohji, T. Imaida, and T. Yoshikawa, "Bilateral control with energy balance monitoring under time-varying communication delay," *In Proceedings of the IEEE international conference on robotics and automation*, Vol. 3, San Francisco, CA, USA, 2000, pp. 2684-2689.
- [11] C. Secchi, S. Stramigioli, and C. Fantuzzi, "Digital passive geometric telemanipulation," *In Proceedings of the IEEE international conference on robotics and automation* Vol. 3, 2003, pp. 3290-3295.
- [12] W. Wang and K. Yuan, "Teleoperated manipulator for leak detection of sealed radioactive sources," *In Proceedings of the IEEE international conference on robotics and automation*, Vol. 2, 2004, pp. 1682-1687.
- [13] W. K. Yoon, T. Goshozono, H. Kawabe, M. Kinami, Y. Tsumaki, and M. Uchiyama, "Model-based space robot teleoperation of ETS-VII manipulator," *IEEE Transactions on Robotics and Automation*, 2004.
- [14] T. Imaida, Y. Yokokohji, T. Doi, M. Oda, and T. Yoshikawa, "Groundspace bilateral teleoperation of ETS-VII robot arm by direct bilateral coupling under 7-s time delay condition," *IEEE Transactions on Robotics and Automation*, 2004.
- [15] A. J. Madhani, G. Niemeyer, and J. K. Salisbury, "The black falcon: A teleoperated surgical instrument for minimally invasive surgery," *In Proceedings of the IEEE/RSJ international conference on intelligent robots and systems* Vol. 2, 1998, pp. 936-944.
- [16] N. Diolaiti and C. Melchiorri, "Teleoperation of a mobile robot through haptic feedback" *In IEEE international workshop on haptic virtual environments and their applications*, 2002, pp. 67-72.
- [17] O. J. Rösch, K. Schilling, and H. Roth, "Haptic interfaces for the remote control of mobile robots" *Control Engineering Practice*, 2002.
- [18] L. Dongjun, M. P. Oscar, and M. W. Spong, "Bilateral teleoperation of a wheeled mobile robot over delayed communication network," *Proceedings of the IEEE International Conference on Robotics and Automation*, Orlando, Florida - May 2006, pp. 3298-3303.
- [19] N. Diolaiti and C. Melchiorri, "Haptic tele-operation of a mobile robot", *IFAC* 2003.
- [20] Z. Xiu, A. Kitagawa, H. Tsukagoshi, C. Liu, and M. Ido, "Internet-based tele-rehabilitation system bilateral tele-control with variable time delay," *Proceeding of the 2006 IEEE/RSJ, International Conference on Intelligent Robots and Systems*, pp. 5208-5213, Beijing, China, October 2006.
- [21] M. P. Oscar, L. Dongjun, M. W. Spong, I. Lopez, and C. T. Abdallah, "Bilateral teleoperation of mobile robot over delayed communication network: Implementation," *Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems*, Beijing, China, October 9 - 15, 2006.
- [22] N. Xi and T. J. Tarn, "Action synchronization and control of Internet based telerobotic systems," *IEEE Int. Conf. on Robotics and Auto*, May 1999.