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Brushless DC Motor Model Incorporating Fuzzy Controller for Prosthetic Hand Application

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ABSTRACT: This paper presents a model of Brushless DC(BLDC) motor with fuzzy logic controller for myoelectric prosthetic hand applications. The modelling of BLDC motor and fuzzy controller is done in MATLAB-Simulink. From the given input electromyography(EMG) the fuzzy controller identifies in which direction the person thinks to move his hand. The magnitude and location of EMG signal is different for different movements. Based on the output of fuzzy controller two BLDC motors rotates in forward or reverse direction to produce flexion/extension and supination/pronation movements of the hand. The torque and speed output of the BLDC motor obtained in MATLAB-Simulink verifies the proposed system.

KEYWORDS: Electromyography(EMG), Brushless DC(BLDC), Prosthetic, Fuzzy, MATLAB-Simulink.

I.INTRODUCTION

Prosthetic hands are very necessary to maintain the quality of life for hand/forearm amputees. The major requirement of a prosthetic hand is that its ability should be as close to the natural arm. Different types of prosthetic arms are electrical, mechanical and myoelectric arm. Mechanical prosthetic armuse some motion of the body to give the force required to operate the prosthetic arm. Electrical arms consist a motor which is driven by micro switches and relays. Myoelectric arm is stimulated by signals from muscle of the amputee. The myoelectric arm uses processed EMG signal.EMG signal is a biomedical signal generated in muscles during its contraction representing neuro muscular activities. These signals are directly connected to the movement intention.

The key step in myoelectric prosthetic hand is the accurate recognition of the user's intent to move from the EMG signal. The magnitude of EMG signal is different for different movements such as, flexion-extension of elbow and supination-pronation of forearm. Fuzzy logic controller a powerful tool for pattern recognition can be used for identifying the movement intention. After recognizing the movement intention, based on this two Brushless DC(BLDC) motors are to be controlled either in forward or reverse direction for allowing the movement. The BLDC motor has found its use inbiomedical applications due to its properties such as great control range, higher efficiency and power density. The BLDC motor is driven by a PWM inverter so it can be controlled by controlling the PWM signal to the inverter in response to the EMG signal. The basic block diagram of the proposed model is shown in Fig. 1.

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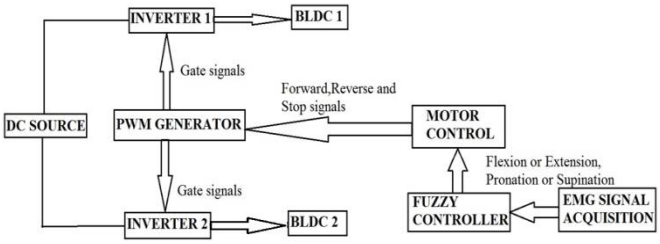

Fig. 1 Block diagram of proposed model

II.SIMULINK MODEL OF FUZZY CONTROLLER

The fuzzy controller identifies the movement intention whether it is flexion, extension, supination or pronation from the acquired EMG signals and it decides which motor to rotate in which direction. For producing these four movements two BLDC motors are required. The control system is same for bothmotor. The fuzzy EMG signal classifier designed in MATLAB-Simulink is shown in Fig. 2.

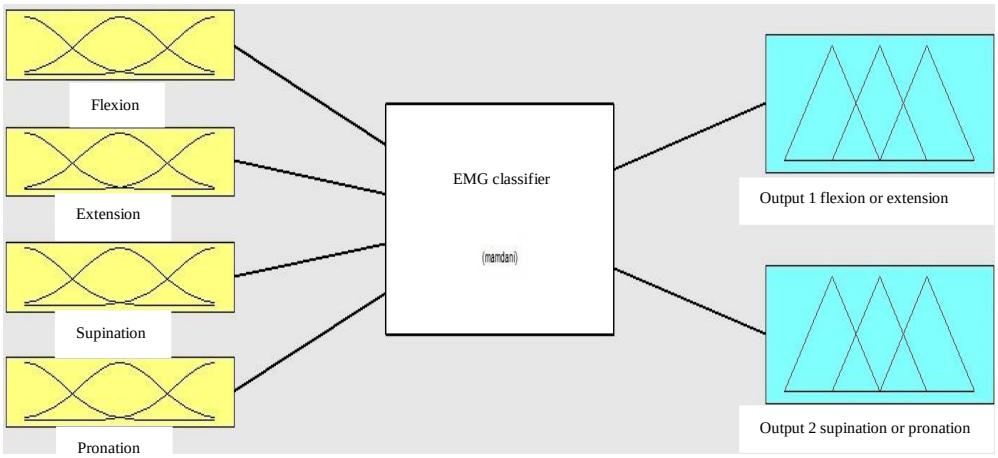

Fig. 2 Fuzzy EMG classifier

The four inputs are the EMG signals from four different muscle locations corresponds to flexion, extension, supination, pronation. The fuzzy classifier unit identifies which inputs are dominant based on the magnitude of inputs present. The magnitude of the EMG signal varies from 0-30mV and the input signal magnitude is the crisp variable and is converted to fuzzy variable as shown in Fig. 3. The input membership function is same for all the four inputs. For the entire voltage range the input is divided into off, low, medium and high each have a membership value between 0 and 1.

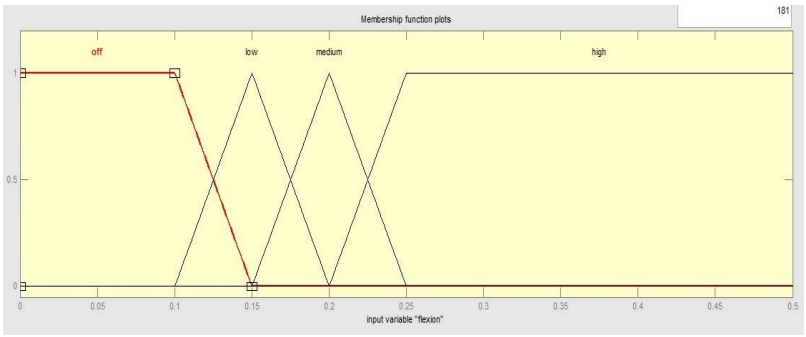

Fig. 3 Input membership function

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The classifier identifies the movement intention based on the simple vernacular rule in the rule base. This is one of the main advantages of the fuzzy control system. At any time according to the requirement this rules can be edited according to the requirement. All these rules point to any of the two outputs corresponds to flexion or extension and supination or pronation.

After identifying the movement intention the next is to control the two BLDC motor. This control is incorporated in the PWM side of the inverter. The direction control is such that if the movement intention is extension then the BLDC motor 1 rotates in the forward direction and for flexion it rotates in the reverse direction. Similarly for the BLDC motor 2 it rotates in the forward direction for pronation and rotes in the reverse direction for supination. A three phase voltage source inverter using power MOSFET is used. By reversing the switching sequence it is possible to change thedirection of rotation of the BLDC motor. Reversing the switching sequence means giving the switching pulse to the other switch of the same limb. The inverter simulated in Simulink is shown in Fig. 4.

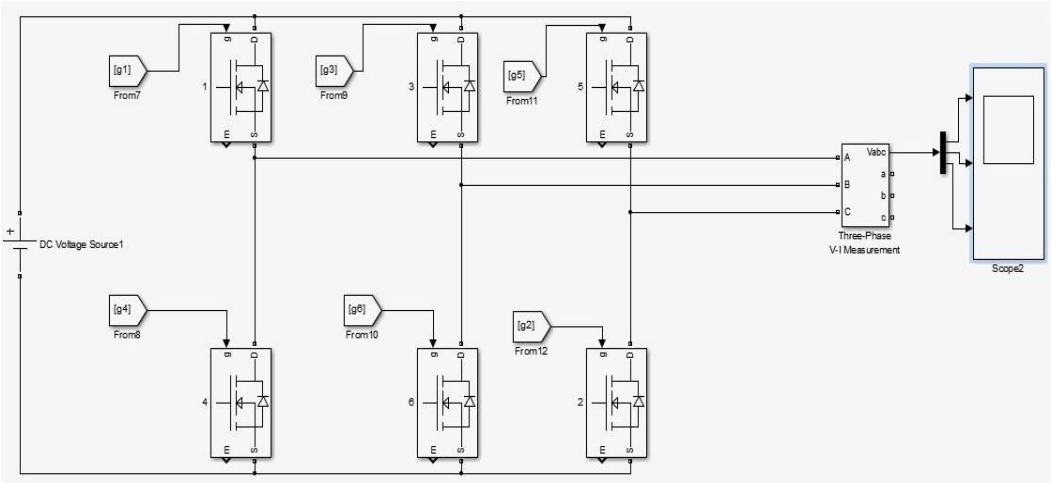

Fig. 4 Voltage source inverter

The switching sequence of inverter for forward and reverse rotation of the BLDC motor is different. Switching sequence reversal can be obtained using simple logic gates. The fuzzy controller and inverter modelled in Simulink can be verified by giving test input signals. The inverter output in response to flexion and extension input is shown in Fig. 5 and Fig. 6.

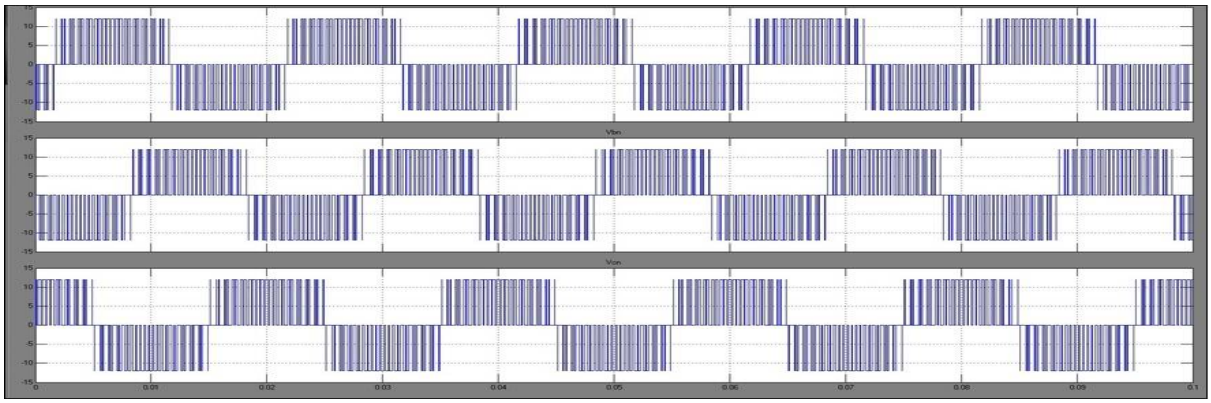

Fig. 5 Inverter output for flexion

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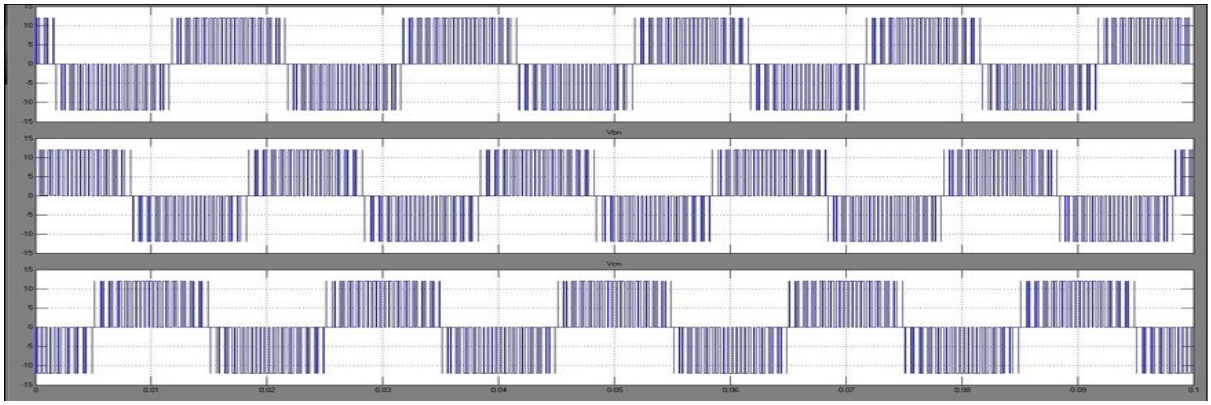

Fig. 6Inverter output for extension

By observing the inverter output it is clear that the inverter output also reverses for flexion and extension. So one BLDC motor rotates in opposite direction for flexion and extension. Similarly the other BLDC motor rotates in opposite direction for supination and pronation. So the movement intention can be clearly identified from the EMG signals and based on its inverter output to BLDC motor changes.

III.SIMULINK MODEL OF BLDC MOTOR

Constructionally BLDC motor is similar to a synchronous machine with permanent magnet rotor. So BLDC motor can be modelled similar to a synchronous machine. But few dynamic characteristics are different. The BLDC motor is fed from a three phase voltage source inverter. The Simulink model of a BLDC motor is shown in Fig. 7.

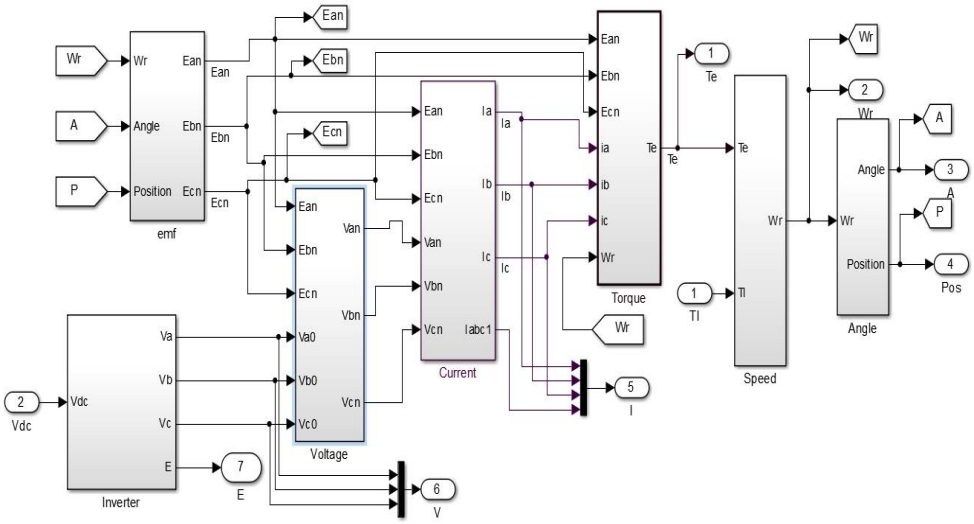

Fig. 7 BLDC motor drive system

In a BLDC motor commutation is done electronically. To rotate the BLDC motor stator winding should be energised in a sequence and for reverse rotation the sequence should be reversed. For energising a stator winding it is important to understand the rotor position. The rotor position can be identified by the hall effect sensor placed in the stator. The direction of rotation of BLDC motor is based on the input EMG signal. To identify the movement intention and control the BLDC motor a fuzzy controller explained earlier is used in the BLDC motor as shown in Fig. 8.

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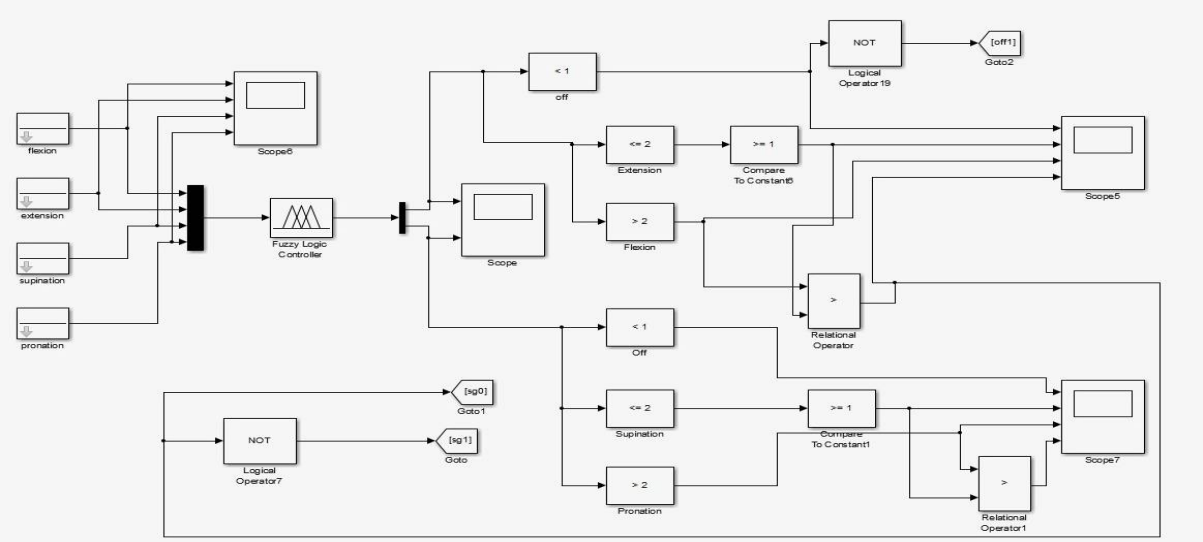

Fig. 8 Fuzzy controller

The fuzzy controller output can be extracted using logic operations and a control signals sg0,sg1 and off is produced corresponds to flexion, extension and no rotation respectively. These control signals control the gate pulse generation and thus the inverter output and direction of rotation of BLDC motor.

IV. RESULT AND DISCUSSION

The modelling of BLDC motor incorporating fuzzy controller is done in MATLAB-Simulink. The model and the used fuzzy control can be verified by giving test signals. When an input corresponds to flexion is given the output torque is obtained as shown in Fig. 9.

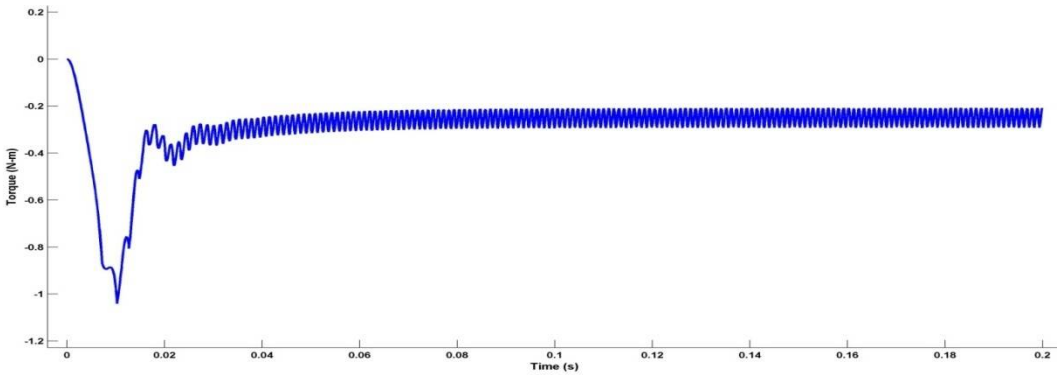

Fig. 9 Torque for flexion

The torque is negative for flexion input. The speed corresponds to flexion input is shown in Fig. 10.

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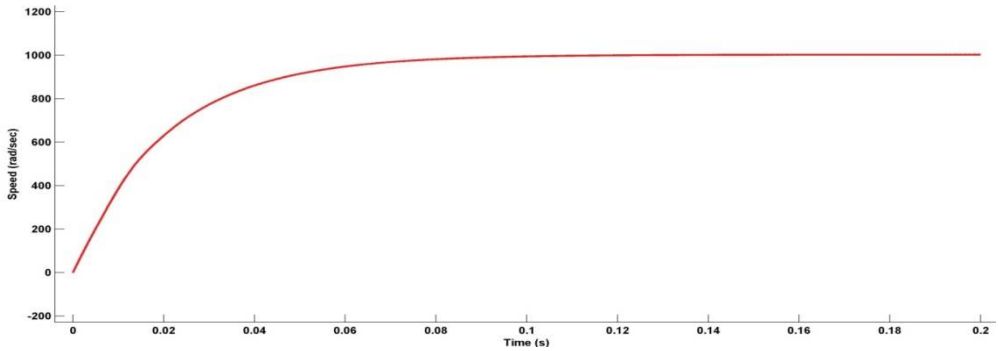

Fig. 10 Speed for flexion

The speed is positive for flexion input. Now an input test signal corresponds to extension is given and the output torque and speed of BLDC motor is observed. The output torque is obtained as shown in Fig. 11.

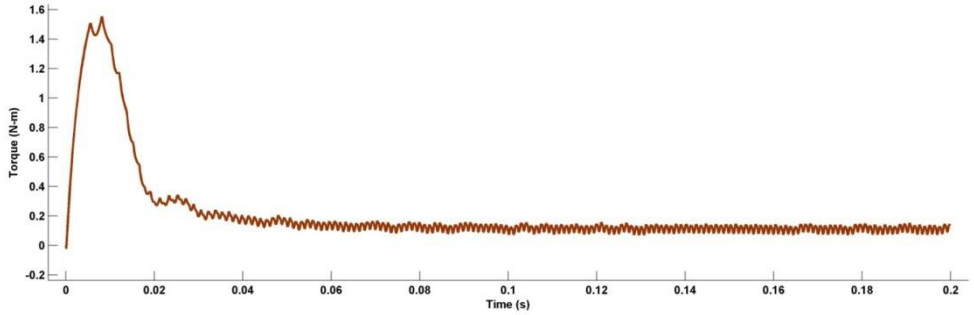

Fig. 11 Torque for extension

The torque obtained is positive for extension input. The speed for extension input is obtained as shown in Fig. 12.

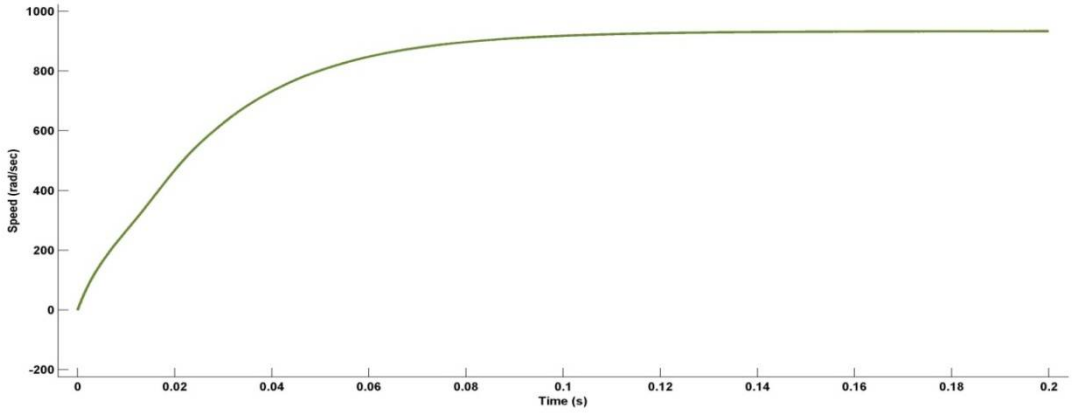

Fig. 12Speed for extension

The speed for extension input is got positive. The speed of BLDC motor is same for both flexion and extension input. The torque is negative for flexion and positive for extension input. This shows that for flexion and extension input BLDC motor rotates in opposite directions. Thus the BLDC motor model including fuzzy controller is verified. Similar control has to be employed for producing supination and pronation movement of forearm.

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VI.CONCLUSION

Modelling of BLDC motor including fuzzy controller for myoelectric prosthetic hand is done in MATLAB-Simulink. The proposed fuzzy controller identifies the movement intention whether it is flexion/extension and supination/pronation from the input test EMG signals. The fuzzy controller output is the parameter which determines the direction of rotation of the BLDC motor. Depends on the fuzzy controller outputs the direction of rotation of BLDC motor changes to replicate the natural movement of hand.

REFERENCES

[1] Pyeong-Gook Jung, Gukchan Lim, "A wearable gesture recognition device for detecting muscular activities based on air pressure sensors," in IEEE Trans. Industrial Informatics, vol. 11, no. 2, Apr. 2015.
[2] F. Khanam, M. Ahmed, "Estimation of work done in lower limb using EMG," in IEEE ICECE 2015, pp. 431-434, Dec. 2015
[3] K. Yuan, S. Sun, Z. Wang, Q, Wang, L. Wang, "A fuzzy logic based terrain identification approach to prosthesis control using multi-sensor fusion," in Proc. IEEE ICRA 2013, May 6-10, 2013.
[4] G. Prasad, N. Sree Ramya, P. V. N. Prasad, G. Tulasi Ram Das, "Modelling and simulation analysis of the brushless DC motor by using MATLAB," IJITEE, vol. 1, issue. 5,Oct.2012.
[5] A. B. Ajiboye, Richard F, "A heuristic fuzzy logic approach to EMG pattern recognition for multifunctional prosthesis control," IEEE Trans. Neural Systems and Rehabilitation Engineering, vol. 13, no. 3, Sept. 2005.